Energy use in dwellings: decarbonising the stock and people

In his presentation, Kevin Lomas drew on work conducted in the inter-disciplinary Carbon Reduction in Buildings (CaRB) project, with the aim of clarifying what is important in controlling carbon emission and helping identify the role that the economic and social sciences might play.

The seminar brief describes the problem of CO_2 emissions in terms of people's choices and their attitudes, motivates, behaviour, incentives, psychology. This conveys the notion that emissions are our fault and even perhaps that save for our 'bad attitude, wayward motives, dreadful behaviour, perverse incentives, and aberrant psychology' all would be 'right with the world': I don't think this is a correct view to take.

The CaRB project

- CaRB is a consortium of five UK universities, supported by the Carbon Vision Initiative, which is funded by the Carbon Trust and the Engineering and Physical Sciences Research Council, with additional support from the Economic and Social Research Council and Natural Environment Research Council. The university partners are assisted by a steering panel drawn from UK industry and Government.
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Our experience in the CaRB and other projects is that people are rather ignorant of matters to do with energy and are not much interested in the subject. They do not know how much energy they use, and how they use it, and they have even less idea of what they might do about their energy use – what consumes a lot of energy and what does not, what energy saving action they might take etc. And even those that do know are beset by frustrations if they wish to act, because it can be very hard or very expensive to do so.

However, when addressing the problem of energy consumption in buildings we need to take account of all those who have a stake in our carbon dioxide emissions – from central to local government, through the house building chain, to plumbers and electricians and the DIY industry, and finally, to the occupants of dwellings themselves.

Carbon emission targets

- Kyoto target – CO_2 levels to 12.5 per cent below 1990 level by 2008 – 2012
- Aspire to reduce UK CO_2 to 20 per cent below 1990 level by 2010
- Royal Commission on Environmental Pollution, Energy White Paper (2003) – reduce UK CO_2 levels by 60 per cent by 2050
- Generate 10 per cent of UK energy from renewables by 2010, but Business Enterprise and Regulatory Reform consultation proposed 15 per cent by 2020.

The UK emissions targets are concerned with the emissions covered by the Kyoto protocol, ie those in the UN Framework Convention on Climate Change (UNFCC). But progress so far has been limited and in 2004 it was announced that we certainly wouldn't cut CO_2 emissions by 20 per cent by 2010.

Nevertheless, in October last year, the new climate change secretary, Ed Miliband, raised the Government target for a reduction in carbon emissions from 60 per cent to 80 per cent by 2050.

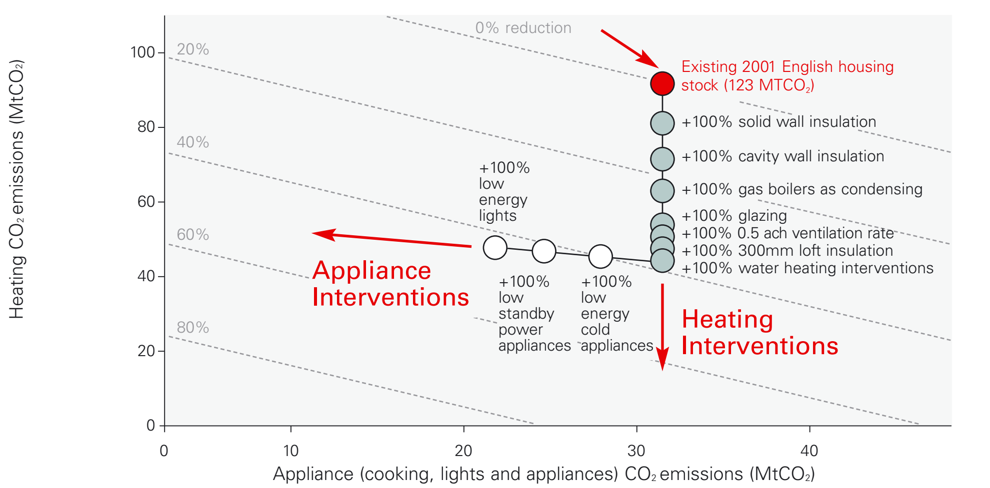
It is hard to imagine, given the limited progress and current lack of momentum, that this is remotely achievable.

The carbon intensity of the fuel supply tends to be the domain of 'big engineering', the physical form of the dwellings the domain of 'building scientists' and the inhabitants the domain of the 'social sciences'. However, it is increasingly apparent that the interaction between a dwelling's energy systems and its occupants has a profound influence on the energy use and the demand profile, which in turn affects the supply system. Decarbonisation is becoming increasingly seen as a multi-disciplinary problem.

Within the CaRB project we have built a model of the English domestic housing stock. Our model represents 47 'types' of house. The dwellings are scaled in size, and given different fabric heat losses and heating systems types, to represent the diversity within each type.

Working with this model we can predict how the stock's CO_2 emissions will change as we install different energy efficiency measures.

Figure 1: Energy efficiency predictions: 2001 English housing stock



Source: Based on 1971 to 2000 average climate data

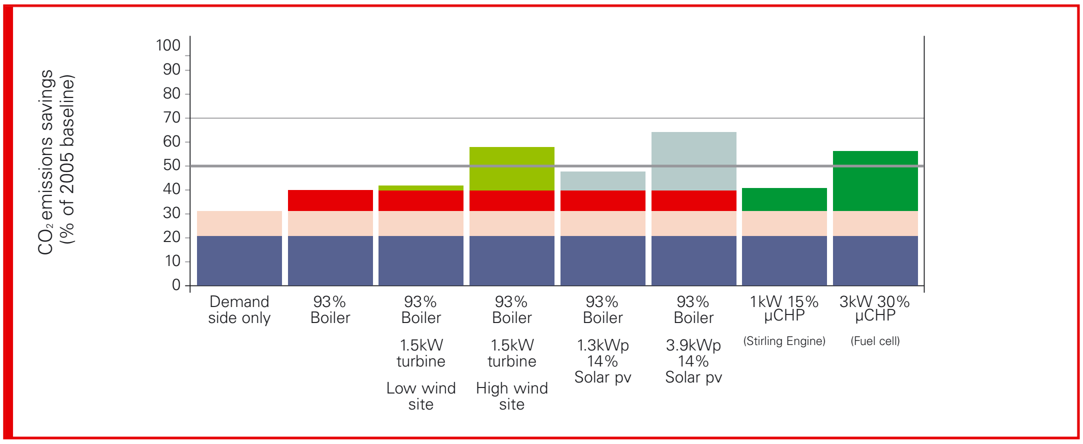
The heating and hot water emissions (mostly from gas burning) are shown on the Y-axis and the emissions from other sources (mostly from using electricity) on the X-axis. The contours show lines of equal CO_2 emissions. From our starting point, the emissions from the 2001 stock, we can move either vertically downwards or horizontally to the left to show reducing emissions. Using the model we can hypothesize about the impact of measures to improve efficiency, such as 100 per cent cavity wall insulation and condensing boilers and so on.

Our analysis shows that through reasonable energy efficiency measures we can reduce emissions for space heating by about 38 per cent. Others have done a similar analysis and come up with similar figures. It would be very hard, with the stock as is, to achieve greater cuts.

Reducing electrical energy use through reasonable energy efficiency measures is predicted to take us down only a further six per cent or so, to 44 per cent. We can see that attention to lights, stand by power and appliance efficiency achieves only one sixth of the savings gained through building fabric and energy system efficiencies.

Other colleagues in the Tarbase project have predicted rather similar emissions savings for some individual specific house types, and have gone on to show the contribution that embedded renewable energy systems like wind turbines might make.

Figure 2: Technological interventions: Tarbase project



Source: A Peacock, Heriot Watt, Tarbase project

The graph shows that relatively large installations are needed to get a 60 per cent emissions cut, e.g. many more photovoltaic panels (PV) at today's efficiencies than is plausible on a house roof and this is still nowhere near the 80 per cent cut we seek.

The modelling results also assume that all the locally generated energy can be exported to the grid and will remain as a useful source of energy for other people.

A Herculean task

The first problem in achieving domestic energy efficiency relates to numbers and time.

