Comments on the Heat Call for Evidence   Gordon Taylor   2008-03-28

The repetition in these comments reflects that in the Heat Call for Evidence. However I have also prepared a document without such repetition. (Ref. Taylor G., 2008, ‘Criteria and Heat Measures for Carbon Reduction’).

Foreword

P 2. ‘..the EU target (for renewables) will require us to go further..’.
The UK should be not just reactive, but pro-active in such matters. Then we could be ahead of the EU targets.

P 2. ‘The Government will issue a consultation later this year on policy options for the heat, transport and electricity sectors to...’
All three sectors should be addressed together, so as to exploit the ‘synergies’ in the production of heat, transport fuels and electricity. The co-generation of heat and electricity in Combined Heat and Power (CHP) plants is already common practice. If the CHP plants are large and efficient, the heat is produced with fuel and carbon savings of about 80% relative to boiler plant. (See under Para 156). Moreover the production of electricity and heat may be combined with that of biofuels in ‘biorefineries’. For example, when gasifying biomass, the energy balance could be biogas 70%, district heat 20% and losses only 10%. (Ref. Svensen B. 2007, ‘Biomethane for vehicles creates a new industry’, Slide 20.
http://www.businessregiongoteborg.com/download/18.5534da6a116154d21fc80003045/Biomethane+for+vehicles+creates+a+new+industry-++BRG.pdf).

P 2. ‘..to increase the supply of renewable energy in the UK...’.
Energy savings must be considered alongside any energy supply. They are inherently indigenous and hence the most secure measure for delivering not energy supply but energy service, which is what is really required. Also savings are at least as effective in reducing carbon emissions. Energy supply measures are usually considered in terms of the running or fuel cost, but energy savings and renewable supply should be assessed in terms of the capital or investment energy cost. The appropriate metric is known as the ‘Energy Return On (Energy) Invested’ (EROI). This is equal to the Lifetime of the asset over the Energy Payback Time (EPT). These parameters may be determined by Life Cycle Analysis (LCA). Then energy saving measures should be deployed until their energy cost exceeds that of energy supply. Energy savings may well provide most of the energy service. Examples include the Passive House (PH) standard, which gives a saving in space heating energy of 90%, so that only 10% has to be supplied.

P 2. ‘Certainly not all of this surplus heat can be used’.
This is quite untrue. Denmark requires all power stations to be built as Combined Heat and Power (CHP) stations. Moreover, they use all the co-generated heat from CHP plant fuelled by fossil fuels, waste and biomass for District Heating (DH). In addition, they use industrial reject heat, and increasing amounts of solar and geothermal heat. Such DH supplies about 60% of all space and water heating.

P 2. ‘..because it is often in the wrong place, or at the wrong time, or at the wrong temperature’.
These are all untrue in varying degree. Most fossil power stations are near existing towns and cities which could use their ‘surplus’ heat. The only fossil fuelled exceptions might be ‘mine mouth’ coal-fired power stations. Now that the output of UK coal mines is much reduced and much coal imported, this siting constraint is no longer sensible. Hence all new fossil power stations should be CHP and sited to deliver co-generated heat to suitable towns and cities.

Fossil power stations operate to meet the increased demand for electricity in winter, which is more or less coincident with the demand for heat. Moreover, unlike electricity, heat can easily be stored for several hours in ‘heat accumulators’, so that both electricity and heat demands can be met at very high fuel efficiency.

It is very easy to build new or convert existing power stations for CHP operation. In principle, it only requires that steam be tapped off the final steam turbine casing before the end and therefore at a somewhat higher temperature. If all such heat can be sold, then the last rows of turbine blades may be omitted or removed.

These are only minor hurdles when the carbon saving offered by co-generated heat from CHP plants, distributed via District Heating, is so huge – typically 80% when displacing gas boilers.

