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Subsidy as an agent to enhance the effectiveness of the energy performance certificate

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ABSTRACT

Since more than two-thirds of the United Kingdom housing stock in 2050 will comprise houses that have already been built, the need for a focus of policy on the already-built private housing stock is apparent. This study examines the impact that subsidy can make in bolstering the performance of the Energy Performance Certificate by reducing carbon emissions in the residential sector. The results of a survey of new homeowners' uptake of nine commonly installed energy saving measures in response to subsidy are examined. A cost–benefit analysis is performed using the recently introduced concept of the *Shadow Price of Carbon* and a model is presented which allows the carbon savings for any level of subsidy to be calculated. The model suggests that subsidisation of the installation of hot water tank insulation, draught proofing measures, loft insulation and cavity wall insulation may be cost-effective, but that the subsidisation of others, most notably interior solid wall insulation, are unlikely to significantly bolster carbon savings.

1. Introduction[1]

The Climate Change Act 2008 requires that the government of the United Kingdom reduce carbon dioxide (CO_2) emissions by at least 26% by 2020 and make further reductions in greenhouse gases amounting to 80% by 2050 with reference to the 1990 baseline (Great Britain, Climate Change Act, 2008). Following implementation of the policies announced in the 2007 Energy White Paper and recent proposals on the EU emissions trading system, the UK remains on target to achieve the 26% figure, the savings of 24–29 megatonnes of carbon dioxide ($MtCO_2$)[2] expected of the residential sector amounting to a 30–36% sectoral reduction [DECC (Department of Energy and Climate Change), 2008; DEFRA (Department for Environment, Food and Rural Affairs), 2006]. No strategy outlining a roadmap to the 2050 target has yet been set.

The residential sector accounts for 27% of CO_2 emissions (DEFRA, 2006). Savings made in this sector can, therefore, make a significant contribution towards the achievement of the 80% target. Although no sectoral targets have been set in the Energy White Paper 2007 with regard to 2050, a government inter-departmental analysts group estimates the technical potential within the residential sector to be as high as 32.1 megatonnes of carbon (MtC) per year (IAG (Inter-departmental Analysts Group), 2002), the equivalent of a 76% reduction on 1990 levels. Since more than two-thirds of the housing stock in 2050 will comprise houses that have already been built [DCLG (Department of Government and Local Communities), 2007a], the need for a focus of policy on the already-built private housing stock is apparent.

The Energy Performance of Buildings Directive (EPBD) has been proposed as offering considerable potential with regard to the reduction of carbon emissions in the already-built domestic sector (Boardman, 2007). Its principal requirement, as it affects existing private households, is that an Energy Performance Certificate (EPC) must be made available to the new owner or prospective buyer/tenant when a home is sold or let. Essentially a tool of communication, the EPC must not only state the amount of energy consumed with a standardised use of the building, but, most crucially, must also include cost-effective recommendations suggesting how energy performance might be improved [EC

Abbreviations: BREDEM, British Research Establishment Domestic Energy Model; CERT, Carbon Emissions Reduction Target; CO_2, carbon dioxide; DIY, do-it-yourself; EPBD, Energy Performance of Buildings Directive; EPC, Energy Performance Certificate; ESM, energy saving measure; ktC, kilotonne of carbon; MtC, megatonne of carbon; $MtCO_2$, megatonne of carbon dioxide; $MtCO_2e$, megatonne of carbon dioxide equivalents; NPV, net present value; SCC, social cost of carbon; SPC, shadow price of carbon; TRV, thermostatic radiator valve; VAT, value added tax

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[1] *Household subsidy* is used to denote the amount of subsidy received by a single household installing a single energy saving measure. *National subsidy* is used to denote the sum total of all the household subsidies for households installing an energy saving measure of a given type or given types.

[2] Under a central fossil fuel price scenario, residential emissions are calculated at 51–56 $MtCO_2$ in 2020.

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(European Commission), 2003]. Included as part of the Home Information Pack and rolled out in three stages over the course of 2007, no home could be put on the market for sale without an EPC after 14 December 2007 (DCLG, 2007b).

Despite the potential resident within the EPC, modelling has suggested that there is no significant difference in the level of carbon savings between that arising from the business-as-usual scenario and that deriving from the EPC when used purely as an instrument of communication (Sunikka, 2006). This accords with the similarly poor prognosis of annual savings of only 14.7 kilotonnes of carbon (ktC) (53.9 $MtCO_2$) by 2010 by new home-owners in the residential sector, a mere 0.3% of the 4.8 MtC annual domestic savings anticipated by 2010 by the government in its 2006 Climate Change Programme (McGilligan et al., 2008).

As useful a tool as is the instrument of communication, it has been argued that such a tool should not be used in isolation as a substitute for regulation or tax, but rather as an additional instrument to aid performance (Kemp, 2000). This paper examines the potential impact that subsidy (grant, reduced tax, tax rebate, preferential loan, etc.) can make in bolstering the effectiveness of the EPC by determining which energy saving measures (ESMs) are most suitably linked with subsidy, identifying the optimal spending regime such that the level of carbon savings for any particular level of subsidy can be measured.

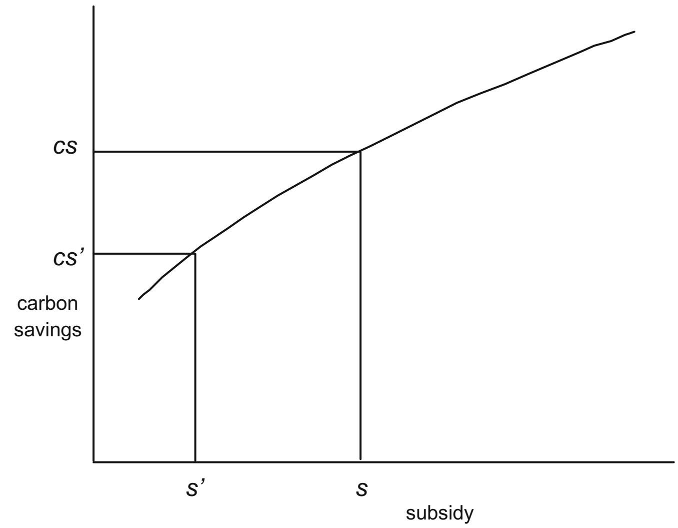

Fig. 1. ESM subsidy footprint—principle upon which the model is based showing relationship between subsidy and carbon savings.

2. Basis of the model

The fundament upon which the model relies is the assumption that, for a given dwelling type of given occupancy, there is an identifiable correlation between level of subsidy and resultant household carbon savings following installation of a given ESM such as cavity wall insulation or loft insulation.

A base case dwelling, a microcosm of the nation's entire housing stock in a single notional composite, the same as that used by the government in its calculation of the carbon savings expected of the Carbon Emissions Reduction Target (CERT) programme (DEFRA, 2007a, 2008a), is used to model the 2010 national stock in the present instance. The annual energy savings arising from the installation of ESMs are calculated the British Research Establishment Domestic Energy Model (BREDEM) [BRE (Building Research Establishment), 1985].

Since householders do not form a homogeneous population group, the relationship between ESM uptake and subsidy can only be ascertained by gathering data in the field, in this case by survey. The non-linear relationship is a function of the *net value* householders attach to the benefits which ensue following installation of an ESM. Whilst, for example, the proportion of householders willing to install solid wall insulation is expected to increase as the installation costs diminish (or subsidy increases), the increments of increase cannot be predicted as the *net value* attached to its installation varies between householders. Being affected by a range of unknowable variables such as level of disposable income, size of heating bill, concern for the environment, value attached to inconvenience caused by installation, the *net value* is known only to the householder and, what is more, is only evaluated when the matter is considered prior to making a purchase or when asked in a survey.

3. Level of optimal subsidy

Elucidation of the relation between carbon savings and subsidy for a given ESM allows the calculation of the *optimal level* of subsidy, that lowest level of cost-effective subsidy which will bring about the maximum benefit. With reference to Fig. 1, one has to establish, for example, whether subsidy *s*', which encourages *u*' householders to install an ESM which will bring about nationwide carbon savings of *cs*', represents better value than subsidy *s* which, albeit costing more, achieves a higher level of carbon savings *cs*.

Even if subsidy *s*' does bring about a higher level of carbon savings per unit of subsidy spent, subsidy *s* may, nevertheless, represent better value since the absolute level of carbon savings is of critical importance and subsidy *s*' may not achieve sufficient savings if the government is to meet the targets it has set for itself in the Energy White Paper.

In the present instance, and in accord with a government mandate obliging its use when carrying out an Impact Assessment for any proposed central government policy that would affect the private, public or voluntary sector (DEFRA, 2007d), the recently introduced *Shadow Price of Carbon (SPC)* is used to carry out a cost–benefit analysis. The Shadow Price of Carbon captures the damage costs of climate change caused by attaching a monetary value to each additional tonne of greenhouse gas released into the atmosphere (DEFRA, 2008b). In essence, the two types of savings – monetary savings (measured in pounds sterling (£)) and carbon dioxide savings (measured in megatonnes of carbon dioxide equivalents ($MtCO_2e$)) – are brought together on the same scale so that they can be comparatively measured in the same units of pounds sterling (£). Based on the *Social Cost of Carbon (SCC)*, as used in the Stern Review which examined the effect of climate change on the world economy (HM Treasury, 2007), the SPC takes more account of uncertainty than the SCC, its value being based on a trajectory stabilising towards the top of the optimal range of 450–550 ppm CO_2e (DEFRA, 2007c). The SPC sums the full global cost of the damage caused by a GHG (in this case CO_2) over the whole of its time in the atmosphere. The SPC is not fixed but increases year-on-year according to different schedules. Not only does it increase at a rate of 2% to account for assumed inflation, but it also increases at a rate of a further 2% to account for rising damage costs where one tonne of CO_2 emitted in the future will cause more damage than one tonne of CO_2 emitted in the present (DEFRA, 2007c).

The optimal level of subsidy is that level of subsidy which occurs when the costs exactly equal the benefits: a subsidy less than this and less carbon is saved than is possible whilst still remaining in credit, whilst a subsidy in excess of this is counter-

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productive inasmuch as the additional expenditure is more judiciously used in rectifying the damage which would otherwise have been caused had the additional carbon emissions continued unabated.[3]

Since the present value which people attach to goods and services received in the future diminishes in decrements which inflation alone cannot accommodate, the monetised carbon savings, which accrue over a different timeframe from the costs, are calculated using the concept of *Net Present Value (NPV)* which brings all costs and benefits together at the same point in time. The primary criterion used by the government in deciding whether or not a government action can be justified (HM Treasury, 2003), the NPV of the costs and monetised carbon savings associated with installation of an ESM can be expressed as

$$NPV = \sum_{t=0}^{N} C_m/(1+r)^t \tag{1}$$

where C_m is the net cash flow (i.e. monetised carbon savings − costs) for a particular year; t the year of cash flow, where t=0 for 2009, t=1 for 2010, etc.…; N the lifetime of energy saving measure; r the discount rate[4]

where

$$\text{monetised carbon savings} = CO_2 savings\ (tonnes) \times SPC\ for\ a\ particular\ year$$

The theoretical optimal level of subsidy for any particular ESM is simply determined when the NPV is zero, this being the point where there is parity between costs and benefits.

4. Method

A questionnaire and covering letter were sent to 628 randomly chosen new homeowners in Great Britain on 29 May 2008[5] (see Appendix). All English and Welsh transactions had taken place in March 2008 (the April figures not having been released at that time), whilst the Scottish transactions had taken place in February 2008 (the Scottish March figures not having been released at that time). The questionnaire presented the homeowners with a series of ESMs and asked them how low in price an ESM would have to be to persuade them to have it installed within the following 24 months. As such, the difference between a particular homeowner's named price and the actual full cost is tantamount to the level of subsidy which would be sufficient to encourage that particular new homeowner to install the ESM. Only the responses of those homeowners who could possibly benefit from the installation of a particular ESM were accepted. In the case of cavity wall insulation, for example, responses were not sought from homeowners whose homes (i) had solid walls, (ii) were of timber-frame construction or (iii) had cavity walls which had already been insulated. The homeowners were made aware of the full, unsubsidised cost of each ESM at today's market prices. The costs quoted in the questionnaire were actually in 2009 prices (DEFRA, 2008a; Dunbabin, 2008a), the model's base year and the proposed start year for the policy of subsidy that this study explores.

Since it had to be assumed that not all the recipients of the questionnaire would be in possession of an EPC, such similar information had to be provided so that respondents would be better able to make informed decisions with regard to the amount of money that they would be prepared to spend on installing ESMs. However, as the EPC is property-specific and is issued following inspection of the dwelling by an accredited surveyor, it was impossible to tailor- specific recommendations (and thereby detail resultant associated savings), for every household receiving a questionnaire. Therefore, in substitute, the annual savings deriving from installation of nine of the 10 most cost-effective heating/insulation ESMs[6] listed in DEFRA's *llustrative Mix of Measures for CERT 2008–11* (DEFRA, 2007a, 2008a) for the previously mentioned base case dwelling were stated (Table 1).

The savings quoted in the questionnaires were calculated in 2007 prices (see section *Financial Savings and Costs*).

4.1. *Base case dwelling*

The specification for each of the ESMs considered in the study is described below (DEFRA, 2007a).

4.1.1. *Hot water cylinder insulation*

75 mm of insulation.

4.1.2. *Draught proofing*

The nature of air infiltration is such that it is impossible to precisely state the level of air infiltration before the installation of draught stripping measures. Since the ventilation rates in the CERT base case dwelling are based on ventilation rates *at the higher end of the range*, only those dwellings with either (i) no draught proofed windows or (ii) less than 20% of windows draught proofed as determined in the *Domestic Energy Fact File (2006)* (BRE, 2006) are considered.

4.1.3. *Double glazing*

The savings associated with double glazing relate to the marginal savings which arise from the installation of C-rated glazing over E-rated glazing (the minimum permitted standard for new glazing), i.e. the subsidy on offer is designed to encourage a greater uptake of higher energy-performance glazing by homeowners who have already stated an intention to install double glazing.

4.1.4. *Improved heating controls (no new boiler)*

The heating controls improvement results from the installation of thermostatic radiator valves (TRVs) and the setting up of a boiler interlock.

[3] This relationship between cost and benefit is only valid up to the point where the cost of the ESM is fully subsidised since further subsidy would not act to increase carbon savings but would rather be taken as a windfall by the householder; in this case where the subsidy would exceed the full cost of the ESM, the optimal subsidy is that subsidy which exactly matches the cost of the ESM.

[4] The recommended discount rate, the annual percentage rate at which the present value of a future pound (£) is assumed to fall through time, is 3.5% for evaluations covering years 0–30, and 3.0% for years 31–75 (HM Treasury, 2003).

[5] The website, *UpMyStreet*, was used to source the new households (Upmystreet, 2008); the website does not include details of transactions in N Ireland.

[6] This study focuses on ESMs which effect a more efficient use of the energy supply currently in place and thus fuel switching and microgeneration are excluded. A number of cost-effective ESMs are excluded from the analysis:

(i) *Lighting*—incandescent bulbs are being phased out and replaced by energy saving bulbs by the current market transformation programme (DEFRA, 2007b).

(ii) Regarding solid wall insulation, neither exterior solid wall insulation nor insulated wallpaper was considered. Application to the Local Authority would be required for planning permission for the attachment of exterior solid wall insulation in very many cases, and, in most instances, the strict regulation in place in the UK would forbid its installation; since planning applications are considered on a case-by-case basis, calculation of the potential offered by this ESM is rendered highly problematic. Insulated wallpaper, although ranked within the top nine, is approximately only half as efficient as internal sold wall insulation in terms of the lifetime carbon savings/installation cost ratio.

Table 1
ESMs ranked in order of normalised[a] cost-effectiveness (kg of CO_2saved/year/£) (data derived from DEFRA, 2008a).

Rank	ESM	CO_2Savings (kg/year)	Installation cost (£)	Lifetime (years)	Savings (kg/year/£)
1	Hot water cylinder insulation (top up)	167.94	13.80	10	122
2	Loft insulation (DIY)	268.76	120.00	40	90
3	Cavity wall insulation	634.36	380.10	40	67
4	Loft insulation (professional)	313.36	286.20	40	44
5	Draught proofing	132.81	100.70	20	26
6	Heating controls (no new boiler)	282.41	148.40	12	23
7	Interior solid wall insulation	2210.16	3000.00	30	22
8	Double Glazing (E→C rated)	82.12	212.00	20	8
9	Heating controls (new boiler)	35.09	90.10	12	5

[a] Normalised savings take account of an ESM's lifetime.

Table 2
U-values for cavity wall insulation.

Year of construction	Uninsulated U-value (W/m2K)	Insulated U-value (W/m2K)
Pre 1976	1.440	0.480
1976–1983	1.000	0.420
Post 1983	0.694	0.343

4.1.5. Improved heating controls (new boiler)

The proposed subsidy is directed at those new homeowners who intend to buy a new boiler and who have a central heating system which could be improved through the installation of TRVs. (Since it is a requirement that controls are upgraded to a reasonable level when a new boiler is installed, savings deriving from the installation of a thermostat and programmer are not considered.)

4.1.6. Loft insulation

4.1.6.1. Professional installation. The loft is insulated to a depth of 270 mm: it is assumed that the loft hatch will also be draught proofed.

4.1.6.2. DIY installation. The loft is insulated to a depth of 270 mm: it is assumed that some of the self-installers miss out areas of the loft and do not draught proof the hatch.

4.1.7. Cavity wall insulation

Account is taken of the fact that the walls of more recently constructed homes have higher *U*-values than those of older homes as a consequence of the introduction and subsequent updating of the Building Regulations (see Table 2).

4.1.8. Interior solid wall insulation

Walls are internally insulated to bring the *U*-value down to 0.45 W/m^2 K.

4.2. Calculation of nationwide carbon savings

Carbon savings in MtC on a national scale (*cs*) are extrapolated from the annual carbon savings for a particular ESM achieved by the base case dwelling (*bcd*) (DEFRA, 2008a) using data drawn from a variety of sources: (i) lifetime of ESM (*l*) (DEFRA, 2008b), (ii) size of the dwelling stock (*ds*)—2001 Census updated to 2007 (DCLG, 2008b), (iii) number of transactions per year (*t*)—Stamp Duty Land Tax database (HMRC (Her Majesty's Revenue and Customs), 2008), (iv) number of households where TRVs could potentially be installed for householders intending to buy a new boiler (*p*)—Domestic Energy Fact File (2006) (BRE, 2006) and analysis of questionnaire returns, (v) number of households where loft insulation could potentially be installed (*p*)—English House Condition Survey (Irving, 2008), (vi) number of households where remaining ESMs (i.e. ESMs other than TRVs and loft insulation) could potentially be installed (*p*)—Domestic Energy Fact File (2006) (BRE, 2006), (vii) percentage uptake of the ESM in question as a proportion of maximal potential uptake for a particular level of household subsidy (*u*)—determined from the present survey), (viii) conversion factor to take account of differences between populations of England and Great Britain—Housing Statistics 2006 (DCLG, 2006). The basic form of the calculation detailing nationwide carbon savings for a particular level of uptake is described thus:

$$cs = bcd \times l \times ds \times t \times p \times u \tag{2}$$

The level of national subsidy (*ns*) associated with a particular level of uptake is extrapolated from household subsidy (*hs*) according to the following equation:

$$ns = hs \times ds \times t \times p \times u \tag{3}$$

The level of monetised carbon savings (*nmcs*) on a national scale deriving from a particular level of uptake is calculated from the household monetised carbon savings achieved by a household over the course of the ESM's lifetime (NPV_h):

$$nmcs = NPV_h \times ds \times t \times p \times u \tag{4}$$

where

$$NPV_h = \sum_{t=0}^{N} hmcs/(1+r)^t \quad \text{(see Eq. (1))} \tag{5}$$

where *hmcs* is a household's monetised carbon savings in a particular year in 2009 prices

$$hmcs = bcd \times SPC \tag{6}$$

where *SPC*=27.6 in 2009 and increases at the rate of 2%/year.

4.2.1. Optimal subsidy

(i) In the event that *ns* is always smaller than *nmcs* for any particular level of uptake, the optimal subsidy (s_o) is calculated as

$$s_o = ds \times t \times p \times u_{max} \times fc \tag{7}$$

where u_{max} is the maximum uptake which occurs when the ESM is completely subsidised; *fc* is the full cost of installing a particular ESM in a household.
The carbon savings associated with the optimal subsidy in such an instance is calculated from Eq. (2) where *u* has the value of u_{max}.

(ii) Otherwise the optimal subsidy calculates as that value of *ns* (Eq. (3)) which is equal to the *nmcs* (Eq. (4)) for the same level of uptake (*u*); the carbon savings associated with the optimal level of subsidy in such an instance is calculated from Eq. (2) using that same value of *u*.

Table 3
General response to questionnaire.

	Response	% Response
Questionnaires sent out	628	
Questionnaires returned	119[a]	19
Not given an EPC	85	
Given an EPC	23	
Do not know whether given an EPC	9	
No reply	2	
Uptake of ESMs (from 116 responses)14		
Would carry out at least 1 ESM in the next 24 months if subsidy were made available	91	79
Have already implemented at least 1 ESM since moving in [b]	6	5

[a] Although there were 119 responses to the 628 questionnaires sent out, not all the replies for all the questions could be used for a variety of reasons; 3 returned questionnaires were not used at all.
[b] Including boilers, double glazing, new central heating system and door to prevent draughts.

It should be pointed out that this model does not attempt to incorporate the administrative costs associated with the proposed policy.

5. Results[7]

Exceeding the reported 13% response rate of Parnell and Popovic Larsen's Study (2005) and the 3.5% response rate of Darby's study (2003), the two most prominent works performed on energy certification, the 19% response rate (Tables 3 and 4) was far in excess of that which was anticipated and no doubt reflective of the large surge in interest amongst the population at large in the dual issues of global warming and soaring energy costs.

Duplicating the result of the 209-questionnaire pilot study (used to fine-tune the final wording and format of the questionnaire) where 80% of respondents stated that they would install at least one ESM within *the following 12 months* should subsidy be made available, 81% of respondents indicated a willingness to do likewise within the following 24 months. Both figures are considerably higher than the intended installation level of 46% over the first 12 months of residence found by Parnell and Popovic Larsen in their study where new homeowners were given an energy certificate but where no subsidy was on offer. This suggests that the offer of a subsidy may play a role in enhancing ESM uptake.

5.1. Hot water cylinder insulation

As indicated in Table 1, the topping-up of hot water cylinder insulation represents the best value in terms of carbon savings achieved per unit of subsidy. Indeed, it is found that subsidisation is justified at all levels of expenditure up to and including the issue of a 100% subsidy where an outlay of £2.6 M secures a return of £8.6 M of monetised carbon savings in terms of the SPC (Fig. 2).

However, the annual savings possible, even when uptake is maximal, is only of the order of 0.3 $MtCO_2$ and, as such, hot water cylinder insulation can only ever make a small contribution to the targets set out in the White Paper. Moreover, the fact that the final £0.6 M of subsidy only secures a further 0.01 $MtCO_2$ of savings begs the question whether or not it might be more judicious to curtail spending at £2.0 M. This question is examined further in Section 8.

Whilst the cost-effectiveness of hot water cylinder insulation is well documented, the importance of the finding that uptake is considerable even at very modest levels of subsidy cannot be overstated since it means that it is a prime candidate for inclusion in the *Local Agenda 21 Programme*.[8] The knowledge, for example, that an outlay of a mere £266 000 (£2.80 per household) is sufficient to encourage approximately 40% of new homeowners to lag their hot water cylinders and thereby realise savings of some 0.16 $MtCO_2$ presents Local Authorities with the ideal marketing opportunity to involve business and community enterprise in the furtherance of its Agenda 21 policies. The fact that this ESM is becoming increasingly *démodé* as householders switch to combination boilers, which do not require hot water storage, is likely to be irrelevant since the typical annual financial savings of £20 per household mean that payback is achieved in less than 12 months (DEFRA, 2008a).

5.2. Draught proofing

Whilst it is seen that it is not cost-effective to subsidise the full installation of draught proofing measures, lower levels of subvention can bring about returns in excess of, or equal to,

Table 4
Useful responses to questionnaire.

	Response	% Response
Hot water cylinder	112	94
Draught proofing	107	90
Double glazing	114	96
Central heating	105	88
Loft insulation	102	86
Wall insulation	102	86

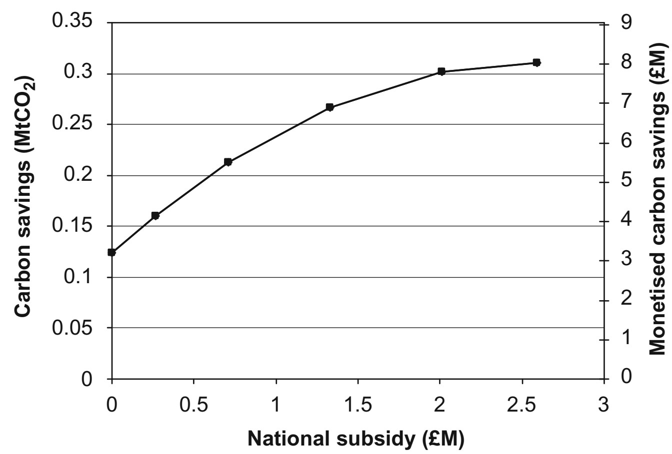

Fig. 2. Relationship between increasing national subsidy and carbon savings in weight/monetised carbon savings from hot water cylinder insulation. Mean amount individual householder willing to spend: £8.12 ± 20% (n=45, $p < 0.05$).

[7] Two types of monetary savings are mentioned in this section and it is important that the two are not confused. Monetised carbon savings are, effectively, the savings made by the government in terms of reduced damage inflicted upon society. Financial savings are the savings made by householders as a result of lower fuel bills.

[8] Part of the United Nations' Agenda 21 Programme, the Local Agenda 21 Programme requires that Local Authorities construct partnerships between sectors of the community such as businesses, voluntary groups and young people to develop strategies à propos the promotion of sustainable development (DEFRA, 2002).

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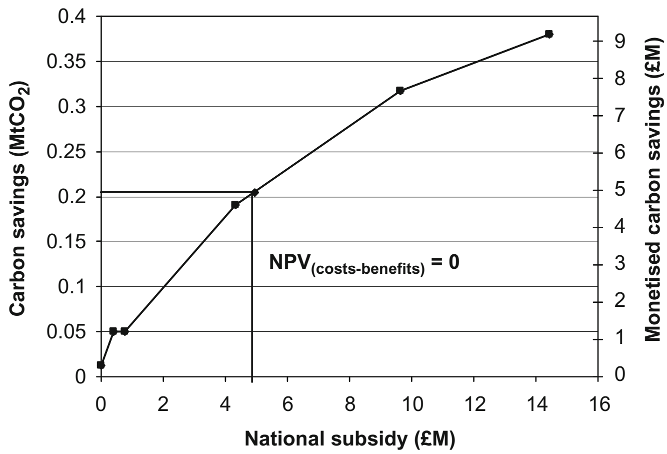

Fig. 3. Relationship between increasing national subsidy and carbon savings in weight/monetised carbon savings for draught proofing measures. Mean amount individual householder willing to spend: £37.16 ± 25% (n=35, $p<0.05$).

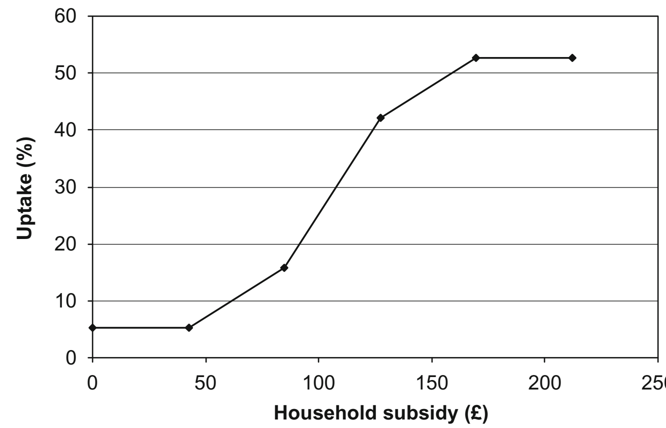

Fig. 5. Relationship between increasing household subsidy and uptake of C-rated double glazing (with reference to savings achieved by E-rated double glazing). Mean amount individual householder willing to spend: £61.61 ± 51% (n=19, $p<0.05$).

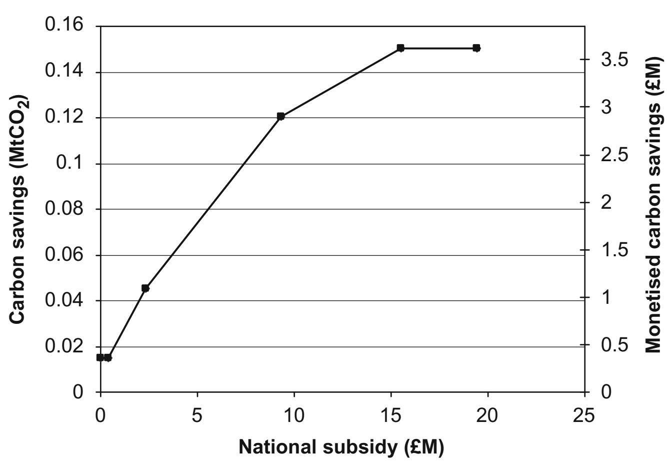

Fig. 4. Relationship between increasing national subsidy and carbon savings in weight/monetised carbon savings for C-rated double glazing (with reference to savings achieved by E-rated double glazing).

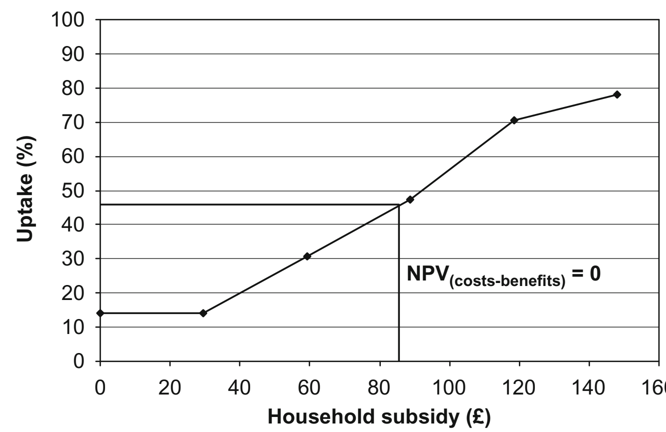

Fig. 6. Relationship between increasing household subsidy and uptake of improved heating controls (no new boiler). Mean amount individual householder willing to spend: £62.20 ± 18% (n=78, $p<0.05$).

expenditure. Costs exactly match benefits for a household subsidy of £64. Such a subsidy is sufficient to persuade approximately 46% of new homeowners to install the ESM, a nationwide investment of £4.9 M realising carbon savings a little over 0.2 $MtCO_2$ (Fig. 3).

In view of the facts that typical annual financial savings for the householder amount to £16 and that the mean length of tenure for owner–occupiers is 15.6 years[9] (DCLG, 2008a), it is perhaps a little surprising that uptake of a £64 household subsidy is only 46% since payback would be completed in a considerably shorter timeframe. Draughts being most particularly associated with sliding sash windows in larger, older (Victorian and Edwardian) houses where perhaps local planning laws forbid the installation of uPVC double glazing, the lack of interest may stem from the fact that such houses tend to be owned by wealthier members of society to whom a dividend of £16 may be seen as too inconsequential an amount to justify the inconvenience caused by the installation.

5.3. Double glazing

Although the data suggests that a national subsidy of the order of £0.4 M (equivalent to a household subsidy of £40) may be cost-effective, the number of data points at such very low levels of subsidy is insufficient to adequately resolve the graphical data to allow a carbon savings forecast to be made, i.e. the apparent cost-effectiveness for this low level of subsidy derives from a single respondent who indicated a willingness to install the ESM even in the absence of subvention (Figs. 4 and 5).

The returns being offered, annual financial savings of £10 to the homeowner, are reason enough to understand why homeowners should eschew installing an upgraded double glazing system. It should be borne in mind, however, that the sample group from which the data were extracted is small in size and substantive conclusions should be reserved until such time as larger sample sizes have been investigated.

5.4. Improved heating controls (no new boiler)

The difficulty in obtaining central heating data precludes a full discussion of the impact of subsidy on the uptake of this ESM. Although offering moderate carbon savings at the household level as shown in Table 1 and being one of the ESMs examined by

[9] The figure relates only to England but is assumed to be representative of the whole country. The median length of tenure, 11.6 years, also far exceeds the payback time.

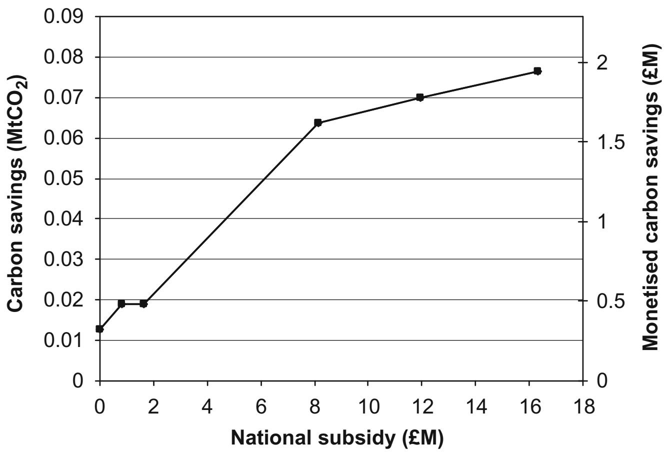

Fig. 7. Relationship between increasing national subsidy and carbon savings in weight/monetised carbon savings for improved heating controls (intention of buying new boiler).

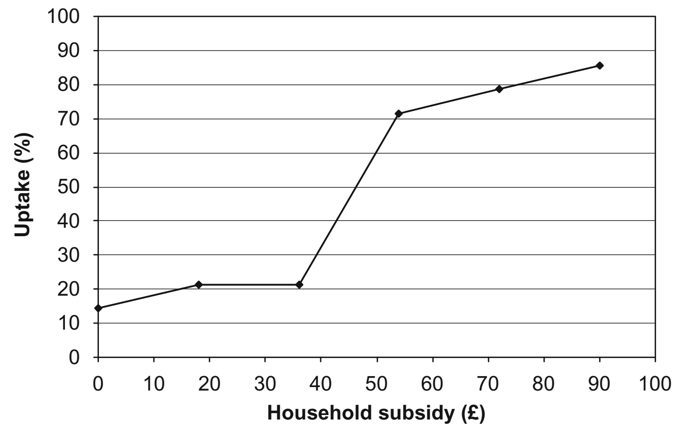

Fig. 8. Relationship between increasing household subsidy and uptake of improved heating controls (intention of buying new boiler). Mean amount individual householder willing to spend: £44.04 ± 37% (n=14, $p<0.05$).

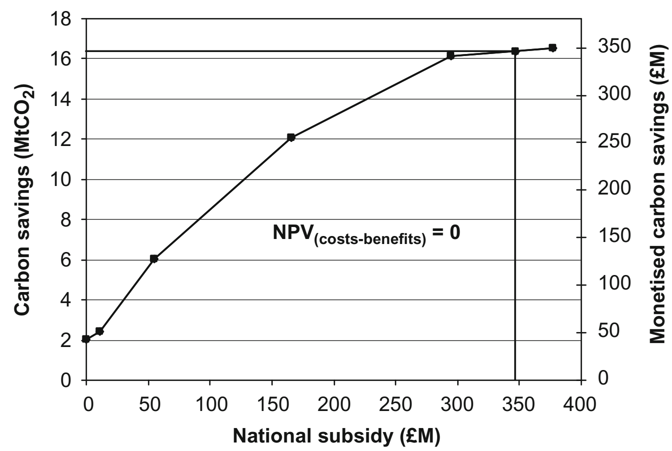

Fig. 9. Relationship between increasing national subsidy and carbon savings in weight/monetised carbon savings for loft insulation (professional installation). Mean amount individual householder willing to spend: £133.43 ± 18% (n=49, $p<0.05$).

DEFRA in its *Illustrative Mix of Measures for CERT 2008–11* (DEFRA, 2008a), DEFRA were, unfortunately, unable to give an indication of the number of central heating systems without boiler interlocks and TRVs to which this ESM relates (Dunbabin, 2008b). Thus only the relation between uptake and household subsidy can be plotted (Fig. 6) where an optimal household subsidy of £86 results in a 46% uptake.

Even though the number of central heating systems in the owner–occupier sector is known – 15.9 M (BRE, 2006) – it would appear that there are a significantly smaller number which fit the criteria demanded by this ESM. The combination of the facts that boiler interlocks have been required by the Building Regulations since 1995 (Honeywell, 2001) and that approximately one million boilers are replaced annually (IAG, 2002) suggests that a minority of boilers presently lack an interlock. It is, therefore, unlikely that this particular ESM can make a significant impact in bolstering nationwide carbon savings.

5.5. *Improved heating controls (new boiler)*

Even though the survey indicates that TRVs are absent in 64% of the central heating systems of that group of householders who will purchase a new boiler,[10] there are an insufficient number of data points at low levels of uptake to allow a forecast of carbon savings which are achievable to be made, i.e. the apparent cost-effectiveness for this low level of subsidy derives from two respondents who indicated a willingness to install the ESM even in the absence of subvention (Figs. 7 and 8).

Although the data suggests that a national subsidy of the order of £0.4 M (equivalent to a household subsidy of £11) is cost-effective, ironically, the benefits (annual financial savings of £4) to the householder, are so small in comparison to the installation costs (£90) that the provision of such information in an EPC may actually act to discourage uptake. Again though, caution must be attached to the interpretation of the data revealed in this part of the study due to the very small sample size.

5.6. *Loft insulation*

5.6.1. *Professional installation*

Subsidy of professionally installed loft insulation remains cost-effective almost all the way across all subsidy levels. Not until national subsidy reaches £346 M does it become ineffective to further subsidise its installation, this being the point of optimal subsidy where the NPV of the monetised carbon savings per household amounts to £265. This level of subsidy accumulates nationwide carbon savings of 16.4 $MtCO_2$ (Fig. 9).

5.6.2. *DIY installation*

Self-installed loft insulation is extremely cost-effective for all levels of subsidy. A household subsidy of £120 achieves an uptake of 82% resulting in total carbon savings of 13.8 $MtCO_2$ for a national expenditure of £154 M (Fig. 10).

5.7. *Cavity wall insulation*

Cavity wall insulation is effective across the whole range of subsidies, albeit that savings once again fall away at the higher levels of subsidy, the optimal NPV subsidy of £180 M (£380/household) achieving nationwide savings of 12.0 $MtCO_2$ (Fig. 11).

5.8. *Interior solid wall insulation*

In spite of the fact that the savings capacity of 29.2 $MtCO_2$ borne by interior solid wall insulation far exceeds that of any other ESM, its apparent unpopularity with new homeowners

[10] 14 out of sample size of 22.

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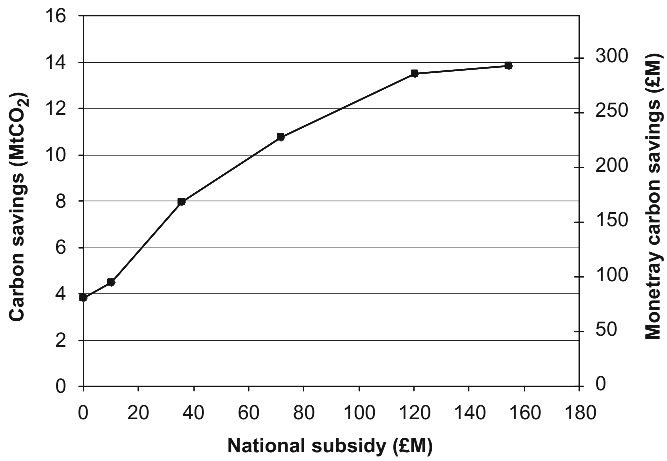

Fig. 10. Relationship between increasing national subsidy and carbon savings in weight/monetised carbon savings for loft insulation (DIY installation). Mean amount individual householder willing to spend: £64.68 ± 19% (n=49, $p<0.05$).

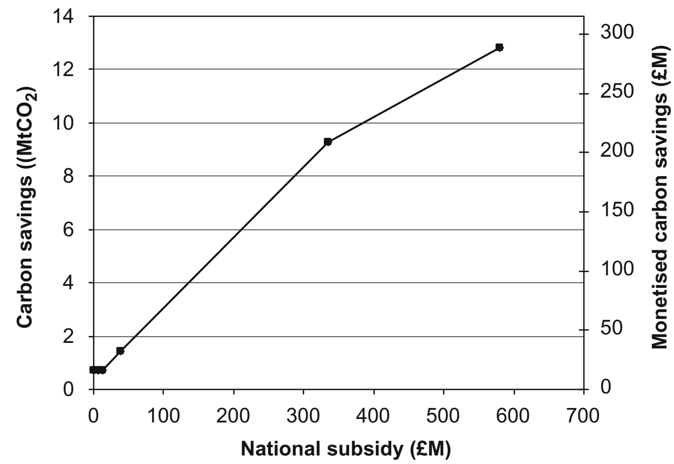

Fig. 12. Relationship between increasing national subsidy and carbon savings in weight/monetised carbon savings for interior solid wall insulation. Mean amount individual householder willing to spend: £388.01 ± 48% (n=41, $p<0.05$).

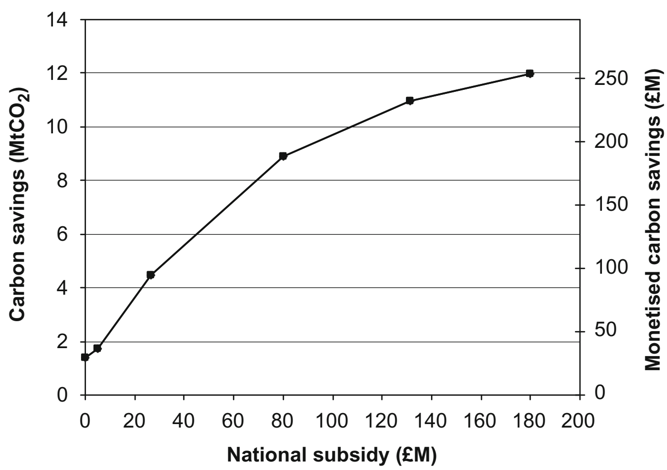

Fig. 11. Relationship between increasing national subsidy and carbon savings in weight/monetised carbon savings for cavity wall insulation. Mean amount individual householder willing to spend: £158.11 ± 23% (n=46, $p<0.05$).

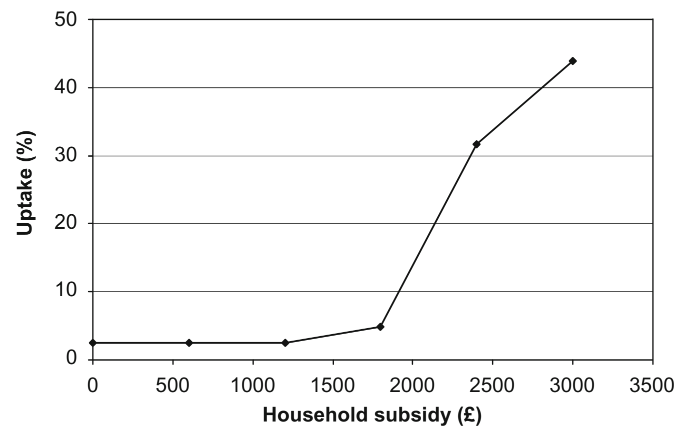

Fig. 13. Relationship between increasing household subsidy and uptake of interior solid wall insulation.

means that its potential is likely to remain untapped. Although Fig. 12 suggests that a very low level of subsidy (less than £20 M) is capable of achieving monetised carbon savings in excess of the outlay, the result should be viewed with caution since actual subsidy plays no part in the relatively elevated savings associated with this part of the graph, deriving from a single respondent who stated that he/she would be prepared to pay the full £3000 cost of this ESM without the aid of any subvention at all.

Fig. 13 more clearly shows why even low levels of subsidy remain largely ineffectual in raising carbon savings: there is no further increase in uptake until household subsidy exceeds £1500, yet household subsidy only remains cost-effective up to a maximum of £1500. Although removal of the lower decile from the results would have the effect of making any level of subsidy appear to be non-cost-effective, such an action is to be avoided since datum points at the extremities bear as much significance as those elsewhere in determining the shape of the S-curve; there is as much chance of a *rogue* datum point occurring at some intermediate point on the curve as at an extremity. In common with the double glazing and improved heating controls (new boiler), one cannot totally exclude the possibility that very low levels of subsidy may be effective in returning very low levels of carbon savings.

Although the low uptake at low levels of subsidy can be explained in terms of opportunity cost (the opportunity forsaken in spending the capital elsewhere) and long payback time where a large capital cost is not recouped for many years, this fails to explain why 55% of new homeowners are not prepared to pay anything at all for the installation of this ESM. Examination of the respondents' answers to questions *7f* and *7k* (see Appendix) reveal some of the factors involved in explaining its unpopularity. Whilst a number of respondents in leasehold properties claim that the onus is/should be borne by the landlord, other respondents dislike the idea of smaller rooms where a new false wall would encroach on living space by 70–120 mm depending upon the type of interior insulation installed (EST (Energy Saving Trust), 2006). The cost of redecorating, not included in the subsidy, and inconvenience caused by the works are also likely to be factors in discouraging uptake, especially if redecoration has already taken place since moving in. However, it should be remembered that these latter two drawbacks can be lessened if subsidy is linked to the receipt of an EPC, as is proposed, as the works can be carried out before moving in.

The results are summarised in Table 5.

6. Summary of the cost-effectiveness of the ESMs

The ESMs meriting of subsidy essentially fall into two groups, one group in which maximal carbon savings are small (less than

Table 5
Summary of impact of subsidy on carbon savings arising from ESM installation.

ESM	Theoretical maximum possible nationwide carbon savings (100% uptake) ($MtCO_2$)	Maximum possible uptake (100% subsidisation) (%)	Optimal household subsidy (£)	Uptake at optimal subsidy (%)	Optimal national subsidy (£M)	Nationwide carbon savings at optimal subsidy ($MtCO_2$)
Hot water cylinder insulation	0.4	78	14	78	2.6	0.3
Draught proofing	0.4	86	64	46	4.9	0.2
Double glazing	0.3	53	40	–	–	–
Improved heating controls (no new boiler)	–	78	86	46	–	–
Improved heating controls (new boiler)	0.1	86	11	–	–	–
Loft insulation (professionally installed)	19.8	84	265	83	346	16.4
Loft insulation (self-installed)	16.9	82	120	82	154	13.8
Cavity wall insulation	15.8	76	380	76	180	12.0
Solid wall insulation	29.2	44	1492	–	–	–

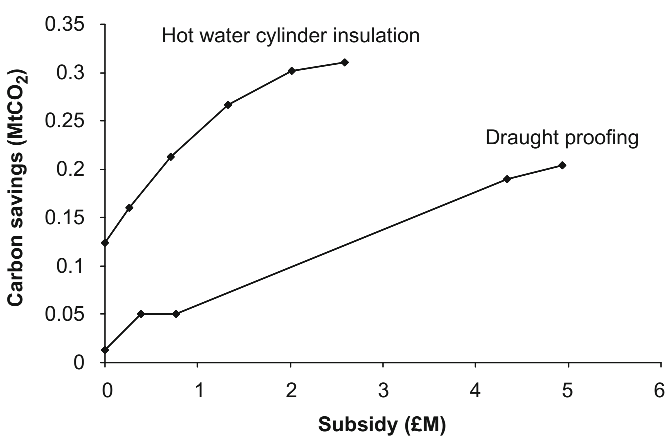

Fig. 14. Relationship between increasing national subsidy and carbon savings in weight for ESMs which achieve a low level of carbon savings.

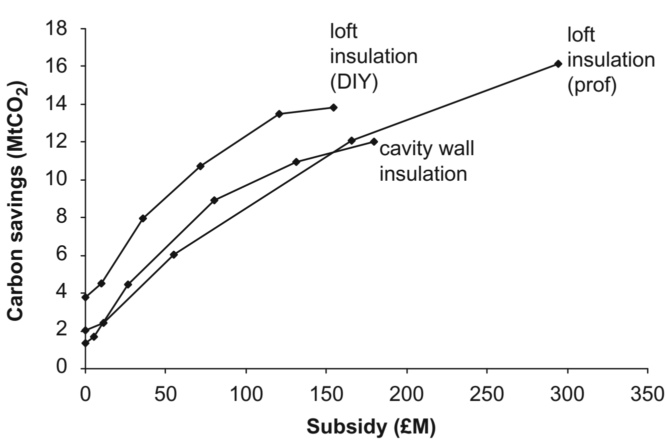

Fig. 15. Relationship between increasing national subsidy and carbon savings in weight for ESMs which achieve a high level of carbon savings.

0.5 $MtCO_2$) and another in which maximal savings are large (in excess of 10 $MtCO_2$). Figs. 14 and 15 summarise the effectiveness of the two groups of ESMs.

The low-level savings derive from hot water cylinder insulation and draught proofing (Fig. 14).

Initial subsidy is, therefore, most profitably invested in hot water cylinder insulation with draught proofing attracting later investment.

The high-level savings derive from loft insulation and cavity wall insulation (Fig. 15).

Whilst self-installed loft insulation is most cost-effective (accumulating savings faster than professionally installed insulation), professionally installed insulation goes on to achieve a higher level of carbon savings; cavity wall insulation savings parallel those of self-installed loft insulation, albeit that the rate of return is slightly lower.

Heating controls (no new boiler installed) are also likely to be cost-effective but the lack of data on a national scale prevents the absolute level of savings being calculated.

Although the remaining ESMs do not appear to be attractive vehicles for accumulating carbon savings, there remains the possibility that very low levels of subsidy may be cost-effective in causing very small increased rates in the uptake of the double glazing, heating controls (new boiler installed) and solid wall insulation ESMs. The very low numbers of householders in the survey prepared to install these ESMs at low levels of subsidy preclude extrapolation of the data to a national scale.

7. Sensitivity analysis

Recognising the fact that an allowance has to be made for future uncertainty and that *spurious accuracy should be avoided*, the Treasury states that a sensitivity analysis is fundamental to the appraisal of any policy, programme or project requiring of government funds (HM Treasury, 2003); DEFRA further recommends that a variance of $\pm 5\%$ in the SPC is used in the performance of the sensitivity analysis (DEFRA, 2007d). Indeed a 5% change necessarily changes the level of carbon savings realisable for all levels of subsidy. However, analysis of the data reveals that neither is a +5% change sufficient to make any of the least effective ESMs – double glazing, heating controls and solid wall insulation – significantly more cost-effective, nor is a –5% change sufficient to justify the removal of subsidy from any of the most effective ESMs – hot water cylinder insulation, draught proofing, loft insulation and cavity wall insulation.

8. Case for non-optimal subsidy

In isolation, where the absolute levels of savings are of paramount importance, the wisest course of action is to subsidise all ESMs to the optimal extents as indicated above. However, there is an argument to be made that it might be most judicious to curtail spending on certain of the ESMs before the calculated level of optimal subsidisation occurs in the case where funds are limited.

Whilst it remains true that subsidy is cost-effective across the whole range of subsidies for self-installed loft insulation, it does, however, become increasingly less effective at the higher end where, for example, the final £34 M of subsidy brings about less than 0.35 $MtCO_2$ of savings (cf. the first £36 M achieve savings of 8.0 $MtCO_2$). Carbon savings similarly begin to taper off as optimal subsidy of professionally installed loft insulation is approached where the last £52 M of subsidy only secures weight savings of approximately 0.25 $MtCO_2$. Although the taper is less pronounced than for cavity wall insulation, the final £48 M of subsidy, nevertheless, still only achieves weight savings in of the order of 1.0 $MtCO_2$.

In view of the fact that the ESMs considered in this study are but nine amongst a number of others including microgeneration and fuel switching, the size of the purse available will ultimately determine whether funds should be re-directed at subsidising such latter ESMs than optimally subsidising loft/cavity wall insulation.

9. Robustness of predictive capacity of model

Having established that certain ESMs are more appropriately subsidised than others and having created scales which allow one to calculate the carbon savings which follow subsidy, the question must be asked whether or not the quality of the raw data is of a sufficiently high standard to merit the analysis so performed. Moreover, one has to assess whether or not the error accrued in the process of the data is sufficiently large so as to invalidate the model as a tool of forecast for subsidy. These sources of error are examined in turn.

9.1. Questionnaire

9.1.1. Human factor element

Inherent in all surveys reliant upon a questionnaire is the discrepancy that can occur between stated response and actual action. The likelihood of such disparity in the present instance is high, surveyed respondents in receipt of a home energy report only installing 70% of those ESMs that they had indicated that they intended to install within the subsequent 12 months (Parnell and Popovic Larsen, 2005). Termed the *human factor element*, the occurrence of which results in householders tending to over-predict the number of ESMs that they intend to install (McGilligan et al., 2008), its likely to have manifest itself in the present instance as an over-estimation of the actual prices that new homeowners are really prepared to pay. Such an overly optimistic outlook is, perhaps, a consequence of the excitement engendered by the *new home experience* or the desire to be seen to possess *green credentials.*

9.1.2. Self-reporting inaccuracies

There is likely to be a degree of inaccuracy in the self-reporting of ESMs currently in place/not in place, as evidenced by the fact that 26 out of 47 respondents (55%) stated that their loft insulation was at least 270 mm in depth, this being far in excess of the 1% of homes which reach this standard as suggested by the English House Condition Survey (Irving, 2008). Excepting for cavity wall insulation, in which case it is considered that a homeowner would have reported a *don't know* response if uncertain, it appears unlikely, however, that identifying the presence/absence of the remaining ESMs would have presented the homeowners with much of a problem.

9.1.3. Incorrect responses

Whilst the smallness of certain of the sample groups was, in part, a consequence of low nationwide demand for a particular ESM (e.g. improved heating controls when it is intended to buy a new boiler) and therefore beyond the capacity of the authors to remedy, the problem was exacerbated by having to reject a proportion of incorrectly answered (or unanswered questions). Whilst some derived from errors of logic where, for example, a price was named for the installation of cavity wall insulation even though it was already present, in other instances the respondent failed to mark the scale but gave a reason for being unwilling to install an ESM—in such a case it was impossible to know whether the respondent was unwilling to pay anything or had simply made a mistake.

9.1.4. Time period for ESM installation

The decision to limit the time period in which homeowners would install an ESM was very deliberately chosen at 24 months although it is apparent that any persuasive powers borne by the EPC do not abruptly cease 2 years subsequent to receipt. The time stipulation was intended to make the respondent aware of the fact that he/she was being personally addressed and that he/she was not being asked to give a reasonable answer on behalf of a notional third person, since the same instruction, when re-read without the 24 month addendum, loses some of its personal focus. Since intent becomes increasingly disconnected with actuality as time increases, it was deemed that the benefits of limiting the ESM installation period to 24 months outweighed the disadvantages as that the vast majority of improvements carried out in the home occur within the first six months of the purchase of the property (DTI (Department of Trade and Industry), 2006). Further support for this decision, based on the reasoning that ESMs are most likely to be implemented during the early part of residence, comes from the finding that 50% of new homeowners, when surveyed 14–20 months following transaction, stated that they had either never looked at their EPC or had only looked at it once since moving in (Darby, 2003).

9.1.5. Respondents unwilling to pay

In attempting to ascertain why a respondent would not be prepared to spend anything on the installation of an ESM, the respondent was given the options of *too much bother, intend to move again soon* and *other*. The assumption was that such respondents did not want to install the ESM for a reason other than cost. However, one cannot rule out the possibility that a proportion of these respondents would be prepared to install the ESM so long as it cost him/her nothing at all, the impact of which on the model would result an under-estimation of carbon savings for high levels of subsidy.

9.2. Demographic errors

Unfortunately the survey cannot report on the demographic profile of the respondent group, the decision to omit any questions of this nature being taken reluctantly so as not to compromise the need for brevity. It is probable, however, that the respondents did not constitute a representative cross-section of

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the home buying public; 36% of Darby's respondents possessed degree level qualifications, this being significantly higher than the level in the working-age population (Darby, 2003). However, it is also unlikely that those new homeowners who react to the EPC and install ESMs are representative of the larger home buying public, the former group being expected to exhibit more of the same pro-active nature as those who responded to the survey than is typical of the home buying public at large.

9.3. Sample size

The small size of the sample groups necessarily introduces error into the model: certain ESMs, already present in large numbers in the nation's housing stock and for which the remaining capacity is limited, are necessarily more susceptible to this error than others.

Since the ultimate goal of the survey is the evaluation of the optimal subsidy for each ESM, this being determined by the shape of the S-curve, the goodness-of-fit test represents the ideal with regard to testing the reliability of the sample data. Yet such a test cannot be performed since there is no curve from the general population against which it can be compared. Resultantly, the researcher is left with no other alternative than to examine a single parameter, such as the mean of the household subsidy. Although its actual value is of no importance per se, it is, nonetheless, a measure of the sample data and, as such, can be used to examine the representativeness of the sample data.

A two-sided t-test was chosen as the best possible test. For a given level of confidence (95% in the present instance), the t-test identifies the extent to which the interval either side of the mean in the sample group must be extended so that the mean of the population at large would be included within the interval. In this way, the size of the confidence interval is a measure of the (un)representativeness of the sample group: whilst a small interval may or may not indicate close correspondence between the sample group and the general population, a large interval indicates dissimilarity between the two. Thus, it is perhaps more accurate to view the test rather less as a test of the reliability of the sample data and rather more as a test of the unreliability of the data.

It should be noted that even if uptake in the population is not normally distributed across the seven categories of subsidy (ranging from £0 to full cost of the ESM), the means of samples will approach a normal distribution by the central limit theorem. In consequence, the t-test remains a valid test even for internal solid wall insulation, the distribution of which may be positively skewed across the range of categories of subsidy.

Analysis of the results shows that whilst the confidence intervals (and therefore sample size-associated errors) that occur with (i) improvement to double glazing (ii) improved heating controls (new boiler), and (iii) interior solid wall insulation are significant (37–51%), these are also the ESMs which would appear least likely to benefit from linkage with subsidy. Conversely, the confidence intervals associated with those ESMS showing the most potential for linkage with subsidy are significantly smaller, ranging from 19% in the case of self-installed loft insulation to 25% for draught proofing measures.

The staccato-appearance of the graphs derives from the fact that the number of data points and range of subsidy categories are limited. It follows, therefore, that caution must be employed when interpreting the results since the pattern of uptake is likely to be smoother than the graphs tend to indicate.

9.4. Financial savings and costs

The savings quoted in the questionnaire, being based on energy prices taken from the 2nd quarter of 2007 (DEFRA, 2008a) correlate with the 2007 average energy bill stated in the cover letter, 2007 being the last full calendar year for which data was obtainable at the time the survey was carried out. There were, however, increases in the prices of gas and electricity of 5% and 7% in real terms over the course of the following 12 months (BERR (Department for Business Enterprise and Regulatory Reform), 2008), the consequential effect being that carbon savings could be higher than indicated as a result of decreased consumption.

Although the ESM installation costs quoted in the questionnaire were in 2009 prices (2007 prices using an inflation factor of 5%) (DEFRA, 2008a; Dunbabin, 2008a), it is not considered that the survey response would have been significantly different had 2008 prices been used, the difference in cost price being generally small in comparison to the potential savings.

9.5. Carbon savings

The model is highly reliant upon the premise that the potential savings, as derived from the BREDEM-based CERT base case dwelling, are a near match to the savings that would be recorded in an EPC if each new homeowner were to receive one. Whilst this can almost never be the case at the individual household level, the average savings for a particular ESM across the nation should be in close agreement to the extrapolated savings predicted by the base case dwelling. If the assumption holds true then the responses by the group of new householders who did not receive an EPC should be in close agreement with the group who did receive an EPC, the latter group having had the advantage of being able to check the *real* savings potential borne by their homes with the BREDEM-based savings potential stated in the questionnaire. Unfortunately, there are insufficient data to render statistical comparison across the range of seven different price bands and nine ESMs meaningful.

9.6. Economic forecast

Despite the proclamations made by the government that an increment of 2% should be applied to future evaluations of the SPC to account for the rising damage costs associated with higher CO_2 concentrations and that the net present value of a policy 40 years hence can be measured by applying a 3.0% discount factor, a measure of caution must be reserved before too keenly embracing such figures. It remains to be seen whether the extremely unsettled economic period through which we are currently passing, as evidenced by the Bank of England's reduction in bank interest rates to 0.5% (Bank of England, 2009), the lowest since its foundation in 1694, will have long-term effects upon the economy.

9.7. Administration costs

Since the costs of administering this policy are beyond the scope of this study they must be borne elsewhere if the conclusions reached are to remain valid. Whether raised through taxes or passed on to ESM manufacturers and suppliers (who would benefit from increased custom), a precedent having been set in the latter case where energy suppliers bear the cost of running the CERT programme, it is not envisaged that the administration costs would be exorbitant since the vehicle upon which the policy of subsidy would sit, viz. the EPC, is already in place.

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Table 6
Percentage of optimal savings due to free-rider effect as estimated from carbon savings-subsidy graphs.

ESM	*Proximate free-rider effect (%)*
Hot water cylinder insulation (top up)	40
Draught proofing	6
Loft insulation (professional)	12
Loft insulation (DIY)	28
Cavity wall insulation	11

9.8. *Free-rider errors*

In estimating the carbons savings realised by an ESM for a given level of subsidy, it should be remembered that not all of the subsidy is *useful* inasmuch as a proportion of it is taken as a windfall by so-called free-riders who would have installed the ESM even were subvention not available (business-as-usual). The proportion of free-riders has been estimated to be as high as 60% (Egmond et al., 2006) and even 70% (Haugland, 1996). In theory, the data gathered in the survey should be sufficient to allow the free-rider effect to be calculated directly from the set of graphs presented in the results, being the ratio of carbon savings accrued at zero subsidy divided by that accrued at optimal subsidy (Table 6).

Since the number of data points from which the ratios are calculated is limited, even these proximate figures should be viewed with caution. What is more, such a calculation method may, however, over-estimate the size of the free-rider effect as a consequence of the afore-mentioned human factor element.

10. Application of the subsidy

A number of devices are identified as possible mechanisms for the distribution of government subsidy, the Environmental Change Institute proposing in particular Value Added Tax (VAT) reduction, Council Tax rebate, and Stamp Duty rebate (Boardman, 2007).

A *green mortgage* system, as has been implemented by the Ministry of Housing, Spatial Planning and the Environment in the Netherlands in its *Green Funds Scheme* could also prove to be effective: savers investing in the fund are offered a tax advantage and mortgagors benefit from a rate of interest generally 1% lower than current commercial rates in return for installing ESMs (Senternovem, 2008). The attractiveness of such a green mortgage scheme is further enhanced once account is taken of the finding that up-front costs play a particularly important role in householders' reluctance to install ESMs (Parnell et al., 2002).

The simple award of subsidy in the form of traditional grants should not go overlooked since it has proved very cost-effective in the past and continues to deliver carbon savings in the form of the CERT programme today. Its success may derive from its being perceived as an award/gift rather than merely the lessening of a demand forced upon the householder as is the case with a reduction in tax.

11. Conclusion

Using the EPC as a gateway for its delivery, the model described in this study details which ESMs in owner–occupier homes most befit subsidisation, and, furthermore, forecasts carbon savings which accrue for different levels of subsidy. The model cautiously predicts, for example, that an investment in 2009 of approximately £200 M of subsidy split between self-installed loft insulation and cavity wall insulation would result in an absolute reduction of 22 $MtCO_2$ over the course of the following 40 years (this being the equivalent of annual savings of over 0.55 $MtCO_2$). What is more, the annual savings of 0.55 $MtCO_2$ resulting from such a subsidy, solely to new homeowners, compare very favourably with the annual savings of 0.7 $MtCO_2$ expected of the whole of the EPBD across the whole of the residential sector (DECC, 2008), and with the 96.8 $ktCO_2$ expected of the EPC by 2012 in the new homeowner–occupier sector in the absence of subsidy (Mcgilligan et al., 2008). Although these subsidy-derived savings incorporate free-riders' savings which would have come about naturally in the business-as-usual scenario in the absence of subsidy, meaning that the marginal cost-effectiveness cannot be calculated, such a subsidy is, nevertheless, cost-effective in absolute terms where more monetised savings are delivered than subsidy is expended.

It should be kept in mind that the residential sector is but one of several energy-intensive sectors, some or all of which may be more readily able to find carbon savings than the residential sector. This study, therefore, sets a benchmark for the new homeowner sector within the larger residential sector, setting out what can be achieved and for how much cost, in order that cross-sector comparison can be made.

12. Further research

Whilst the carbon savings in this model derived from the CERT base case dwelling, future surveys would benefit from using the actual savings predicted by EPCs issued by energy assessors.

The determination of the optimum levels of subsidy for contemporaneously subsidised self- and professionally installed loft insulation is problematic since the level of subsidy of one necessarily affects the level of subsidy of the other, where, in market terms, both ESMs are competing for the same group of customers. Requiring a survey of its very own to establish the optimal spending regimes, this can only be done by presenting homeowners with a series of paired costs (one for professionally installed loft insulation and the other for self-installed loft insulation) and asking which of the two ESM costs they found most attractive and how likely it would be that they would install it at that price.

It would be beneficial to ascertain the NPV of carbon savings in the new homeowner sector in the business-as-usual scenario where no subsidy is offered to the new homeowner. The subtraction of the carbon savings which arise in the business-as-usual scenario from the policy-derived savings calculated in this study would allow the evaluation of the marginal impact of subsidisation to be carried out.

13. Postscript

Although the subdued level of activity observed in the property market in the last few months due to the unforeseen severe economic downturn necessarily serves to reduce the levels of carbon savings predicted by the model as a consequence of fewer EPCs being issued in the short term, the conclusion that subsidy is merited as an option in the challenge to curtail GHG emissions remains valid. It should be remembered that carbon savings resulting from the installation of the cost-effective ESMs are measured, for the most part, in decades.

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Appendix

NEW HOMEOWNER SURVEY

1 ENERGY CERTIFICATE

Were you given an *Energy Performance Certificate* when you moved into your new home?

- ☐ Yes — *Now go to question 2*
- ☐ No — *Now go to question 2*
- ☐ Don't know — *Now go to question 2*

2 HOT WATER CYLINDER

Does your home have a hot water cylinder?

- ☐ Yes — *Now go to question 2a*
- ☐ No — *Now go to question 3*
- ☐ Don't know — *Now go to question 2b*

2a Does your cylinder have less than 3" (75mm) of insulation?

- ☐ Yes — *Now go to question 2b*
- ☐ No — *Now go to question 3*
- ☐ Don't know — *Now go to question 2b*

2b If it was found that you had a cylinder whose insulation could be topped up to a thickness of 3" (75mm), indicate how much you would be prepared to spend on this energy saving measure. **(Typical annual savings: £20)**

£0 — £3.50 — £7 — £10.50 — £14

If you answered £0 go to question 2c, otherwise go to question 3

2c Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *Now go to question 3*
- ☐ Intend to move again soon — *Now go to question 3*
- ☐ Other.............................. .... — *Now go to question 3*

3 DRAUGHT PROOFING

Are there any draughts around the edges of your windows or doors?

- ☐ Yes — *Now go to question 3a*
- ☐ No — *Now go to question 4*
- ☐ Don't know — *Now go to question 3a*

3 DRAUGHT PROOFING ctd

3a If it was found that there were draughts around the edges of your windows and/or doors which could be reduced by installing draught-stripping, indicate how much you would be prepared to spend on this energy saving measure.
(Typical annual savings: £16)

£0 — £25 — £51 — £76 — £101

If you answered £0 go to question 3b, otherwise go to question 4

3b Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *Now go to question 4*
- ☐ Intend to move again soon — *Now go to question 4*
- ☐ Other.............................. .... — *Now go to question 4*

4 DOUBLE GLAZING

Does your home have double glazing?

- ☐ Yes — *Now go to question 5*
- ☐ No — *Now go to question 4a*
- ☐ Don't know — *Now go to question 5*

4a Are you thinking of having double glazing installed within the next 24 months?

- ☐ Yes — *Now go to question 4b*
- ☐ No — *Now go to question 5*

4b Indicate **how much extra** you would be prepared to spend on having high energy performance glazed units (C-rated) installed instead of units of standard energy performance (E-rated). **(Typical annual savings: £10)**

£0 — £53 — £106 — £159 — £212

If you answered £0 go to question 4c otherwise go to question 5

4c Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *Now go to question 5*
- ☐ Intend to move again soon — *Now go to question 5*
- ☐ Other.............................. .... — *Now go to question 5*

5 CENTRAL HEATING

Do you have central heating?

- ☐ Yes — *Now go to question 5a*
- ☐ No — *Now go to question 6*
- ☐ Don't know — *Now go to question 5b*

5a Do you intend to have a new boiler installed within the next 24 months?

- ☐ Yes — *Now go to question 5c*
- ☐ No — *Now go to question 5b*
- ☐ Don't know — *Now go to question 5b*

5b If it was found that you had a central heating system whose heating controls could be improved, indicate how much you would be prepared to spend on this energy saving measure. **(Typical annual savings: £35)**

£0 | £37 | £74 | £111 | £148

If you answered £0 go to question 5e, otherwise go to question 6

5c Does your current central heating system have thermostatic radiator valves?

- ☐ Yes — *Now go to question 6*
- ☐ No — *Now go to question 5d*
- ☐ Don't know — *Now go to question 5d*

5d If it was found that thermostatic radiator valves could be attached to your radiators, indicate **how much extra** you would be prepared to spend on having them installed. **(Typical annual savings: £4)**

£0 | £23 | £45 | £68 | £90

If you answered £0 go to question 5e, otherwise go to question 6

5e Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *Now go to question 6*
- ☐ Intend to move again soon — *Now go to question 6*
- ☐ Other.............................. .... — *Now go to question 6*

6 LOFT INSULATION

Does your home a have loft?

- ☐ Yes — *Now go to question 6a*
- ☐ No — *Now go to question 7*
- ☐ Don't know — *Now go to question 6b*

6 LOFT INSULATION ctd

6a Does your loft have less than 11" (270mm) of insulation?

- ☐ Yes — *Now go to question 6b*
- ☐ No — *Now go to question 7*
- ☐ Don't know — *Now go to question 6b*

6b Loft insulation can either be (i) professionally installed by a contractor or (ii) done as a DIY project.

ATTENTION

Even though you would have to make a choice between option (i) and option (ii) above when it actually came to installing the insulation, please answer both parts 6b(i) and 6b(ii) below. It may be the case, for example, that whilst you would generally prefer to have it professionally installed and would pay a contractor £250 to do the job, you would be just as likely to do the job yourself if you could buy the insulation for only £100.

Remember, you are answering on behalf of yourself – if it could be purchased at the price you indicate, you would be very likely to have it installed within the next 24 months.

If it was found that you had a loft whose insulation could be topped up to a depth of 11" (270mm), indicate:-

6b(i) how much you would be prepared to spend on having a **contractor** fully insulate the loft. **(Typical annual savings: £38)**

£0 | £72 | £143 | £215 | £286

Now go to part 6b(ii)

6b(ii) how much you would be prepared to spend on the insulation if you installed it yourself (ie **DIY**). **(Typical annual savings: £33)**

£0 | £30 | £60 | £90 | £120

If you answered £0 for both (i) and (ii) go to question 6c, otherwise go to question 7

6c Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *Now go to question 7*
- ☐ Intend to move again soon — *Now go to question 7*
- ☐ Other.............................. .... — *Now go to question 7*

7 WALL INSULATION

What type of walls does your home have?

- ☐ Cavity walls — *Now go to question 7a*
- ☐ Solid walls — *Now go to question 7d*
- ☐ Timber frame — *That was your last question*
- ☐ Don't know — *Now go to question 7g*

7 WALL INSULATION ctd

7a Does your home have cavity wall insulation? (ie a layer of insulation between two masonry walls)

- ☐ Yes — *That was your last question*
- ☐ No — *Now go to question 7b*
- ☐ Don't know — *Now go to question 7b*

7b If it was found that your home had cavity walls which could be filled with cavity wall insulation, indicate how much you would be prepared to spend on this energy saving measure.
(Typical annual savings: £78)

£0 — £95 — £190 — £285 — £380

If you answered £0 go to question 7c, otherwise that was your last question

7c Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *That was your last question*
- ☐ Intend to move again soon — *That was your last question*
- ☐ Other.............................. .... *That was your last question*

7d Does your home have insulation fitted to the inside of the exterior walls (typically a layer of insulation between the structural part of the wall and an interior face of plasterboard?

- ☐ Yes — *That was your last question*
- ☐ No — *Now go to question 7e*
- ☐ Don't know — *Now go to question 7e*

7e If it was found that insulation could be fitted to the **inside of the exterior walls** of your home, indicate how much you would be prepared to spend on this energy saving measure.

Rooms with an exterior wall would decrease in size by 3.5-6" (70 – 120mm). Typically, a layer of insulation is placed between the existing masonry wall and a new plasterboard facing. The wall will require subsequent redecoration.
(Typical annual savings: £256)

£0 — £750 — £1500 — £2250 — £3000

If you answered £0 go to question 7f, otherwise that was your last question

7f Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *That was your last question*
- ☐ Too expensive — *That was your last question*
- ☐ Do not want smaller rooms — *That was your last question*
- ☐ Intend to move again soon — *That was your last question*
- ☐ Other.............................. .... *That was your last question*

7 WALL INSULATION ctd

7g If it was found that your home had cavity walls which could be filled with cavity wall insulation, indicate how much you would be prepared to spend on this energy saving measure.
(Typical annual savings: £78)

£0 — £95 — £190 — £285 — £380

If you answered £0 go to question 7h, otherwise go to question 7i

7h Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *That was your last question*
- ☐ Intend to move again soon — *That was your last question*
- ☐ Other.............................. .... *That was your last question*

7i Does your home have insulation fitted to the inside of the exterior walls (typically a layer of insulation between the structural part of the wall and an interior face of plasterboard?

- ☐ Yes — *That was your last question*
- ☐ No — *Now go to question 7j*
- ☐ Don't know — *Now go to question 7j*

7j If it was found that your home had solid walls rather than cavity walls and that insulation could be fitted to the **inside of the exterior walls** of your home, indicate how much you would be prepared to spend on this energy saving measure.

Rooms with an exterior wall would decrease in size by 3.5-6" (70 – 120mm). Typically, a layer of insulation is placed between the existing masonry wall and a new plasterboard facing. The wall will require subsequent redecoration.
(Typical annual savings: £256)

£0 — £750 — £1500 — £2250 — £3000

If you answered £0 go to question 7k, otherwise that was your last question

7k Indicate why you would be unwilling to spend anything.

- ☐ Too much bother — *That was your last question*
- ☐ Intend to move again soon — *That was your last question*
- ☐ Other.............................. .... *That was your last question*

Please use the other side of this sheet of paper if you wish to make any comments.

If you have already installed any of these energy saving measures since moving in, please indicate which ones.

If you would like to take part in a follow-up survey to be carried out in 12 months time, please include your contact details.

Thank you.

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