Rising Fuel Prices:

the challenge for affordable warmth in hard to heat homes

Final Report
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Association for the Conservation of Energy

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"Rising Fuel Prices: the Challenge for Affordable Warmth in Hard to Heat Homes"
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We are also deeply indebted to our Steering Group and other stakeholders who gave their time and expertise to this project, and whose comments may be cited in the text as personal communications or incorporated into the User Guide on the project website.

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EXECUTIVE SUMMARY

The primary purpose of the Rising Fuel Prices project is to inform UK fuel poverty strategists and enable social housing providers to plan affordable warmth strategies in the context of increasing fuel prices. Specifically, the aim is to equip housing providers and expert commentators with a publicly available tool, Fuel Prophet, that indicates treatments of hard to heat homes which are both cost-effective and eliminate fuel poverty, taking into account various, fluctuating fuel price conditions.

Rising Fuel Prices focuses on 'hard to heat' or 'hard to treat' homes for two main reasons. First, hard to heat homes are generally expensive to heat, making them an even bigger priority for tackling fuel poverty through improving energy efficiency. Second, they are expensive to treat and while improvements are often not regarded as cost-effective, this may change when faced with rising fuel prices. Despite previous work (Pett, 2002 and 2004) which raised awareness of the scale of this issue, policy makers have not addressed the problem that improving these homes to an appropriate standard will cost less money than demolishing and rebuilding them.

Various elements of this problem have been tackled in work by others, focusing on either fuel price increases and scenarios, hard to heat homes, fuel poverty or energy modelling. This project is unique as it addresses all four elements. Rising Fuel Prices has produced a tool that takes account of changes in the cost-effectiveness of energy efficiency measures[1], indicating which are best suited to alleviating fuel poverty in hard to heat homes in times of fuel price uncertainty.

Defining cost-effectiveness of measures

One of the most difficult areas to establish was the precise meaning of 'cost-effectiveness' when applied to the selection of measures to address energy efficiency in dwellings. Defra (and programmes supported by EST), use payback, i.e. the number of years to recover the cost of installation from the savings in fuel costs. For the EEC, the definition used is simple cost-effectiveness, i.e. the amount of money saved over the life of the measure compared with the cost of the measure. This can also be discounted, so that pounds saved in the future are worth less than pounds saved now. In business, the concept of net present value (NPV) is often used, which considers the value of savings, discounted at an appropriate rate, over the life of the measure. During the development of the project a number of other concerns arose, so that both payback and NPV approaches were deemed necessary, with both end of life (EOL) NPV and cumulative NPV being provided.

The principal difference in outcome between these two approaches is the weaker cost-effectiveness of longer-life measures under the payback mechanism, and improved attractiveness under NPV calculations.

Broader issues such as the wider benefits of health improvement, urban regeneration, employment and economic renewal are not considered in the benefits of improving the energy efficiency of the dwellings or the reduction in fuel poverty. Only NPV, payback and the effect on reducing fuel poverty are addressed in this project.

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[1] For the purposes of this project 'energy efficiency measures' include insulation, heating and micro-generation technologies which reduce fuel bills when installed. These are referred to as 'measures' in this report.

Fuel Price scenarios

The initial approach to this problem was to consider a 'ready-reckoner' approach, i.e. to use a sliding scale of price increases so that users could set their own levels of increases or decreases. This was identified as both impractical and unrealistic, therefore a set of fuel price scenarios were developed for a thirty-year period (this being the maximum product lifetime amongst the measures considered), based on well-established fuel and economic scenarios. These incorporate the DTI forecasts for fuel prices in the early years.

Six fuel price scenarios are available:

1. base case – moderate increase in demand, rising prices
2. high prices – higher demand and prices than base case
3. very high prices (a) – fuel poverty eliminated
4. very high prices (b) – record levels of winter fuel poverty; summer mortality due to heat
5. low prices – similar price to base case in short term but access to cheap gas in longer term
6. very low prices – plentiful fuel and weak global markets; personal carbon allowances

Development of Fuel Prophet

The development of the model, called Fuel Prophet, covers four issues:

- Development of the base buildings
- Selection of appropriate measures and combinations of measures
- Development of the cost-effectiveness methodology and indicators
- Selection of fuel poverty and other indicators

The approach adopted was to limit the buildings modelled to a series of theoretical or 'base buildings' that satisfied our main objective: these were primarily hard to heat homes in social housing and are listed in Table 9.

Table 1: Base Building Summary

Base Build	**Detached** ($100m^2$)	**Semi-detached** ($85m^2$)	**Terrace** ($74m^2$)	**Flat** ($60m^2$)
Wall / Heating type	Solid / gas Solid / electric Solid / coal Cavity / gas Cavity / electric	Solid / gas Solid / electric Solid / coal Cavity / gas Cavity / electric	Solid / gas Solid / electric Solid / coal Cavity / gas Cavity / electric	Solid / gas Solid / electric

Measures to be modelled were selected according to three categories: building fabric including insulation measures to improve heat retention, heating systems to improve fuel efficiency, and micro-generation to reduce fuel. It was considered useful for the model to allow the application of these in any reasonable combination. Savings from these measures were calculated using Builder™, based on the BREDEM model. Solar, wind and CHP are not modelled in Builder™ and so assumptions were made based on information from manufacturers and trade associations

Table 2: Measures modelled, by type

Building fabric	Heating system	Renewable electricity
Loft insulation	Gas combi condensing boiler	Solar PV
Wall insulation: cavity	Ground source heat pump	Micro wind turbine
Wall insulation: internal	Air source heat pump	
Wall insulation: external	Oil condensing boiler	
Draught stripping	Wood pellet boiler	
Compact fluorescent lights	Solar hot water	
Double glazing	Micro CHP	
Primary pipe insulation		
Insulation package L		
Insulation package C		
Insulation package E		
Insulation package I		

Four insulation packages are shown in Table 10. These were introduced as there are measures that are cost-effective in the sense they are relatively inexpensive to install, but the effect on yearly energy bills is negligible when adopted in isolation. The packages each include loft insulation to 270 mm, draught sealing, and compact fluorescent lights fitted throughout the house, with variations adding wall insulation:

- INSL – Loft insulation only, no wall insulation
- INSC – Cavity wall insulation
- INSE – External wall insulation
- INSI – Internal wall insulation

U-values for relevant measures were either calculated by the Builder software, given the material construction, or were entered manually using values from the EST best practice guidelines. Data from the EST and other secondary sources were used to verify the calculations where possible.

The model simulates 21 measures or measure ‘packages’. Decisions had to be made on treatment of various issues especially regarding prices, product specifications, maintenance costs and product lifetimes, all of which give rise to levels of uncertainty and the potential for changing assumed values as the markets change. The decisions adopted are visible in the model and can be amended by the user to take account of local robust data especially price considerations.

The wide range of grants and discounts available often depend entirely on the proposed project, making it impossible to estimate. The user can add their own grants and discounts or to adjust the installation costs to match their estimates more closely.

Fuel Poverty Indicators

In England, the minimum income of a household is considered to be £5000 per annum if all benefits are taken. Theoretically, fuel poverty should be eradicated if the energy bill of all dwellings is £500 or less. Therefore, year on year saving to the occupier is graphed and can be compared to a fuel poverty line set to be 10% of the minimum income expected, currently £500. A line is also provided at £800 to take account of the wider definition of income within the UK Fuel Poverty Strategy.

User Guide

A description of the use of Fuel Prophet is described in the research report. A user guide has been developed to enable housing association users in particular to apply the model. This is available to download from the project website as well as being designed into the instructions on the site itself.

Preliminary findings using the Fuel Prophet

The model is far more advanced than the original concept and requires extensive testing to be confident that the first indications analysed below apply to all base buildings, under all fuel price scenarios and under all methods of indicating cost-effectiveness. Analysis presented in this report is limited to general effects relating to house type, wall type and fuel type, then further comment is based on the semi-detached, solid wall, electric base building variant, unless otherwise explicitly stated.

Key preliminary findings

The method used has indicated that, on the whole, fuel prices will have a significant impact upon the ability of different measures to improve the energy efficiency and, reduce the fuel costs in Hard to Heat and other homes. However there is one vital caveat: Despite their fuel savings being more heavily discounted, **insulation measures generally remain most cost effective, in terms of NPV, under all scenarios modelled: the choice of measure installed next, will depend on fuel prices**

- Uncertainty is further removed as the hierarchy of measures (in NPV) remain quite stable, even when the costs of some measures relative to others change quite drastically (e.g. +/- 30%).
- The major finding is that not only are remarkable savings in fuel bills achievable (over 50%) by installing cost-effective measures, but these bills remain much more resistant to fuel price fluctuations over time. This *'fuel proofing' can be seen as a key strategy* for alleviating fuel poverty during periods of rising fuel prices.
- In certain situations, specific measures are likely to be more appropriate for removing people from the risk of fuel poverty than more cost-effective ones due to the amount of reduction in fuel used.
- The long lifetime of many insulation measures (e.g. 30 years) means that their overall value is under-represented when combined with shorter-lived measures. This is relevant when considering wall insulation compared with shorter-term measures such as boilers (15 years). This may be a failure of the model but also reflects the current policy approach to decision making on payback versus whole life costing approaches.

Generic findings

- Between terraced, semi detached, and detached houses, given the same initial wall and heating type, the cost-effectiveness of one measure relative to another does not change.
- Within the same house type, with differing wall and/or heating, the cost-effectiveness of a particular measure will change because each base building has a different initial fuel bill. For example, loft insulation is more cost-effective in a semi detached house with electric storage heating (high fuel bill) compared to a semi detached house with gas central heating (lower bill).
- A solid wall, on gas, mid-level flat should not be classed as hard to heat, because its fuel bill is below £500 and it has a SAP of 70.
- Installing a measure in a more efficient house is less cost-effective. This implies that the priority for measures should be the least efficient dwellings.
- Cavity and internal wall insulation are very cost-effective.

- Loft insulation is the second most cost-effective insulation measure with the second most significant savings. Topping up loft insulation from 100 mm to 270 mm has a much smaller effect. However it is considerably cheaper so payback is better.

Specific issues requiring further testing

- The external wall insulation package has the longest payback period and the lowest final NPV, but has been costed at full price rather than at marginal cost. It responds best to the fuel price scenario because it achieves the greatest savings. If the very high fuel price scenarios were realised, payback could be achieved in 15 years and the final NPV (after 30 years) is the same as that of the loft insulation package.
- The cost-effectiveness of the insulation packages fall into the following hierarchy (best to worst).
  - Insulation package with Internal wall insulation (INSI) (for solid wall dwellings)
  - Insulation package with Cavity wall insulation (INSC) (for cavity wall dwellings)
  - Insulation package with Loft insulation only (INSL) (both)
  - Insulation package with External wall insulation (INSE) (for solid wall dwellings)
  -
- For a solid wall semi-detached house with electric heating, where there is to be no change to the heating, the insulation package with internal wall insulation is preferred, unless the condition of the walls means that refurbishment work is required anyway, in which case the cost of external wall insulation should be revised and the ranking reviewed.
- Improving the efficiency of the heating system is the single most effective measure for reducing fuel bills, all other things being equal. This can be considerably more expensive than insulation, however, if the building is off the gas network and without a central heating system already
- If all fuel types are available, the most cost-effective solution using currently available data is a micro-CHP unit followed by condensing combi-boiler, ground source heat pump (GSHP), air source heat pump, and biomass boiler.
- An oil condensing boiler only pays back under high and very high (b) fuel price scenarios, and it does not take a dwelling out of fuel poverty, even in combination with a full insulation package. This initial finding has significant implications for the new Warm Front grants.
- Solar hot water does not pay back its installation costs and the savings are small.
- Photovoltaic panels (PV) and micro wind turbines (MWT) are the only two renewables considered since solar hot water is classed as a heating system. As currently modelled, the installation cost of PV is over 4 times higher than MWT (£6700 cf. £1500) but does not produce 4 times the electricity (1500 kWh cf. 1000 kWh). However, without significant financial assistance, neither option is cost-effective. ROCs have not been included in the model.
- Under the highest fuel price scenario, the standard package of wall insulation and combi condensing boiler does not take people out of fuel poverty – it will be necessary to install further measures within the next 10 years. For an off gas house, this target cannot be reached without using new technology and renewables.
- The cost of installing a new (non-gas) heating system in a cavity wall building is the same as in a solid wall building, but as the building is initially more energy efficient, it reduces its cost-effectiveness substantially. With the effects of discounting also considered, no heating measure in a cavity wall building which includes a central heating system will pay back in its 15 year lifetime. The only exception is a ground

source heat pump which can function for 28 years and achieves payback only after 20 or more years, depending on the fuel price scenario.

- A cavity wall, on gas building is not classed as hard to treat, but is the easiest base building to reduce energy costs below £500 a year in order to 'fuel poverty proof' the household. The simplest and most affordable action is to install a cavity wall insulation package and a condensing combi-boiler.
- Initial results indicate that introducing cost-effective measures can lead to dramatic reductions in energy bills and therefore specific measures offer very considerable solutions for those in fuel poverty presently.
- While changes in fuel prices do not tend to alter the *relative* appeal of specific measures, (in terms of NPV and fuel savings) their integration does successfully repel the effects of higher prices over time: fuel bills are lower *and* more resistant to price fluctuations over time. This effect is a measure of 'fuel proofing' houses, reducing occupiers' exposure to high fuel prices.

Future model development

The two specific target audiences for the project are social housing providers and fuel poverty/energy efficiency policy researchers. However during the course of the project a number of other users and more details of the key groups have been identified. These can be divided into those needing the outputs for research and issues of policy, and those selecting measures for homes.

Fuel Prophet is currently in the form needed by the policy group and is available to download as an Excel spreadsheet. The underlying assumptions, data sets and calculation functions are accessible, and some of these will be open to manipulation.

The needs of the housing group centre on use of the model to derive outputs needed to inform investment decisions. The intention is to make Fuel Prophet simpler and more accessible. This is to be achieved through a website with simple inputs and easily accessible features.

The website is accessible from the ACE Research website:

www.ukace.org/research/fuelprophet

Conclusions

The aim of this project was to construct a method by which decision makers could identify the long term implications of choices to improve energy efficiency of dwellings in their care, in order to help remove the occupants from fuel poverty, under conditions of fluctuating fuel prices. As usual with ambitious projects, more questions have been raised by the findings. On the one hand a useful model has been developed that will aid social landlords and energy policy researchers to consider the implications of investment decisions based on two approaches to 'cost-effective' measures for hard to heat homes. On the other hand, the question "Why would social landlords want to do this?" has been raised and a further set of indicators that would be of more interest to them uncovered.

The method used has indicated that on the whole measures such draft stripping and loft and cavity wall insulation should always be installed first; the measures to follow will depend on fuel price projections. The model shows the disadvantage placed on long-life measures when considering the value of each type for reducing fuel use. Further work is needed to analyse the effects under all the conditions presented in this model, and as such a stream of projects may follow from this one. It is believed to be a sound platform for such work and feedback from stakeholders is always welcome.

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FIGURES

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ABBREVIATIONS

ACE	Association for the Conservation of Energy
BRE	Building Research Establishment
BREDEM	Building Research Establishment Domestic Energy Model
CCGT	Combined Cycle Gas Turbine
CHCHP	Community Heating Combined Heat & Power
CHP	Combined Heat and Power
COP	Coefficient of Performance
CSE	Centre for Sustainable Energy
Defra	Department for Environment, Food and Rural Affairs
DTI	Department of Trade and Industry
EAS	Energy Action Scotland
EEC	Energy Efficiency Commitment
EEPfH	Energy Efficiency Partnership for Homes
EHCS	English House Condition Survey
EoL	End of life
EST	Energy Saving Trust
ETS	(EU) Emissions Trading Scheme
GSHP	Ground Source Heat Pump
INSC	Insulation package of small measures plus loft and cavity wall insulation
INSE	Insulation package of small measures plus loft and external wall insulation
INSI	Insulation package of small measures plus loft and internal wall insulation
INSL	Insulation package of small measures plus loft insulation
LNG	Liquefied Natural Gas
LZC	Low & Zero Carbon (dwellings)
MWT	Micro Wind Turbine
NEA	National Energy Action
NES	National Energy Services
NHER	National Home Energy Rating
NHS	National Health Service
NPV	Net present value
ODPM	Office of the Deputy Prime Minister
PV	(solar) photovoltaic (systems)
RO	Renewables Obligation
SAP	Standard Assessment Procedure
TCO	Total Cost of Ownership
TRVs	Thermostatic Radiator Valves
U-value	A measure of thermal transmittance

CHAPTER 1: INTRODUCTION

In the summer of 2004, a number of economic and political developments, both globally and in the UK, coalesced around the issue of fuel prices. The war in Iraq, targeting of expatriate employees of oil companies in Saudi Arabia, accelerated energy demand growth in China and India, and announcements by UK energy suppliers that the North Sea oil and gas fields were due to run out in 15 to 20 years, all put upward pressure on fuel prices in the UK.

This situation gave rise to the question: how, in a climate where liberalised energy markets simply cannot provide stable fuel prices, can policy and project decisions related to tackling hard to heat homes and fuel poverty be made?

The primary purpose of the Rising Fuel Prices project is to inform UK fuel poverty strategists and enable social housing providers to plan affordable warmth strategies in the context of increasing fuel prices. Specifically, the aim is to equip housing providers and expert commentators with a publicly available tool that indicates treatments of hard to heat homes which are both cost-effective and eliminate fuel poverty, taking into account various, fluctuating fuel price conditions.

Box 1: Hard to heat Homes

Installing both cavity wall insulation and an efficient gas boiler has traditionally been regarded as the most cost-effective approach to improving the energy efficiency of a home. This is not possible for buildings with solid walls or homes not connected to the gas network and so they are classed as 'hard to heat' or 'hard to treat'. They are not necessarily technically hard to heat or to treat; it is just expensive to bring these homes to an acceptable standard for energy efficiency and/or thermal comfort compared to a non hard to treat/heat home. By definition, the measures required are classed as not cost-effective (using payback).

Rising Fuel Prices focuses on 'hard to heat' or 'hard to treat' homes (see Box 1), particularly in social housing, for two main reasons. First, hard to heat homes are generally expensive to heat, making them an even bigger priority for tackling fuel poverty through improving energy efficiency. Second, they are expensive to treat and while improvements are often not regarded as cost-effective, this may change when faced with rising fuel prices. Despite previous work (Pett, 2002 and 2004) which raised awareness of the scale of this issue, policy makers have not addressed the fact that improving these homes to an appropriate standard will cost less money than demolishing and rebuilding them. At least 30% of UK housing can be classed as hard to heat, and this problem is intractable due to the very low rates of demolition currently taking place.

Housing providers have to make investments to improve their housing stocks, to comply with various governmental requirements, such as the Decent Homes Standard[2]. Hard to heat homes often form part of these stocks and the investment decisions might not favour houses facing particular problems in reaching a Decent Standard of thermal comfort. Consequently, tenants struggle to pay their fuel bills, which may in turn lead to rent arrears, or to them living with unacceptable levels of discomfort in the home.

Furthermore, we have seen a surge in the number of people suffering from fuel poverty (see Box 2), due to increasing fuel prices, over the last two years. The DTI and other sources anticipate that prices will continue to fluctuate in the near term due to tightness in gas supply and electricity generation 2010 (DTI, 2004a) although work for the Fuel

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[2] The Decent Homes Standard is a Government commitment to raise all public sector housing to a standard which accommodates: all statutory housing requirements; a reasonable state of repair; reasonably modern facilities and services; and reasonable levels of thermal comfort.

Poverty Action Plan suggests fuel poverty will fall due to economic effects over the period 2006-2010 (Matejic, pers.comm), as oil prices reduce to 2010, due to new production capacity. With further increases in fuel prices a distinct possibility, it has become rather more urgent that the homes of those suffering from or at risk of fuel poverty be in some way 'fuel poverty proofed' or shielded from the risk of rising fuel prices. Whilst Government programmes have started to be amenable to measures for hard to heat homes, the problem remains that a higher percentage of these homes contain households that are in fuel poverty compared with cavity wall homes; this proportion of fuel poor households is rising as cavity wall homes are being addressed while hard to heat homes are not (Pett, 2004).

Various elements of this problem have been tackled in work by others, focusing on fuel price increases and scenarios, hard to heat homes, fuel poverty or energy modelling. This project is unique as it addresses all four elements. Rising Fuel Prices has produced a tool that takes account of changes in the cost-effectiveness of energy efficiency measures[3], indicating which are best suited to alleviating fuel poverty in hard to heat homes in times of fuel price uncertainty.

Box 2: Fuel poverty

A household is said to be in fuel poverty if 10% or more of their income is spent on fuel to maintain healthy living conditions. The energy required for cooking, hot water, lighting, and electrical appliances must be included amongst the criteria of a healthy home as well as the requirement from space heating, which is recommended at 18 °C in bedrooms and 21 °C in the main living space. Fuel poverty, however, is not simply a case of having to spend a large proportion of income on fuel. Instead, homes are often inadequately heated and households cannot afford to buy sufficient groceries, let alone afford any unexpected costs, which might, for example, arise from illness. As a consequence of fuel poverty, people's quality of life can be damaged, they may be unable to work, children may miss school, and social isolation – particularly for the elderly and vulnerable – may occur, thus creating a downward spiral. If fuel prices rise, more people will be pushed into fuel poverty and the people who are already fuel poor must make further sacrifices to their living standards.

The complex interplay of problems that cause fuel poverty means there is no single solution. Assistance must be provided in a manner that is best suited to the particular situation and makes best use of limited resources; it must be a cost-effective solution that offers affordable warmth.

As such, the benefits of the project extend beyond housing providers to include policy and programme designers, manufacturers, funders and financiers, developers and householder in general. For example, Government might wish to consider how much exposure domestic fuel prices should have to global energy markets, or how current funding support tips cost-effectiveness in favour of one measure over another and whether this is acceptable.