P 2. ..how all heat emissions might be included in a carbon market'.
This implies an approach that is unsuited to addressing the problem. No solutions will ever be delivered by short term trading. All measures capable of adequately addressing the problem require a long-term 'framework', wherein the long-lived capital investments can earn a solid return. Under 'Heat Planning' in Denmark, gas networks are granted a local franchise for 10 years and district heating for 25 years. While gas heating seems quite low in carbon, district heating offers – via CHP and renewables – huge carbon savings of 80 to 100%. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction').

P 3. '..will be difficult and must be achieved cost-effectively'.
Carbon savings are the first objective, so there should be the minimum of secondary objectives or constraints. Hence it is wrong to compare only the cost of energy supply. The cost of energy savings must also be considered. Moreover, energy costs are almost invariably 'levelised', which means that the cost of fuel is assumed to prevail for the life of the plant – e.g. 20 to 50 years. This is clearly wrong. Choosing energy measures on such a basis would increase the costs (both money and energy) and prevent the objective being achieved. Use of the appropriate engineering criteria identifies the measures that can achieve the carbon savings of 80 to 100% required for sustainability. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction'). There are only DH-CHP and renewables, and PH with biomass heating - so by definition they are the most cost-effective. This does not preclude energy saving with insulation etc. but in existing buildings the scope is often limited.

P 3. '..renewable heat including biogas, what role should low-carbon electricity play in heating..'.
Energy varies in quality, known as 'exergy', with a ranking – low to high – hot water, fuels such as gas, and electricity. Exergy analysis of the UK energy system has shown that the greatest losses – about 17% - occur in space and water heating. (Ref. Hammond et al, 2001. 'Exergy Analysis of the UK Energy System', Proc. I Mech E, Vol. 215, 2001, Part A, p 141). This is because gas and electricity have exergies that are too high for such heating. However, the losses may be minimised by 'exergy-matching' – matching the energy quality of carrier and load. Hence space and water heating loads are best met from piped hot/warm water, known as district heating (DH). Also it is the only carrier that can deliver co-generated heat from CHP plant as well as from waste, biomass, solar and geothermal sources. However, to achieve high efficiency and low specific cost, these plants must be large in scale. Hence DH networks are used to aggregate the building heat loads for whole towns and cities.

P 3. 'The provision of affordable, low carbon heat from diverse and reliable sources is fundamental to our objectives on fuel poverty, climate change and energy security'.
If savings measures are omitted, there is no chance of the heat service being affordable, or sufficiently low in carbon, or secure. Instead this should read: 'Heat service measures should be chosen to meet the objectives on climate change, energy security and fuel poverty' - in that priority order. As it turns out, the only measures that can meet the climate change objective - i.e. 100% carbon reduction - also meet the energy security and fuel poverty objectives. These are DH-CHP for at least 80% of buildings, and PH for some, with biomass heating for the rest.

Of all energy carriers, DH is the most capable in harnessing heat sources, as well as enabling CHP that alone offers carbon savings of about 80%. Also, fuel poverty is unheard of in towns and cities with DH, because – due to CHP savings of 80% - the fuel cost is so low. The Vienna DH system has a Primary Energy Factor of 0.3, which from a pre-existing value of 1.3, implies a fossil fuel saving of (1 – 0.3/1.3) = 77%. The price of heat for household customers has not risen since 1991. (Ref. Wallisch A, 2007, 'From energy savings to savings of resources', http://www.rehva.com/projects/clima2007/WSs/WS16/WS_pres/WS16_b_Wallisch.pdf Slides 7 and 9).

Chapter 1 Introduction

Para 3. '..sought the views of stakeholders..'.
However all stakeholders have vested interests. This includes the gas and electric utilities, as the current incumbents, and the microgeneration suppliers, who want the 'Merton Rule' and 'feed-in' tariffs. Hence the Government should pay professional consulting engineering firms for scientifically sound and independent advice.

Para 4. 'To put ourselves on a path to cutting the UK's carbon dioxide emissions .. by some 60% by 2050, with real progress by 2020'.
Hence the measures chosen should be only those capable of reductions all the way to 100%. (See under P 3).

