Assessing potential carbon dioxide savings through the application of energy-efficiency measures in the housing stock.

R Hay, G A Walters and L D Shorrock
Building Research Establishment Ltd. Garston, Watford, WD2 7JR.
K Lane and B Boardman
Environmental Change Unit, University of Oxford, 5 South Parks Road, Oxford, OX1 3UB.

This paper examines the potential for carbon dioxide savings in the housing stock. The analyses undertaken rely on the BRE database of information relating to the ownership of insulation and other energy efficiency measures in housing (BREHOMES [1,2]), and the Environmental Change Unit's data relating to household electrical appliances (DECADE [3]).

The paper presents an overview of two related areas of work. The first investigates the potential savings, and the associated cost-effectiveness, of introducing energy-efficiency measures. The second concerns the development of scenarios for the carbon dioxide emissions of the domestic sector.

The results indicate that the Government's target of a 20% lower carbon dioxide emission in 2010, relative to 1990, will require an acceleration to the rate at which energy-efficiency is currently improving in the housing stock.

Assessing the scope for savings and their cost-effectiveness

To assess the potential importance of any energy-efficiency measure requires consideration of how much energy it might typically save and whether those savings are likely to be cost-effective. Such calculations provide a convenient method of ranking measures and offer a first-order estimate of overall potential savings, thereby providing policy makers with important information on which to base decisions relating to the design of policies.

Twenty four key energy-efficiency measures have been considered. Roughly half of these concern the fabric and heating provision in a typical house with the other half relating to major electrical appliances and lighting. For the former measures, energy savings have been calculated using the BREDEM [4] model and then reduced by 30% to account for savings that are likely to be taken in improved comfort.

For the appliances and lighting measures, figures have been derived from the results of the DECADE study [3], the energy savings being the difference between the consumption of the average appliance in the stock and the consumption that could ultimately be achieved. The consumption that could ultimately be achieved was taken, slightly conservatively, as the projected average consumption of that appliance type in the DECADE "Scenario 1" in 2020 (see following section for an outline explanation of what this scenario assumes).

For both groups of measures, information on the present (actually 1996) levels and overall scope for ownership were taken from the respective data sources, BREHOMES and DECADE. Thus, national potential energy savings could be calculated from the savings determined as described above. Data on costs and lifetimes of measures and on fuel prices were also assembled from the above and various other sources. Wherever possible, both low and high capital cost figures were specified because these figures help to illustrate the possible range of cost-effective savings. For the measures relating to fabric and heating, the gas fuel price was used to calculate the cost savings. Corresponding carbon dioxide savings were calculated using the fuel mix for heating as derived from the BREHOMES model. Carbon dioxide savings relating to electricity were based on the emission factor of the marginal plant as estimated by DTI. For 1996, this is close to the emission factor associated with a typical coal-fired plant. As discussed in the following calculations have also been undertaken for 2010, and for this year the assumed emission factor is close to that for a combined cycle gas turbine (CCGT) plant.

As an aside, it is worth noting that the electricity emission factors used for the scenarios that are discussed later are averages based on the fuel mix for generating electricity that is anticipated in the DTI's "central GDP, low fuel prices" scenario, rather than being marginal plant values. This means that they implicitly include all changes to the electricity supply industry that are foreseen in this DTI scenario, such as the increasing move towards CCGT generation, the likely decline of coal-fired generation and the gradually growing importance of renewable energy sources.

Having assembled all the information described above, cost-effectiveness calculations can be undertaken for the individual measures. The method used consists of expressing capital costs in terms of their equivalent annual costs (making appropriate assumptions about lifetimes and discount rates) and subtracting annual energy-related cost savings from these to produce a net annual cost. The net annual cost is then divided by the carbon dioxide saving (expressed in terms of carbon) that the measure typically produces to give a net annual cost per tonne of carbon saved. If this cost is negative, the measure is cost-effective; if it is positive, the measure is not cost-effective. Larger negative numbers indicate greater cost-effectiveness so measures can be ranked according to their cost-effectiveness. By also presenting the potential national carbon dioxide savings of each measure, it is easy to see from the ranking the overall scope for cost-effective savings.

By using alternative assumptions for the costs of measures and for discount rates, the method allows a rapid appreciation of the likely range of the potential cost-effective national savings, and highlights those measures that offer the best options. This is illustrated in Figures 1 to 4, where the effect of alternative assumptions on potential savings is quite apparent. Thus, for example, Figure 1 indicates that, for a discount rate of 8%, almost all of the energy-efficiency measures considered are cost-effective and could provide savings of about 17.5MtC/year. By substituting high costs for the energy efficiency measures the potential falls to about 8MtC/year, as shown in Figure 2.

If the discount rate is increased to 15% and the calculations repeated the results are as shown in Figures 3 and 4. Low costs for the measures still imply potential savings of slightly over 13MtC/year, but high costs reduce the potential to about 5.5MtC/year. Interestingly, for the extreme combination of high discount rate and high costs, the measures that are still cost-effective are almost exclusively those relating to electrical appliances. An important message that emerges from this work, therefore, is that measures other than those relating to the traditional concerns of improving the fabric and heating of buildings must be considered.

Because of the policy interest in the year 2010, similar calculations to those described above have also been carried out for this year. To do this, it is necessary to estimate what the situation in 2010 is likely to be, assuming that current trends continue. This can be done using the information from the scenarios work that is described in the following section. The detailed results of the 2010 calculations are not presented here due to lack of space, but it is worth noting that they strongly resemble the results in Figures 1 to 4 but with overall potential carbon savings between about 40% and 60% lower. In other words, unless current trends change dramatically, roughly 50% of the present potential for carbon dioxide savings is likely to remain in 2010.

Information such as that described above is clearly important for assisting policy makers in deciding which measures to target and for identifying feasible mechanisms for encouraging the improvements and the possible public expenditure implications. Nevertheless, it has to be recognised that such calculations only provide static estimates and that these will not necessarily indicate overall savings that match figures calculated by using more realistic modelling procedures that take account of dynamic effects. In other words, the results are not particularly well suited to assessing likely trends in carbon dioxide emissions for the housing stock. For this, there is a need for more detailed scenario calculations, in which there is an explicit time dimension.

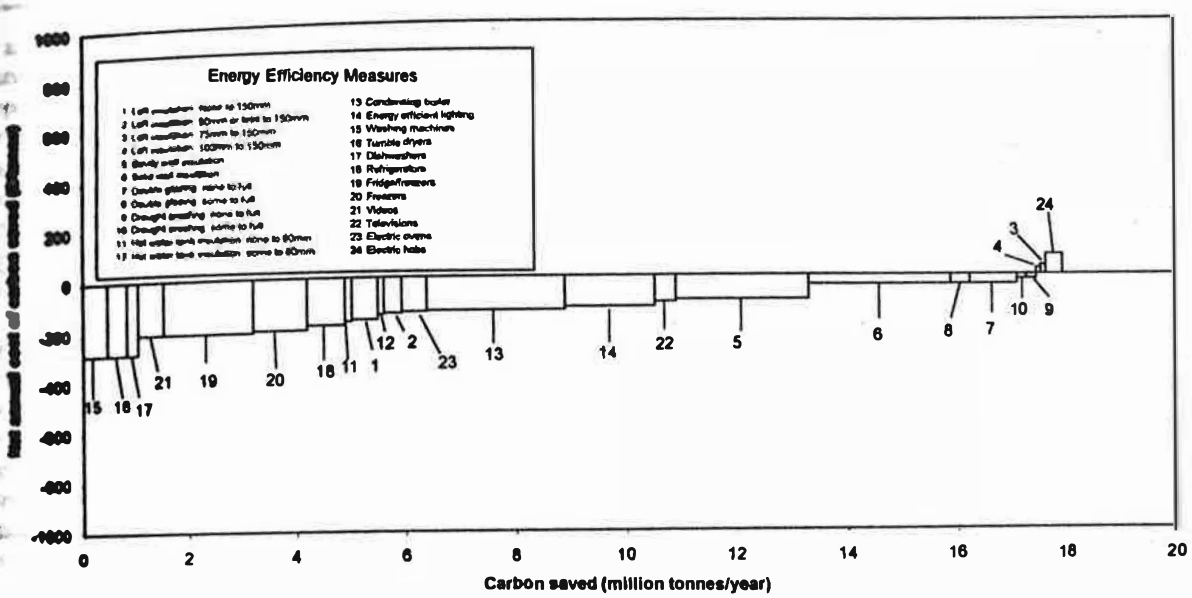

Figure 1 – Potential national carbon savings – 1996 (low costs – 8% discount rate)

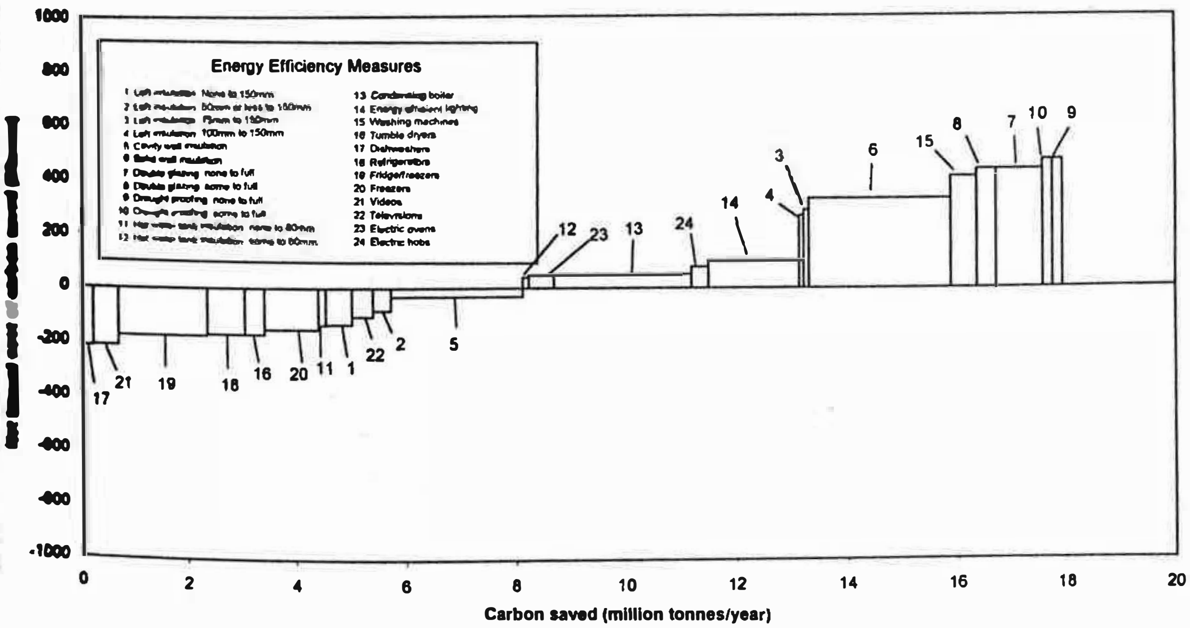

Figure 2 – Potential national carbon savings – 1996 (high costs – 8% discount rate)

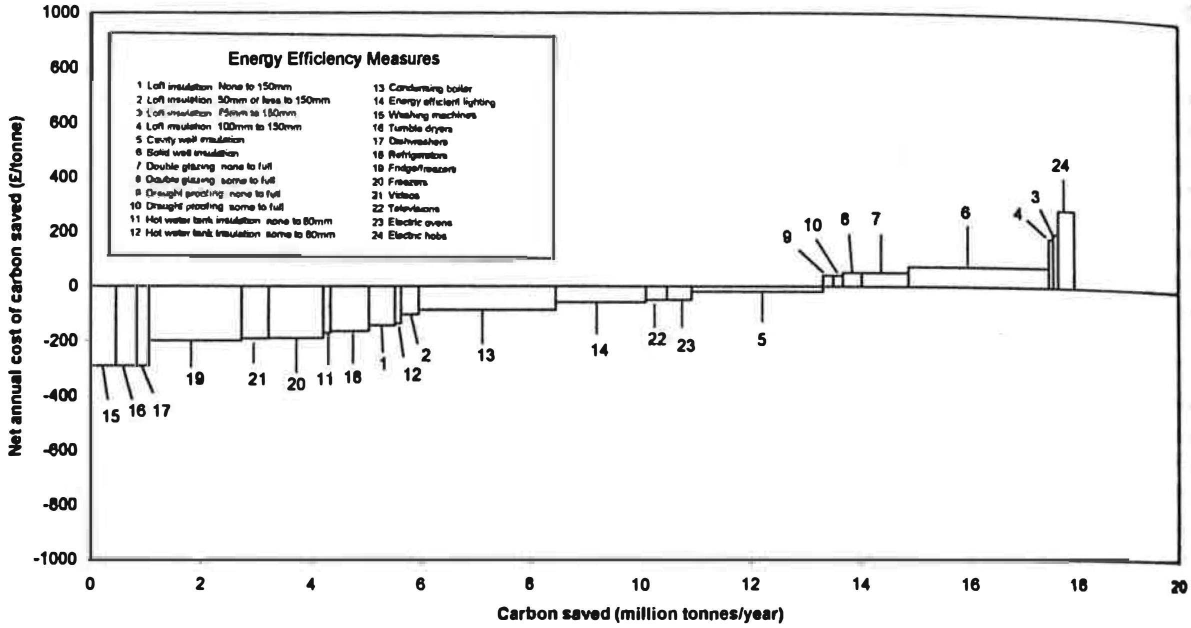

Figure 3 – Potential national carbon savings – 1996 (low costs – 15% discount rate)

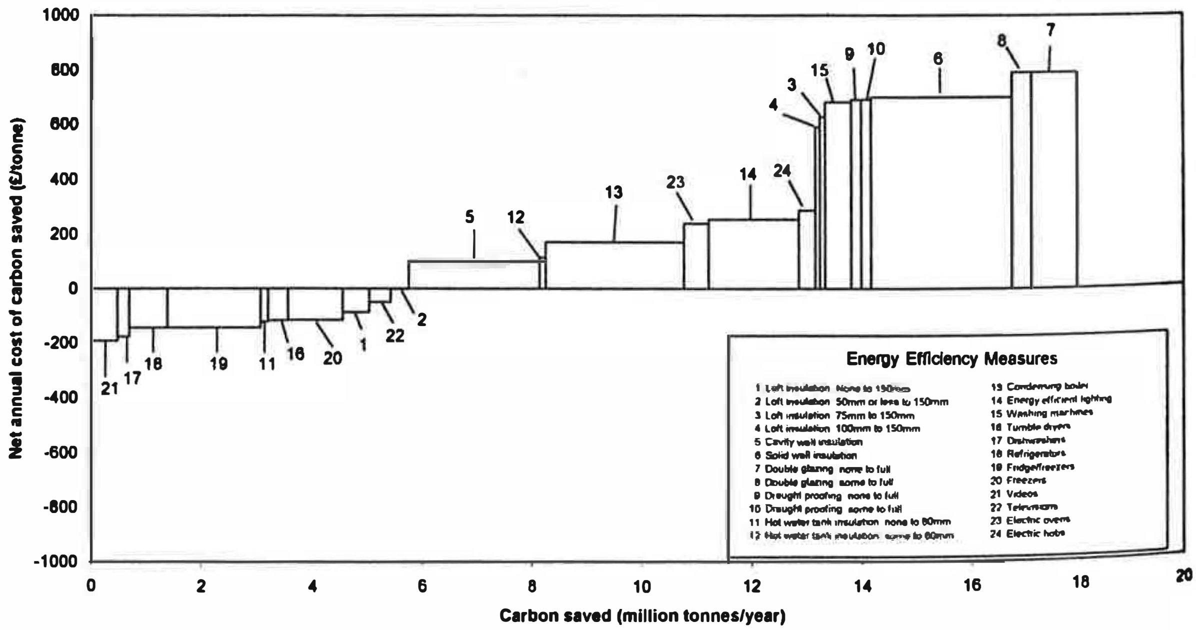

Figure 4 – Potential national carbon savings – 1996 (high costs – 15% discount rate)

Assessing possible trends in carbon dioxide emissions for the housing stock.

To make future projections of energy use and carbon dioxide emissions, good historical data on the multitude of factors that have an influence are required. In the case of the housing stock, most of the relevant data can be found in the two main sources referred to in this paper, BREHOMES and DECADE.

As an example of how historical data can indicate future trends, Figure 5 shows actual data on ownership of double glazing and loft insulation, together with fitted S-curves that are based on the assumption that the rate of uptake is proportional to time and to the size of the remaining market. It is clear that the S-curves are able to describe these particular markets rather well, and so provide a good indication of what is likely to happen in the future. Similar analyses can be applied to individual measures and appliances to provide information on the situation that is likely to exist in future years. Armed with this information, together with various other key data (such as projections of population and nu bers of households, trends in domestic heating and appliances markets, trends in internal temperatures, estimates of carbon dioxide emission factors for electricity, etc) it is possible to undertake energy use calculations that will indicate the housing stock's emissions of carbon dioxide for future years.

The scenario developed as outlined above describes the business-as-usual situation. It is called the Reference scenario in this paper. For lights, appliances and cookers, the Reference scenario uses the "Reference case" scenario results of the DECADE study. Figure 6 illustrates the carbon dioxide emissions of the Reference scenario broken down by fuel type. This shows a marked reduction in emissions by the early part of the next century relative to 1990 even though the energy use, which is not presented here, shows a rising trend throughout the whole period. The primary reason for this is that, although electricity use rises steadily, the emission factor associated with electricity is expected to fall markedly as generation by gas becomes increasingly common. Figure 6 illustrates the falling emissions associated with electricity quite clearly.

Overall, the Reference scenario suggests that by 2010 domestic carbon dioxide emissions are likely to be roughly 8MtC/year below their 1990 level (about 6.5MtC/year below the 1996 level). This corresponds to a reduction in annual emissions of about 19% relative to 1990. Given that the emissions from certain other sectors, transport in particular, are very likely to rise this indicates that achieving the Government's 20% target will require the uptake of energy efficiency measures in housing to be acc lerated. Another scenario, called the Efficiency scenario, has been developed to investigate what might be possible.

Many of the assumptions of the Efficiency scenario are exactly the same as those of the Reference scenario (same population and household growth, same assumptions about improving comfort levels, etc.) but the uptake rates for energy efficiency measures have been increased to levels that ought to be realistic, provided specific energy-efficiency initiatives are introduced. Rates of uptake for insulation measures, for example, have been guided by acquisition rates that have be n seen to occur in the past. Similarly, for lights, appliances and cookers, the Efficiency scenario uses the "Scenario 1" results from the DECADE study, this being a scenario in which the introduction of efficient appliances into the stock is increased to levels that are realistically achievable.

Figure 7 illustrates the carbon dioxide emissions of the Efficiency scenario broken down by fuel type. Since energy use falls in this scenario, it shows a much more pronounced reduction in emissions between 1990 and the early part of the next century than that illustrated in Figure 6. For example, as can be clearly seen in Figure 7, the carbon dioxide emissions associated with gas consumption reduce between 1995 and 2010, whereas in Figure 6 they remain fairly constant. Overall, the Efficiency scenario suggests that by 2010 domestic carbon dioxide emissions could be roughly 13.5MtC/year below their 1990 level (about 12MtC/year below the 1996 level). This corresponds to a reduction in annual e issions of about 32% relative to 1990.

Figure 8 illustrates the difference between the carbon dioxide emissions of the Reference and Efficiency scenarios more clearly. It can be seen that the results suggest that by 2010 carbon dioxide e issions could be about 5.5MtC below the level that they might then be at if current trends continue. In fact, this difference is greatest around 2010. The reason for this is that emissions in the Efficiency scenario start to rise beyond 2010 because the major part of the improvements in this sc nario have taken place by then – and so there is an increase in energy use due to the still rising number of households.

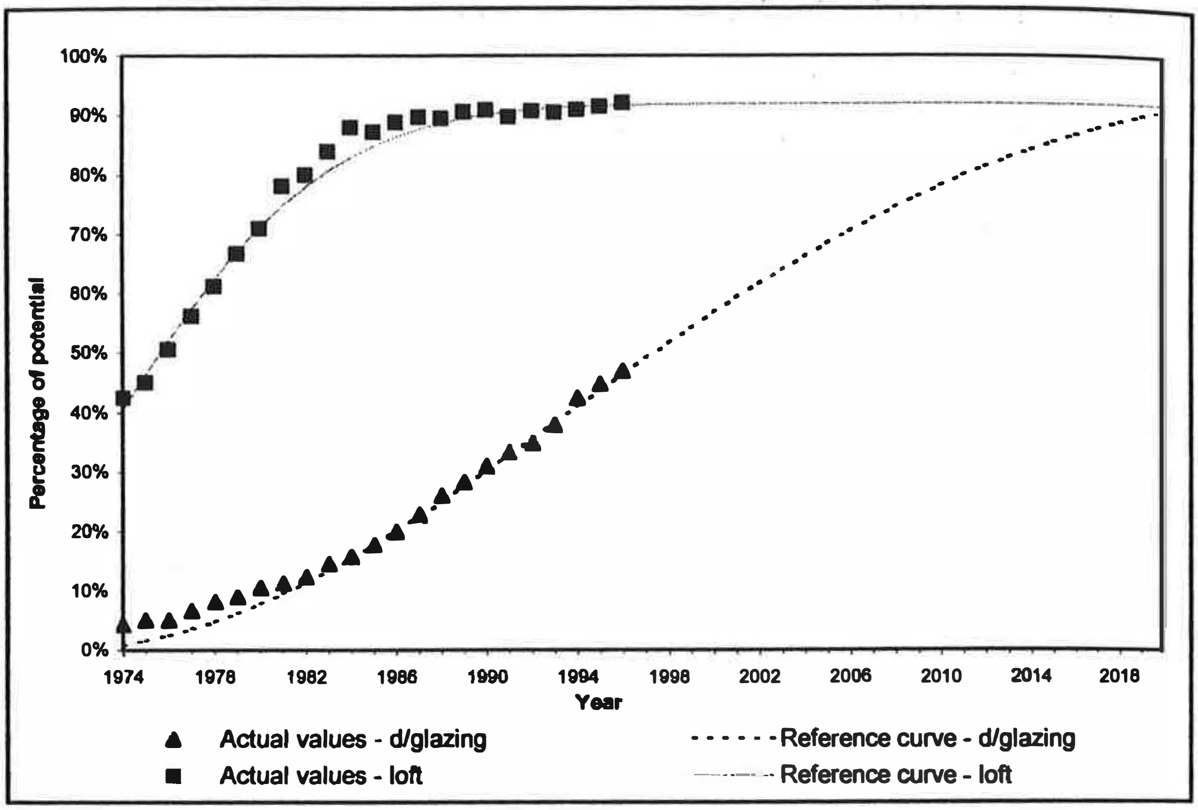

Figure 5 - Double glazing and loft insulation scenarios

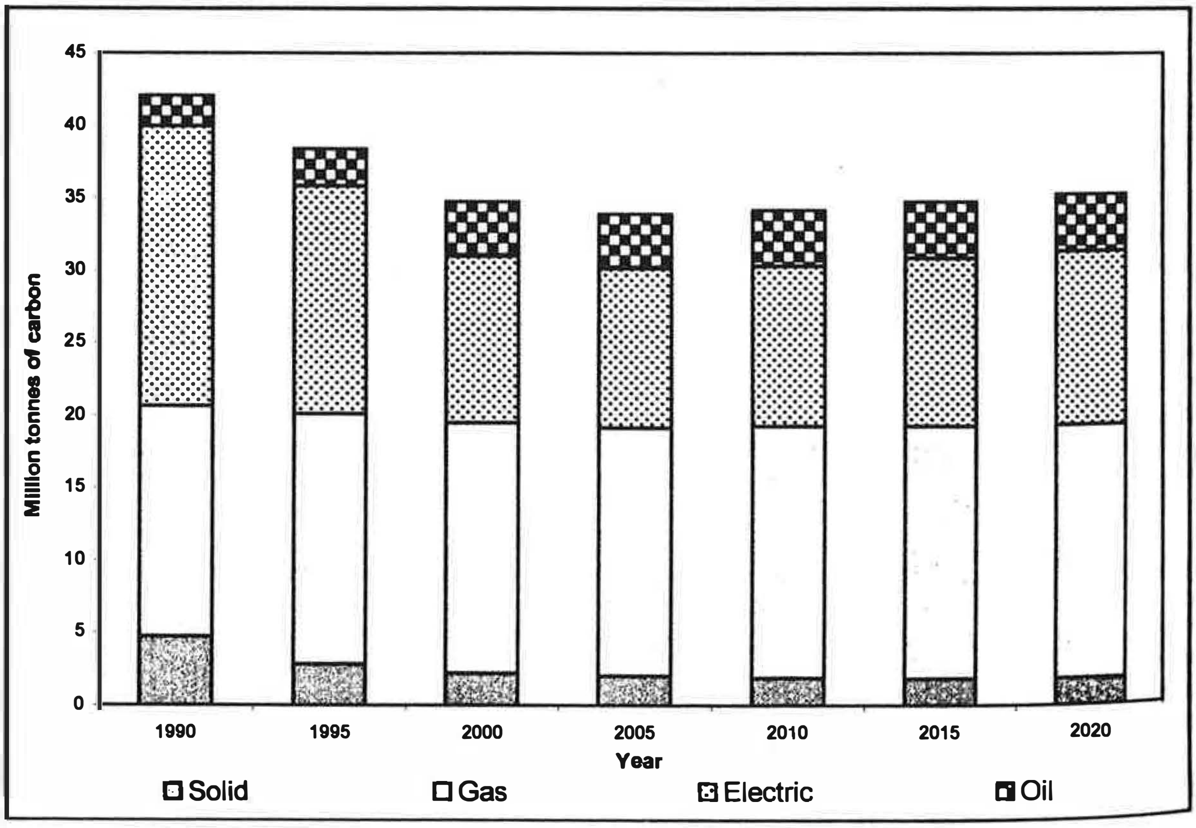

Figure 6 - Reference scenario - carbon emission by fuel type

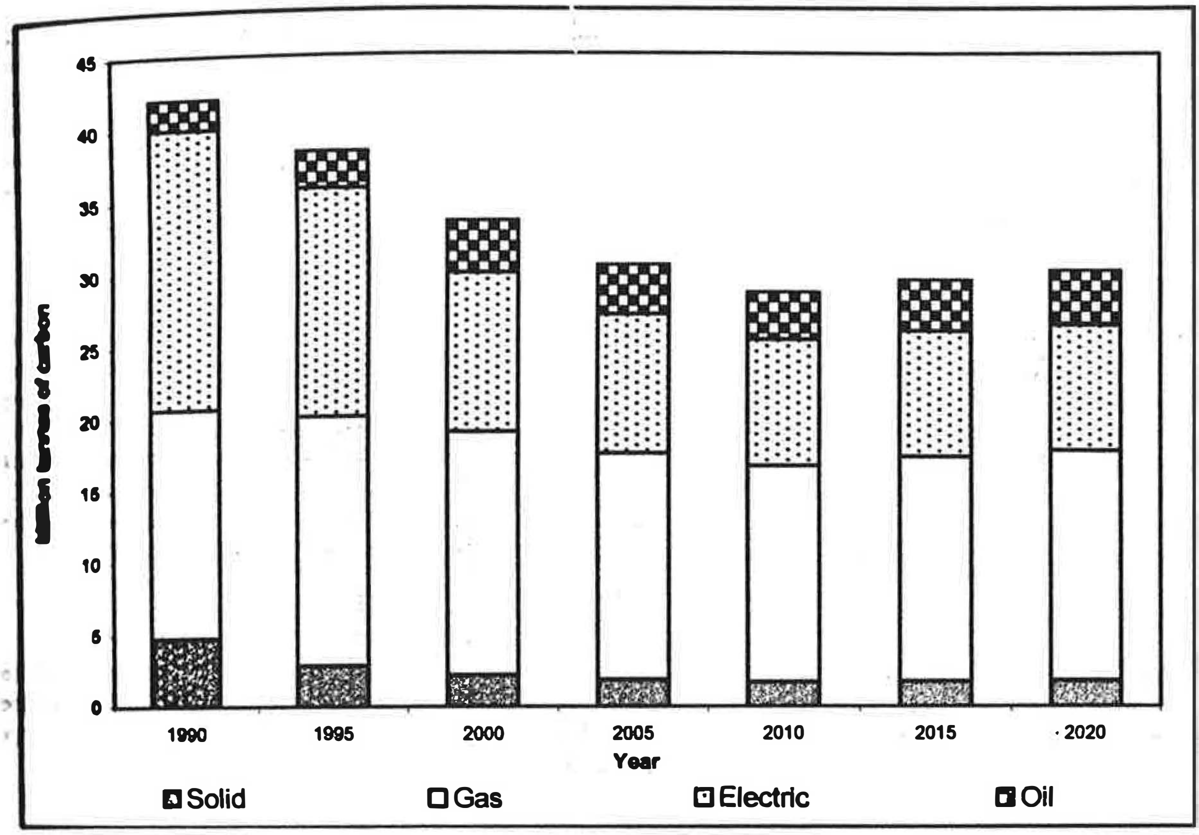

Figure 7 - Efficiency scenario - carbon emission by fuel type

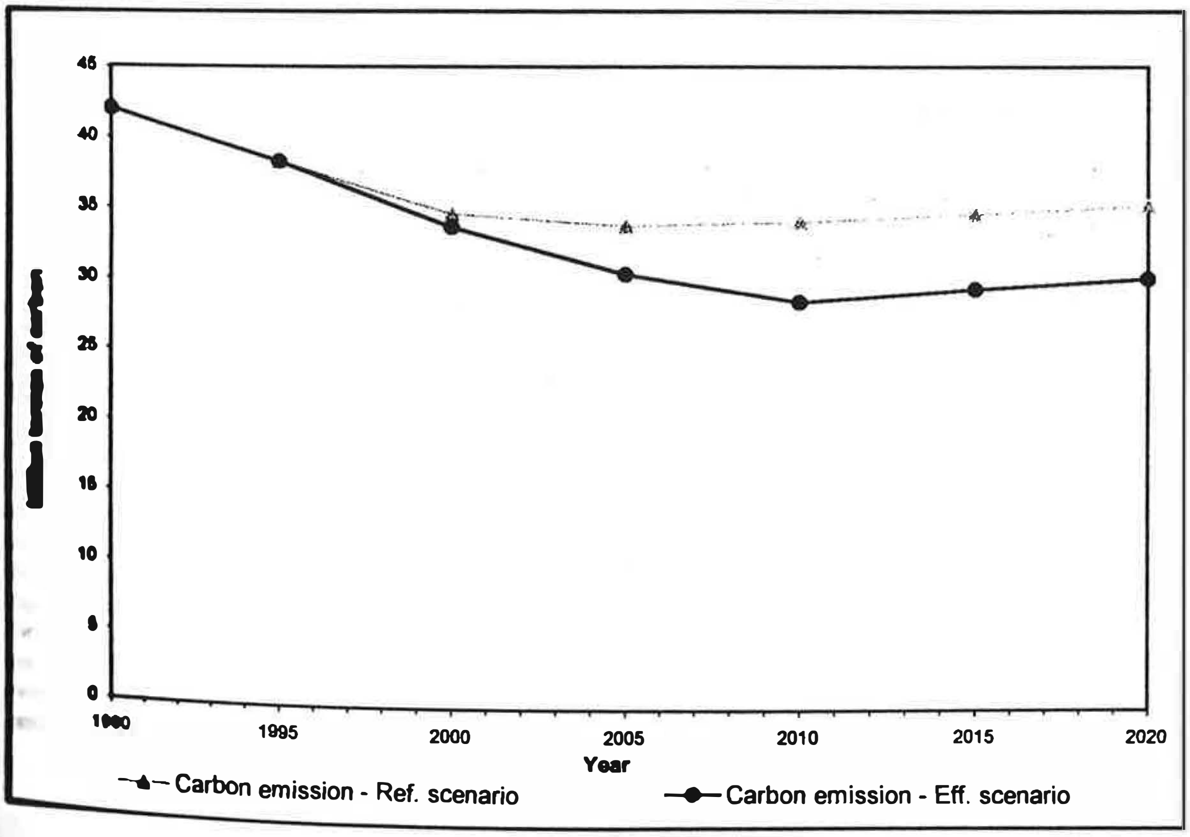

Figure 8 - Carbon emission - comparison of scenarios

To conclude, it is interesting to compare the scenario results with the cost-effectiveness calculations. As indicated above, the Efficiency scenario suggests potential savings relative to 1996 of about 12MtC. The cost-effectiveness calculations suggested, depending on the particular assumptions used, anywhere between 5.5MtC and 17.5MtC, so the scenarios results are fairly close to the middle of the range. The Reference scenario results suggest potential savings relative to 1996 of about 6.5MtC. In other words, under the Reference scenario about 45% of the potential savings indicated by the Efficiency scenario will remain in 2010. This is quite close to the figure of roughly 50% that the cost-effectiveness calculations indicated.

Conclusion

This paper has described results from two complementary areas of work that both aim to provide information to assist with the task of developing policies for the reduction of carbon dioxide emissions from the housing stock. Static calculations have produced information on the cost-effectiveness of energy efficiency improvements and have provided first-order estimates of the potential national savings. Possible future carbon dioxide emissions have been calculated for a Reference and an Efficiency scenario, and these allow a more thorough assessment of the potential national savings. The results indicate that the Government's target of a 20% lower carbon dioxide emission in 2010, relative to 1990, will require an acceleration to the rate at which energy-efficiency is currently improving in the housing stock. The Efficiency scenario suggests that a reduction of up to 32% is feasible for the housing stock.

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