Meeting the United Kingdom's CO_2 Emissions Reduction Targets: the Role of Energy Efficiency in Residential Buildings

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ABSTRACT

This paper examines the contribution that energy efficiency in residential buildings can make towards meeting the UK government's commitment to reduce the country's CO_2 emissions by 20% relative to 1990 levels by the year 2010. It is based on work carried out by the authors and their colleagues, funded by the UK Electricity Association.

Following a bottom-up modelling approach, the technological options available for use in residential buildings in the UK have been assessed. The potential they offer for avoiding carbon emissions in the year 2010 and the lifetime cost per tonne of carbon avoided for each option implemented are used to identify key options on which policy activity could be focused.

Possible policy measures are discussed, as are the investment levels which would be required to implement them. A potential strategy for accessing the technical potential in this sector is then defined, and the impact on total national carbon dioxide emissions quantified. The potential role of government, utilities and other private sector organisations is considered.

The results are discussed with reference to the technical potential and associated costs for emissions reductions identified for other energy end-use sectors, and also the potential for changes in energy use behaviour. The results from the study are compared with those from other recent UK studies. From this discussion, some preliminary suggestions are made for the role which may be played by energy efficiency investment in residential buildings.

Introduction

Government policies to reduce emissions of greenhouse gases in the UK are collected together in the Climate Change Programme (UK Government, 1994 and 1997). The programme emphasises the use of market mechanisms in preference to regulation, and the provision of information and other measures to remove market barriers. Between the publication of the first and second reports on the programme, the expected role of gas as a fuel for electricity generation increased significantly. Partly as a result of this, the UK expects to meet its commitment to return CO_2 emissions to 1990 levels by the year 2000, despite a lower level of policy activity for end-use efficiency than originally envisaged. Savings from the electricity generation and energy supply sectors are estimated to contribute almost 50% of the emissions reductions forecast for the year 2000. However, the latest report does state that 'based on current measures, overall CO_2 emissions are projected to rise by 2010'. Table 1 summarises these emissions projections.

The UK Government is committed to reducing national carbon dioxide emissions by 20% relative to 1990 levels by the year 2010. This suggests a need to reduce annual emissions in 2010 by around 35MtC relative to business-as-usual projected levels. In addition to this national commitment, the UK will be legally bound by its contribution to the EU target of a 7% reduction in a basket of six greenhouse gases, agreed in Kyoto. The differentiated targets for each EU Member State will be agreed in the summer of 1998.

Table 1: UK Carbon Dioxide Emissions Projections

	Carbon dioxide emissions from energy end-uses (MtC)		
Sector	**1990**	**2000**	**2010**
Residential	42	37	37
Commercial and Public	23	20	23
Industry	48	44	48
Agriculture	2	1	1
Transport	38	43	49
Other	14	12	12
Total	**166**	**157**	**169**

Source: DTI, 1995

This paper, based on a broader study funded by the UK Electricity Association (a trade association representing the interests of electricity generation, distribution and supply companies), examines the ensuing possibilities for more policy activity, focusing on the residential buildings sector. Energy use in the residential sector accounts for approximately 30% of final user energy demand in the UK (DTI, 1997). Government projections suggest that this share may fall somewhat by 2010, but will remain significant, at around 25% (DTI, 1995). Therefore the sector could potentially be expected to make a significant contribution to meeting emissions reduction targets. The paper identifies the opportunities available and suggests some policy options which may form part of the toolbox used to access this potential.

Methodology

The general approach begins with the 'Business as Usual' (BaU) scenario, which is the Department of Trade and Industry's *Energy Paper 65* (EP65) CL (Central growth, Low oil price) scenario, and its estimates of final user energy consumption and emissions by fuel and by sector. The aim then is to construct a 'Realistic High Efficiency' (RHE) scenario, based on a rank ordering of technical options that provide extra energy and emissions savings beyond those resulting from the continuing end-use improvements embedded in the EP65 BaU scenario.

Work on EP65 has enabled us to construct estimates of these embedded efficiency improvements; they define the starting-point for the pursuit of further technical options in the RHE scenario. The estimates of net costs and of energy and carbon savings are then built up by fuel and by broad sub-sector to enable the construction of sectoral rankings of the cost-effectiveness of carbon-saving measures, calculated as levelised cost per unit of carbon saved.

One further aspect of the approach worth mentioning at this point, is the general use of a 10 per cent discount rate. This rate represents a commercial discount rate (higher than the Government's 6 per cent real test discount rate), and has been used for the majority of cost estimates. A limited sensitivity analysis demonstrated that, whilst varying the discount rate did have a small impact on the estimated cost-effectiveness of measures, it had very limited effect on their ranking.

Projections of fuel prices are based on the assumptions made by the DTI for EP65, following their low price scenario. The price projections for each sector were obtained directly from the DTI, as precise figures are not reported in EP65. The prices used are in 1996 constant value terms, and are exclusive of taxes such as Value Added Tax (VAT). Assessment of the cost-effectiveness of measures is undertaken using ex-tax prices, to properly reflect government's perspective when taking a strategic view of the merits for the UK of alternative investments.

Emission factors are reported in many sources, with some variations due to levels of aggregation, assumptions concerning fuel quality and sources. The figures used for direct combustion of primary fuels are those assembled by Pout (1994) for the Buildings Research Establishment (BRE), which are widely used in the BRE's own assessments of carbon reduction measures. Emission factors for all primary fuels are assumed to remain constant over the assessment period. Emission factors for electricity are based on average generation mixes for day and night tariffs, and projections for this sector are based on those used by the DTI in the EP65 CL scenario, following the projected fuel mix.

In a scenario of strong energy efficiency improvement, it is likely that several measures will be applied to dwellings at one time, or that further measure will be implemented at some later date. Individual percentage savings achieved by measures which affect the same 'component' of energy use are not simply additive, as one measure reduces the energy loss affected by the second - individual percentage savings are thus broadly multiplicative. A good example is two measures which affect the same element of a building's heat loss (e.g. building fabric insulation measures and installation of a condensing boiler). The approach used here is to assume that certain measures are installed first, and that subsequent measures make decreasing savings. It is thus necessary to make some assumptions about the order in which measures are installed. This approach has an intuitive appeal if it is assumed that measures with a lower investment cost and at least acceptable payback times are installed first.

The costs and energy savings of measures are based largely on results reported in ETSU (1994), collated for their broad appraisal of technology development status. Where ranges of costs are given by ETSU for a single measure, values towards the upper end were chosen to avoid an overly optimistic assessment of cost-effectiveness.

The 'cost basis' for each measure reflects whether the full investment cost for a measure is used in the analysis, or whether instead just the incremental cost of purchasing a high energy efficiency model is used. The cost basis is tied directly to the assumptions made concerning the timing of installation of measures. For example, where a household is renovating the building fabric anyway, or replacing an appliance at the end of its life, the choice of higher efficiency materials or appliance is assumed to incur only the incremental cost - these cases are described as installation on 'Turnover'. Premature installations and replacements made for the sake of energy savings alone are charged the full cost of the measures.

Several of the measures are modelled for both turnover and premature replacement, reflecting the mixture of decisions actually made by consumers. The number of investors adopting measures in any year through natural turnover are estimated using a simple stock model and the remaining consumers may choose to replace prematurely.

The diffusion of measures for the RHE scenario is described through the use of Sigmoid or S-curves. Following much empirical observation and explanatory theoretical work, S-curves broadly encapsulate the typical response to new products or new policy to promote existing products: slow initial response, rising uptake rates as information spreads and perceived risk reduces, followed by a decline towards saturation. Further discussion of the role of S-curves in energy efficiency investment analysis and policy effectiveness may be found in, for example, Leach and Lucas (1995).

Identified technical potential

The study considered a range of technical measures available for use in the residential sector. These covered the insulation of the building, heating system improvements and increased efficiency in lighting and appliances. The measures are summarised in Table 2. Note that fuel switching was outside the scope of the study. However, since approximately 75% of UK homes use gas for heating and, under a Business-as-Usual scenario, this proportion is expected to increase, the scope for additional carbon emissions reductions from this measure is limited.

Table 2: Measures Included in the Analysis

End-use	Measure
Space heating	Loft, cavity wall, and solid wall insulation, draught proofing, double glazing, condensing boilers
Water heating	Cylinder insulation
Lighting	CFLs
Appliances	High efficiency refrigerators, freezers and washing machines, electric stove tops and ovens

Note that in the calculation of technical potential, where appropriate, distinctions have been made between replacement of existing equipment on turnover or prematurely, and between installation of a new measure and extension of an existing one (e.g. full loft insulation or additional thickness of insulation). Note also that heating controls have been omitted from the basic technical measures considered here. Their impact may be significant (potential savings could be as high as 0.5 - 0.7MtC per year by 2010, with the majority of this coming from reduced use of gas). However, the data available are far more uncertain than for the measures listed here, because little information has been recorded about the way such controls are actually used, and therefore it is difficult to estimate their actual impact on energy use and emissions.

Technical Potential Accessible by 2010

The results of this study suggest that the total potential which could be accessed by 2010 would result in the avoidance of 9.7MtC emissions per year, relative to the business as usual scenario. Reductions in the use of natural gas for space and water heating account for 4.9MtC annual emissions avoided, whilst reduced electricity use in heating, lighting and appliances accounts for another 4.2MtC. The remainder of emissions avoided result from reduced use of oil and solid fuels for space and water heating. Table 3 shows a more detailed disaggregation of the results.

Cost per Tonne of Carbon Avoided

As stated above, the study considered the financial costs and benefits associated with the avoidance of emissions, from a government perspective. Table 4 shows the total accessible potential for a range of net cost thresholds, at a 10% discount rate. Note that, at a 6% discount rate, the accessible potential with net cost less than £0/tC increases from 6.1 to 6.3MtC.

Table 3: Summary of Potential by 2010, split by End-use and Fuel

End-use	Fuel	Energy saving in 2010 (PJ/yr)	Carbon avoided in 2010 (MtC/yr)
Space heating	Electricity - standard	23.6	0.85
	Electricity - off peak	29.9	0.97
	Gas	332.4	4.92
	Oil	3.9	0.08
	Solid fuels	20.5	0.51
	(Total	*410.3*	*7.32)*
Water heating	Electricity - standard	1.1	0.04
	Electricity - off peak	0.3	0.01
	Gas	1.4	0.02
	Oil	0.0	0.00
	Solid fuels	0.0	0.00
	(Total	*2.8*	*0.07)*
Lighting	Electricity	20.5	0.74
Cooking	Electricity	5.3	0.19
Refrigeration and freezing	Electricity	35.5	1.28
Washing	Electricity	2.2	0.08
Total	**All**	**476.5**	**9.69**

Table 4: Potential at Different Levels of Net Cost per Tonne of Carbon Emissions Avoided

Net cost less than (£/tC lifetime savings)[1]	Total accessible potential in 2010 (MtC/yr)
-500	0.1
-100	3.1
0	6.1
100	6.1[2]
500	8.9
5000	9.7

1. £1 = approx. 1.6US$
2. Measures with net cost between £0/tC and £100/tC account for less than 0.05MtC

The work also included rough estimates of the initial investment costs associated with implementing the measures identified. For example, accessing the potential with a net cost of less than £0/tC lifetime savings would require investments totalling some £11 billion over the 13 years to 2010. Accessing all the potential identified here would involve investment in the region of £45 billion. To put this in context, £11 billion over 13 years equates to £35 per household per year: the same amount is spent by the average UK household on fuel and power in less than 3 weeks, and on general household repairs, maintenance and decoration in under 5 weeks (ONS, 1997). Note that this cost does not include programme administration, but nor does it account for bulk discounts generated by such programmes.

Key Options to 2010

The significance of the contribution to CO_2 emissions reduction from any given measure is dependent on both the net cost of the measure and the potential for CO_2 reduction it represents. The costings (£/tC lifetime) and CO_2 emissions reduction potential (MtC/yr in 2010) identified in the technical assessment lead to the identification of the key measures listed below. These key measures were chosen because they each deliver at least 0.1MtC avoided annual emissions in the year 2010, and all have a net economic cost of less than £0/tC lifetime savings. These cut-off points are to some extent arbitrary, and the impact of altering them will be discussed later.

The key measures are:

Building fabric. Full loft insulation (gas heated homes); top-up loft insulation (gas and electrically heated homes); cavity wall insulation (all fuels except oil); full draught proofing (gas and electrically heated homes); additional draught proofing (gas heated homes); solid wall insulation (on-peak electrically heated homes)

Space and water heating. Condensing boilers, at natural replacement rate

Lighting and appliances. CFLs in high and medium use applications; high efficiency fridges and freezers, at natural replacement rate.

Policy Possibilities

Barriers to the uptake of measures are well known, and do not need to be discussed in detail here. Rather, the discussion will now turn to an assessment of the policy options which may be used to overcome these barriers.

Potential within Existing Policy Programmes

The Energy Saving Trust. In the residential sector, much of the policy activity at the present time occurs through the Energy Saving Trust (EST). EST residential sector programmes include: management of the energy efficiency Standards of Performance (SoP) programme, which requires Public Electricity Suppliers (PESs) to invest in demand side energy efficiency measures to achieve a given level of energy savings; the 'Energy Efficiency' marketing campaign; a network of Energy Efficiency Advice Centres (EEACs); HECA Action, a competitive bidding programme with funds to support local authority energy efficiency schemes implementing the Home Energy Conservation Act 1995; and a number of cashback programmes to stimulate markets for a range of energy efficiency measures. By the year 2000, the results of the EST's activities planned to date are expected to contribute avoidance of emissions of around 0.5 MtC (1.8 Mt CO_2) per year.

Information remains a barrier to most investment decisions in the residential sector, and therefore the EST's activities in this area should be continued. However, general marketing of energy efficiency needs to be backed up with more detailed information on how to invest and on the benefits of investment, and this points to a definite role for the EEAC network.

The SoP scheme to date has delivered significant cost-effective efficiency improvements (EST, 1997). Continuation of the scheme will help to overcome financial barriers to a wide range of measures, including insulation, heating controls, and efficient lighting and appliances, in electrically heated homes. Note, however, that the current level of investment stimulated by the scheme, roughly £35 million per year (EST, 1997b), is less than 5% of the nominal additional investment requirement identified here.

Schemes funded under the HECA Action programme address a wide range of barriers, but essentially aim to generate increased local markets for energy efficiency options. The present scheme will input around £10 million of public money over three years, and winning schemes have to ensure that Government funds are supplemented by at least 30% with money from the private sector (on average a far higher level of leverage than this minimum amount is achieved). A continuation of the scheme at its present level may lead to annual investment levels of perhaps £15 - £20 million per year.

Cashback schemes to promote cavity wall insulation and condensing boilers have led to increased activity in the markets for these measures. The effect may be due to a reduction in the 'access to capital' barrier but is perhaps equally a result of the endorsement value of the schemes, which are focused on technologies for which there is an identified lack of consumer trust.

The HEES scheme. For low-income households, the Home Energy Efficiency Scheme (HEES) provides an increased chance of affordable warmth via publicly funded investment in energy efficiency measures. The scheme has provided loft insulation and draught proofing for a significant number of low-income households. However, at its current level of funding (£70 million per year), it is unlikely to be able to access the larger majority of available potential in low-income homes before the year 2010. Note that, because HEES is exclusively focused on low-income consumers, the extent to which energy efficiency improvements result in comfort increases rather than CO_2 emissions reductions will be higher for this programme than for other options.

Other policy options. Other options already employed include: imposition of VAT onto residential sector fuel use (recently partially revoked); increasing energy efficiency requirements in the Building Regulations; provision of information to housing professionals through the energy efficiency Best Practice Programme; and the implementation of EU Directives on appliance labelling and minimum efficiency standards.

Significant scope remains for further tightening of the Regulations in future years. Other issues, such as the fact that the current regulations take no account of the longevity of the different energy efficiency features in assigning a rating to the building, need to be considered to ensure that the most cost-effective way of providing an energy efficient stock of new buildings is determined.

Information for housing professionals is provided by the Best Practice Programme. This is expected to result in an annual residential sector CO_2 emissions saving of 0.5 MtC by the year 2000. In addition to providing information about energy efficiency measures, the programme is working with social and private sector landlords to set realistic target energy efficiency levels in excess of the minimum requirements of the Building Regulations. The programme's educational and promotional work will continue to be needed.

In addition to UK specific policy initiatives, the electrical appliance labelling and minimum efficiency standards Directives from the European Commission will have an impact on UK residential sector emissions, although the magnitude of the effect is difficult to determine as yet. Appliance labelling may help to overcome the information barriers associated with efficient cold appliances, but the impact of the policy is being hampered by the retailer information barrier. Minimum efficiency standards will compensate somewhat for the lack of demand pull, but these are unpopular with manufacturers, and their development and negotiation does involve significant administrative effort.

Amendments and New Policy Suggestions

Levy on electricity and gas distribution. As noted above, the SoP programme has delivered cost-effective energy efficiency improvements. Amending the programme such that it was funded from a levy on the monopoly electricity distribution and gas transportation businesses would address concerns that continued concentration on the PESs would result in unfair competitive advantages for competing electricity suppliers and gas companies following residential sector market liberalisation.

The technical review has demonstrated that significant cost-effective potential for action in gas-heated homes exists, and a programme funded by a gas levy could begin to address the barriers to action in this sector in much the same way that SoP currently acts in the electrically heated sector. Therefore, the programme would assist in overcoming barriers to all the key measures identified above.

If such a policy is to make a significant contribution to accessing the technical potential, the level of funds used will have to be increased dramatically. Perhaps a realistic contribution from this option could be obtained with a levy set at £10 per household. This is a significant increase from the £1 per customer per year funding raised under the present SoP system.

Levies could be set at a standard amount per household, as for the SoP scheme. Alternatively, the levy could be set at a fixed amount per kWh of energy distributed to the customer. This would have the advantage of following the 'polluter pays' principle, but would have to be complemented by serious action to improve the condition of the worst housing stock, to ensure that low-income households in these properties were not disadvantaged. The monies raised from the levy could be spent by the monopoly companies from whose activities they were collected. Alternatively, organisations could bid in schemes to a central co-ordinating agency.

VAT equalisation. At the present time VAT on fuel is charged at a lower rate (5%) than VAT on investment in energy efficiency (17.5%). This market distortion could be removed by increasing VAT on fuel, but this is politically unacceptable. Alternatively, VAT on energy efficiency investments could be reduced. The Government has agreed to implement this option partially, covering Government-funded grant schemes. Wider application may occur eventually.

New investment financing options. These are primarily required to allow lower-income households to access the benefits of energy efficiency investments. Many measures cost less than the lower limit for loans offered by banks and other mainstream financial institutions, and therefore cannot be financed through this route. Also, the householders involved are often reluctant to take on additional debt when they are not confident of their ability to repay. Thus, mechanisms are needed for providing small loans at attractive interest rates, and explaining how these will be affordable because of the energy cost savings the investments produce.

There is already an established interest in such schemes amongst local authorities, and example schemes exist which could be used to facilitate the spread of the idea. Public funding to provide initial capital for loans would speed up the process, but these schemes will essentially be self-sustaining.

Other policy options. In addition to the options described above, further policies are available to support and expand upon the present programme. These include: home energy certification; mandatory energy audits for larger properties; technology procurement; and appliance retailer training. All these options have been implemented in other countries and appear to have been effective.

A Potential Strategy

The size of the untapped potential identified here, together with the level of additional investment required, suggest that a significant increase in policy activity will be needed. Continuation or expansion of existing initiatives would access some of the potential, but amendments to these programmes and the introduction of new, complementary policies will also be required.

Information barriers are being addressed, although some areas of weakness remain: more explanation of energy labelling is needed, and more detailed 'how to' information on specific measures should be made more readily available to the general public. Implicit government endorsement of energy efficiency investments, via VAT equalisation, would complement awareness raising activities such as the 'Energy Efficiency' campaign. VAT equalisation would also reduce the level of additional investment required.

The SoP scheme has overcome some of the information, lack of capital and competing priorities barriers *in electrically heated homes*. 20% of the remaining potential for savings in 2010 relates to building fabric in these homes, and perhaps another 2 or 3% to lighting and appliances used in them. 44% is accounted for by building fabric and space heating measures in gas heated homes, and another 20-25% by lighting and appliances in these dwellings. Therefore, if a continuation of this type of activity is considered appropriate, it should be extended to include gas customers. Concerns about competitiveness in the liberalised market mean that a levy on the monopoly sectors of gas and electricity would be preferable to a simple expansion of the SoP scheme as it now operates.

A possible advantage of extending this type of action is that minimal public finance is required. However, the overall level of funding generated by a levy will have to be significantly higher than for the present SoP scheme. Note that the SoP scheme benefits from supplier bulk prices which are significantly lower than the 'one-off' investment costs used here. So, an increase in funds collected to £10 per household per year would cover 25% of the nominal investment funding required for the key options identified above, but the price reduction per measure could mean that perhaps one third of the required investment would be achieved. If the additional amounts required were reduced by VAT equalisation, this £10 per household levy could account for up to 40% of the actual amount required.

Activities under HECA could be supported by an expanded HECA Action programme. This has been successful to date in attracting significant private sector finance using relatively small amounts of public sector money. If the HECA Action programme was continued, with funding at perhaps two or three times its present level, it could potentially stimulate a large proportion of the remaining investment required.

Also, opportunities for installations in new housing should be accessed by further tightening of the Building Regulations. This policy is necessary to ensure that sensible opportunities for energy efficiency improvements are not missed, and would have very significant long-term benefits, but its direct impact on investment levels and the overall energy efficiency of the housing stock by the year 2010 may be relatively small. Widening the regulations to incorporate tightening of standards whenever substantial improvements are made to the fabric of existing buildings would increase the impact of this policy option.

Additional measures for the supply chain are needed: retailer training and technology procurement are two areas which show promise here, and would complement an expansion of existing labelling and minimum efficiency standards / voluntary agreements. If the overall impact of such activity was to reduce the price differential between efficient appliances and other models, the overall consumer investment level needed would fall by over £1.5 billion.

The main barrier which is not addressed by any of the policy initiatives described so far is that of future uncertainty about fuel prices. This essentially will mean that additional effort is required to achieve any given reduction in emissions. Since the Government seems unwilling to use the tax system to overcome this barrier in the residential sector, it will have to accept the need for increased activity in other policy areas if the cost effective potential in this sector is to be accessed.

Discussion

The key options identified above would, if fully implemented to the potential accessible by 2010, result in the avoidance of some 5.5MtC emissions per year. This represents 90% of the total identified potential with a cost of less than £0/tC. The remaining 10% of this potential rests in measures such as improved glazing in electrically heated homes and hot water tank insulation, each of which have a far smaller impact individually than the key measures considered above. However, together the options provide the potential for an additional 0.6MtC annual emissions saving, and therefore they should not be ignored. The policy framework defined above is capable of including activities aimed at these measures and therefore their potential can be included in the possible impact of the policies.

Policy options to assist the fuel poor are likely to encourage the uptake of measures which in energy terms alone have a net cost per tonne of carbon avoided which is greater than £0 (e.g. some glazing measures and solid wall insulation). Policies aimed at the fuel rich may wish to encourage investment in measures with a nominally positive cost, if these are the least expensive option for meeting emissions reduction targets. Thus it is worth briefly considering the impact of investments up to several £/tC thresholds in terms of their impact on overall national emissions.

Table 4 showed the potential emissions avoided at different thresholds. Table 5, below, translates these into percentage contributions towards the total (35MtC) emissions avoidance required to meet the national emissions reduction target.

Table 5: Contribution to UK Emissions Reduction Target, at Various Net Cost Thresholds

Net cost less than (£/tC lifetime savings)	Proportion of emissions avoidance offered by residential sector potential (%)
-100	9
0	17
100	17
1000	27

Note that these estimates are based on the assumption that all the benefits of energy efficiency improvements are translated into energy demand reductions. This will not be the case, as some households will choose to increase their comfort levels by increasing their demand for energy services. There is little agreement on the overall impact this will have on energy demand levels, but it is often assumed to be in the region of 20% (i.e. the potential energy demand reduction may be 80% of the theoretical levels used for this study). However, note also that the study has not considered the impact of changes in behaviour resulting from increased awareness of the social costs of energy use. These could be significant, and would at the very least reduce the overall negative impact of projected changes in energy service demands.

One final uncertainty which must be highlighted is the business-as-usual scenario itself. The projections of future emissions levels is inherently imprecise, and potentially made more so at the present time by the rapid changes in energy markets.

Contributions from Other End-use Sectors

The study also considered the commercial and public sectors, industrial energy use, and the transport sector. Note that the analysis of these other sectors was less comprehensive due to limitations in the data available. However, Table 6 summarises the preliminary results in terms of contributions to the overall 20% emissions reduction target. Note that, as for the residential sector, these figures do not take account of possible changes in behaviour, and hence in the demand for energy services. This is likely to be particularly important for the transport sector, where the Government is committed to implementing a demand restraint strategy.

Table 6: Contributions from other end-use sectors

Net cost less than (£/tC lifetime savings)	Proportion of emissions avoidance offered by sector potential (%)		
	Commercial	Industrial	Transport
-100	5	0	0.1
0	5	8	11
100	5	10	18
1000	5	13	31

Results of Other Studies

There are two other recently published UK studies of relevance to this paper. Firstly, the Energy Saving Trust considered the potential in the residential sector from a somewhat different perspective. Their study was based on a realistic growth path for the energy efficiency measures market in the UK. This was intended to provide an estimate of the realistically achievable potential from a supply side point of view. The results produced - 5.6MtC avoided annually, at an investment cost of £9.4 billion (EST, 1997c) - were very similar to the levels of emissions avoided and investment needed for the measures identified here as having a net cost of less than £0/tC lifetime emissions avoided.

Secondly, the DECADE project at the University of Oxford has considered in great detail the potential for increasing efficiency in residential sector electrical appliances. Our estimate of potential from these end-uses (1.7-2.3MtC) is broadly consistent with the 2MtC 'economically justified technical potential' identified by the DECADE team (Boardman *et al*, 1997).

Summary: a Role for Energy Efficiency in Residential Buildings

Energy efficiency in residential buildings can make a major contribution to the meeting of UK carbon emissions reduction targets. For example, taking only measures which have a net cost of less than £0/tC avoided, there is the potential to access 17% of the overall 35MtC national emissions reduction target. The results of this study are broadly consistent with other recent UK studies of the sector. Information on other sectors is less comprehensive, but a preliminary examination suggests that the residential and transport sectors offer the greatest scope for low cost emissions avoidance.

Further definition of a precise role for the sector will require a comparison of potential and costs with other carbon abatement options (e.g. alternatives for electricity supply and increased use of CHP). A key element of the UK's programme must be the development of a framework for these comparisons and a mechanism for regular review of the effectiveness of policies such as those put forward here.

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