Para 4, ‘The Climate Change Bill will also be setting legally binding intermediate five yearly carbon budgets’. According to the draft Climate Change Bill (Ref. http://www.official-documents.gov.uk/document/cm70/7040/7040.pdf) Box 1, ‘The Kyoto Protocol strengthens the framework by committing developed countries to individual, legally binding targets that limit or reduce their emissions’. Clearly the UK will have to forego the present piecemeal approach, and – as the Continentals did from the beginning - put the determination and delivery of the solution to the climate and energy challenges into the hands of professional engineers who understand the subject. The role of Government should be limited to establishing a suitable framework and monitoring progress. Delivery of the carbon savings could not possibly be by individuals or house-owners, since they have not the capacity, and in any case, are voters. Hence all the UK energy markets - heat, electricity, transport fuels - should be divided into franchises held by ‘corporations’ – i.e. limited companies who have entered into a contractual arrangement with acceptable risks and rewards. Under this ‘outcome based’ scheme, they would be Energy Service Companies, subject to absolute Carbon Emission Obligations that aggregate to the UK’s carbon targets or budgets. (See under Para 47). Monitoring the fuel inputs would require the least data. Moreover those for oil and gas are already collected for the Petroleum Revenue Tax and for all fuels for the GHG emission returns made under the Kyoto Protocol etc.

Para 4. ‘To maintain the reliability of energy supplies’.
Energy savings – including increased energy efficiency, such as CHP - are the first choice, since they are inherently indigenous. Studies in Continental countries show that they can effect major reductions in fuel use and carbon emissions. (Ref. Jochem E. (ed), 2004, ‘Steps towards a sustainable development’, http://www.cepe.ethz.ch/publications/Jochem_WhiteBook_on_RD_energyefficient_technologies.pdf). They are about half to two-thirds and sometimes more - as in the case of the Passive House standard which saves 90% of the space heating energy. Only the balance need be supplied. Hence the task is to improve the reliability when fossil and nuclear fuels are depleting. This means renewables, of which all are indigenous save for imported biomass.

Para 4. ‘To promote competitive markets..’.
However as practised in the UK, their time horizon is minutes to months, while the climate and energy solutions require decades to centuries. It is the role of the State, and hence the Government, to have such a perspective, and therefore to establish a ‘framework’ within which private or public/private companies can deliver such solutions.

Para 4. ‘..to raise the rate of sustainable economic growth...’.
Sustainability requires an end to growth of fossil energy consumption – indeed marked and rapid reductions. Whether any economic growth is possible is down to the quality of the energy choices made. In Denmark carbon emissions have decreased even while the economy has doubled. This growth has included products and services in energy savings and renewables such as DH-CHP, municipal waste, biomass, and wind turbines, of which last they hold about 50% of the world market.

Para 4. ‘..end fuel poverty..’.
This is unknown on the Continent. Hence the UK should do as they have done, and for towns and cities deploy District Heating from large Combined Heat and Power stations (DH-CHP) and the for buildings outside the heat networks, refurbishment to Passive House standards and biomass heating. (See under P. 3).

Para. 28. ‘Total heat demand in 2020 is equivalent to around 80 GW of continuous demand. Meeting this from electricity would require a 130% increase in total generation capacity’.
Since electricity cannot be stored on any significant scale, the seasonality of the heat demand means that the increase in capacity would be far more than 130%. Even a 2:1 variation would imply 120 GWe peak and 195%.

Chapter 2 Decarbonising Existing Homes

Para 30. ‘...for the building fabric (e.g. insulation)..’.
As built, the UK has amongst the lowest standards in Europe. This is because there is no quality control for the thermal properties of buildings. Even the measurement of air tightness with the ‘blower door’ test is infrequent. Moreover this can only be glimpsed, because there is no systematic measurement and analysis of such data. Conversely, the Passive House standards require that all buildings be tested for air tightness, and the insulation be checked throughout with infra-red cameras. The small cost of heating can thus be guaranteed, subject only to occupant variability.

Para 30. '..equipment that uses or converts energy (e.g. condensing boilers)'.
The UK was very slow to adopt these. Moreover, due to the poor understanding of installers, most of them lack the controls and commissioning needed to ensure high efficiency in service. Yet their efficiency in service is unknown, again due to the lack of systematic measurement and analysis of such data.

Para 30. '..access to energy audits and advice on energy savings measures'.
Energy audits are purely visual, which is far less effective than measurements. Moreover, such audits and measures are insufficient for delivering the required fuel and carbon savings.

Para 32. 'Current and proposed policies are expected to deliver enough CO2 emission reductions...'.
This is almost impossible, since most modelling done for Government is erroneous. It is usually carried out by economists, who do not understand energy engineering. Moreover it is based on no hard evidence, so the projections are hopelessly optimistic. (See under Para 35). Where evidence is sparse, it should be assessed by engineers who are knowledgeable in the relevant science and technologies. This can show where claims and even measurements are suspect or false.

Para 33. 'Zero Carbon Homes'.
'Building a Greener Future', para 3.40 notes 'Indeed we are the first country to set such an ambitious target'. Yet these savings are highly implausible because 'zero carbon' is of very doubtful effectiveness. No measurements have been made. More importantly, it would be hopelessly poor in cost-effectiveness, since it would go far beyond the 'Point of Diminishing Returns'. (See under Para. 35). It is wrong to imagine that 'zero carbon' is a worthy objective for individual homes. Indeed, by so mis-spending the limited resources, this would actually reduce the carbon savings possible. What matters is the carbon saving for the nation as a whole, and which measures have been shown to be able to deliver it – especially with existing towns, cities and heritage buildings. This is large-scale DH-CHP and renewables, as has been repeated demonstrated on the Continent. (See under Q 21). Moreover, it has already achieved 90% carbon reduction in West Copenhagen, and could achieve 100%. (See under Q 29).

Para 33. 'Energy Performance Certificates....Others..'.
Unless Energy Performance Certificates are based on measurements, they would be a misnomer. The effectiveness of any and all of these policy measures is in doubt, again because of the lack of measurement and analysis. For any system to be correctly guided, 'feedback' is necessary. This means measurements and analysis, carried out by engineers who are knowledgeable about the systems in question.

Para 34. 'Houses built to the current (2005)...(and later) standards...will make up only 30% of total housing,...'.
However, as shown in Figure 2.1, the pre-2005 housing would still account for about 335 of 360 TWh/y (93%) in 2020 and about 327 of 390 TWh/y (84%) in 2050. Moreover there is a huge discrepancy – factor 7 - between the claimed and estimated space heating loads of new housing. (See under Para. 35). Therefore not much credence can be placed on this data, nor on that for existing housing. When developing policy, 'sensitivity analyses' should be carried out to determine the critical parameters, and then high quality measurement and analysis campaigns commissioned of professional engineers who know the subject.

Para 35. 'Housing built under current building regulations has an average space heating load of 2 MWh/y and a hot water load of 5 MWh/y'.
No evidence supporting this claim is cited here or to be found on the web. However, an estimate from a member of ASHRAE is that 'an 80 m2 semi-detached house is likely to use nearer to 15,000 kWh/y of gas for space heating'. After allowing for an annual average condensing gas boiler efficiency of say 90%, this would be 13,500 kWh/y, which is almost seven times as much as claimed. This suggests that the claimed energy and carbon savings are false, and no help for policy development. Indeed, they are worse than that, they are positively misleading.

Assuming the 'housing built to the current building regulations' to have a floor area of 80 m2, then a space heating load of 2 MWh/y implies 2000/80 = 25 kWh/m2,y. The Passive House standard specifies 15 kWh/m2,y and has been proven repeatedly – by measurements - to reduce the space heating energy by 90%. This standard is carefully devised to avoid the cost of a separate space heating system, without incurring the expense of additional energy measures following 'The Law of Diminishing Returns'. (Ref. Feist W., No Date, 'Passive Houses from Pilot to Mainstream in Germany', http://malmo.se/download/18.1f60430104c0456fc68000698/Feist.ppt, