

The Performance of Energy Efficiency Measures

It is proposed that Green Deal assessors would use a calculation model based on SAP. However, this has weaknesses because it is based on 'simplified' buildings. Very little building energy research has been done in the UK since the privatisation of the gas industry (1986), the electricity industry (1991) and the Building Research Establishment (1997). So SAP and derivatives such as RDSAP have received very little validation with actual measured data. This applies particularly to buildings with higher standards of insulation and airtightness, such as are envisaged for the Green Deal scheme. Yet buildings with such higher standards are much more vulnerable to leaks of heat and air, such as thermal bridges and these are much more likely when the measures are retro-fitted. Moreover, they do not lend themselves to 'simplified' calculations. Yet for the measures to be installed under the Green Deal, 'no saving' would mean 'no return' on the investment.

One reason why there is so little measured data on the performance of energy efficiency measures is that acquiring it is expensive in time and money. Most tests require a full year and 'before' and 'after' tests require more than one. One or more real houses are required and these must be heated. Also there should either be real occupants using appliances or these may be simulated with timed electric heaters. The instrumentation and data logging equipment is modestly expensive as are the services of the personnel needed to look after the equipment and to analyse the resulting data. Such work requires an organization with a sustained mission and budget.

This Call for Evidence seems to expect a lot for free, especially from engineers, the professionals who understand energy. Yet they are no different from doctors, lawyers and accountants in having professional knowledge that rightly commands an appropriate price. I am a Chartered Engineer and – as part of my self-funded energy research - have been measuring the energy efficiency performance of my own house and heating system. This involves data logging on a computer of 21 channels – 8 flowrates and 13 temperatures – at one-minute intervals. It has been running for over 10 years, yielding over 5 million scans and over 100 million data items. I have also developed and carried out the necessary analysis and calculations. However I do not propose to give my ten year's research or a lifetime's relevant experience for free. In view of the huge money and carbon savings that would be achieved by energy efficiency measures that actually work, I am prepared to accept reasonable fees. This would amount to belated payment for the research that any country or company should expect to carry out if it wishes to keep its costs down and remain internationally competitive. Indeed they would be cheap at the price, since the results already exist where time cannot be bought and prior payment for research can never guarantee them.

For free, I am prepared to say that the heat output and thermal efficiency of the gas-fired condensing boiler were measured with the aid of the gas meter, two heat and flow meters, and a rain-gauge (to measure the condensate produced), together with various temperatures. The electricity input to the heating system – boiler controller and fan, pumps and diverter valve – was measured with a digital sub-meter. With this 'in-situ' data I have so far measured the performance of several measures:

- a gas condensing boiler with the correct controls, correctly adjusted, and with radiators. The annual average thermal efficiency has been consistent at about 96% (on the Higher Heat Value).
- the electricity input to the heating system before and after fitting a high-efficiency pump. This reduced the electricity input by about 80%.
- the heat loss of a 'top-spec' DHW cylinder and associated pipework.
- the Gross Heat Loss of the house before and after adding a further thickness of insulation in the loft. This reduced it by about 10%.
- the 'free' solar heat gains through the windows after this as contributing about 20% of the annual gross heat loss.

For the last two, I have developed a method of measuring the house heat loss and the solar gains (which has not previously been possible) by a novel analysis of the data. The results are independent of the weather, so the method can be used before and after installing an energy saving measure such as insulation, to determine the actual saving achieved. This method may be published at the Solar World Congress in Kassel in late August, for which I have submitted an Abstract on the method and initial results.

The house also has cavity wall insulation, loft insulation, double-glazed windows and external doors with PVC frames, Outside Compensation control of the boiler and Thermostatic Radiator Valves on all the radiators. However these were all installed more than 10 years ago, before the start of the monitoring.

The four measures above – gas condensing boiler, high efficiency pump, low heat loss cylinder and additional loft insulation – are representative of those listed in the Call for Evidence. Hence these methods could be used to measure the performance of buildings with all the measures listed, including the 'saving' measures, ground and air source heat pumps, solar DHW heating, solar PV, biomass boilers and micro-chp.

Measures - microgeneration

I believe that heat pumps have been grouped with microgeneration because they may be made eligible for the Renewable Heat Incentive. This would be a serious error, since the fuel and carbon intensities of electricity - and also the prices per unit - are far higher than those of gas. Moreover, it will take many decades to decarbonise the grid, particularly for peaking power. Yet this would be needed in ever-greater amounts to supply the electric heaters of heat pump systems that are usually sized for about half the design peak load.

I have already analysed the microgeneration measures listed in the Call for Evidence and found some to have very low annual energy production and all but biomass heating to have very long payback times. These were at least 64 years for solar DHW and solar PV to over 100 years for GSHPs and infinity for ASHPs and micro-chp. At the WEET Forum, I heard it suggested that microgeneration measures may be justified as persuading consumers to go ahead with a whole package. However, this would be a deliberate deception of the consumer and would greatly reduce the overall effectiveness and cost-effectiveness of the package.

The Choice of Energy Efficiency Measures:

- Packages of insulation and air-tightness measures to 'conventional' UK levels could reduce energy and carbon emissions by only around 30%.
- Packages of insulation, air-tightness and heat recovery measures to Continental 'Passive House' standards can be applied to new buildings - including housing, social, commercial, and industrial - and save about 80% of energy and carbon. While retrofitting existing buildings to such standards is possible, it would take far more time and money and almost certainly change their appearance.
- However District Heating from large-scale Combined Heat and Power (CHP) plants can save about 80% of energy and carbon, while switching heat supply to biomass, wind and solar heat could increase the carbon saving to 100%. This could supply both new and – more importantly – existing buildings without changing their appearance. This should be well-known to Government, since it has long enjoyed the benefits of the Whitehall CHP scheme.
- District Heating can also power 'heat-driven' air conditioning for District Cooling, which would save about 70% of input energy and emissions compared with electric air conditioning.

I have developed a thermodynamic analysis of heat from CHP (known as 'co-generated' heat), which agrees exactly with the German 'Primary Energy Factor'. The benefits of District Heating and Cooling are well-understood on the Continent. Indeed the Building Research Establishment has published a report on it subtitled '1000 cities can't be wrong'. Since District Heating and Cooling from large-scale CHP offers proven savings of about 80% for both new and existing buildings, it should be included in the Green Deal measures.

The Organizational Framework

It is essential for the organizational framework to be right from the beginning, rather than starting up many millions of individual Green Deals, all locked in for a decade or more but none with guaranteed savings.

According to the Call for Evidence, p 3, 'The Government is establishing a framework to enable private firms to offer consumers energy efficiency improvement to their homes and businesses at no upfront cost, and recoup payments through a change in installments on the energy bill' yet on p 5, 'The Government will consult separately on the framework for the Green Deal measures in Autumn 2011'. These two statements seem contradictory. However, I believe that the Framework should be established first, with the choice being between one targetted at the individual consumer and one targetted at Energy Service Companies (ESCOs). This has a major effect on the type of measures (where ESCOs could well choose DH-CHP), the cost of measures (which ESCOs would only implement at scale) and the cost of capital (where - as corporates - ESCOs could borrow at far lower interest rates).

In Addition

- These proposals fail to recognize the essential contributions that can come only from professional engineers. They seem to imagine that 14 million (later 24 million) house and building owners will know enough about heat transfer and thermodynamics to be able to judge the validity of the claims as to what each measure could contribute, and - with the cost - the value for money. In reality, householders do not know how to evaluate energy efficiency measures and this often applies also to installers. So many such choices and installations would perform very poorly.
- In any case it would make no sense for every householder in a street or even a town each to consider energy efficiency measures and choose different ones. Neither would it be sensible for providers to install such measures piecemeal, as this would be far too costly. All measures are less costly if carried out at scale and rolled out across an area.
- The most effective energy efficiency measures can only be deployed at scale – as where all homes and buildings are connected to District Heating and those in city centres also to District Cooling.
- Large-scale networks exhibit a 'diversity factor' whereby the maximum demand is far less than the total of the individual demands – typically only 0.6. Hence the required central plant is smaller and less costly.
- Large-scale central plants exhibit 'scale effects', with higher efficiency and lower cost per unit of output. The former increases the savings and the latter often varies as the 0.6 power of the unit size.
- The savings resulting from 'individual actions' cannot be guaranteed, due to variations in family size and lifestyle. However, those resulting from 'collective actions' can be guaranteed, because of the large numbers of homes and buildings involved. For this their performance should be monitored, which is already standard practice on large networks, where such data is used to maximise the savings.
- Private individuals can only borrow at high cost – put at 11% p.a. or more in the Green Deal Summary. Conversely 'corporates' – both public (municipalities) and private – can borrow at far lower rates.

Meeting The Golden Rule

To meet the Golden Rule, the borrowing cost for the measures must not exceed the value of the expected savings in energy and the length of the payment period must not exceed the expected lifetime of the measures. Thus there must a positive 'solution space' between the four constraints – C1, the magnitude of the energy saving due to the measures, C2, the cost of the measures, C3, the cost of the capital borrowed to pay for the measures and C4, the expected lifetime of the measures. C1 and C2 will vary with the type of measure (e.g. insulation) and it's degree (e.g. thickness). C3 depends on C2 and the cost of borrowed capital.

The solution space would be reduced:

- if C1, the energy savings, are low. Hence the performance of the measures must be determined by field trials for a range of building types and climates. These have been done for several types of microgeneration and should be done for insulation and air-tightness measures before their deployment under the Green Deal.
- if C2, the cost of measures is high and the quality and savings low due to piecemeal acquisition and installation.
- if C3, the cost of capital is high. The Government proposal is that individual house and building owners will in effect be borrowing the capital cost, to be repaid via their energy bills. Yet the Green Deal Summary puts the interest rate for such people at about 11% p.a and 'considerably more for some consumers'.
- if C4, the expected lifetime of the measures, is short. This is all too likely for microgeneration measures, several of which have parts that are moving, wearing and often hot. The cost of maintenance and replacements could soon exceed the value of any savings.

These could well result in there being no positive solution space, so no solution is possible that satisfies the constraints. Indeed at the WEET Forum, Matilda Quiney of British Gas (on secondment from DECC) said that it was very hard to put together a package that meets the Golden Rule and is attractive to customer and provider, while involving piecemeal delivery, consistent with the individual action framework currently proposed for the Green Deal. Moreover, technical failure due to C1 or C4 would translate to financial risk because the bill-payer is likely to object to paying if the measures fail to deliver the expected savings.

Conversely, the solution space would be enlarged:

- If the measure is capable of larger energy savings – e.g. not conventional UK Building Standards (~ 30%) but Passive House standards (~ 80%) or large-scale District Heating from CHP (~ 80%).
- If the measure is implemented at large scale – e.g. a whole town or city via a rolling programme. The cost per unit will enjoy 'economies of scale' for both acquisition and installation and the quality and savings will also increase. This requires that the provider be a corporate such as a Local Authority or an ESCO.
- If the cost of capital is low. At the WEET Forum, Dr Andy Johnston of the Local Government Information Unit said that local authorities can borrow money at 6 to 7% p.a. This requires that the borrower be a corporate such as a Local Authority or an ESCO.
- If the expected lifetime of the measures is long. This is most likely for stationary measures like insulation and for pipework and central CHP plant that is monitored, operated and maintained by professionals.

At the WEET Forum, it was suggested that collective actions would be 'statist' while individual actions would allow the 'free market' to operate. Yet a 'free market' can never exist, since it would require complete knowledge of material pertinent to the decision - e.g. to buy or invest – by all the participants and no differential taxes or subsidies. In fact, the energy market in the UK and worldwide is very highly regulated by the likes of OFGEM. Also all nuclear power plants and supporting facilities operate with negligible insurance relative to the 'risk' or more correctly the 'consequences' of a radioactive release. Since the potential liabilities are infinite, they are carried by the states, together with those of the storage of nuclear waste. Since the half-life of uranium 238 is about 4.6 billion years, these amount to two infinite subsidies, which is a considerable departure from a 'free market'. Yet the nuclear interests are still seeking loan guarantees measured in billions from their states before building further nuclear power plants, since no rational business would touch such a proposition following Sellafield, Chernobyl and now Fukushima.

Thus collective actions maximise the solution space, so solutions can be chosen that would be both more effective and less costly. Compared with collective actions, individual actions would increase the cost and reduce the quality of the measures, and increase the cost of capital, so it would reduce effectiveness and greatly increase cost. Moreover, choosing a framework based on individual actions would fly in the face of the evidence from both the UK and abroad, where energy efficiency measures - especially to benefit those in fuel poverty - are always done at scale. Indeed, but for the UK, fuel poverty is almost unknown in Western Europe. This is largely due to successful collective actions on the housing stock, implementing energy efficiency measures including large-scale DH-CHP.

As the existing CERT and CESP schemes are both collective actions, financed by the low-cost borrowing of corporates, and presumably effective and cost-effective, why is it proposed that the Green Deal be based on individual actions, financed by the high-cost borrowing of bill-payers ?

Guaranteeing the Savings

Consumers are voters and failures - whether technical or financial – of 'individual actions' would only cause further disillusion with government. Conversely 'collective actions' via Local Authorities and ESCOs would advance the 'regionalism' agenda. This could become crucial if or when the 'powers taken' are used. Use of these on individuals such as landlords would be resented. Use on corporates (who are not voters) could only be to enforce compliance with contracts freely agreed between them and government.

It is acknowledged in the Call for Evidence that the actual energy saving performance of measures would be affected by consumer behaviour. Since the savings for individual actions could not be guaranteed, they would be inherently unenforceable. Conversely the performance of collective actions and community-scale measures would - as a result of the large numbers of households and buildings involved - be inherently enforceable. Indeed the only way to guarantee the savings in energy and carbon emissions is to make them agreed contractual obligations, expressed quantitatively, with 'corporates'. Thus the framework should require all towns and cities to prepare Heat Plans, as has been done in Denmark for 30 years. Moreover, having used CHP for 100 years, the Danes have identified this with District Heating and Cooling as offering savings of about 80%. So the Heat Plans have areas marked for existing and near-term district heating, with the rest supplied with gas until they too are eventually replaced with district heating. Energy saving measures may also be deployed in both areas. At the WEET Forum, Dr Andy Johnston of the Local Government Information Unit said that they liked the idea of Carbon Budgets whereas Cap and Trade made them nervous.

The Heat Plan areas would be divided into one or more franchises and Energy Service Companies (ESCOs) contracted to deliver the services with agreed reduced energy and emissions by specified dates. Since the energy efficiency measures should reduce gas and electricity use, the existing energy supply companies should become ESCOs, alongside those established as such. They are found increasingly on the Continent, notably in Germany, France and Austria. ESCOs are even more widespread in Denmark, Finland and Sweden, where they are often owned by the municipalities. The measures offered to householders in their franchise areas would be chosen by professionals working for the ESCOs, who would then contract with installers and others to carry them out. Thus there would still be benefits to employment, but the government would be assured of guaranteed savings, with corresponding benefits to energy security and the balance of trade. Only such collective actions and agreed contractual obligations meet both the crucial criteria in the Green Deal Summary – guaranteed effectiveness and 'keeping financing costs to the absolute minimum'. This framework should also be adopted for the ECO scheme.

The WEET Forum on 'Delivering the Green Deal' was held at the Royal Society, London on 31st March 2011.

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