Review of context and need for the project

Policy

Improving energy efficiency is recognised as a vital and cross-departmental policy component of lifting people out of fuel poverty. Policy support for this approach is evident in the *UK Fuel Poverty Strategy* (Defra/DTI, 2001) and its associated Progress Reports, the Energy White Paper *Our energy future: creating a low carbon economy* (DTI, 2003), *Fuel Poverty in England: The Government's Plan for Action* (Defra, 2004) and the recent five year plan – facilitated in particular by the Decent Homes standard – *Sustainable Communities: Homes for All* (ODPM, 2005). The ultimate target is to

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[3] For the purposes of this project 'energy efficiency measures' include insulation, heating and micro-generation technologies which reduce fuel bills when installed. These are categorically referred to as 'measures' in this report.

eradicate all fuel poverty in the UK by 2016-18 (the targets vary between the devolved nations). With respect to hard to heat homes, the Fuel Poverty Strategy clearly identifies them as a priority area for action, because they are expensive to heat and no cheap solutions exist compared to approaches available for more 'standard' housing. What is particularly relevant is that the Strategy recognised that unusual improvement measures need to be implemented in hard to heat homes, and announced two large-scale trials for micro-CHP and micro-renewables respectively.

Implementation of the Government's fuel poverty policy is through the frameworks provided by the Decent Homes standard, Building Regulations, and through the Energy Efficiency Commitment (EEC) and Warm Front or the equivalent programmes in Scotland, Wales and Northern Ireland[4]. The English Fuel Poverty Action Plan (Defra, op.cit) concluded that Warm Front could not deal adequately with hard to heat homes in terms of providing affordable warmth, and highlighted the need for revising the programme if it is to tackle fuel poverty in hard to heat homes successfully. The revised Warm Front arrangements became operational in April 2005. Due to the nature of EEC, energy suppliers are more flexible in the measures they may provide for their customers, but face similar obstacles. In the context of 'fuel-proofing' homes, the DTI's Clear Skies programme (or its successor, as determined by the Microgeneration Strategy, currently in consultation) – providing grants for micro-renewables – is likely to play an increasingly important role in contributing to the eradication of fuel poverty in hard to heat homes.

Research[5]

The problems of addressing fuel poverty in hard to heat homes have been thoroughly researched in previous publications by the Association for the Conservation of Energy, funded by Eaga Partnership Charitable Trust, namely *Affordable Warmth in Hard to Heat Homes: finding a way forward* (Pett, 2002) and *Affordable Warmth in Hard to Heat Homes: progress report* (Pett, 2004). That the current project has its ancestry in this earlier work is reflected by its full title: *Rising Fuel Prices: the challenge for affordable warmth in hard to heat homes*.

The scope of and statistics relating to hard to heat homes were fully assessed in these earlier projects, and figures for fuel poverty have been updated from published sources including work by EAS (Energy Action Scotland, 2004) and CSE (Research and Information Unit, 2005). A number of reports have been produced that considered the effects of fuel price rises on fuel poverty numbers in general. Of particular value was the work by NEA (Merleau-Ponty pers. comm.) – reported informally in a number of references – highlighting that the numbers in fuel poverty have risen by 200,000 since 2001, largely due to the latest fuel price increases. This research has now been published (Moore, 2005). The Third Annual UK Fuel Poverty Strategy Annual Progress Report estimates that in 2006 the number of vulnerable households in fuel poverty in England after energy price and income movements will be about 1.4 million. Fuel price increases alone would have added about 600,000 to the number of vulnerable fuel poor, but income increases reduced numbers by about 200,000, resulting in a net increase of 400,000 (DTI, [2005a]). DTI published a "ready reckoner" that considered a number of scenarios including gas and electricity prices rising independently of each other and also income increases for each of these combinations (DTI, 2004b). It is interesting to note that this project had originally proposed to predict the effect of specific fuel prices rises

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[4] The equivalent programmes are Warm Deal in Scotland (plus the Scottish Central Heating Programme), HEES in Wales, and Warm Homes in Northern Ireland. For brevity, when referring to Warm Front in the UK context, this should be taken to include these programmes.

[5] DTI (2005). The UK Fuel Poverty Strategy. 3rd Annual Progress Report.

on cost-effectiveness (e.g. select any number from 1% to 100%, to see the effect on given measures). This would be the normal expectation of a 'ready reckoner' approach. In the event it was found to be impractical to do so, as explained later, and a scenarios approach was adopted. Effectively the same approach was taken by the DTI for its ready reckoner. The choice of fuel scenarios detailed in Chapter 2 takes into account the DTI predictions as well as other scenarios work, particularly '*Open Horizons: Three Scenarios for 2020*'; (RIIA, 1998) and the energy scenarios from Imperial College London for the PIU report (PIU, 2001). Assumptions on fuel prices, influences and trends were also drawn from *Energy – the Changing Climate* (RCEP, 2000) and *Energy Price Trends* (DTI, 2004a).

A number of assessments and tools for measures were reviewed to inform the development of the model and to utilise approaches that were consistent with current practice, so as to enable like for like comparisons, and to inform choices between conflicting data. The assessment of options for treating hard to heat homes prepared for the Fuel Poverty Advisory Group by Transco (Transco, 2002) was extremely valuable in identifying both strategies and the form for typical building types, although some assumptions were challenged and these have been detailed where appropriate. Projects commissioned by the Energy Efficiency Partnership for Homes Hard to Treat Homes Sub-group were particularly useful as they address specific technical issues surrounding the application of measures for these homes, with special reference to the needs of the social housing sector. These included the BRE Matrix, the Impetus report on solid wall insulation, the Places for People report on ground and air source heat pumps, and the CSE work on Non-traditional Housing (all accessible at EEPfH 2005).

Finally, the standard tools for assessing domestic building energy performance were reviewed with particular reference to their sensitivity to fuel prices, bearing in mind that it would not have been appropriate, in this project, to reinvent a building energy model. Various tools for assessing energy and fuel use (including SAP and NHER rating systems,) depending on different parameters, were considered, including Builder, BREDEM and ESP-r.

Defining cost-effectiveness of measures

One of the most difficult areas to establish was the precise meaning of 'cost-effectiveness' when applied to the selection of measures to address energy efficiency in dwellings. It is apparent that for Defra (and in programmes supported by EST), payback is sufficient, i.e. the number of years it takes to recover the cost of installation from the savings in fuel costs. For the EEC, the definition used is simple cost-effectiveness, i.e. the amount of money saved over the life of the measure compared with the cost of the measure. This can also be discounted, so that pounds saved in the future are worth less than pounds saved now. In business, the concept of net present value (NPV) is often used, which considers the value of savings, discounted at an appropriate rate, over the life of the measure. The mathematics of this are different from the simple cost-effectiveness method. As the principal audience for this research is housing associations, who may consider the houses as their assets, it was thought this might be appropriate. However there is a complication because savings do not accrue to the housing association but to the tenant. During the development of the project a number of other concerns arose, so that both payback and NPV approaches were deemed necessary.

It should be noted that the principal difference in outcome between these two approaches is the weaker cost-effectiveness of longer-life measures under the payback mechanism, and their improved attractiveness under NPV calculations

A full discussion of these issues is included in Chapter 3. Broader issues such as the wider benefits of health improvement, urban regeneration, employment and economic renewal are not considered in the benefits of improving the energy efficiency of the dwellings or the reduction in fuel poverty. Only NPV, payback and the effect on reducing fuel poverty are addressed in this project.

Structure of the report and project

Chapter 2 presents the outcomes of work phase two of the project. Work phase two analyses the background to the UK energy market and discusses possible scenarios for fuel price changes in the future. The original concept of the model was to be able to say that for any given fuel price rise, "x" was the preferred solution. It quickly became apparent that this was not an appropriate approach, as each of four fuel prices (for gas, electricity, coal and oil) could change independently of each other and the ensuing complexity was not practical to simulate within the scope of the project. These scenarios therefore became fundamental to the workings of the model, providing reasonable scope for users to assess the cost-effectiveness of various measures under different fuel price conditions.

Chapter 3 discusses the development of base buildings and specification of measures, and includes the development of indicators used to assist investment decisions. These key components form the basis of the model constructed in work phase three. There is an extensive discussion of the ways of considering 'cost-effectiveness' with four typical approaches examined; payback, simple cost-effectiveness and net present value (end of life or amortised). A brief description of community heating, its benefits, and why it has not been modelled are shown in Appendix 2, as this is a measure of interest to many potential users.

The use of the model – christened 'Fuel Prophet' – to assess cost-effectiveness is then elaborated with the use of indicators in Chapter 4, with examples of the approach for various measures and measure combinations for the different base buildings.

Chapter 5 is concerned with the analysis of model outputs. It covers the dynamic manner in which the model can be manipulated, as well as a description of the graphs and how the underlying mechanisms work. The section identifies how the model can be used to determine the best options to eliminate fuel poverty in hard to heat homes. It addresses both cost-effectiveness and savings to the occupier by house, wall, fuel and heating system type, and by measures, price scenario and combinations of interest to users. A sensitivity analysis illustrates the degree to which differing costs of measures affect the overall cost-effectiveness.

In the final chapter modifications made as a result of the project stakeholder workshop are described, and a set of recommendations for future development are made, together with a brief discussion of the wider implications, both for the model itself and as a result of the preliminary findings. It should be noted that the development of the model has not at this stage given rise to exhaustive analysis of the outputs, and further work is needed to discover the full implications of the project.

First, the report addresses the issues that affect fuel prices and the forecasts or scenarios for prices in the future.

CHAPTER 2: UK ENERGY MARKET AND FUEL PRICE SCENARIOS

One objective of the project was to assess the relationship between wholesale markets and domestic retail gas and electricity prices, identifying drivers such as market conditions, political forces and regulatory influences. This was intended to allow readers to reflect upon energy price trends, relying on a sounder understanding of how various drivers and factors have combined to affect these in the past, and how they might affect prices in the future[6].

This analysis also addressed issues that were needed to inform development of the model itself, such as how the cost of possible measures installed might change with increased energy costs, or what fuel (e.g. coal, electricity) would need to be modelled. More importantly, the analysis guided the development of the fuel price scenarios, revealing realistic parameters, underlying drivers and structural conditions.

Factors affecting UK fuel prices

Factors affecting domestic electricity and gas prices in the UK are numerous, complex, and often rather vague. However, most of the recent changes in fuel prices can in some way be explained by the impact of market-based reforms that have transformed the energy sector over the last two decades. But while these upheavals have largely settled, new drivers are at work, primarily relating to issues of climate change mitigation and energy security (including resource scarcity). It will be these two factors that have the most marked effect on fuel prices in the medium and long term. Whilst a full explanation of these forces is outside the scope of this project, this summary provides an overview explaining recent price changes and factors that may affect future movements.

Market-based reforms

Privatisation of much of the UK energy sector involved separating the functions of retail and generation from the 'natural monopoly'[7] functions of distribution and transmission. It also involved establishing greater competition through a wholesale electricity market for electricity generation, and a retail market for electricity and gas supply. These reforms were reputedly intended to introduce new incentives leading to greater efficiencies, which would be passed to the consumer in the form of lower fuel prices. Currently, generation forms the main cost component (ca 50%) of consumers' electricity bills, with distribution and transmission costs accounting for about 25% and 5% respectively (Thomas, 2002 and IEA, 2005). The remainder are supply costs (mainly billing and metering).

The wholesale electricity reforms culminated in the replacement of the previous "Pool System" with the New Electricity Trading Arrangements (NETA) in 2001. This was due to alleged pricing abuses suffered by the old system and the greater efficiencies and transparency offered by the new system (Ofgem, 2000). As a result of this new trading system and the increasing number of generators and retailers, many operators struggled for profits. This was particularly true for those locked into older generation technologies and high-priced long-term forward contracts at a time when fossil fuel prices were falling (Thomas, 2001). However, as a result of these cheaper energy inputs, and the introduction of competition and new technologies, householders' electricity costs did in fact fall.

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[6] This analysis is based on price information available in the spring of 2005; DTI have recently published new fossil fuel price projections to 2020 (Matejic, pers. comm.). The fuel price scenarios used here can be modified in the model to take account of new information.

[7] Natural Monopoly: A situation where one firm can produce a given level of output at a lower total cost than can any combination of multiple firms.

Looking forward, it is estimated that 40% of the UK's power stations will be closed by 2015, through a combination of nuclear plant retirement and EU initiatives such as the Emissions Trading Scheme (ETS) and the Large Combustion Plant Directive. E.ON estimates that it will take up to £70 billion to build the new power stations and infrastructure needed to meet our future energy requirements (Haigh, 2005). Currently, electricity in the UK is primarily produced from three sources; coal, gas and nuclear power, with remaining small contributions from hydro and other renewables. These sources are affected by additional forces, outlined below.

Gas - supply and distribution

Natural gas represents around 70% of domestic fuel consumption in the UK, which is the world's third largest consumer and fourth largest producer. However, production declined by 13% in 2004, and this trend is set to continue (Simmons & Co, 2004). Indeed, the UK is now a net importer of gas and this greater dependence on external sources will produce upward pressure on domestic gas prices for a number of reasons. First, while gas-exporters Norway and Holland cannot be considered geopolitically 'risky' sources of fuel, these are sovereign states and this implies a risk premium. Second, there are added costs of distribution, including the maintenance and doubling of capacity of the existing Bacton-Zeebrugge Interconnector, and the planned development of three major LNG[8] terminals as demand for imported gas increases as expected. Third, increased reliance on continental gas supplies means higher wholesale gas prices for four related reasons: a) continental gas prices are contractually linked to oil prices, which are currently high; b) this continental gas is imported in winter, leading to higher prices in the UK as well, c) during summer, gas is exported to Europe to take advantage of higher prices there, leading to higher prices in the UK and pushing up the cost of storing gas for the coming winter and d) gas is currently the marginal generation fuel, so that any spikes encountered at peak times are usually dealt with by gas power stations. This leads to volatile and often very high prices on UK prompt (i.e. short term) markets (Haigh, op cit). Finally, new storage facilities and additional production plant are needed to cope with rising demand, and higher prices help signal the need for such investment (DTI, 2004a).

Gas – generation

The emergence of modular Combined Cycle Gas Turbines (CCGTs) in the 1990s has been the primary driver for gas-fired generation in the UK (Ofgem 2004a). These new generators have tended to militate against higher fuel prices as they are generally cheaper to bring on-line and can be bought 'off-the-shelf'. CCGTs have increased in number from one in 1991 to 33 in 2002 and by 2004 accounted for 40% of the UK's total generation capacity (ibid.). However, many of these are now coming to the end of their operating lives or are being 'sweated' – extending their lives through expensive retrofitting (Hugh, pers. comm[9].).

Although historically low and perhaps economically unsustainable fuel prices have been significant contributors to the current pattern of generation, further price rises will probably be needed to signal the need for additional generation capacity (DTI, 2004a).

Coal

Coal accounted for 84% of the UK's electricity generating capacity in 1980 (British Biogen, 2000), in stark contrast to the 30% contribution it makes today. This is largely due to the rapid development of CCGT technologies over the past 20 years. Additionally, coal, now coming from as far as Colombia and Australia, has become more costly due to greater global demand, leading to higher electricity generation costs

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[8] LNG=Liquefied Natural Gas

[9] Hugh, M (2004)

(Ofgem, 2004b). This has not been helped by a shortage of shipping capacity, leading to freight rates increasing in excess of 100% (DTI, 2004a).

The Large Combustion Plant Directive and Emissions Trading Scheme (ETS, see later in this chapter) are expected to diminish the economic viability of coal generation, leading to further plant closures (Haigh, op cit).

Nuclear

Nuclear power accounts for around one quarter of the UK's electricity production capacity, with a number of plants due for decommissioning over the next few years. The privatisation process revealed that Britain's nuclear power plants were heavy loss-makers; up until 1996 the Fossil Fuel Levy (FFL) accounted for 10% of customers' electricity bills and represented about 50% of the nuclear industry's income. At the time those plants that could be made more efficient were sold into private ownership and the levy was removed. However, it is argued (Thomas, 2002) that in so doing the longer term costs such as radioactive waste disposal and decommissioning have been shifted from today's energy bill to future generations of taxpayers.

Oil

The amount of oil used in the UK for electricity generation or domestic heating is insignificant, and yet oil prices have a profound effect on the prices householders pay for their fuel. The clearest connection has already been mentioned: the contractual pegging of European wholesale gas prices to oil price indices. There are other connections however, but these are indirect. Forward contract prices for both coal and gas tend to track oil prices, as traders use them as a key indicator. More broadly, oil prices underpin both regional economies and the global economic climate and thus affect large energy-related investment decisions. The factors affecting oil prices are too numerous and complex to mention here in any detail, however below is a summary of the primary forces affecting oil prices.

Broadly, on the demand side, there have been recent surges on the global market primarily due to the increases in economic activity in China and the USA, and to a lesser extent, India (DTI, 2004a).

In over 90% of oil producing countries, both OPEC and non-OPEC, the trend is for the growth rate of domestic oil demand to outstrip the growth rate of oil production. Net exports, therefore, will always tend to grow more slowly than domestic production.

Actual decline in production is also a factor. In the majority of non-OPEC producers (nearly all except Russia and some Central Asian producers), the rate of *decline* is increasing, despite technological improvements. For example, the OECD's largest three producers – the UK, USA and Norway – are losing capacity at around 4-5.5% per annum, where the *Oil and Gas Journal* estimated the UK decline in production at around 13% in 2004. In both the UK and Norway, these rates could increase sharply, despite any conceivable technological advances, due to the geological limits and the types of oil basins exploited offshore by these two countries (McKillop, 2005).

There are also competitive forces at play. Although OPEC can expect its share of world oil supply to increase over the next two decades, competition within OPEC, between OPEC and non-OPEC producers, and with other energy sources (notably natural gas) are expected to be robust enough to forestall any efforts by the cartel to raise oil prices significantly, in the longer term (Rivlin, 2000).

There are other unforeseen or uncontrollable geopolitical events that can compromise the security and supply, and therefore price of oil. For example the recent war and occupation in Iraq, pipeline sabotage in Colombia and civil unrest in Nigeria have all helped push oil prices to recent highs (Peterson, 2005). Similarly, while it is acknowledged that Russia has a key role in world oil and gas supplies, there remain 'enormous uncertainties surrounding Russia's energy future' (IEA, 2004). Finally, weather events linked to climate change are increasingly likely to affect fuel prices, particularly for oil and gas, as evident in the recent hurricanes in the gulf of Mexico, disrupting supply and pushing up crude oil prices (Associated Press, 2005).

Government, EU policy and renewable energy

Current and impending Government and EU policies will have further effects on fuel prices. The Energy White Paper estimates that distribution costs will rise, as extensions to the network will be needed to connect new sources – especially off-shore wind. These costs are estimated to be in the vicinity of £300m to £1,500m, depending on location (Ofgem, 2004b), whereas some industry experts believe the costs will be higher, although this will depend on how these are meted out between consumers and taxpayers (Electrical Review, 2005). What is clear is that more renewable energy will need to be brought on-line if the Government is to meet its target of sourcing 10% of all electricity from renewables by 2010, provided the costs are acceptable to the consumer.

To 2004, the Renewables Obligation added around 2% to the price of domestic electricity, and the DTI projects that, if set at 10% of total generation, the longer-term price impact will be a premium of about 4% (DTI, 2004a). Similarly, the Energy Efficiency Commitment (EEC) has a "small" effect on gas prices, and adds a 3% premium to the price of electricity by 2010. However, this will not affect all customers, since some will benefit from lower fuel bills due to increased energy efficiency achieved under EEC. Implementation of the EU Emissions Trading Scheme (ETS), based on a carbon price of €5-25/tCO_2 has been estimated to lead to price increases of between 3-14% in the UK, although the lower-end impact is more likely (ibid.).

Conclusion

It is arguable whether the low fuel prices seen since UK energy markets were liberalised have been achieved through greater efficiencies caused by market forces and tough regulation. They may have instead occurred due to 30-40% reductions in fossil fuel prices; the effective write-off of much of the pre-privatisation (state-owned) asset base; under-investment in generation, and the shifting of nuclear-related liabilities from current consumers to future taxpayers.

Factors affecting future domestic electricity and gas prices are likely to include the source and supply of conventional energy; its reliability, availability, associated production and infrastructure costs, and global demand. These factors are related to the development and cost of *alternative* production and generation technologies. Additionally, the nature of this relationship will be substantially influenced by Government and EU policy, and international agreements. The degree of cost internalisation imposed (e.g. through carbon taxes or emissions trading) and the degree of support granted to micro and renewable generation (e.g. via the renewables obligation, EEC or building codes) will affect fuel prices.

Fuel Price Scenarios

Having reviewed the factors involved in rising fuel prices, it is necessary to build alternative views of how these prices might change in the future, as it is not appropriate simply to increase one fuel price by a given percentage to obtain any real information for improving the fuel costs for a particular dwelling.

Other things being equal, rising fuel prices cause rising fuel bills, which are of particular concern to those who are, or are at risk of becoming, fuel poor. Because fuel is paid for per unit consumed (i.e. per kilowatt-hour, kWh), a percentage change in fuel prices has a much greater absolute impact on a large fuel bill than on a small bill. For example, a 10% rise in fuel price for a £1000 bill amounts to £100, whereas 10% of £300 bill is a more manageable £30. This means there is even greater urgency to reduce fuel bills for the fuel poor when they live in homes that are costly to keep warm or hard to heat.

Additionally, any intervention measure that generates fuel bill savings becomes more cost-effective as per-unit fuel prices increase. However, the *relative* cost-effectiveness of insulation and same-fuel heating measures will not change, because they both lower the amount of energy required by a fixed amount. Intervention measures that use different fuel types, however, will show shifts in cost-effectiveness relative to one another because price changes are non-uniform across fuel types. Renewable 'fuel' technologies (e.g. wind turbines) become especially cost-effective in comparison.

The scenarios below aim to help users select a view of the future that they consider to give plausible percentage changes in fuel prices. These changes have been calculated over a thirty-year period, as this is the maximum product lifetime amongst the measures modelled.

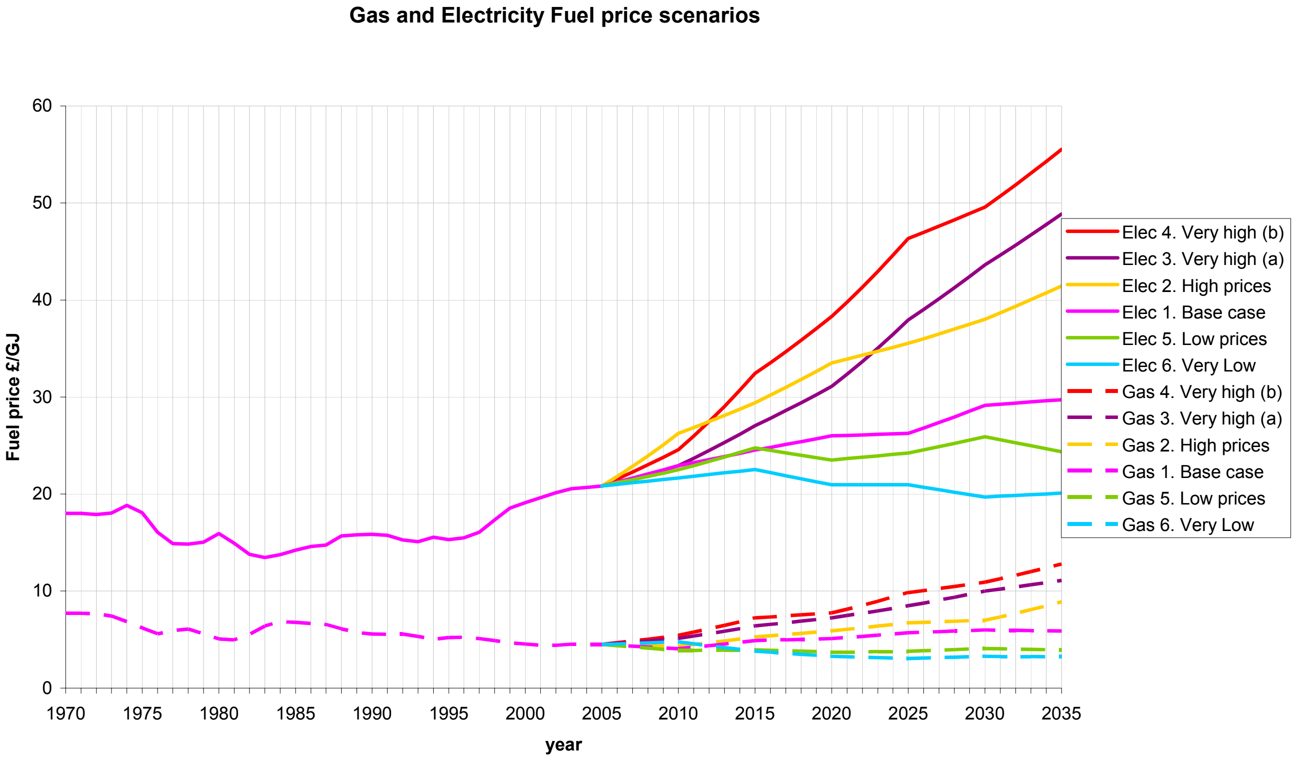

Figure 1: Gas and electricity price scenarios

The scenario descriptions below are intended to encourage the user to consider a range of factors that affect fuel prices, and so combine these in six different configurations, to produce six different price scenarios for each fuel. The trends of the scenarios are shown in Figure 1. These descriptions are intended to be internally consistent insofar as they describe the associated fuel price changes, but of course there are many other plausible configurations. The *Very Low* and *Very High* price scenarios are intended to denote plausible *parameters* to 2035.

The development of the scenarios was informed by other similar work, such as the Royal Commission on Environmental Pollution (RCEP, 2000) and the Chatham House "Open Horizons 2020 Scenarios" (RIIA, 1998). The DTI have projected trends in fuel prices to between 2005 and 2010(DTI 2004a), and these form the departure points for the *Base, High* and *Low* scenarios (highlighted grey in the tables below). These are the most recently published DTI domestic energy price scenarios. More recent revised fossil fuel price scenarios have been made available at http://www.dti.gov.uk/energy/sepn/fossil_fuel_price_assumptions.pdf.

In all the descriptions, 'short term' denotes from 2005 – 2010; 'medium term' is from 2010 to 2020, and 'long term' is beyond 2020.

Scenario One - Base Case

In this scenario, *energy demand is increasing* moderately from 2005, in line with current trends and in a context of *moderate GDP growth*. Over the *short to medium term fuel prices are rising*, and this is a feature common to all scenarios. In the short term, gas supplies are tight as the UK suffers from reduced North Sea gas production, while supply from the continent's more expensive gas reserves is also restricted, due to a lack of storage and transfer infrastructure. Looking to the medium term, gas from the continent becomes more readily available but there is a shortage in generation capacity, as existing generators reach the end of their economic lifetimes. This requires greater use of more expensive marginal plant, and demands further capital expenditure on new plant. These forces tend to keep prices high over this period.

In this scenario the long term sees the Renewables Obligation (RO) succeed till 2010, while nuclear capacity is halved, with only a few new reactors being commissioned. The ETS is tightened but gas pipelines from Russia lead to a moderate fall in both gas and electricity prices from their formers heights. Greater liberalisation of the European gas and electricity markets augments this trend, as greater decoupling of gas and the still-high oil prices is achieved. More CCGT technology is brought on-line.

Global political relations do not adversely affect UK fuel prices. Newer, cleaner coal-fired plant remains competitive and retains a role in the generation mix, despite being subject to higher carbon taxes. Energy efficiency policies continue with moderate success; 80% of cavity wall homes are filled where they can be and tighter building regulations are successfully implemented. Distributed generation remains low. The overall trend is one of moderate fuel price increases, broadly in line with price increases over the last twenty years.

Table 3: Percentage Change in Fuel Prices - Scenario One

Scenario 1 Base Case	% Change in price			
	Gas	Electricity	Coal	Heating oil
Yr 1-5 ('05-'10)	-10	10	7	16
Yr 6-10	21	7	-2	8
Yr 11-15	4	6	2	-6
Yr 16-20	12	1	8	7
Yr 21-25	5	11	3	9
Yr 26-30	-2	2	0	3

The overall assumptions for the changes in gas, electricity, coal and heating oil changes for the base case are shown in Table 3 above. The shaded figures shown are consistent with the DTI scenarios for Yr 1-5[10], the other figures are as determined from the underlying forces described above[11].

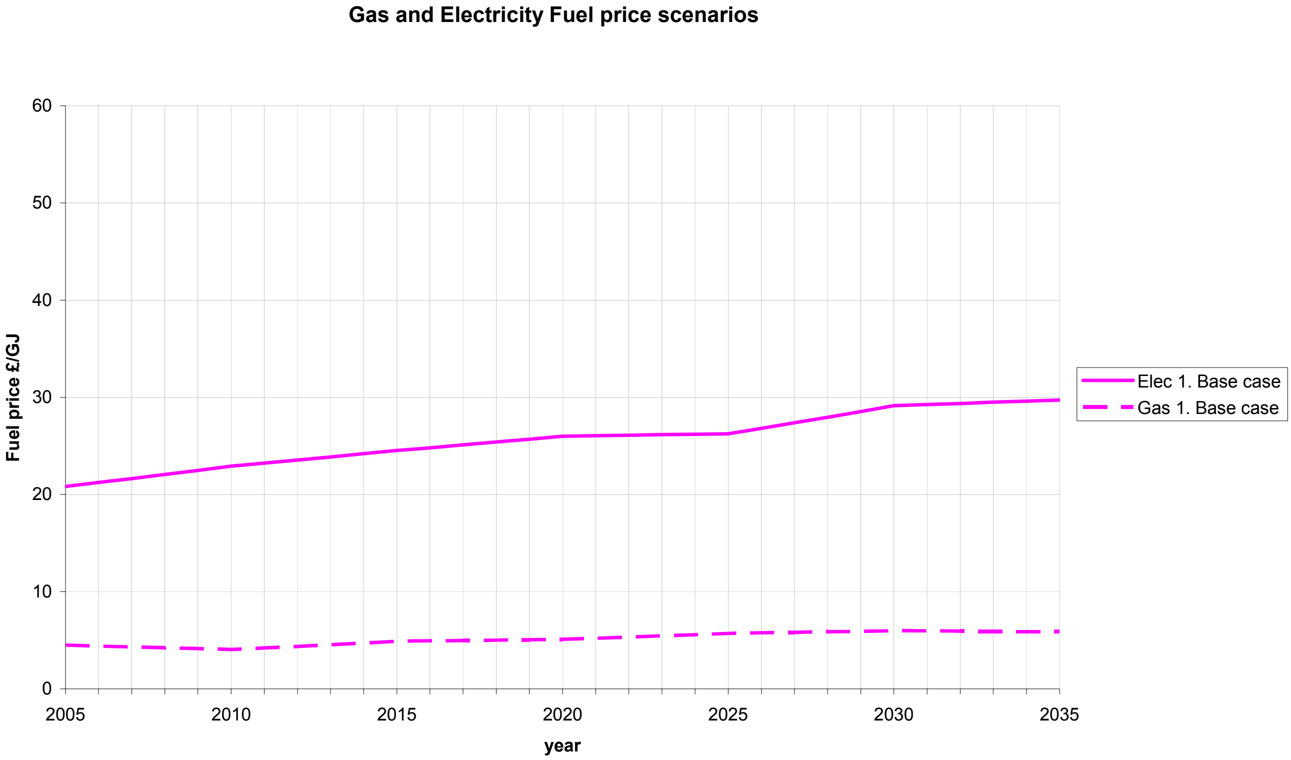

Figure 2: Gas and electricity fuel prices to 2035 – Scenario One

Scenario Two - High Prices

Energy demand is rising at a faster rate than in the base case. Consequently fuel prices over the *short to medium term are slightly higher*. Over the longer term, the Renewables Obligation (RO) to 2020 is met in full, mainly in the form of wind, wave and tidal technologies, with a new Obligation put in place beyond 2030. These place upward pressure on prices. Coal supplies are tight, largely due to strong demand in China and India. Older generators have had to be decommissioned and replaced due to the Large Combustion Plant Directive, or retrofitted with expensive scrubbing technologies. However, this form of generation is able to compete, as Russian gas supply remains rather measured in a context of strong continental demand. Although significant gas storage facilities and several continental gas pipelines have been built connecting the UK, European markets remain linked to global oil markets strained by continued security problems relating to US/Middle East conflict. The EU ETS is capped allowing fewer emissions than in the base case but energy efficiency measures lack the sophistication needed to reduce rebound effects[12] in buildings and the domestic sector generally.

The grey shaded areas in Table 2 below represent DTI projections. In this scenario fuel price increases are fairly uniform across fuel types.

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[10] DTI price projections for years 1-5 have been used in Scenarios 1 (Base), 2 (High) and 5 (Low).

[11] The year bands will be maintained at 1-5 etc. in order to provide consistency as time goes on. Only the labels of the charts themselves show specific dates

[12] Rebound effect – where as a result of a lower cost of fuel, more fuel is demanded to provide greater levels of the energy service previously restricted by cost

Table 4: Percentage Change in Fuel Prices - Scenario Two

Scenario 2 High Prices	% Change in price			
	Gas	Electricity	Coal	Oil
Yr 1-5	-4	26	22	27
Yr 6-10	22	12	14	4
Yr 11-15	12	8	12	7
Yr 16-20	14	6	18	15
Yr 21-25	4	11	6	21
Yr 26-30	27	7	9	3

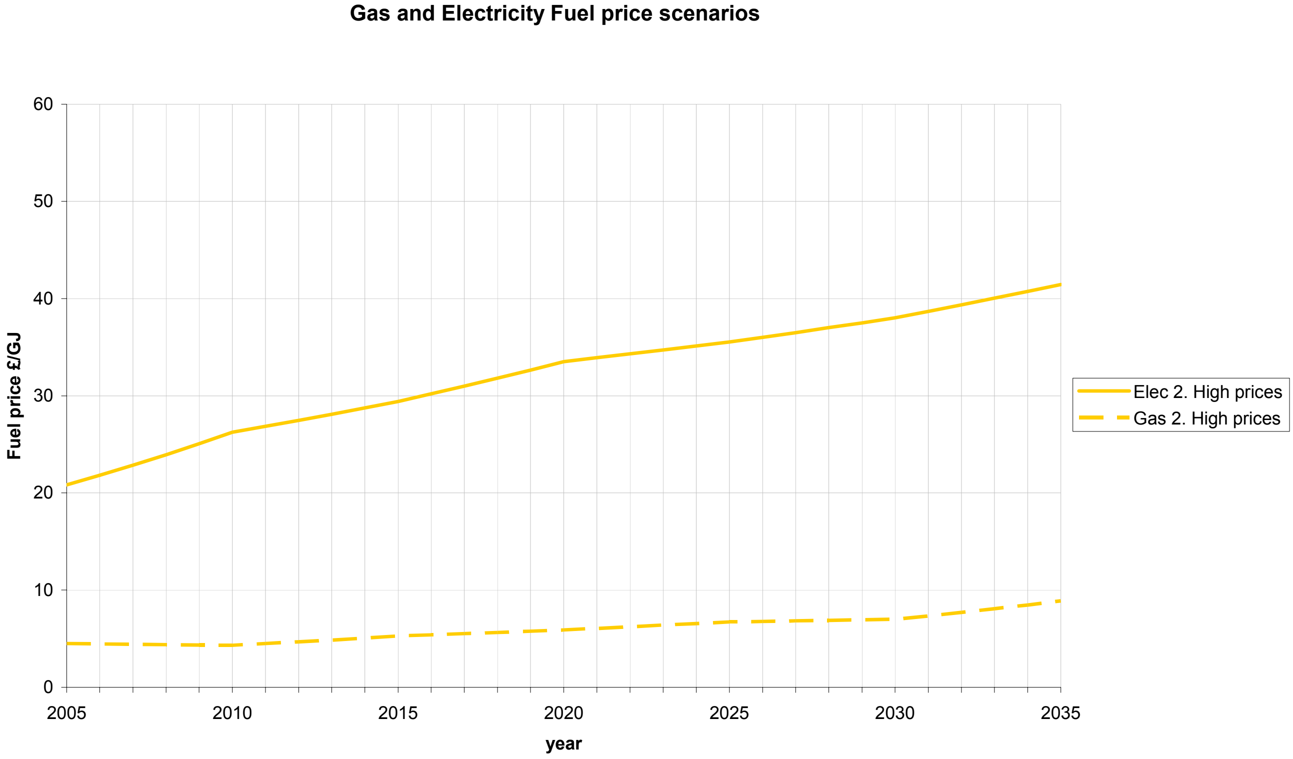

Figure 3: Gas and electricity fuel prices to 2035 – Scenario Two

Scenario Three - Very High Prices (a)

This scenario exhibits *short to medium term trends similar to those in the High Price Scenario*. Prices are very high in comparison to the base case (over double by 2035), due in large part to assertive energy conservation and cost internalisation policies. Taken together, this means that on average most householders spend similar amounts on fuel in real terms as they did in 2005. Fuel poverty, in line with current UK policy promoting fuel price-resistant housing, has been practically eliminated.

Stringent ETS quotas, extended throughout the business sector, have been successfully combined with a personal carbon allowance scheme (integrated with new identity cards) and the prevalence of energy services contracting. These schemes, together with a successful mix of Government incentives and Public-Private Partnership-based marketing initiatives eventually led to the phasing out of EEC-4.

Low and Zero Carbon (LZC) technologies have become significantly cheaper due to Government support, scale economies and technological progress. By 2017 micro-generation is practically mandatory for major refurbishments, *all* rented housing and all but the most 'passive' new buildings. Community heating and cooling becomes mandatory for all new large developments.

The Renewables Obligation (RO) is extended and by 2030 more than 35% of electricity is generated from renewable sources, mainly wind, wave, tidal flow and biomass. Nuclear generation is phased out due to stringent cost internalisation policies imposed by Government, and due to reduced energy demand in line with the Government's target to 2050. Modern coal-fired production survives having adopted (expensive) Carbon Capture and Storage (CCS) technologies.

As shown in Table 3, oil prices are volatile and high but, due to Government policies, have a moderate effect on the more stable prices of gas and electricity.

Table 5: Percentage Change in Fuel Prices - Scenario Three

Scenario 3 Very high (a)	% Change			
	Gas	Electricity	Coal	Oil
yr 1-5	14	10	22	34
yr 6-10	25	18	16	11
yr 11-15	13	13	19	6
yr 16-20	17	21	25	30
yr 21-25	16	11	20	23
yr 26-30	27	14	19	28

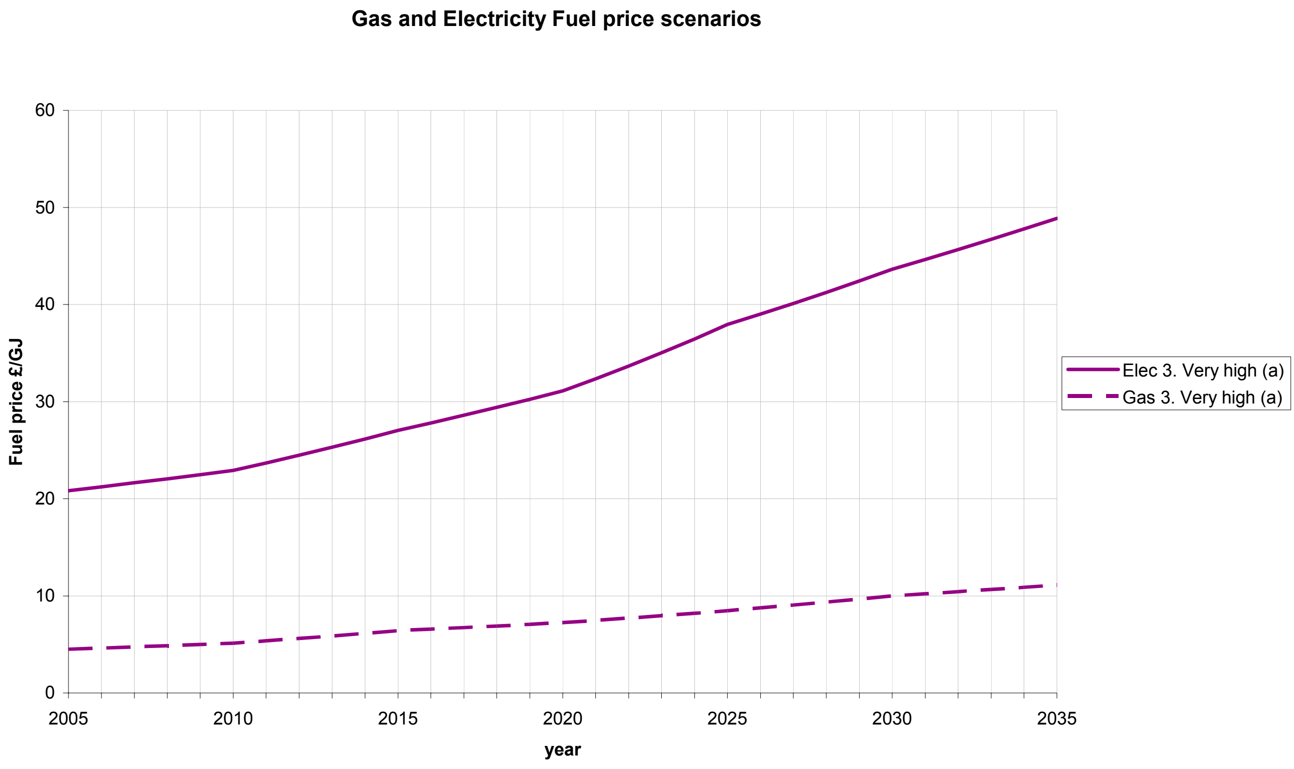

Figure 4: Gas and electricity fuel prices to 2035 – Scenario Three

Scenario Four - Very High Prices (b)

In this scenario global markets largely determine fuel prices. The ETS remains but imposes moderate limits, and the ROs 2015 and 2020 are not achieved. Nuclear-based production remains at current levels, although financial support from Government diminishes, as new reactors are commissioned. While European markets are deregulated, links remain between oil and gas prices, both of which soar due to strong demand in Asia and continued security problems in North Africa, Russia and Central Asia. Frequent disruptions to offshore oil and gas installations, particularly in the Gulf of Mexico, have been attributed to climate change. As a result of both security and climate-related disruptions colossal insurance premiums are now paid by extraction companies; as a result they have increased prices. Similarly, while cooling demand is on the rise and 'summer mortality' becomes an issue, the UK experiences some of the coldest winters on record, winter mortality rates climb and fuel poverty figures hit record levels. This trend is augmented by a recession, induced by high-fuel prices, which increases unemployment and leads to cuts in the Government's climate change budget.

Table 6: Percentage Change in Fuel Prices - Scenario Four

Scenario 4 Very High (b)	% Change			
	Gas	Electricity	Coal	Oil
Yr 1-5	21	18	22	24
Yr 6-10	33	32	25	30
Yr 11-15	7	11	20	8
Yr 16-20	27	17	18	22
Yr 21-25	9	7	18	12
Yr 26-30	21	10	14	22

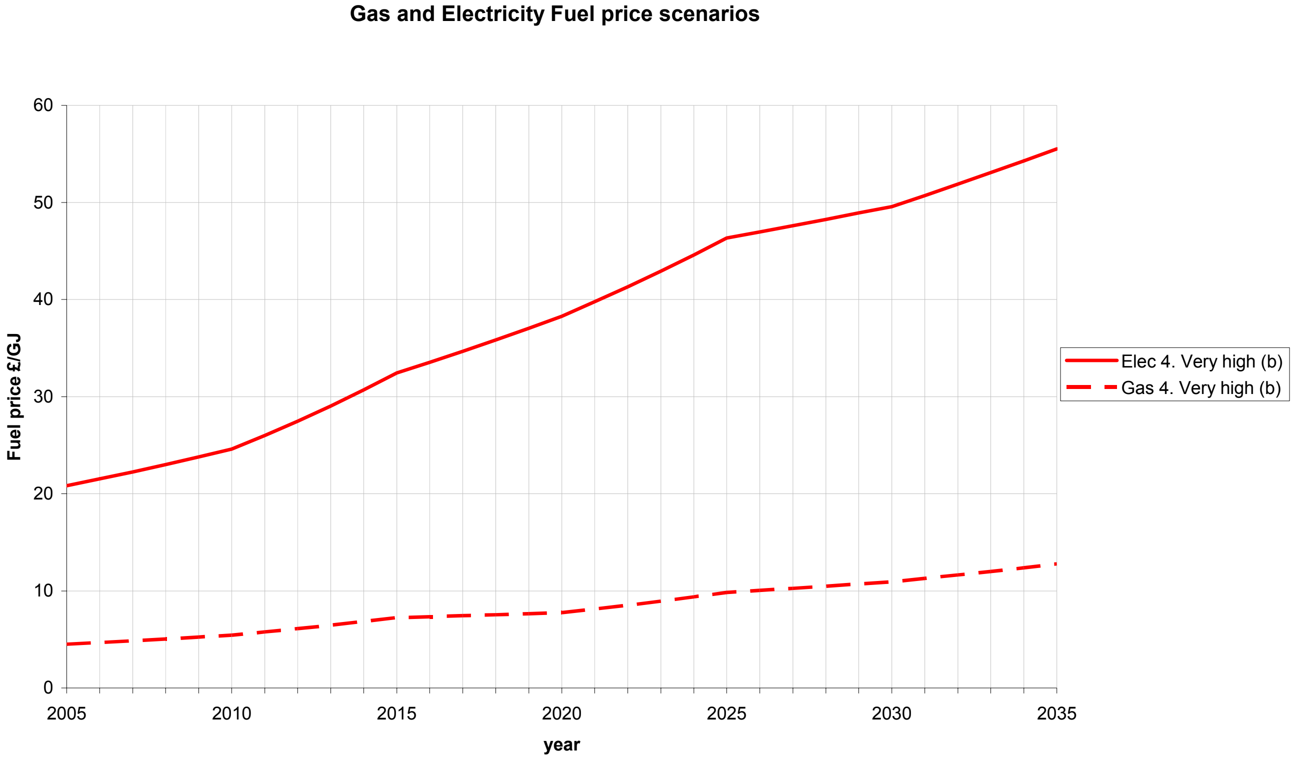

Figure 5: Gas and electricity fuel prices to 2035 – Scenario Four

Table 4 and Figure 5 describe these forces at work; gas and electricity prices are more volatile than in Scenario 3 and links between gas and oil prices are more evident

Scenario Five – Low Prices

Short to medium term prices are similar to other scenarios, but in the long run deregulation of the European energy market allows the UK access to cheaper gas. This, compounded by steady demand for coal in developing countries, effectively prices coal out of the UK market. Both coal and nuclear generation is usurped largely by cheaper gas and 'super CCGT' technology.

Over this longer timeframe *GDP growth is strong*, and the government has devoted significant funding to development of renewable energy systems. Technological breakthroughs in wind, wave and photovoltaic systems have meant that vast progress has been made in the production of energy from renewable sources, at little cost to the consumer. Energy efficiency policies suffer from continued low take-up, as the public remain largely disinterested in the substantial incentives offered by government. The significant presence of renewables in the generation mix tends to stabilise electricity prices. (See Table 5 and Figure 6.)

Table 7: Percentage Change in Fuel Prices - Scenario Five

Scenario 5 Low	% Change			
	Gas	Electricity	Coal	Oil
Yr 1-5	-14	8	10	15
Yr 6-10	2	4	12	3
Yr 11-15	-6	-3	8	6
Yr 16-20	2	1	7	8
Yr 21-25	8	2	N/a	-4
Yr 26-30	-4	-4	N/a	-8

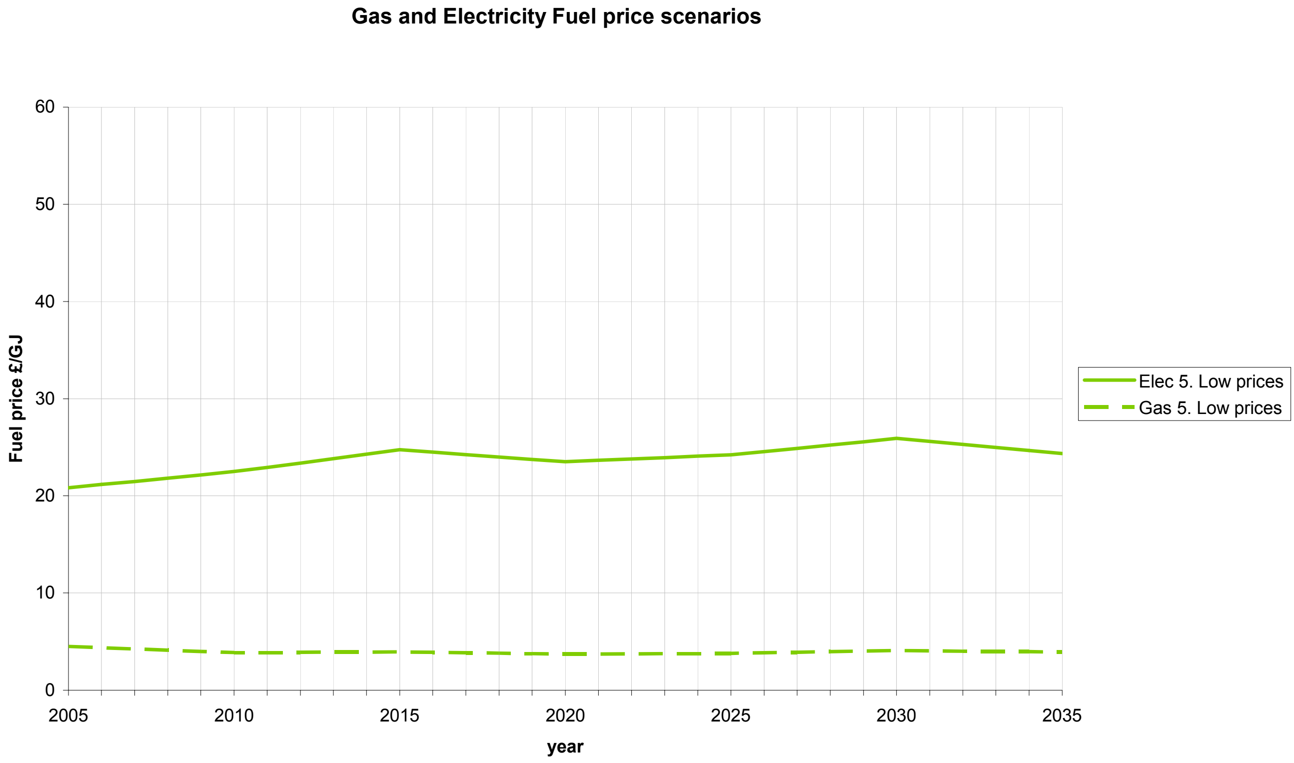

Figure 6: Gas and electricity fuel prices to 2035 – Scenario Five

Scenario Six - Very Low Prices

This price scenario is largely due to *plentiful fuel supply and weak demand* on global markets. Surplus fuel supply occurs as new gas and oil reserves are found in Russia and North Africa, and low global demand occurs as Asian economies decelerate while developed-world economies remain steady state or slow growing.

Table 8: Percentage Change in Fuel Prices - Scenario Six

Scenario 6 Very low	% Change			
	Gas	Electricity	Coal	Oil
Yr 1-5	6	4	8	7
Yr 6-10	-20	4	9	-6
Yr 11-15	-14	-7	8	-3
Yr 16-20	-7	0	n/a	4
Yr 21-25	7	-6	n/a	6
Yr 26-30	-1	-2	n/a	0

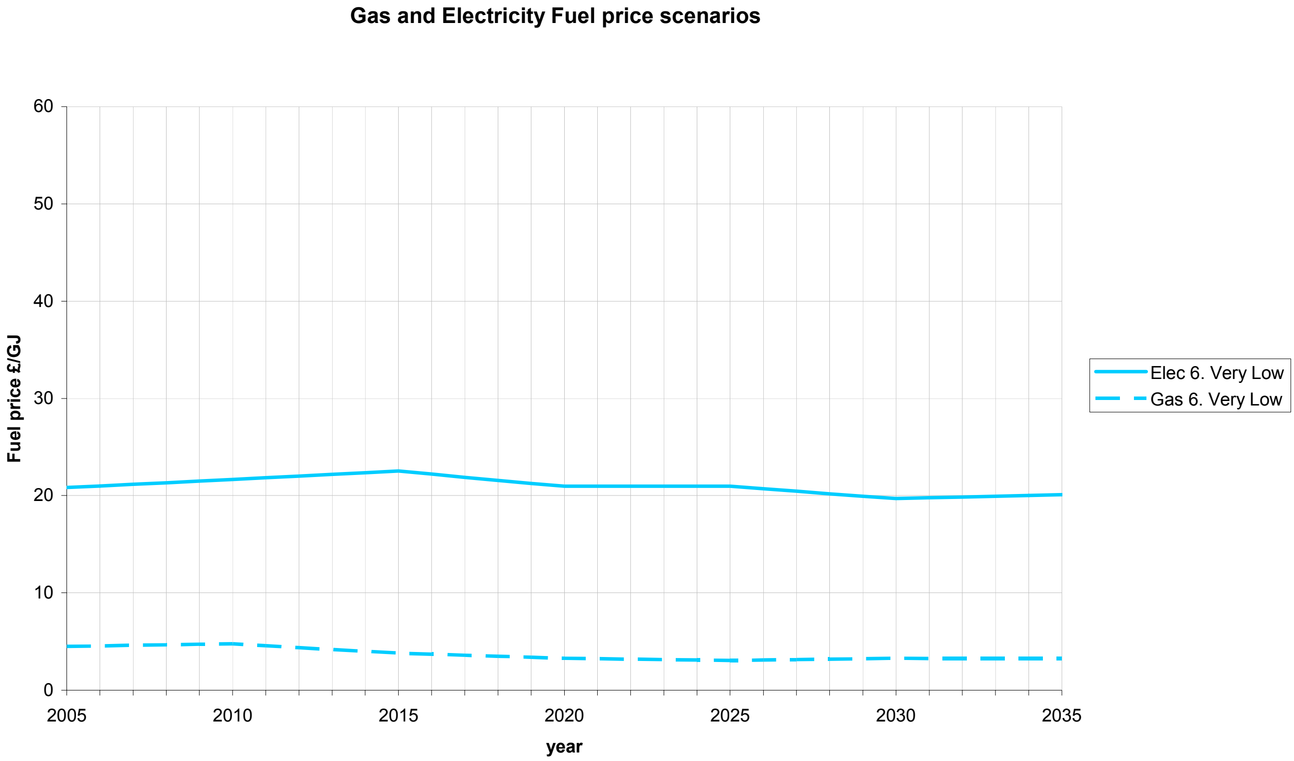

Figure 7: Gas and electricity fuel prices to 2035 – Scenario Six

Despite this global recession, the geopolitical climate remains stable. Within the UK, stringent new-build and refurbishment regulations combine with higher demolition rates to help stimulate the economy and maintain employment levels. Personal carbon allowances also help *reduce energy demand*. The Renewables Obligation to 2020 is achieved at little cost and Fuel Poverty is practically eliminated. Coal-fired production is unable to compete at these low prices and nuclear is phased out due to contained demand and public concerns over the storage and disposal of nuclear waste. CCGT technology remains the dominant source of energy, but is losing ground to renewable energy sources. See Table 6 and Figure 7.

Summary

This chapter identified the key factors that affect fuel prices in the United Kingdom. It then went on to show how these factors might combine together, and with new forces, to create six fuel price scenarios:

7. base case – moderate increase in demand, rising prices
8. high prices – higher demand and prices than base case
9. very high prices (a) – fuel poverty eliminated
10. very high prices (b) – record levels of winter fuel poverty; summer mortality due to heat
11. low prices – similar price to base case in short term but access to cheap gas in longer term
12. very low prices – plentiful fuel and weak global markets; personal carbon allowances

These scenarios are integral to the model, as they are used to illustrate how the cost-effectiveness of potential measures, when added to different dwelling types, change in both relative and absolute terms over time. The focus of this report now switches to the model itself, then the scenarios are used to identify key issues for hard to heat homes.

CHAPTER 3: DEVELOPMENT OF THE MODEL

In this chapter, four strands of the development of the model are described:

- Development of the base buildings
- Selection of appropriate measures and combinations of measures
- Development of the cost-effectiveness methodology and indicators
- Selection of fuel poverty and other indicators

It was not intended within this project to develop a tool that modelled the various measures, under different fuel price scenarios, in any given building; the aim was to provide a guide to the use of appropriate measures in a typical home, focusing on hard to heat homes, in view of possible future fuel prices. It is due to this focus on cost-effectiveness, and fuel prices looking forward, that the model has been called "Fuel Prophet".

Base Building Approach

As the main objective was to consider how fuel prices affect measures currently considered too costly in hard to heat homes, it was important to address those buildings that were of solid wall construction, were off the gas network, or both. It was decided that cavity wall dwellings connected to the gas network should be included for comparative purposes. It should be noted that whilst non-cavity wall homes include those with solid walls, some hard to heat homes have cavity walls that cannot be filled, and that there are other forms of non-cavity wall.

The approach adopted was to limit the buildings modelled to a series of theoretical or 'base buildings' that satisfied our main objective: this was to target primarily hard to heat homes in social housing. The English House Condition Survey (EHCS) 2001 (ODPM, 2003) revealed that most social housing consists of low-rise flats, terraced houses and semi-detached houses, and these formed the foundation for our base buildings. Detached housing was added in order to complete the profile of major house types in the UK.

Within each of these, further variants were added; by wall type and by heating fuel. This produced a total of 17 base buildings as shown in Table 9; a manageable number from a modelling point of view, with a sufficient mix of specifications so that most hard to heat social housing could be simulated.

Previous work by Transco (Hine & Lafferty, 2004; Transco, 2002) and National Energy Services (NES, 2002) had produced some detailed base-build specifications for hard to heat homes. Whilst arguments can be put forward for using a different set of specifications, it was decided to replicate these as far as reasonably possible due to their inherent robustness and for the sake of comparison and consistency. Full base build specifications for the semi-detached house can be found in Appendix One and all are included within the model.

Table 9: Base Building Summary (see key below)

Base Build	**Detached** (100m^2)	**Semi-detached** (85m^2)	**Terrace** (74m^2)	**Flat** (60m^2)
Wall / Heating type	Solid / gas Solid / electric Solid / coal Cavity / gas Cavity / electric	Solid / gas Solid / electric Solid / coal Cavity / gas Cavity / electric	Solid / gas Solid / electric Solid / coal Cavity / gas Cavity / electric	Solid / gas Solid / electric

Key:

Solid Wall Building	Wall U-value 2.1, no loft insulation
Cavity Wall Building	Wall U-value 1.5, 100 mm loft insulation, 50% double-glazed
Electric Heating	Electric storage heating Economy 7, 80-litre hot water tank
Gas Heating	Old gas boiler with water tank, radiators, programmer, thermostat
Coal heating	One open coal fire

The use of base buildings limited the outputs of the model to indicative values only, when applied to a housing provider's actual building stock. However it is emerging that the *relative* merits of each measure or measure combination, by any indicator, do not change when the building specification is slightly altered, even though the absolute values do.

Base Building Descriptions

Detached, semi detached and terraces

The previous work by Transco and National Energy Services used the same archetypal base buildings, including basic information on the building dimensions, fabric and heating system. Later work by Transco then increased the floor area of the base building by approximately 20%. Given that hard to treat homes tend to be older stock and that average floor areas are decreasing, the larger floor areas were adopted and the dimensions of the archetypal base buildings adjusted accordingly. For each base building, a plan was drafted to include the information required by Builder ™, the software used to derive each base building's energy demand (see below). Some specifications were altered so that the base building would represent a dwelling which could be constructed, rather than a mix of average dimensions from the housing stock which might not be feasible in a real building.

Flats

Adopting the theoretical or base building approach meant that the very diverse range of flats in the UK's housing stock could not all be modelled. So the more common, mid-floor low-rise flat types were developed as proxies. These base building variants reflect the greatest proportion of flats generally, but the thermal properties modelled will be at odds with a greater number of actual flats when compared to other base building types (i.e. the semi-detached building, for example, is more representative of the actual English stock). The flat base building dimensions were built upon the average floor area from the EHCS 2001 data and from examples of real floor plans of low rise flats provided by SPH Housing (Bird, pers. comm.).

Wall types

Brick is by far the most common material for house construction and can have either a solid cross section or a cavity between an inner and outer wall. Consequently these are the two wall variations modelled in all but the Flat base buildings, where only solid wall variants were modelled. The wall type also indicates the age of the building (Pett, 2004), and the level of insulation that is installed. Cavity wall houses are generally newer and have higher levels of insulation and the corresponding base buildings reflect this, as do the assumptions made in the latter Transco report.

Heating system

Only older housing is considered in this model and so generally the heating systems will also be older, simpler and less efficient. The most basic heating is an open coal fire, which has no distribution system or controls. Electric storage heating is more commonly found in hard to treat homes, especially where there is no gas connection. Gas central heating is currently the most cost effective of the heating systems *in the base buildings*, but there remains room for improvement, such as installing better controls and more efficient boilers. Every base building uses portable electric heaters for secondary heating.

Measure Selection

Ways of achieving savings

Heating the home can be split into a three step cycle:

1. The occupant must buy fuel, e.g. coal, electricity, or gas
2. The fuel is used to provide heat and distribute it around the house e.g. electric heaters, gas central heating.
3. The heat slowly escapes from the house and more fuel is needed.

In order to make savings and improve energy efficiency, it is more efficient) to work back through this cycle. Preventing the heat from escaping can be one of the easiest solutions. This is achieved by stopping the warm air from leaking out (draught sealing), and by reducing the rate at which heat conducts through the walls, floors and roof (insulating). Since this is a passive effect and reduces the total heat demand, it guarantees less fuel will be needed, regardless of any other factors (such as the efficiency of the fuel or heating system). From a technical standpoint, insulating and draught sealing should be the primary method of saving. This is because it is virtually free from maintenance, lowers the amount of heat required, and maintains a more even house temperature. Insulation is the component least sensitive to future changes in climate, economics, and technology.

Newer technology is able to provide useful heat from fuel at higher efficiencies than older designs. Good examples of this are condensing gas boilers and electric heat pumps. Therefore, less fuel is needed per unit of heat output and, assuming the heat requirement does not increase, savings will be realised.

If the technology for a particular fuel is limited, or different fuels vary in price, switching to a different energy source may be a solution. Primary fuels are also cheaper than a secondary source, i.e. electricity, so there can be savings by switching fuels even if there is no gain in efficiency. Micro-generation, including renewables, often *generates* energy more cheaply than it can bought, although it does not reduce the amount of heat or energy needed.

Calculating the saving

Given the measures and the base building, software was needed to calculate the typical annual energy consumption, split into fuel type and tariff. Builder™ is based on BREDEM (Building Research Establishment Domestic Energy Model), a simple, non-dynamic simulator which initially calculates the space heating requirement and then calculates how much fuel is needed to provide this given the heat losses, which depens on the insulation, and the heating system specification. Solar, wind and CHP are not modelled in Builder™. Solar PV and wind were assumed to produce 1,500 kWh[13] and 1,000 kWh[14] of electricity respectively, based on available data.

Micro-CHP efficiency has been rounded from Whispertech claims to 80% heat efficiency and 15% electricity. The electricity was subtracted from the overall bill and, in doing so, it is assumed that any excess electricity is bought by the supplier at the same price as it is sold (which may not be the case).

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[13] www.pv-uk.org.uk

[14] www.windsave.com/

Selection of measures

Measures to be modelled were selected with a view to improving the performance of the three step cycle: insulation measures to improve heat retention, heating systems to improve fuel efficiency, and micro-generation to reduce fuel use. Modelling common, existing products - and their corresponding performance values - would serve best when choosing measures and, in order to model a mix of micro-generation measures, some near-market products were also included (e.g. micro-wind turbines).

Fuel bills can also be reduced by other means, such as using more efficient, A-rated white and brown appliances, or different usage patterns adopted by the occupier, such as by using cold-cycle washes or using off-peak electricity. These issues are mostly beyond the scope of the model insofar as these variables are assumed to conform to a standard occupancy pattern.

For greater ease of use, the measures modelled were separated according to the three categories outlined above and shown in Table 10: building fabric (insulation), heating system, and renewable electricity micro-generation. It was considered useful for the model to allow the application of these in any reasonable combination.

Table 10: Measures modelled, by type

Building fabric	Heating system	Renewable electricity
Loft insulation Wall insulation: cavity Wall insulation: internal Wall insulation: external Draught stripping Compact fluorescent lights Double glazing Primary pipe insulation Insulation package L Insulation package C Insulation package E Insulation package I	Gas combi condensing boiler Ground source heat pump Air source heat pump Oil condensing boiler Wood pellet boiler Solar hot water Micro CHP	Solar PV Micro wind turbine

The performance of these measures within each base building was calculated by NHER Builder ™ software as explained in the previous section. Four insulation packages are shown in Table 10. These were introduced as there are measures that are cost-effective in the sense they are relatively inexpensive to install, but the effect on yearly energy bills is negligible when adopted in isolation. These measures were therefore bundled together. The packages each include one major form of insulation (e.g. cavity) as well as loft insulation to 270 mm, draught sealing, and compact fluorescent lights fitted throughout the house.

The last letter indicates the type of insulation added to the package:

- INSL – Loft insulation only, no wall insulation
- INSC – Cavity wall insulation
- INSE – External wall insulation
- INSI – Internal wall insulation

U-values for relevant measures were either calculated by the Builder ™ software, given the material construction, or were entered manually using values from the EST best practice guidelines. Data from the EST and other secondary sources were used to verify the calculations where possible.

Cost of measures

The model simulates 21 measures or measure 'packages'. However, when costing these measures, the following issues were considered and the solutions developed as shown.

Costs vary between sources

The initial installed costs of measures primarily came from four sources: the EST Save Energy website, the Hard to Treat best practice Matrix (EEPfH website), the 'Hard to Heat Homes' report (Transco, 2002) and from the later 'Community Household Energy Modelling – A study of hard to treat homes' report (Hine & Lafferty, 2004). These values were verified where possible with those from more commercial sources, and in some cases trade associations were also consulted. Wide variations in values led to assumptions, calculations or extrapolations by the research team. Further details are shown in Appendix 3.

In some cases, costs vary between 'base building' (e.g. full double glazing costs less for a flat vs. a detached house)

It was not always possible to obtain cost values tailored to the base building. This was addressed by weighting costs from other base buildings, using the relevant characteristic, such as ceiling area or number of windows. The model also allows the user to manipulate cost values, so more specific figures can be used.

Maintenance and administrative costs are debatable

Maintenance costs modelled generally follow estimates from manufacturers. Service contract prices were considered as conservative proxies for maintenance costs, although these too may vary.

Costs vary between similar products (e.g. Halstead vs. Riva combi-condensing boilers).

Where costs vary between products of the same type, the product most likely to be installed in social housing was chose or, where this could not be determined, an average was taken. However, it is essential that the measure corresponding with these new values achieves the same energy performance as the default measure costed, as applied to the base building in question rather than to the building the user is simulating.

Costs vary over time, especially with emergent technologies (e.g. micro wind turbines).

Costs will inevitably vary over time and this has been addressed by allowing the user to substitute default cost values with more current ones. It is also intended to update default values periodically, through verified submissions by users of the model.

In view of the Fuel Prophet's intended primary user (social housing providers), final costs vary according to bulk purchasing, funding and financing arrangements.

Features of the model include allowing the user to discount the costs in percentage terms and/or by a fixed amount. This, in addition to the feature mentioned just above, allows sufficient scope for modelling the bulk discounts and various grants and funding open to social housing providers.

Costs vary if marginal rather than full costing approach is adopted (e.g. when installing external wall insulation).

It was decided to use full rather than marginal installed costs, to minimise the risk of misinterpretation of model outputs. Therefore costs are inclusive of all the work undertaken and equipment and materials that need to be provided. For example, the external wall insulation value includes the cost of wall preparation, work to cables and pipes, the insulation and render to walls, as well as fitting beads, flashings, seals and joints. Heating systems will include fitting an entire central heating system where appropriate, including radiators, thermostats, programmers, and TRVs.

Amortised costs and NPV are affected by the lifetime of the measure, which is difficult to establish, especially in the case of new technologies.

Generally, manufacturers' guidelines were followed when establishing the economic lifetime of measures. This period is broadly determined by a measure's performance; once performance begins to deteriorate, its 'economic' lifetime is at an end, as replacement is preferable to high administrative, maintenance and discomfort costs. However, is recognised that, especially in the case of newer technologies, there is room for speculation over the values used. Consequently, in addition to the facility allowing users to amend costs, they can also amend lifetimes of measures. Lifetime significantly affects NPV and amortised costs, and is discussed in more detail in the section below, on indicators.

Grants and bulk discounts user input

It was thought desirable that users could modify the installed costs if they were eligible for grants or other funding. The EST website currently lists 60 different available grants in its database which vary depending on geographic region, economic situation and the type of measure to be installed. Grants and discounts available to large scale projects depend entirely on the proposed project, making it impossible to estimate. Two input cells are available instead for the user to add their own grants and discounts or to adjust the installation costs to match their estimates more closely. These facilities are in addition to that which allows installation costs to be manipulated directly.

Cost-effectiveness indicators

Developing a useful set of indicators was critical to the success of the project. The difficulties encountered derive from the multiplicity of the intended users' requirements when related to the indicators commonly used. For example net present value is a standard term expressing the financial potential of an investment as a sum of all costs and revenues (savings) over its life, in real terms. Yet potential users of Fuel Prophet may not be familiar with this term.

In its broadest sense, cost-effectiveness is a measurement which attempts to differentiate between, and rank options based on, the expense involved to achieve a given effect. The main indicators of cost-effectiveness provide information over different timescales. Basic cost-effectiveness gives the cost per unit impact which is measured over a product's lifetime. It is important to take the whole lifetime into account because there is generally a large initial capital cost which is followed by smaller, ongoing energy savings and maintenance costs. Perhaps un-intuitively, the more cost-effective a measure is, the closer the value [of what – NPV??] is to zero.

Problems defining 'cost' and 'effect'

The 'cost' considered arises from the initial installation cost and the ongoing maintenance cost of the product over its lifetime, whilst the 'effect' is to reduce fuel bills by saving energy and/or switching fuels. This fits well with social housing considerations, as the landlord bears the cost and the occupant receives the benefits. As the cost and benefit streams occur over time, both costs and effects were discounted, using the Treasury social rate of discounting, currently at 3.5%. The approach produces a single value, representing the sum of all costs paid by the housing provider and all savings to the tenant that result over the lifetime of the measure/s but represented in today's pounds. This is called end of life (EoL) net present value, and has been used as a key indicator. Also modelled (and graphed) is cumulative NPV, which illustrates how a measure's NPV changes over time (generally it improves, as most of the costs are incurred first, followed by savings/benefits that accrue over time).

A common measure of cost-effectiveness, used by Defra for assessing measures for energy efficiency programmes, is payback. It assesses how many years it takes for the value of energy saved to pay for the measures installed.

Further information on payback, NPV and treatment of NPV called amortisation is given below; readers familiar with, or not wishing to consider, the detail are directed to the heading "Calculating fuel consumption and savings" on page 26.

NPV and Discount rates

The difficulties surrounding discounting have been extensively researched and discussed and are beyond the scope of this report. However, intervention measures which have high initial costs and relatively low annual returns for long periods, sometimes over 30 years, are a classic example of the discounting problem.

The more controversial aspect of discounting states that society prefers benefits to be enjoyed now rather than later and, conversely, costs in the future rather than now. At the current social rate of discounting of 3.5%, this would mean a £100 saving 30 years from now is worth only £35 in real terms today. The effects of long lifetime measures, such as insulation, are therefore more adversely affected than shorter life solutions such as compact fluorescent lights.

However, the opportunity cost is an element of discounting which needs to be considered. New technologies and other intervention measures may prove more cost-effective in the future and, by choosing an expensive measure now, the opportunity to buy a different measure is foregone.

If there are no other constraints, the best investment will have the highest EoL NPV. The equation below shows the formula used to calculate NPV. Since there are constraints, plotting the NPV over time (*i*) provides more useful information than a single figure. The initial capital is shown at year i=0 and the payback period is given by the line's intersection with the x-axis (NPV=0), which is also a common indicator of cost-effectiveness. The gradient of the curve indicates the size of the saving and therefore whether it will have a significant effect on fuel poverty. The EoL NPV is the last point of the plot. Plotting the NPV gives robust quantitative data which can be used to inform more fully a qualitative decision based on many external factors which cannot be modelled.

$$present\_value = \sum_{i=0}^{lifetime} k^i \cdot (ongoing\_\cos t_i - annual\_fuel\_saving_i)$$

$$net\_present\_value = \left\{ \sum_{i=0}^{lifetime} k^i \cdot (ongoing\_\cos t_i - annual\_fuel\_saving_i) \right\} - initial\_\cos t$$

However, central to the rigour of this indicator is the EoL figure, and this has posed problems when modelling a combination of measures with differing lifetimes. The approach taken to date has been to model the combination for as long as the shortest lived measure. So if the combination includes a gas combi-condensing boiler (15 year lifetime) and cavity wall insulation (30 years), the NPV output will only reflect the savings accruing from the insulation for the first 15 years, effectively underselling its benefits. However if we were to model NPV according to the life of the longest living measure, we would have to assume some sort of heating system replacement, which is probably impractical.

Payback period

As a result of stakeholder consultations it became apparent that, for some housing providers, the choice of measures to adopt is constrained by minimum payback times.

While this value is indicated in the NPV graph, Payback has now been added to Fuel Prophet, as an explicit indicator.

The payback period is the number of years, *p*, it takes for the net savings to recover the initial cost.

$$\left\{ \sum_{i=0}^{p} k^{i} \cdot (annual\_fuel\_saving_{i} - ongoing\_\cos t) \right\} - initial\_\cos t = 0$$

where k=discount factor and i=index year.

The model solves the formula above but payback is often simplified by neglecting discounting:

$$payback\_period, p = \frac{initial\_\cos t}{annual\_fuel\_saving - ongoing\_\cos t}$$

This is a very similar form to cost-effectiveness and is easier to interpret in the real world. However, it ignores the time value of money (discounting) and the benefits a measure can provide beyond the payback period to the end of its life, favouring short lifetime measures over long lifetime measures.

Amortised NPV

Amortising spreads the initial cost into equal repayments over a number of years in a similar way as a mortgage. This can overcome the barrier created by large capital costs but will increase the absolute cost of buying since interest accumulates on the starting capital. The annuity factor calculates how the interest is spread over time, taking into account the repayments of capital, to give an annual figure as a fraction of the initial cost:

$$annuity\_factor = \left(\frac{\mathrm{int} \cdot (1 + \mathrm{int})^{lifetime}}{(1 + \mathrm{int})^{lifetime} - 1} \right)$$

$$amortised\_\cos t = annuity\_factor \cdot initial\_\cos t$$

Amortising can hide the long payback periods of larger, more expensive installations since, in effect, it is averaging out the end of life NPV over the measure's lifetime. This helps compare alternative measures with different lifetimes.

Amortised NPV is also graphed. It is modelled with amortised capital costs by applying the same method used with a one off initial cost. The plot will start at the origin since there are no year 0 payments to be made. The gradient will be positive if the annual energy savings are greater than the repayments or negative if the reverse is true. In this case, the gradient does not indicate the savings to a householder since it is a summation of the energy saving and installation costs. The EoL NPV is still given by the final plot point but the value will be lower for any given measure due to the interest payments accumulated from amortising.

Calculating fuel consumption and savings

Beyond indicating the year one saving to tenants, it was decided to illustrate how these savings might change over time, in view of changing fuel prices, to evaluate a measure's ability to prevent fuel poverty. Therefore, year on year saving to the occupier is graphed and can be compared to a fuel poverty line set at £500, which is currently 10% of the minimum annual income (£5000). (See 'Assessing fuel poverty threshold as an indicator', below)

The amount of fuel used by a household depends largely on the behaviour of the householders since every person has a different daily pattern and wants different levels of comfort. The vulnerable, for example, tend to spend a much larger proportion of their time at home and often require higher room temperatures to feel comfortable. These factors combine to increase the amount of fuel used compared to a younger, more active person in full time employment. It is also incorrect to assume that the fuel poor are able to heat their homes to the 'comfortable level' of 21 °C in the living room and 18 °C elsewhere. Installing a new measure will result, instead, in comfort taking and a warmer, possibly healthier living environment. This emphasises the need for effects to be measured upon a quality of life scale. Additionally those who under-occupy their homes will not heat all parts of them, and this heating pattern will be reflected in a lower fuel bill, when compared to that of an identical home, fully occupied.

These issues have been dealt with by adopting a standard heating pattern, produced by the Builder ^{TM} software. Consequently users will need to be mindful of the occupiers' heating patterns: measures added will produce greater savings in vulnerable homes and lower savings in under under-occupied homes than those indicated by Fuel Prophet. Manipulating heating patterns is possibly an area for further model development, but is outside the scope of this project.

Assessing fuel poverty threshold as an indicator

In England, the minimum income of a household is considered to be £5000 per annum if all benefits are taken. Theoretically, fuel poverty should be eradicated if the energy bill of all dwellings is £500 or less. The Fuel Poverty Action Plan aims to achieve a SAP rating of 65 as this is the 'level where there is minimum risk from fuel poverty' (Defra, 2004). For a dwelling rated SAP 65 the space heating and hot water bills will be £300 pa for a 80m^2 dwelling, i.e. a typical semi-detached base building. This leaves around £200 pa for appliances.

In real terms, the £500 threshold should not alter but the fuel bill may, as a result of rising fuel prices. Discounting is not needed because the fuel bill can only be faced in that particular year and therefore there is no time preference or opportunity cost.

The fuel poverty indicator is not a measure of cost-effectiveness but it clearly shows the significance of the savings which can be hidden in cost-effectiveness calculations. If the model is to be used to identify measures to eliminate fuel poverty then the fuel poverty threshold is an important indicator.

Other Potential Indicators

Also considered was the possibility of indicating the NPV of costs and savings separately, on the grounds of technical completeness. However, in view of the current indicators deemed necessary, these risked adding confusion rather than clarity, and so have been shelved. Restoring these indicators within the model would be straightforward.

A more detailed indicator of costs and benefits would consider the asset value and what the appropriate lifetime of a measure might be. For example, a homeowner who wants to install cavity wall insulation but is planning to move house in five years is not interested in fuel savings over the lifetime of the measure but will consider only the next five years and how the insulation will improve the resale value. This raises the questions: for whom is Fuel Prophet intended; and who else could benefit? For example in its current form the model can easily accommodate the needs of private investment property owners and owner occupiers, although the needs of these groups have not been established and they have not been consulted during this project.

The effect of some measures, from a technical perspective, is not limited to reducing heating costs. Cooling can be provided using heat pumps working in reverse. Insulation slows down the rate of heat transfer in both directions; this prevents the building from getting too hot in the summer broadly in the same way a thermos flask can keep liquids both hot and cold. These effects are particularly important given the expected increase in extreme weather conditions due to climate change: heating a dwelling during extreme cold weather can require more heat than a boiler's capacity since a boiler is rated to maximise efficiency during normal conditions and will perform at 100% load; extreme heat will encourage the use of energy intensive air conditioning units (already a rapidly growing market). These issues have not been addressed by the indicators used.

Carbon dioxide and SAP

Indicating how introducing various measures affect the carbon dioxide (CO_2) emissions of the base building, and how its SAP is affected, could be of benefit to both policy makers and housing providers. Therefore introducing these two indicators, despite the risk of cluttering Fuel Prophet outputs, is under consideration for later work.

Ideally, improving quality of life is the best benchmark by which to rate the effect of these measures. If the occupants are considered in isolation, the improvement in health could reduce medical bills, there may be improved performance at work and in education, and general physical and psychological well-being may increase. Evidence of these benefits exists (MRC, 2002) but the effects often depend on particular circumstances which are too complex to calculate and, more importantly, interpret. This is true to an even greater extent regarding the possible wider effects such as sustainable communities created and reduced load on the NHS, although employment potential through installation projects has been researched (Wade et al, 2000; NES, 2005).

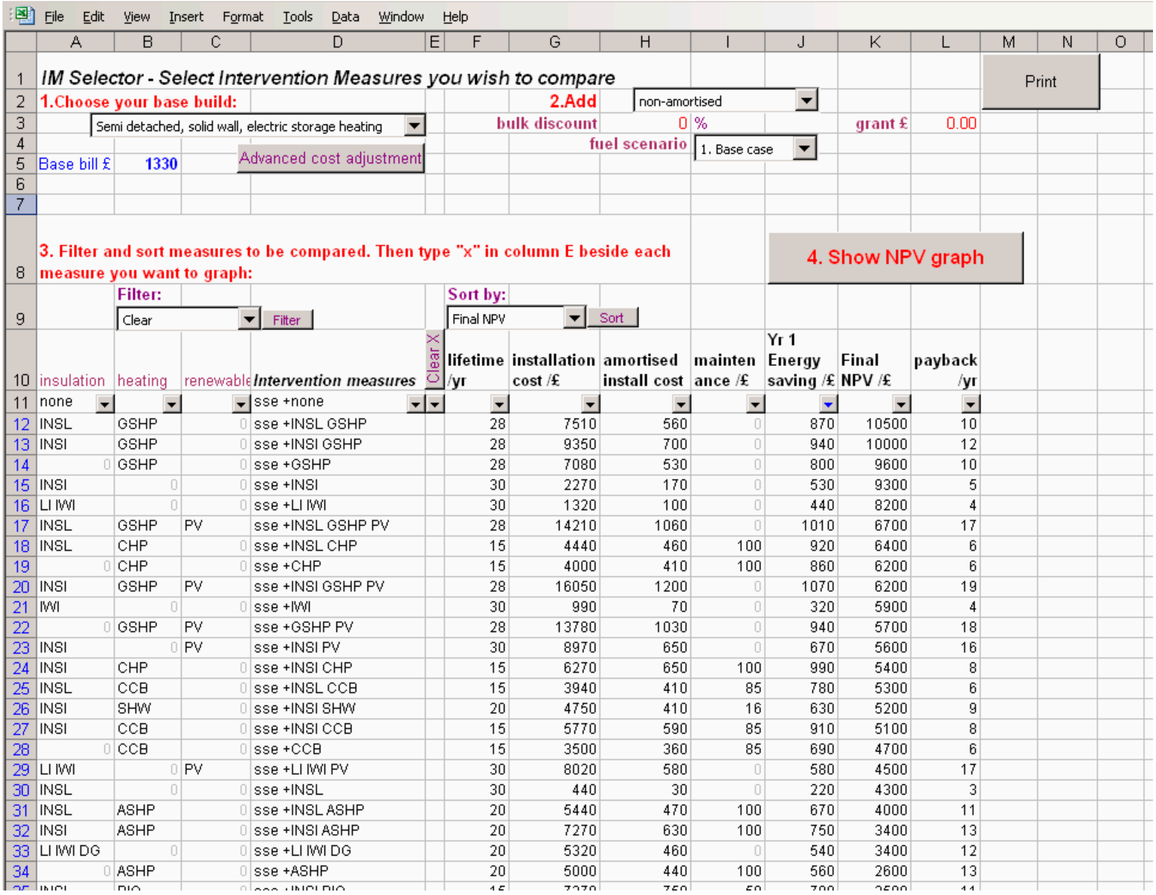
The benefits of measures, beyond the effects they will have on fuel bills, have not been incorporated into the model, and there is much scope for further work linking these issues.

CHAPTER 4: MODEL USE

In this section, the application of the model in the context of selecting measures that provide appropriate solutions to reducing fuel poverty in hard to heat homes is addressed. During the course of the project other uses became apparent, which have provided both information on the development of the interfaces for the project and a list of desirable elements and objectives for future development. However, the immediate objective is to describe the use and value of Fuel Prophet in its current stage of development.

Use of Fuel Prophet

The main controls in the model's interface are located on a single screen (see Figure 8 and an enlarged version in Appendix 5) that allow the data to be manipulated and the results presented, whilst hiding and protecting the original data and calculations. The model is a heuristic tool, not designed to be used with a particular procedure in mind; the order in which the options are manipulated below is chosen to demonstrate the available facilities. A flow chart of the process is shown in Appendix 4.



IM Selector - Select Intervention Measures you wish to compare

1.Choose your base build: Semi detached, solid wall, electric storage heating

2.Add: non-amortised

bulk discount: 0 %

grant £: 0.00

fuel scenario: 1. Base case

Base bill £: 1330

3. Filter and sort measures to be compared. Then type "x" in column E beside each measure you want to graph:

Filter: Clear

Sort by: Final NPV

	insulation	heating	renewable	*Intervention measures*		lifetime /yr	installation cost /£	amortised install cost	maintenance /£	Yr 1 Energy saving /£	Final NPV /£	payback /yr
11	none			sse +none								
12	INSL	GSHP	0	sse +INSL GSHP		28	7510	560	0	870	10500	10
13	INSI	GSHP	0	sse +INSI GSHP		28	9350	700	0	940	10000	12
14	0	GSHP	0	sse +GSHP		28	7080	530	0	800	9600	10
15	INSI	0	0	sse +INSI		30	2270	170	0	530	9300	5
16	LI IWI	0	0	sse +LI IWI		30	1320	100	0	440	8200	4
17	INSL	GSHP	PV	sse +INSL GSHP PV		28	14210	1060	0	1010	6700	17
18	INSL	CHP	0	sse +INSL CHP		15	4440	460	100	920	6400	6
19	0	CHP	0	sse +CHP		15	4000	410	100	860	6200	6
20	INSI	GSHP	PV	sse +INSI GSHP PV		28	16050	1200	0	1070	6200	19
21	IWI	0	0	sse +IWI		30	990	70	0	320	5900	4
22	0	GSHP	PV	sse +GSHP PV		28	13780	1030	0	940	5700	18
23	INSI	0	PV	sse +INSI PV		30	8970	650	0	670	5600	16
24	INSI	CHP	0	sse +INSI CHP		15	6270	650	100	990	5400	8
25	INSL	CCB	0	sse +INSL CCB		15	3940	410	85	780	5300	6
26	INSI	SHW	0	sse +INSI SHW		20	4750	410	16	630	5200	9
27	INSI	CCB	0	sse +INSI CCB		15	5770	590	85	910	5100	8
28	0	CCB	0	sse +CCB		15	3500	360	85	690	4700	6
29	LI IWI	0	PV	sse +LI IWI PV		30	8020	580	0	580	4500	17
30	INSL	0	0	sse +INSL		30	440	30	0	220	4300	3
31	INSL	ASHP	0	sse +INSL ASHP		20	5440	470	100	670	4000	11
32	INSI	ASHP	0	sse +INSI ASHP		20	7270	630	100	750	3400	13
33	LI IWI DG	0	0	sse +LI IWI DG		20	5320	460	0	540	3400	12
34	0	ASHP	0	sse +ASHP		20	5000	440	100	560	2600	13

Figure 8: Main user screen for Fuel Prophet

Selecting Options

Base building

The base building must be chosen first and should be relatively straightforward. The house type, wall type and heating system, in that priority, dictate thermal characteristics of the base building. A drop-down list holds the 17 available options. Selecting a base building loads the energy consumption information for all the available installation measures and calculates the fuel bills, NPV etc.

Choosing measures

Information and indicators for every available measure are available for view in the table below the drop-down box entries. (They can be adjusted by experienced users in a separate screen.) These include the component parts of a measure (insulation, heating and renewables), its lifetime, installation cost, maintenance cost, amortised installation cost, year one energy savings, payback period and final NPV. There are too many possible combinations of components for all to be analysed so these have been reduced to a reasonable selection of popular combinations. On the main input screen a list is displayed with abbreviated information; buttons and drop-down boxes allow the user to sort through the extensive list of measures quickly to select those of interest for analysis.

Filters

Use of filters will display particular subsets of measures, depending on the filtering criteria applied. One of three pre-programmed subsets can be selected using the 'quick filter' drop-down list to show measures of a single type, i.e. insulation only, heating only and renewables only. By doing so, component parts can be analysed in detail and unsuitable measures, including all combinations containing those measures, can be eliminated. This can quickly reduce the potential number of combinations.

Sorting

Analysing the measures is simplified by sorting them by the available economic factors. It is possible to sort the measures based on installation cost, amortised installation cost, payback period, year one energy savings, or final net present value, so that the most favourable combinations of measures are displayed first. The choice can be made from a drop-down list and will depend on what the user considers to be the most important cost factor. Measures can then be compared on a graph.

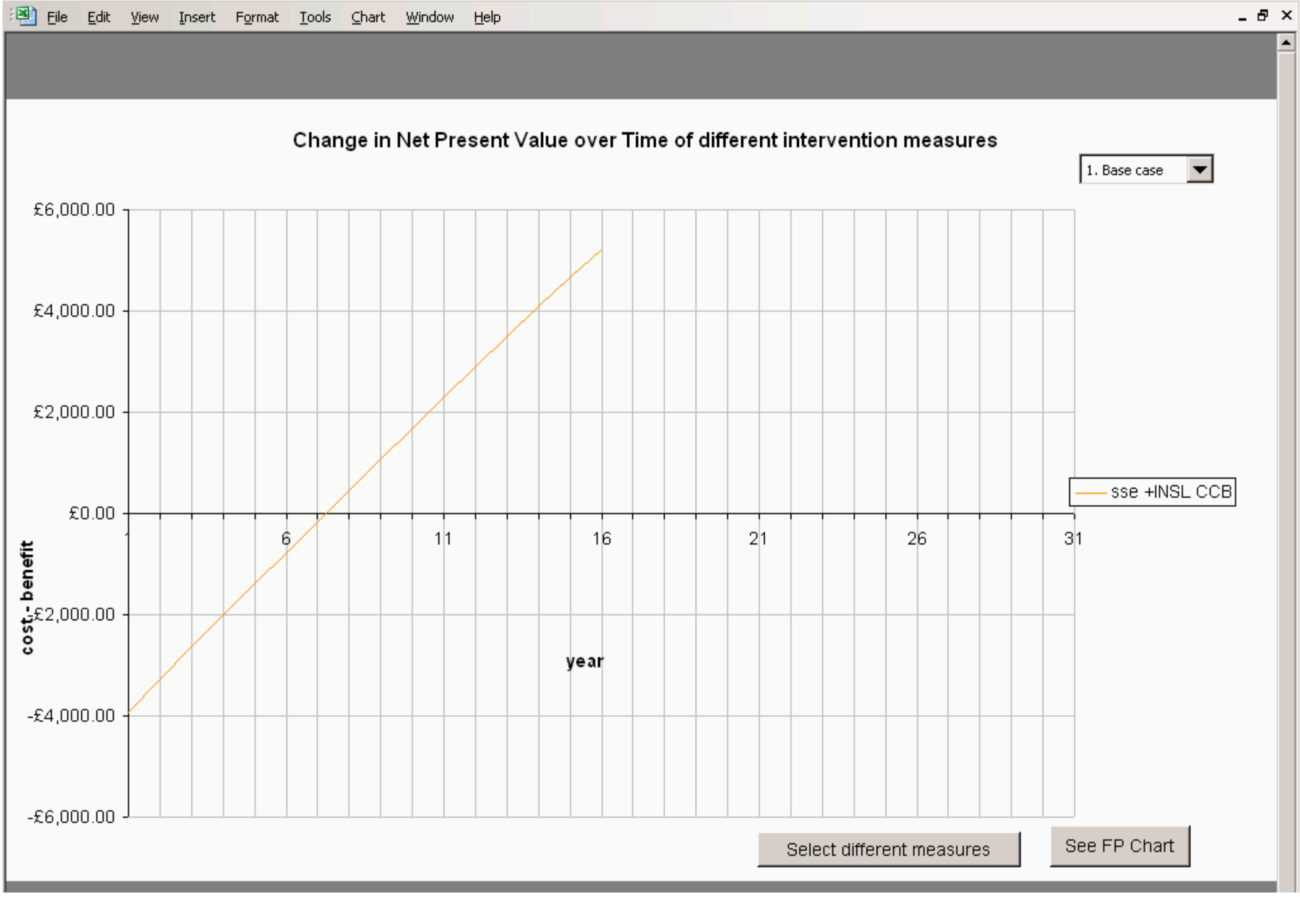


Figure 9: Cumulative NPV graph for Insulation & combi-boiler package, for solid wall semi with electric storage at present, under base case fuel scenario.

Graphing

Placing an 'x' in column E beside the measure selects it for graphing. The graphs must be accessed using button 4. Two graphs can be shown – first NPV then fuel poverty.

The NPV graph shows how the costs and benefits of the measure change over time, when applied to a base building. The chart shown in Figure 9 shows the output for an insulation package with a gas condensing combi boiler in a previously electrically heated solid wall semi. It is possible to amortise the costs to reflect different funding options.

> Non amortised analysis: Net present value is the difference between the expected total costs of ownership (TCO) of the installation measure and the base building at a given point in time, usually the end of life. If there are no other constraints, the best investment will have the highest EoL NPV. Since there are constraints, plotting the NPV over time provides more useful information than a single figure. The initial capital is shown by the year 0 NPV and the payback period is given by the line's intersection with the x-axis (NPV=0), which is also a rough indication of the cost-effectiveness [payback]. The gradient of the curve indicates the size of the saving and whether it will have a significant effect on fuel poverty. The EoL NPV is the last point of the plot.
>
> Amortised analysis: The plot will start at the origin since there are no year 0 payments to be made. The gradient will be positive if the annual energy savings are greater than the repayments or negative if the reverse is true. In this case, the gradient does not indicate the savings to a householder since it is a summation of the energy saving and installation costs. The EoL NPV is still given by the final plot point but the value will be lower for any given measure due the interest accumulated from amortising.

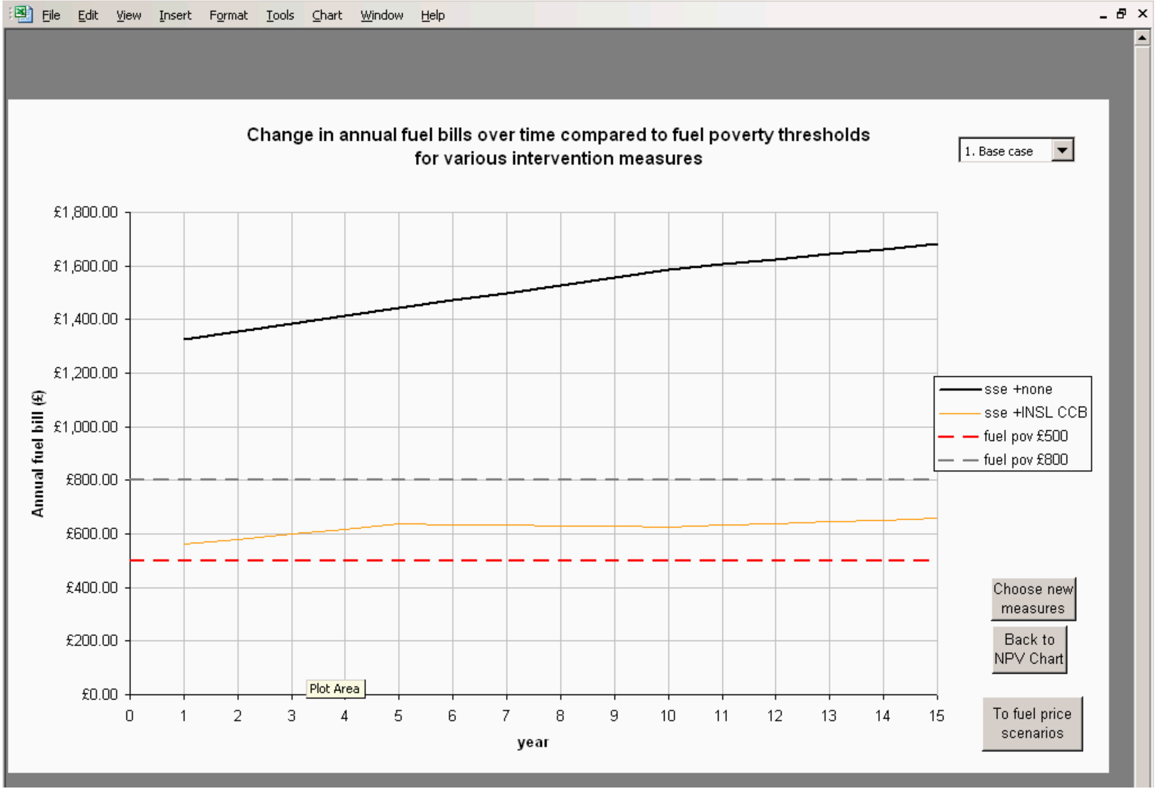


Figure 10: Fuel Poverty chart for same measures combination as Figure 9

The Fuel Poverty graph (Figure 10) shows the annual fuel bill, if the measures were installed, against the fuel poverty threshold £500 (red dotted line) and the bill in the base building (thick black line usually at the top). An additional £800 line is shown based on the fuel poverty definition using income excluding housing benefit and mortgage interest subsidy (Defra/DTI, 2001). The nearer the plot is to the bottom of the graph, the cheaper the fuel bill, and ideally the measure should fall below the £500 threshold to be sure the tenants will not be fuel poor.

The combination of the two should enable an informed choice of possible options to be made which are both cost-effective and present significant savings to the household. The model, however, does not include any practical issues which prevent a system from being used such as having no garden in which to locate a ground source heat pump.

Costs and Finances

Whether to amortise the modelled cost streams depends on the expected funding. If no loan is taken, the non-amortised cost stream should be selected from the drop down list. Percentage discounts and one-off grants can be applied in the cells below.

If a loan is taken, then choosing the amortised option will calculate the annual repayments over the lifetime of the shortest measure in the installation package, at the chosen interest rate. Grants and discounts can still be applied.

Fuel price scenarios

Selecting different fuel price scenarios, in either the main sheet or the box on the chart page, will redraw the graphs and show how the various costs are affected.

How Fuel Prophet works

The main input requirements needed to model the lifetime cost-effectiveness of the installation measures – fuel price scenarios, building energy consumption, and installation and maintenance costs – have been defined. The final outputs are a result of a series of changing cost streams such as the fuel price, installations costs, and fuel bills over 30 years.

Fuel Prices

The fuel price scenarios are converted into year on year percentage increases for each fuel type over the 30 year period, with each 5year increase converted into the equivalent 1 year compound rate. The annual energy price is, therefore, the product of the previous year's energy price and the percentage increase for each fuel type. The year 0 fuel price is the current fuel price quoted in the DTI Quarterly Energy Prices publication (DTI, 2005b).

Fuel bill

Multiplying the fuel price with the building's energy consumption gives the annual cost for the particular fuel type. This is calculated for every fuel type and every year and then discounted at 3.5%, the current social discount rate. The annual fuel bill is simply the sum of all the fuel types without discounting. This is plotted in the fuel poverty chart to show changes over time compared to the £500 fuel poverty line and the base building fuel bill.

The cumulative cost of energy over time is the sum of the preceding annual fuel bills, with discounting.

Funding, installation and maintenance costs

The installation cost is the sum of the individual measure installation costs. Maintenance cost is a fixed annual price discounted over time, representing the average cost of maintenance over a measure's lifetime. Additionally, it is possible to alter the capital costs of measures through grants and discounts.

Discounts and Grants

Discounts are a percentage reduction of the installation cost, and grants are defined as one-off cash sums. Discounts are calculated before grants and they are applied across all measures and packages.

Amortising costs

After discounting and grants, the costs can be amortised over the lifetime of the measure with a user-adjustable interest rate. For packages which include measures of varying lifetimes, the shortest lifetime has been used and plotted. Amortised costs will result in a fixed year-on-year sum comprising installation and maintenance. Non-amortised costs are made up of a single year 0 installation cost and ongoing year-on-year maintenance cost.

Total cost of ownership and net present value

These are the final calculations used to produce the graphs and indicators. Summing the cumulative costs of installation, maintenance and fuel bills, which have all been discounted, results in the total cost of ownership over time. The net present value is the difference in the total cost of ownership between the base building and the installation measure.

Net present value is plotted as the basis for cost-effectiveness analysis.

User Guide

A user guide has been developed to enable housing association users in particular to apply the model. This will be available on the project website as well as being designed into the instructions on the site itself. In the next chapter, the initial outputs from the model are analysed and preliminary findings drawn.

CHAPTER 5: ANALYSIS OF FUEL PROPHET OUTPUTS

The best measure to choose depends on its cost-effectiveness, the size of the saving needed, and its suitability to the particular situation. The ideal measure would be quick and easy to install, cost-effective, and achieve the required level of savings to the tenant, which are all dependent on the base building and the fuel price scenario.

The original concept for this research would have led to a simple table through which it was easy to see what types of measure are most effective in reducing fuel poverty given different fuel prices. Unfortunately, as shown in the report so far, the model is far more advanced and requires extensive testing to be confident that the first indications analysed below apply to all base buildings, under all fuel price scenarios and under all methods of indicating cost-effectiveness.

The model developed has created approximately 100,000 possible combinations to analyse, which is clearly outside the scope of the project as it stands. Analysis presented here is therefore limited to general effects relating to house type, wall type and fuel type, then further comment is based on the **semi-detached, solid wall, electric base building** variant, unless otherwise explicitly stated.

House type

Between terraced, semi detached, and detached houses, given the same initial wall and heating type, the cost-effectiveness of one measure relative to another does not change. This is because the difference in savings is reflected in the cost of installing the measure. For example, a terraced house will need less heat and save less heat, therefore a smaller and cheaper gas boiler is installed.

Within the same house type, with differing wall and/or heating, the cost-effectiveness of a particular measure will change because each base building has a different initial fuel bill. For example, loft insulation is more cost-effective in a semi detached house with electric storage heating (high fuel bill) compared to a semi detached house with gas central heating (lower bill).

A mid-level flat has very little exposed area which makes it naturally more efficient than houses. This results in lower cost-effectiveness for installing measures but also means less needs to be done to bring the fuel bill below £500. It is also not appropriate to install a wide variety of measures such as loft insulation as the flats above and below buffer against heat loss (ceiling or floor insulation could be incorporated if necessary). A solid wall, on gas, mid-level flat should not be classed as hard to heat, because its fuel bill is below £500 and it has a SAP of 70.

Looking at payback times and final NPV, installing a measure in a more efficient house is less cost-effective. This implies that the priority for measures should be the least efficient (and probably the more costly to improve) dwellings.

Wall type and insulation

Wall type has two implications for the model. Firstly it indicates the age of the building, as solid wall buildings are generally older than cavity wall buildings. Secondly it creates an initial premise for the insulation provided by the unimproved dwelling (solid walls being of lower insulation value than cavity walls). Therefore wall type has a significant effect on the suitability of new building measures. Of all the insulation measures, wall insulation provides the largest savings, which in the case of cavity and internal wall insulation is also very cost-effective. The curves for these are shown in Figure 12. The external wall insulation package has the longest payback period and the lowest final NPV, as shown in Figure 11, although it has been costed at full price rather than at marginal cost. However, it also responds best to the fuel price scenario because it achieves the greatest savings. If the very high fuel price scenarios were realised, payback could be achieved in 15 years and the final NPV (after 30 years) is the same as that of the loft insulation package.

External wall insulation is also used as an additional measure when treating older walls to prevent rain penetration or dampness. The cost-benefit of this has not yet been modelled.

Solid walled houses often have minimal loft insulation; in this situation, loft insulation is the second most cost-effective measure with the second most significant savings. Topping up loft insulation from 100 mm to 270 mm has a much smaller effect because the improvement in U-value is far less and whilst it still has a positive NPV, the payback is much longer and the savings are small compared to wall measures. However it is considerably cheaper.

Due to the low cost, low maintenance, and long lifetimes of many of the smaller insulation measures, they show very short paybacks, good final NPV and should be considered in packages. The smaller, longer return in savings means that they are more resistant to changing fuel price scenarios. However, insulation appears unable to produce fuel savings as large as more efficient heating, and only a base building connected to gas can be brought out of fuel poverty with insulation alone. The temperature regulating property of insulation makes it ideal to mitigate extreme weather effects (including hot weather) which heating systems cannot, but this is currently outside the scope of policy and this project.

Finally, double glazing is the least effective insulation measure in the context of fuel poverty because it has very high installation costs and offers only low savings to the tenant.

The cost-effectiveness of the insulation packages fall into the following hierarchy (best to worst).

Insulation package with Internal wall insulation (INSI) (for solid wall dwellings)
Insulation package with Cavity wall insulation (INSC) (for cavity wall dwellings)
Insulation package with Loft insulation only (INSL) (both)
Insulation package with External wall insulation (INSE) (for solid wall dwellings)

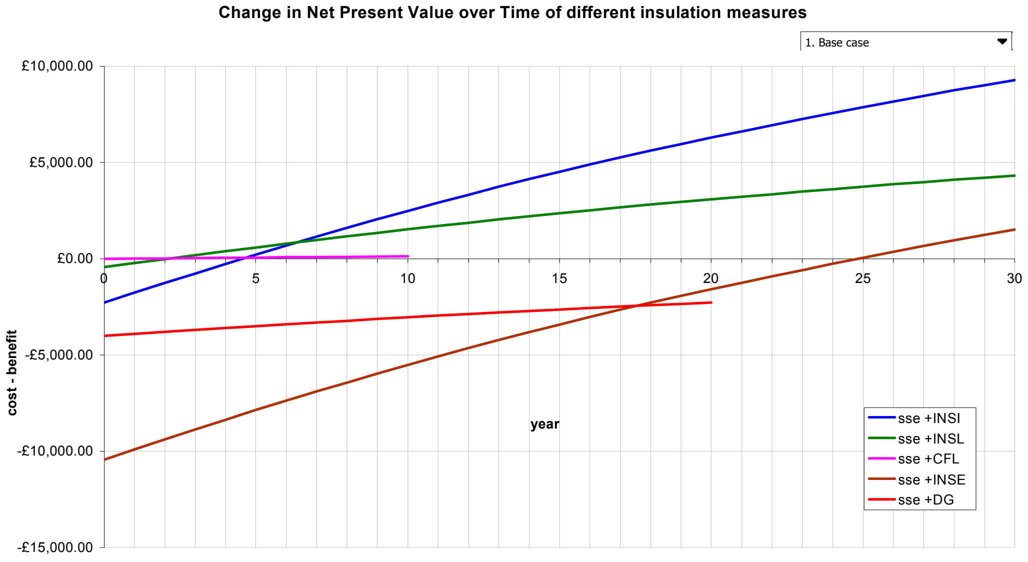


Figure 11: Comparison of insulation measures under base case fuel prices

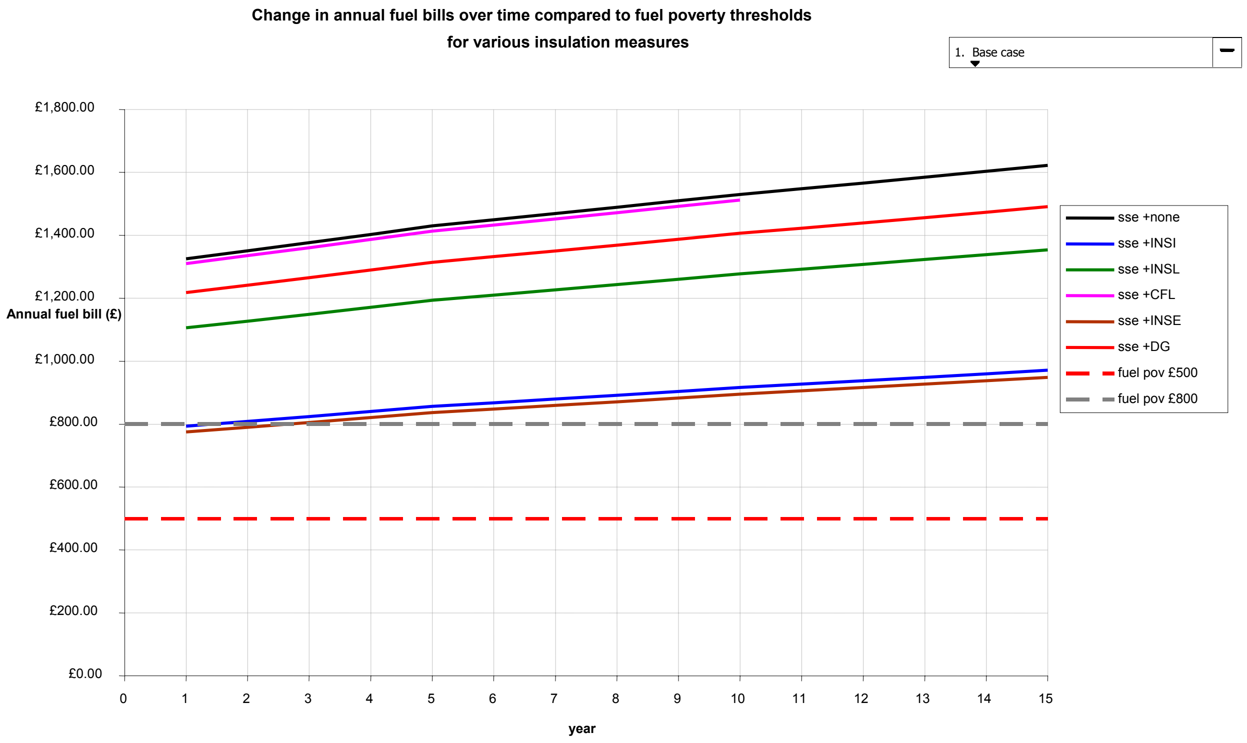
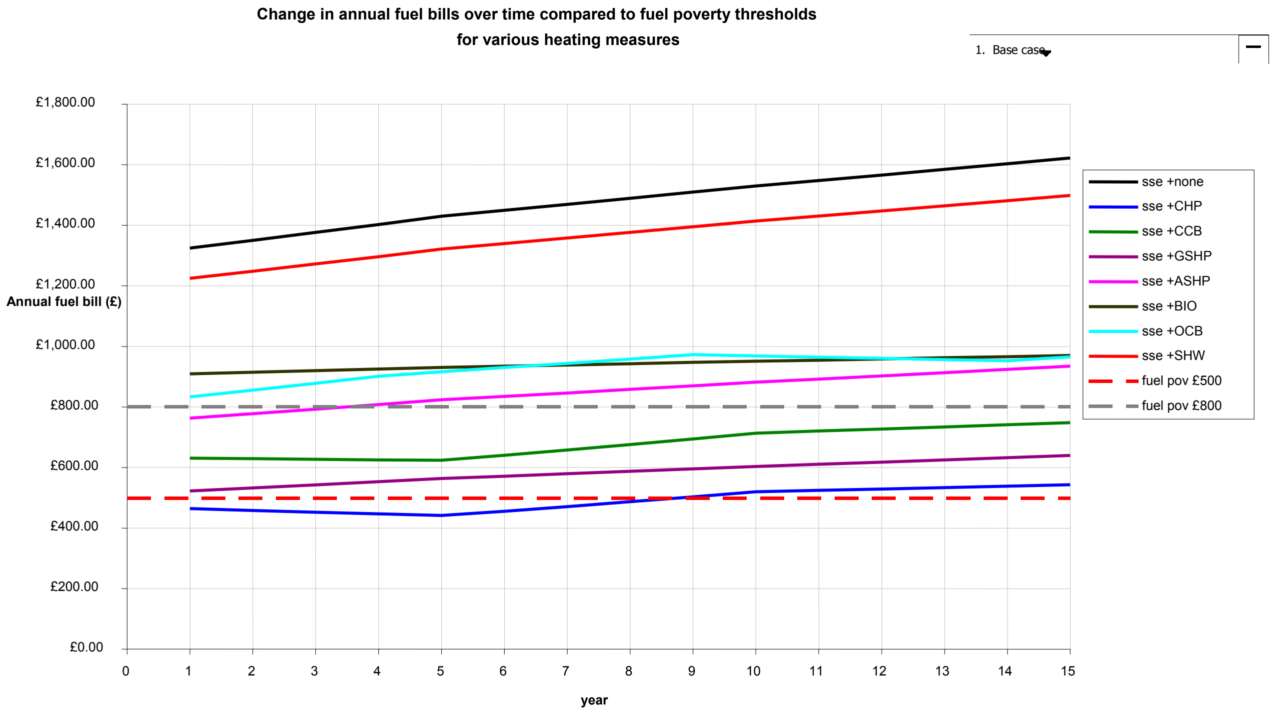


Figure 12: Fuel costs for insulation measures over time

All the insulation packages include the small, low cost-effective solutions, i.e. compact fluorescent lights, draught sealing, and loft insulation to 270 mm.

This means that for a solid wall semi-detached house with electric heating, the insulation package with internal wall insulation is preferred, unless the condition of the walls means that refurbishment work is required anyway, in which case the cost of external wall insulation should be revised and the ranking reviewed.

Figure 13: Reduction in fuel bills for different approaches to heating



Fuel type and heating system

Improving the efficiency of the heating system is the single most effective measure for reducing fuel bills, all other things being equal. This can be considerably more expensive than insulation, however, if the building is off the gas network and without a central heating system already. The heating system also dictates the fuel type and thus, for more difficult properties, more alternatives need to be considered.

If all fuel types are available, the most cost-effective solution based on the model and using currently available data is a micro-CHP unit followed by condensing combi-boiler, ground source heat pump (GSHP), air source heat pump, and biomass boiler (see Figure 13). An oil condensing boiler only pays back under high and very high (b) fuel price scenarios, however, it does not take a dwelling out of fuel poverty, even in combination with a full insulation package. This initial finding has significant implications for the new Warm Front grants.

Solar hot water does not pay back its installation costs and the savings are small.

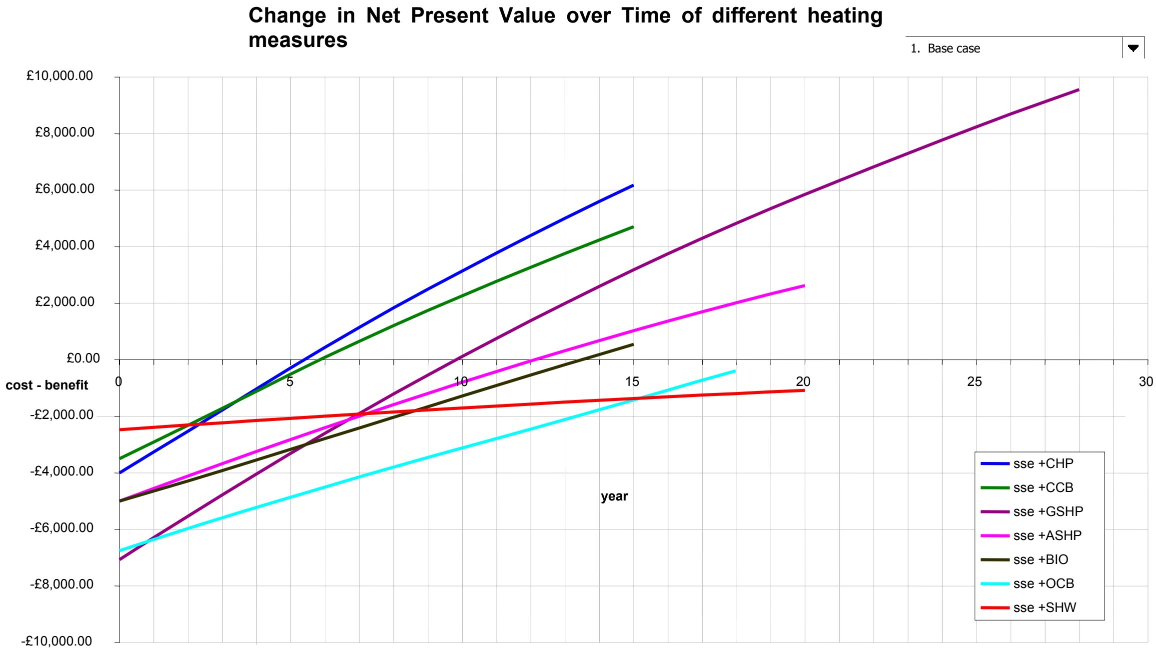


Figure 14: Cost-effectiveness measure (NPV) for heating measures

This ranking is due to the low price of domestic gas (1.6p/kWh) and the higher price of electricity (6p/kWh). Micro-CHP is best able to take advantage of this by consuming cheap gas to produce heat relatively efficiently and offsetting the electricity cost by producing electricity itself with the energy that might otherwise be wasted. It should be expected that new technology will produce the greatest savings; otherwise they would not be introduced to market.

The effective efficiency of heat pumps (COP 3-4) is able to offset the difference in energy price and, under the fuel scenarios modelled, there is no change in relative cost-effectiveness compared to the other heating measures. Furthermore, GSHP has very low maintenance costs[15] and a longer lifetime than the boilers, a significant saving to

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[15] According to the heat pump manufacturers, no maintenance is required

the tenant that offsets the very high capital costs, to produce the highest NPV of any single measure (Figure 14).

Off gas base buildings have been modelled without a heating distribution system (i.e. radiators etc) which creates a large additional cost for installing a central heating system needed for heat pumps and boilers. This factor pushes down the cost-effectiveness of heating systems but has no effect on the energy savings. However, the lifetime of the distribution system is much longer than the average 15 year lifetime of the boiler. It can be assumed that the added efficiency of a new distribution system will extend to any subsequent heating system and increase its cost-effectiveness but this cannot be demonstrated in the model.

Renewables

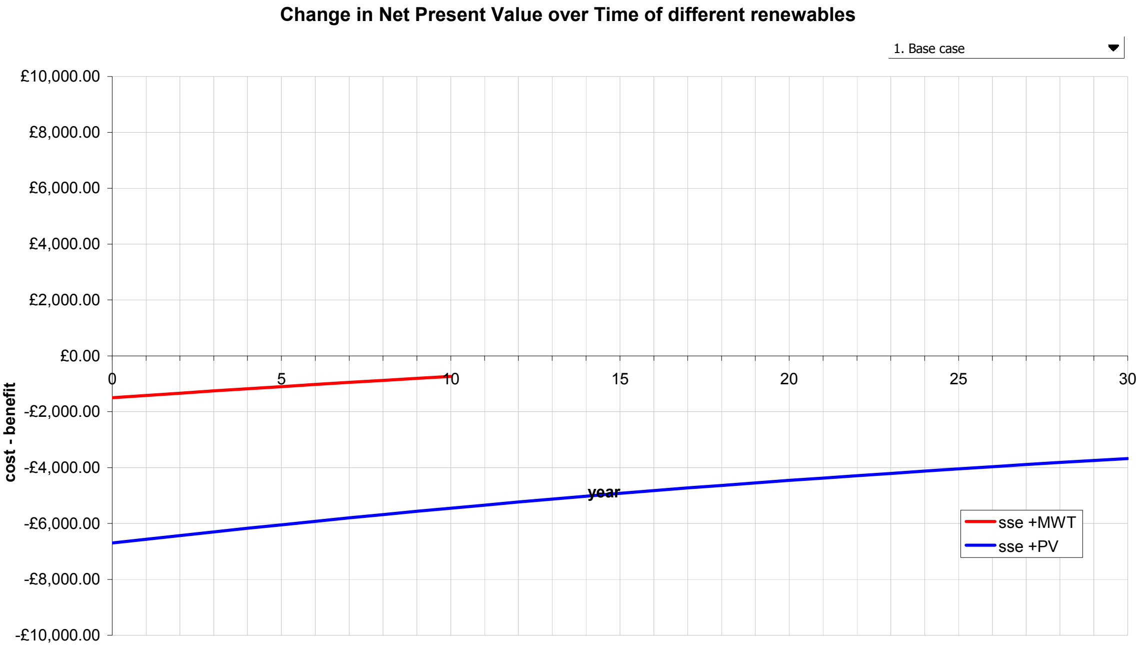

Figure 15: Change in NPV for renewables

Photovoltaic panels (PV) and micro wind turbines (MWT) are the only renewables considered since solar hot water is classed as a heating system. As currently modelled, the installation cost of PV is over 4 times higher than MWT (£6700 cf. £1500) but does not produce 4 times the electricity (1500 kWh cf. 1000 kWh). However, without significant financial assistance, neither option is cost-effective (Figure 15). Energy production from wind, due to significant regional variations, has meant market claims range between 500 kWh – 4000 kWh annual energy production. Another factor which has not been modelled is the eligibility of renewables to receive Renewable Obligation Certificates (ROCs). Valued at £63 per 1000 kWh *of energy produced* this can produce a significant second income stream. All these variations suggest that the model outputs with regard to renewables may require further analysis.

Fuel Price Scenarios

The highest fuel bill increases will result from the highest fuel prices and the highest initial fuel bill. An untreated base building will therefore always show the biggest rise in fuel bill and high fuel prices makes every measure more cost-effective, particularly the measures providing the largest savings, such as external wall insulation and micro-CHP.

Under the highest fuel price scenario, to guarantee a household does not become fuel poor in the next 15 years energy bills must be reduced to a total of around £300. This will offset the approximate 60% increase in fuel prices over the next 15 years. A pro rata adjustment could be made to the other high price scenarios. The standard package of wall insulation and combi-condensing boiler does not achieve this – it will be necessary to install further measures within the next 10 years. For an off gas house, this target cannot be reached without using new technology and renewables.

Solid wall, open coal fire

Open coal fires are extremely inefficient; the base build energy consumption equivalent is £1600 for a terrace and £2100 for semi detached. Solid walls have very high U-values and lose a lot of heat. Large reductions in heat demand can be made through insulation and more efficient production of heat by switching fuel. The savings are therefore much higher than any other base build and measures are much more cost-effective. However, it is necessary to switch fuel types and therefore bear the install cost of a new heating distribution system.

Solid wall, electric storage heating

A similar situation to open coal fire, the options available are the same. Base building energy bills are £1100 terraced and £1300 semi detached. New systems will require a new heating distribution system.

Solid wall, on gas

A house already connected to the gas network is assumed to have central heating. The amount of heat required can be substantially reduced by installing insulation and modest improvements to the heating efficiency can be made. Since a central heating system already exists, it is assumed there are no additional costs so a new boiler is still cost-effective.

Cavity wall, electric storage heating

Cavity wall houses have a better base U-value than solid wall which means less heat is needed to maintain a warm home. At the same time, cavity wall insulation has a higher U-value than other types of wall insulation (0.52). Savings are much lower as a result but they are more than offset by the very low price of installation compared with insulating walls internally or externally.

A lower initial heat requirement also means that the percentage improvement in heating translates into a smaller annual fuel bill saving. The consequence of this, given that the cost of installing a new heating system is the same as in a solid wall building, is to reduce its cost-effectiveness substantially. With the effects of discounting also considered, no heating measure which includes a central heating system will pay back in its 15 year lifetime. The only exception is a ground source heat pump which can function for 28 years and achieves payback only after 20 or more years, depending on the fuel price scenario.

Cavity wall, on gas

Not classed as a hard to treat home, this is the easiest base building to reduce energy costs below £500 a year in order to 'fuel poverty proof' the household. The simplest and most affordable action is to install a cavity wall insulation package and a condensing combi-boiler.

Initial results indicate that introducing cost-effective measures can lead to dramatic reductions in energy bills and therefore specific measures offer very considerable solutions for those in fuel poverty presently.

Also indicated is that while changes in fuel prices do not tend to alter the *relative* appeal of specific measures, (in terms of NPV and fuel savings) their integration does successfully repel the effects of higher prices over time: fuel bills are lower *and* more resistant to price fluctuations over time. This effect is a measure of 'fuel proofing' houses, reducing occupiers' exposure to high fuel prices.

Cost of Measures - Sensitivity Analysis

Changing the installation cost has a clear effect on a measure's cost-effectiveness. Increasing the cost of the installation will lower the final NPV and increase the payback period. The fuel savings, however, do not change. The extent to which the cost-effectiveness is altered depends on the initial cost of the measure, the savings it creates and over what period these savings are made.

Figure 16 shows the default costs; 30% increase in the ground source heat pump installation cost (Figure 17); and 30% reduction in cost (Figure 18). Changes in GSHP cost also affect the combination package of INSI GSHP.

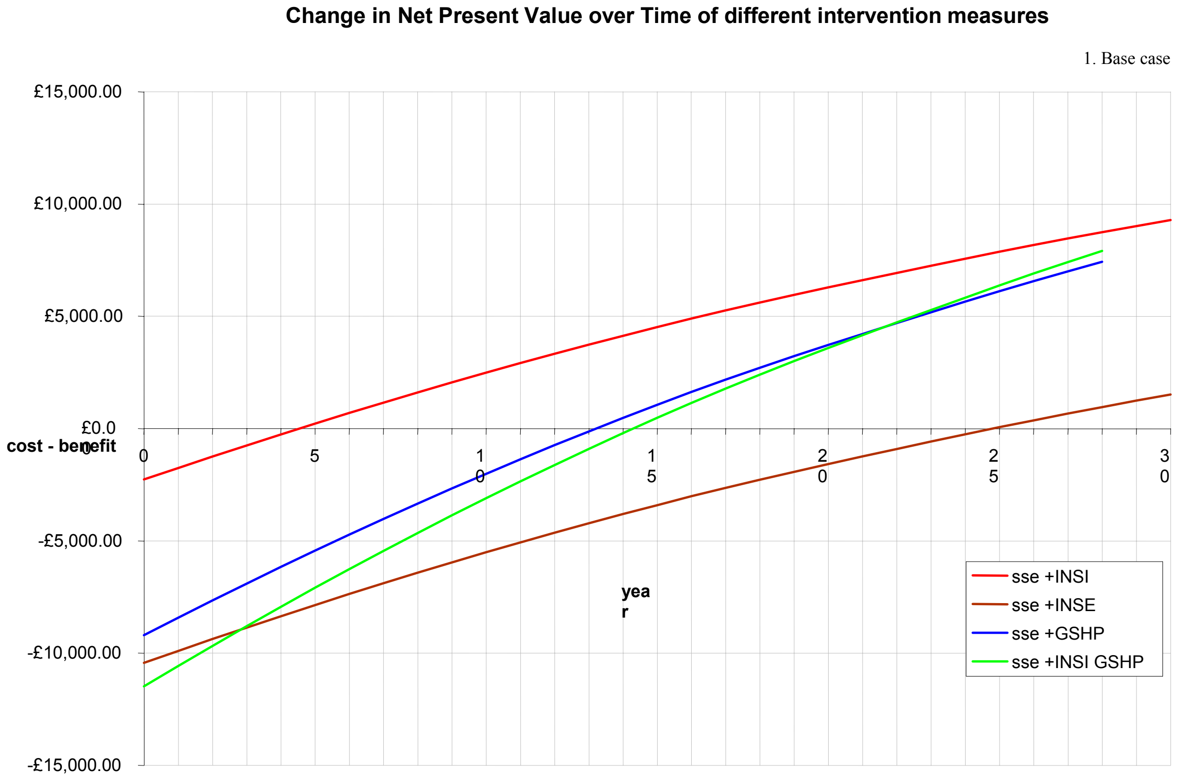

Figure 16: No change in installation cost

Longer paybacks are affected to a greater degree by a change in the installation cost. GSHPs have a long, 10 yr payback which is reduced significantly to just 7 yr by a 30% cost reduction. Higher default installation costs also exhibit greater changes to the final NPV.

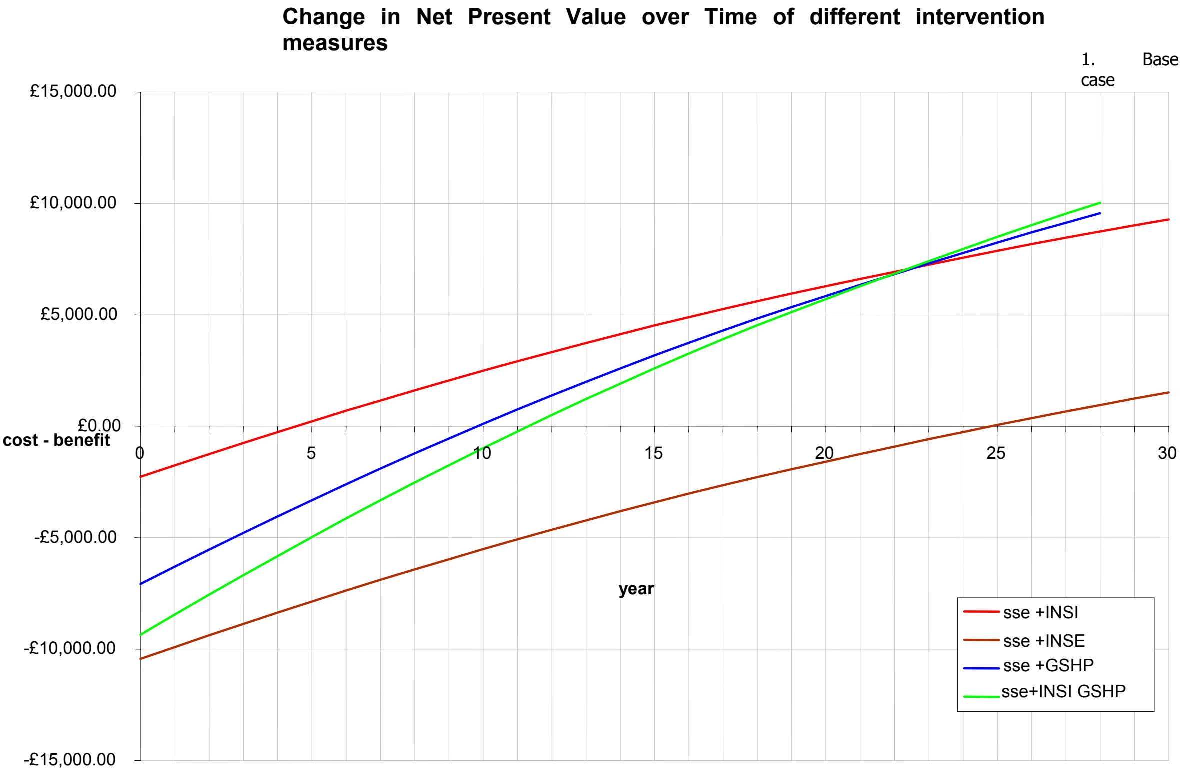

Figure 17: 30% increase in GSHP installation cost

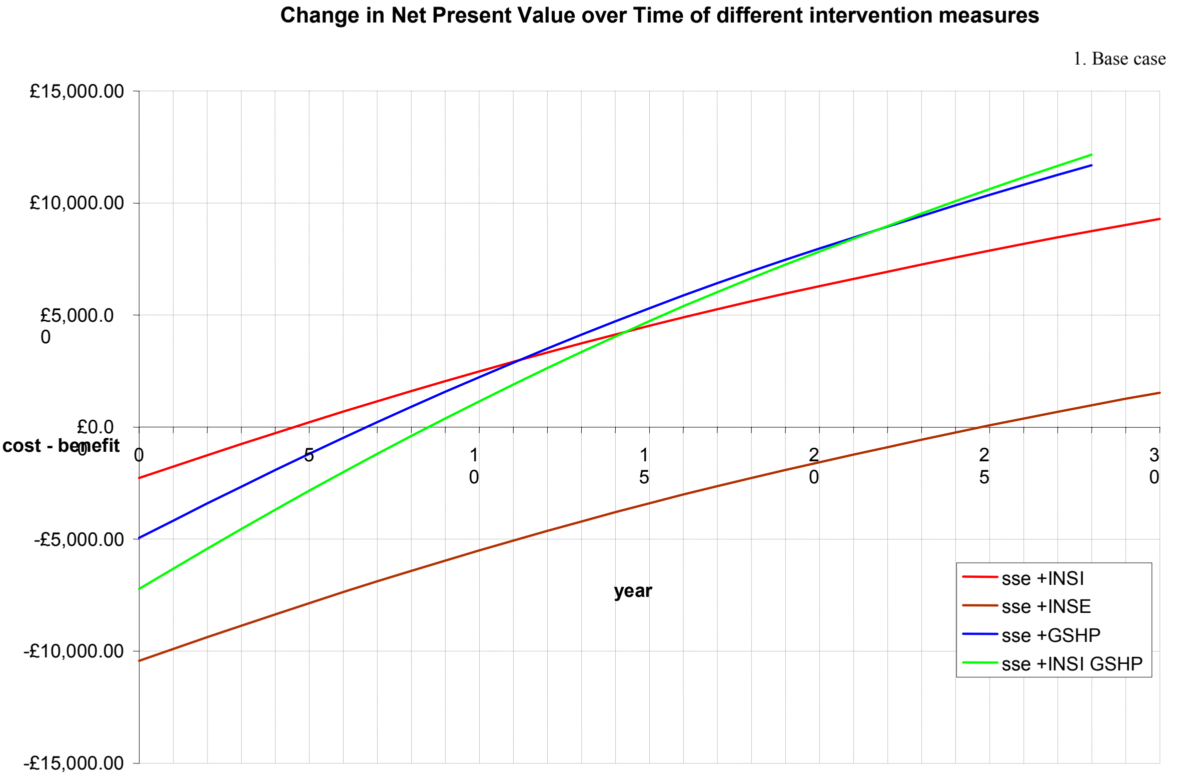

Figure 18: 30% reduction in GSHP installation cost

Future analysis

Further analysis will look at the ability of different measure mixes to maintain a Decent Home Standard over time, considered in view of the different pricing scenarios. There will also be a more detailed review of the insulation options and the effects of standard approaches across different house types, particularly in view of the comments relating to the cost-effectiveness of oil central heating (see page 37). The issues of integrating measures in order to resist the impacts of fuel price rises will also be explored in greater depth. Feedback is welcome from users of Fuel Prophet who have carried out their own analyses.

Key preliminary findings

1. Fuel Prophet indicates that the hierarchy of cost-effective measures, in terms of both savings to tenants and NPV, *will* change under different fuel price scenarios. While housing providers, investors and policymakers can be confident that insulation measures – packages in particular – will remain most cost effective, and ground source heat pumps generally supersede all other heating measures as fuel prices rise, beyond the base case.
2. Uncertainty is further attenuated as the hierarchy of measures (in NPV) remain quite stable, even when the costs of some measures relative to others change quite drastically (e.g. +/- 30%).
3. The major finding is that not only are remarkable savings in fuel bills achievable (over 50%) by installing cost-effective measures, but these bills remain much more resistant to fuel price fluctuations over time. This *'fuel proofing' can be seen as a key strategy* for alleviating fuel poverty during periods of rising fuel prices.
4. In certain situations, specific measures are likely to be more appropriate for removing people from the risk of fuel poverty than more cost-effective ones due to the amount of reduction in fuel used.
5. The long lifetime of many insulation measures (e.g. 30 years) means that their overall value is under-represented when combined with shorter-lived measures. This is relevant when considering wall insulation compared with shorter-term measures such as boilers (15 years). This may be a failure of the model but also reflects the current policy approach to decision making on payback versus whole life costing approaches.

CHAPTER 6: CONCLUSIONS AND FUTURE MODEL DEVELOPMENT

Completion of current project

The major work phase remaining in order to complete the project is the development of a user interface. The two specific target audiences for the project are:

- Social housing providers
- Fuel poverty/energy efficiency policy researchers

During the course of this project a number of other users and more details of the key groups have been identified.

The potential users identified include:

1. Social housing providers: primarily asset managers, investment/procurement officers. In some smaller housing organisations this role might be undertaken by generalists also responsible for maintenance, and rent arrears officers or those responsible for programmes to improve tenant income may also find the outputs useful. It is furthermore likely that specialist consultants would be involved (Bird, pers. comm.)
2. Fuel poverty, energy efficiency, renewables, social and private housing policy and programme designers (the model is of direct relevance to Warm Front, EEC, Clear Skies, Fuel Poverty Strategy and others)
3. Energy modellers and academics
4. Manufacturers and installers of the included measures
5. Agencies such as Sustainable Energy Centres, Citizens Advice Bureau, Home Improvement Foundations
6. Building control and developers (New Part L requirements – to Assess LZC integration)

It would also be conceivable that private householders – i.e. the general public – could use the tool as a guide to measures for their own homes, but it would require some grounding in economic appraisal, and Fuel Prophet has not been designed for this potential audience.

Identifying needs and prioritising design features

From the list above, two key groups of users emerge: the first group include those that have an interest in the model itself – the process by which outputs are calculated, the underlying data and assumptions used. This group would likely include most policy and programme designers, and possibly the manufacturers and trade associations with an interest in the measures modelled.

The second group would include those that require outputs from the model, in order to inform investment decision-making. This group would include housing providers, public agencies developers and the general public (if included). The needs of *some* policy and programme designers might only reach this far also.

According to this categorisation, the needs of the first group (the 'Policy Group') have largely been met. The model is currently in an Excel spreadsheet format. The underlying assumptions, data sets and calculation functions are accessible, and some of these will be open to manipulation. For this group the Fuel Prophet program (rather than interface) will be made available, complete with user guide, for download from the website.

The needs of the housing group centre on use of the model to derive outputs needed to inform investment decisions. Consequently the final phase of this project is to focus on usability of the model. The housing group representatives on the project steering group have been surveyed to obtain their feedback on the model, their proposed use and the key issues for a user interface. In broad terms the intention is to make Fuel Prophet simpler and more accessible. This will be achieved through a website with simple inputs and easily accessible features.

The website's home page will introduce the model concept, potential outputs and applications. The separate model page will look similar but simpler than the 'IM Selector' worksheet in the current Fuel Prophet (Policy) version. The user will be able to select the base building, sort and select the measures of interest, and apply fuel price, loan and grant details. Navigation through the model will be guided by a simple, numbered sequence of actions, each containing a help message accessed by hovering the mouse over the associated icon (or similar). Buttons on this page will allow the user to access graphs such as NPV, amortised NPV, and fuel savings, under differing fuel price scenarios. Separate pages will detail the specifications of the base buildings and measures. Measure costs and lifetimes will be open to manipulation by the user, complete with the necessary precautions that should be heeded when changing these values.

The website will be accessible from the ACE Research website:

www.ukace.org/research/fuelprophet

Other Features

Several other features are to be added to Fuel Prophet before it is released:

- Costs, lifetimes and other measure-related details will become obsolete over time. A data submission function on the website will allow ACE to upgrade these data once verified
- Graphs on the website will incorporate a Print function

Potential model development

Several desirable model features have been identified, but they fall outside the scope of the current project.

- Adding a CO_2 emissions indicator
- Adding a SAP indicator
- Modifying base buildings for closer simulation of housing in question. This could most easily be achieved by allowing the user to integrate measures *within* the base building, to which further measures can then be applied. A more complex alternative is to adapt Fuel Prophet to work directly from, Builder ^{TM} (or similar) so that the actual building(s) in question can be modelled directly, bypassing the base building concept completely
- Adding occupancy heating pattern options, targeting vulnerable or under occupied housing, adding a cooling pattern to heating pattern
- Adding cooling measures, and other options tba
- Specific products in each category (e.g. insulation) could be compared for their cost-effectiveness and a simple table prepared
- Sensitivity function – users might like to introduce input (e.g. cost) ranges
- Non-financial barriers. An analysis of other barriers to installations might like undertaken, in view of the cost-effectiveness of measures
- An analysis of implications for specific policy and programme design, given current treatment of measures and how these change the relative costs. (e.g. Clear Skies, Warm front, EEC)

The integration of such a model with other published work would be needed, notably the Matrix of Measures for hard to treat homes developed by BRE for the Energy Efficiency Partnership for Homes, and Green Street, a website for social landlords to assist them with sustainable refurbishment.

Wider implications

This work raises a number of major issues which have not been researched, for example, how close to the economic rationality of NPV are the criteria which social/private landlords actually use to make business decisions? It seems very likely that investment decisions in this area are guided by unsophisticated views of what is cost-effective. Initiatives to move to whole-life costing (Constructing Excellence, 2004) are part of the changes that will meet with resistance from the construction industry, creating tension between those who make decisions on building costs and those who have to manage the effects. The analysis of cost-effectiveness showed that there is an institutional barrier to longer life measures under the current payback and simple cost-effectiveness indicators; whole life costing methods would eliminate this.

Social landlords are not, on the whole, concerned with fuel poverty; Decent Homes and other issues are greater policy drivers. Many have concerns about wider issues of quality of life, including urban regeneration, social deprivation and good asset management. Some of these issues have been touched on in the report, but developments suggested above still only address some of the housing providers' concerns. How can these key issues relating to climate change be integrated with day to day decisions, especially if energy and climate change policy persists in taking a narrow view, and particularly in relation to the benefits of measures that improve both buildings' and their inhabitants' economic potential?

Conclusions

The aim of this project was to construct a method by which decision makers could identify the long term implications of choices to improve energy efficiency of dwellings in their care, in order to help remove the occupants from fuel poverty, under conditions of fluctuating fuel prices. As usual with ambitious projects, more questions have been raised by the findings. On the one hand, a useful model has been developed that will aid social landlords and energy policy researchers to consider the implications of investment decisions based on two approaches to 'cost-effective' measures for hard to heat homes. On the other hand, the question "Why would social landlords want to do this?" has been raised and a further set of indicators that would be of more interest to them uncovered.

The method used has indicated that, on the whole, fuel prices will have a significant impact upon the ability of different measures to improve the energy efficiency and, reduce the fuel costs in Hard to Heat and other homes. However there is one vital caveat: Despite their fuel savings being more heavily discounted, **insulation measures generally remain most cost effective, in terms of NPV, under all scenarios modelled: the choice of measure installed next, will depend on fuel prices**

Further work is needed to analyse the effects under all the conditions presented in this model and, as a result, a stream of projects may follow from this one. It is believed to be a sound platform for such work and feedback from stakeholders is always welcome. (Contact: research

@ukace.org)

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APPENDIX 1: BASE BUILDING SPECIFICATION; SEMI-DETACHED.

SSE **S**emi detached, **S**olid wall, **E**lectric storage heating

				Semi **off gas** **solid** **electric**
Building				**SSE**
Location factors			Degree day region	midlands
			Height above sea level	20 *m*
			Zone 1 overshading	average
			Zone 2 overshading	average
			Dwelling exposure (sides)	1
			Site exposure	average
			Solar access factor	1 from all directions
Building Dimensions	Built form		built form	semi
			Year built	1929
	Floors	Ground floor	Construction type	suspended timber
			Floor resistance in m^2KW^{-1}	Meet U value target of approx 0.6
			Exposed perimeter	18.6 *m*
			Total area	42.5 m^2
			Zone 1 area	26.8 m^2
			Edge insulation	none
			vents	2 (0.06 m^2)
		Upper floor	Construction type	n/a
			u-value or layer construction	
			total area	
			zone 1 area	
			exposure details	
	Walls	wall type		solid
		u-value		2.1
		total area inc windows		89 m^2
		zone 1 area		35.2 m^2
		extra exposure details		none
		Height		4.8 *m*
	Roof	construction type		Pitched
		insulation	to loft floor (cold roof)	25 m*m*
		U-value		1.36
		main roof area		42.5 m^2
		Zone 1		0
		sec roof		none
		Extra Exposure details		none
		Pitch angle		*35 Degree*
		Loft hatch	insulated?	no
	Storeys – assume to be similar to floors	Number of storeys		2
		Storey area		42.5 m^2
		Storey height		2.4 m
	Openings	total area		18.4 m^2
		for each window	frame	wood
			glazing	single
			orientation	1 large in each direction, rest facing east and west
			area	6 large (2.5 m^2), 1 small (1.5 m^2), total 16.5 m^2
			zone	2 large in zone 1, rest in zone 2
		door		1.9 m^2 solid wooden door
		Draught proofing		25%
Ventilation		Number of chimneys		1 open
		Vents		no vents
		misc		loft hatch, no insulation
Fuels and heating	Heating	fuel type		electric
		open/closed heater type		Night Store
		controls		manual charge control
		secondary heating		Portable electric room heaters
	Hot water	tariffs (may be incl. in model)		single off peak
		water tank size		80 *l*
		jacket insulation		40 m*m* sprayed foam
	Electricity			Economy 7

APPENDIX 2: COMMUNITY HEATING

Community heating (CH), in particular community heating with combined heat and power (CHCHP), differs from all the other measures because it does not serve an individual dwelling. This raises many separate issues related to the installation and financing. It is not possible to buy 'off the shelf' domestic heating components and fit them together. A detailed analysis and survey by specialist installers is needed. Despite the additional initial complexity, it is generally accepted that CHCHP offers economic, social and environmental benefits greater than per dwelling measures over its lifetime, in the right situation.

Case studies and best practice from EST (EST, 1999 and 2004)

Research into CHCHP in the UK has largely been carried out by the EST. The discussion can be split into three headings:

- benefits of CH and CHP
- design and operation of CHCHP system
- economics and financing

Benefits

Economic savings from CHCHP can be higher than any other heating measure. This is because it delivers both heat and power at higher efficiencies. The model does not address these potential benefits in its current form. This is possibly an area for further model development.

Design and operation

Technical specification

A typical CH system is made of a plant, where the heat is generated, a heat distribution system from the plant to the dwelling and final distribution within the dwelling. There are many variations within the general description which can complicate the matter.

The plant needs to provide adequate and reliable heating and hot water to all the dwellings. This can involve a number of smaller boilers and/or CHP. For CHP, the balance between electricity and heat production must also be calibrated to suit the needs of the end users.

The distribution system is a series of pipes running around the community and can be extremely expensive. To reduce its proportional cost, CH is recommended for high density dwelling areas. The system can either pump hot water directly or use a high efficiency heat exchanger at each dwelling.

Each dwelling will also need a control system, radiators and possibly meters to accurately bill the occupants. There are many different ways of billing, which are listed below, under **Charging**.

Fuel

Most CHCHP systems are gas powered but due to the scale of operation a standard domestic tariff is unsuitable and therefore gas is supplied on business tariff. Whilst this is cheaper, it is also more exposed to fluctuations in wholesale prices. Biomass boilers have been effective in remote areas where there is no gas connection.

Financing

Funding

Public Private Partnerships (PPP) and Private Finance Initiatives (PFI) are suggested in the EST best practice guide. This is because the initial costs can be in the millions of £s, although the cost per dwelling is estimated to be £7,000 (EST 1999). This will often have to be recouped in the charges to the tenants.

Charging

Options include:

- Flat rate charge
- Flat rate charge integrated into rent
- Metered use
- Metered plus maintenance costs

All of which have pros and cons that can only be assessed by the LA or specialists.

Modelling

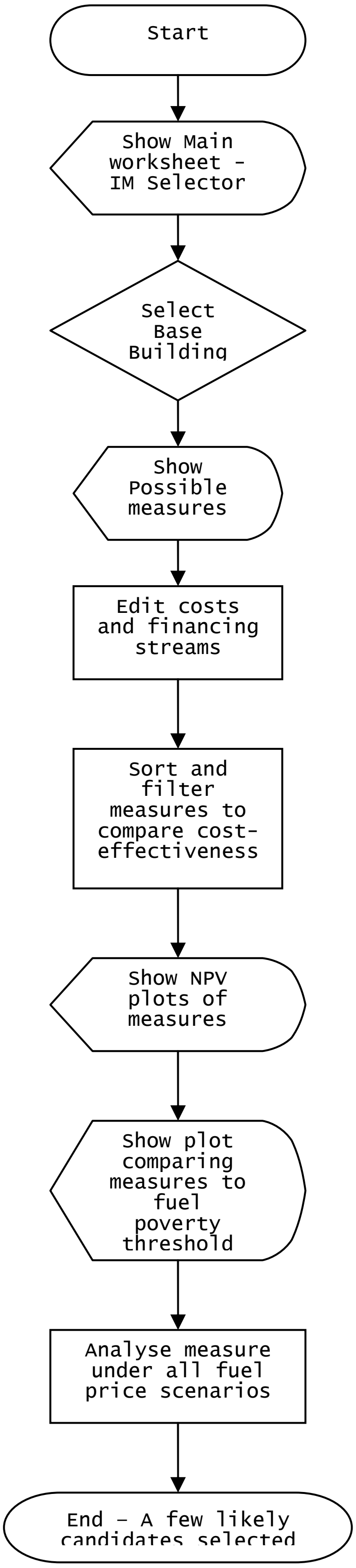
Builder ™ is able to model CHCHP on a per dwelling basis. All the aforementioned technical data, however, is required before it is able to do so, and because each situation must be separately assessed, the model and reality could diverge greatly. Furthermore, not enough information is available to verify the average cost of installation and the deviation from it. The spreadsheet is also unable to calculate the fuel cost of running the boiler because it does not include wholesale gas prices.

Modelling CHCHP is complicated because each situation is unique and therefore the technical details are not known. The financial side is also difficult because there are extra layers of administration including Private Finance Initiatives (PFIs) for funding and systems for charging.

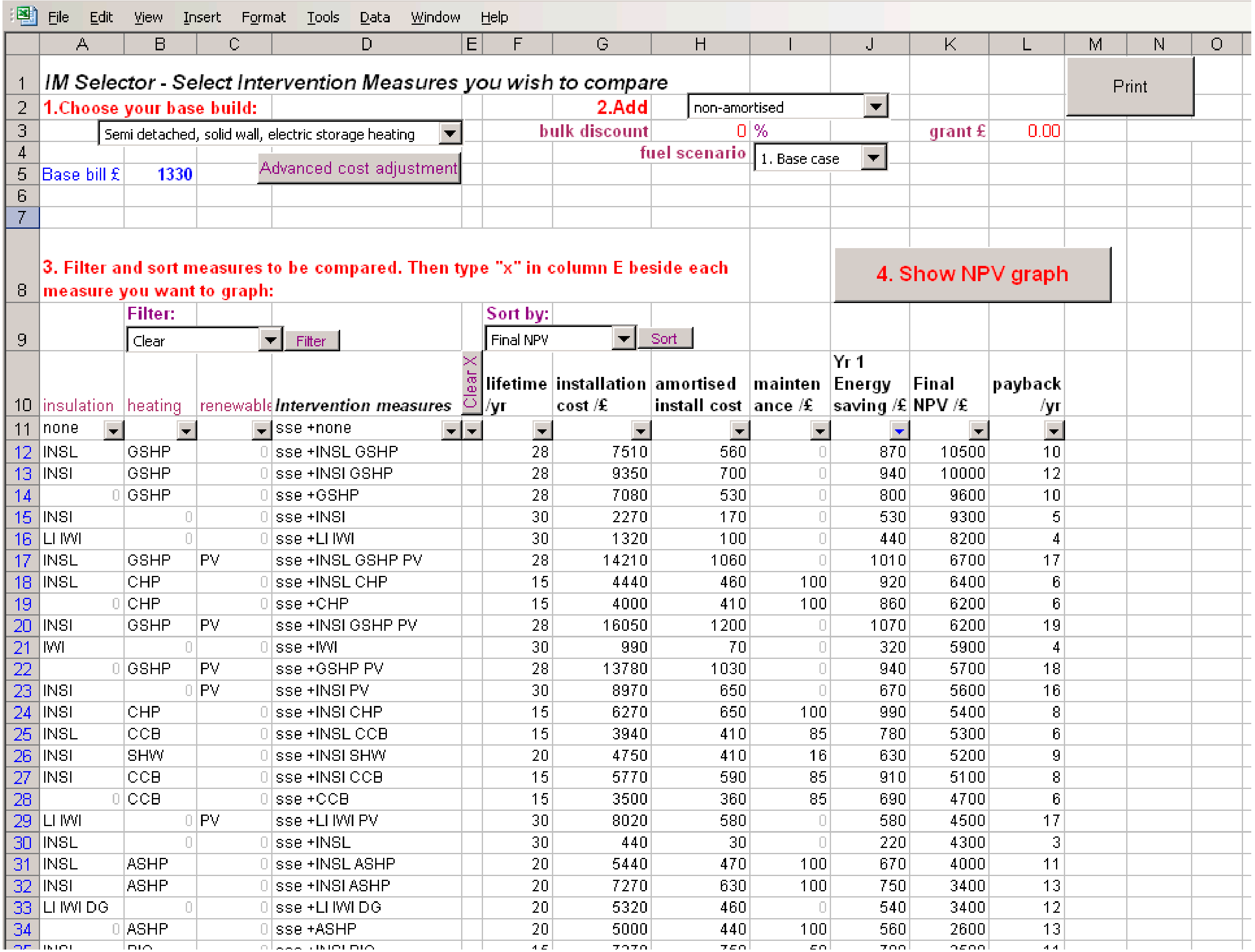
APPENDIX 3: DATA SOURCES - COST OF MEASURES/MAINTENANCE

Source	**Measure**
Marstair Heat King Mr Lightfoot	Air source heat pumps
Transco (2004)	Biomass boilers
Transco (2002)	Cavity wall insulation
Willis R (2005) Small or atomic? Comparing the finances of nuclear and micro-generated energy. Green Alliance. London	CHP
www.windowquoter.com/pdf/115pdf	Double glazing
Transco (2002) EST Best Practice (for appropriate U-value)	Internal wall insulation
Kensa Engineering	Ground source heat pumps
Pett J, (2004) Affordable warmth in hard to heat homes Association for the Conservation of Energy (Updated)	External wall insulation
www.greenstreet.org.uk EST Best Practice (for appropriate U-value)	
EST Best Practice Hard to Treat Matrix	Loft insulation
www.windsave.com	Micro wind turbine
www.greenalliance.org.uk/ourwork	
www.calor.co.uk/installer/burning issues/truth-about-costs.htm	Oil condensing boilers
www.pv-uk.org.uk Transco (2002)	PV
http://www.green-alliance.org.uk/ourwork/EnergyEntrepreneurs/MicroWindTurbines/ Windsave Ltd www.renewabledevices.com/**swift**	Micro wind turbine
www.solarforlondon.org	Solar hot water

APPENDIX 4: FLOW CHART FOR USING FUEL PROPHET



APPENDIX 5: FUEL PROPHET MAIN SCREEN



IM Selector - Select Intervention Measures you wish to compare

1.Choose your base build: Semi detached, solid wall, electric storage heating

2.Add: non-amortised

bulk discount 0 %

grant £ 0.00

fuel scenario: 1. Base case

Base bill £ 1330

Advanced cost adjustment

3. Filter and sort measures to be compared. Then type "x" in column E beside each measure you want to graph:

4. Show NPV graph

Filter: Clear

Sort by: Final NPV

	insulation	heating	renewable	*Intervention measures*		lifetime /yr	installation cost /£	amortised install cost	maintenance /£	Yr 1 Energy saving /£	Final NPV /£	payback /yr
11	none			sse +none								
12	INSL	GSHP	0	sse +INSL GSHP		28	7510	560	0	870	10500	10
13	INSI	GSHP	0	sse +INSI GSHP		28	9350	700	0	940	10000	12
14	0	GSHP	0	sse +GSHP		28	7080	530	0	800	9600	10
15	INSI	0	0	sse +INSI		30	2270	170	0	530	9300	5
16	LI IWI	0	0	sse +LI IWI		30	1320	100	0	440	8200	4
17	INSL	GSHP	PV	sse +INSL GSHP PV		28	14210	1060	0	1010	6700	17
18	INSL	CHP	0	sse +INSL CHP		15	4440	460	100	920	6400	6
19	0	CHP	0	sse +CHP		15	4000	410	100	860	6200	6
20	INSI	GSHP	PV	sse +INSI GSHP PV		28	16050	1200	0	1070	6200	19
21	IWI	0	0	sse +IWI		30	990	70	0	320	5900	4
22	0	GSHP	PV	sse +GSHP PV		28	13780	1030	0	940	5700	18
23	INSI	0	PV	sse +INSI PV		30	8970	650	0	670	5600	16
24	INSI	CHP	0	sse +INSI CHP		15	6270	650	100	990	5400	8
25	INSL	CCB	0	sse +INSL CCB		15	3940	410	85	780	5300	6
26	INSI	SHW	0	sse +INSI SHW		20	4750	410	16	630	5200	9
27	INSI	CCB	0	sse +INSI CCB		15	5770	590	85	910	5100	8
28	0	CCB	0	sse +CCB		15	3500	360	85	690	4700	6
29	LI IWI	0	PV	sse +LI IWI PV		30	8020	580	0	580	4500	17
30	INSL	0	0	sse +INSL		30	440	30	0	220	4300	3
31	INSL	ASHP	0	sse +INSL ASHP		20	5440	470	100	670	4000	11
32	INSI	ASHP	0	sse +INSI ASHP		20	7270	630	100	750	3400	13
33	LI IWI DG	0	0	sse +LI IWI DG		20	5320	460	0	540	3400	12
34	0	ASHP	0	sse +ASHP		20	5000	440	100	560	2600	13