Virtually all the 24million existing buildings in the UK would need some attention to reduce their emissions by just 40 per cent. To complete the task in 40 years we would need to refurbish an entire city the size of Cambridge every month. If we assume that each intervention set would take a team of trained workers two weeks, we would need 23,000 teams of people to work at this rate non-stop for the next 500 months.

External wall insulation is essential if we are to reduce heating energy use in solid wall houses. But this is far from straightforward. Walls are cluttered with satellite dishes, cables, wall plants, etc, and access to the backs of terraces is difficult and the geometries are complicated.

The external wall insulation challenge

The backs of terraces are complicated and whilst much of the heat loss is from the backs, insulating them is far from straightforward.

Table 1: The problem of energy savings and pay-back times

												Payback Period - Years						
Intervention	**Installation**	**Cost £**	**CO_2 (kg/yr)**	**Implementation**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Lights- Change to CFL	DIY	0.50	11	Easy														
Hot Water Tank Insulation	DIY	10.00	150	Easy														
Hot Water Pipes – Insulate	DIY	10.00	60	Easy														
Double Glazing – Secondary	DIY	50.00	150	Easy														
Draught Proofing – Doors/Windows	DIY	100.00	150	Easy														
Draught Proofing – Edge of Floors	DIY	10.00	130	Easy														
Loft Insulation – New	DIY	200.00	1000	Easy														
Loft Insulation – New	Professional	300.00	1000	Easy														
Loft Insulation – Top-up	DIY	150.00	250	Easy														
Floors – Wooden	DIY	200.00	350	Medium														
Walls – Cavity	Professional	500.00	750	Medium														
Heating Controls	Professional	500.00	500	Medium														
Loft Insulation – Top up	Professional	250.00	250	Easy														
Walls Solid – Internal Insulation	Professional	2,500.00	2400	Difficult														
Solar Water Heating	Professional	3,500.00	750	Medium														
Boiler Replacement	Professional	1,500.00	1800	Medium														
Ground Source Heat Pump	Professional	8,000.00	1200	Difficult														
Air Source Heat Pump	Professional	8,000.00	1200	Medium														
Floor – Solid – On Slab	DIY	490.00	250	Medium														
Walls Solid- External Insulation	Professional	5,000.00	2600	Difficult														
Doors-External – Change	Professional	400.00	100	Medium														
Double Glazing – New Units	Professional	500.00	750	Medium														

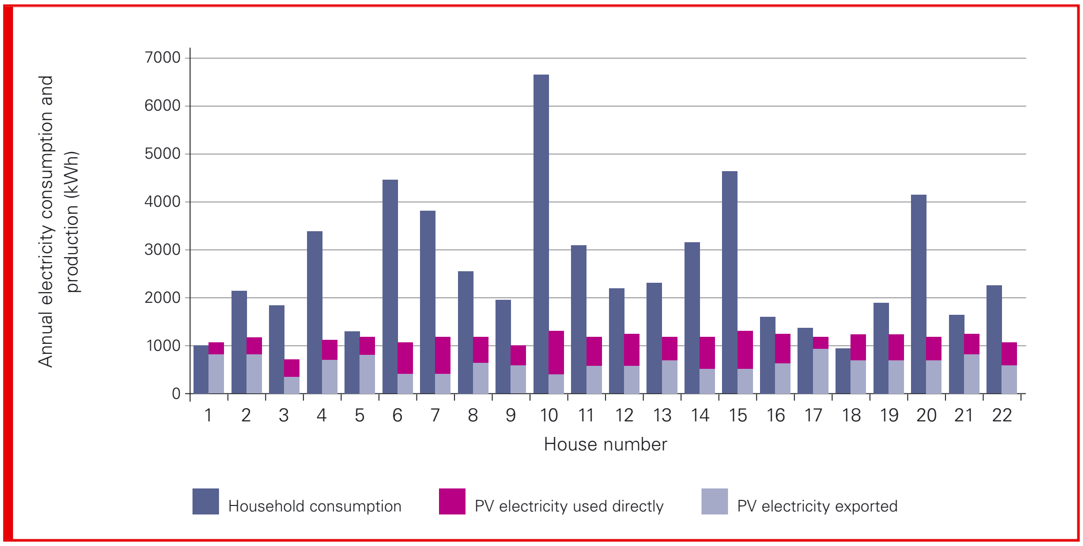
Source: ETI (2008) courtesy K. Seare

This table of refurbishment cost, CO_2 saved and pay back times from the ETI, has the measures ordered by payback time. Those that save over one tonne of CO_2 per year are highlighted and those that cost over £1000 are shaded. The measures that reduce CO_2 emissions a lot are the most expensive and have the longest pay back times.

In England people might stay in their houses for typically seven years. It is estimated that the first 20 per cent to 30 per cent cut in emissions from a terraced house might cost around £3,000 to £4,000, a 40 per cent cut might push costs into the region of £15,000 to £20,000. We are talking about old technologies here so costs are unlikely to change dramatically – who is going to pay?

Micro-generation may not be as effective as we would like. Here are some field results for 22 social houses with photovoltaic panels. In all the houses, whether they use a lot of electricity or a little, the proportion of the electrical energy demand covered by the PV is small.

Figure 3: Annual electricity consumption and production



Micro-generation may not be a solution. Even households with low total electrical energy consumption can make little direct use of energy generated by the solar panels. Only if the export arrangements and payments are satisfactory can such technologies hope to succeed, and they need to be much cheaper.

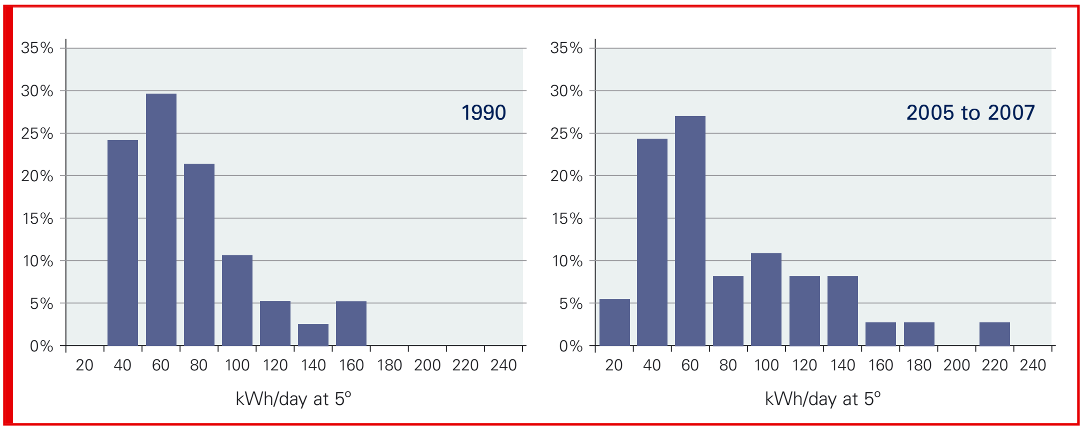
It is evident that the decarbonisation of the existing stock is a Herculean task, particularly in a free democratic society.

> "There is, in my view, no low-hanging fruit, and there are no easy wins: just a myriad of tricky interacting problems to solve."
>
> *Kevin Lomas*

Variations in energy use

National stock modelling is usually based around the idea of quasi-typical types and standardised occupancy. In fact energy use in dwellings, even very similar dwellings, is very variable.

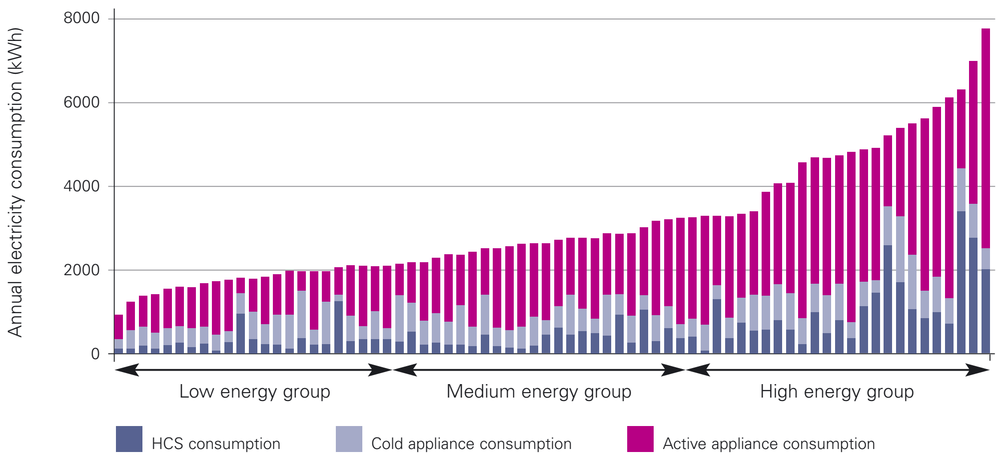
Figure 4: Total energy demand from 40 centrally heated Milton Keynes homes



Source: A.Summerfield, UCL

The electricity and gas consumption in homes in Milton Keynes, measured in the CaRB project, shows a skewed distribution. In these houses there was an increase, over 15 years or so, in both the heating and electrical energy demand. But the highest increases were in those homes that already consumed the most energy; their electrical energy use increased substantially – by about 70 per cent.

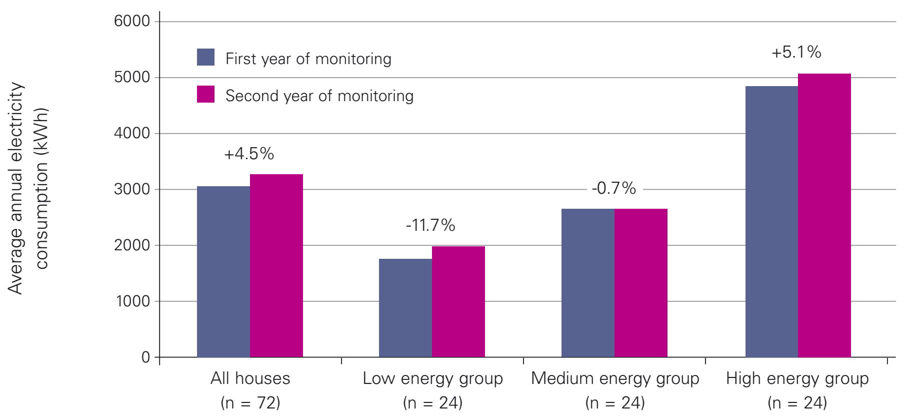
Figure 5: Electrical energy use: 72 homes



Source: S.Firth, K.Lomas, A.Wright and R.Wall. Identifying trends in the use of domestic appliances from household electricity consumption measurements, Energy and Buildings 40 (2008)

The measured electrical energy use of 72 social housing units displayed a similar distribution. The energy use varied by a factor of seven with the highest consumers using much more than the majority. The high-energy consumers have high consumption from appliances that are continuously on or on standby, and also high consumption from other 'active' appliances', e.g. TVs, lights etc.

Figure 6: Electricity use trend: 72 homes, two years



- 4.5% overall increase in electrical energy use – significant
- 10.2% increase for 'continuous and standby' (C&S) appliances
- 4.7% increase for 'active' appliances
- Highest consumers responsible for greatest increase.

Source: Energy and Buildings 40 (2008)

Among the 72 social houses, there was also a significant increase in electricity use over just two years. Again the highest energy users showed the greatest absolute increase in energy used.

It is worth reflecting a little on these results. We would be wrong, I think, to conclude that the households that are high energy consumers are driven by wayward motives and perverse incentives, or that they are in some way psychologically different from the low energy consumers. Rather, perhaps, their consumption is driven by a succession of decisions, none of them particularly remarkable and each of them entirely logical – but with the common feature that they each lead to increased energy use. In fact it is probable that not many of the decisions we make, concerning our homes, actually leads to sustained lower energy demand. Conversely, very many domestic 'developments' will increase energy demand.

It is perhaps, the successive accumulation of these energy-increasing decisions that leads, eventually, to the very high-energy usage of some households. Each of the decisions is relatively benign, and none are made with the intention of increasing energy demand, but the overall effect is a remarkable increase in energy use.

Perhaps a common feature of the high energy users is that they had the opportunity to make lifestyle and other decisions and they were merely exercising this opportunity.

The question is how do we intervene in this process?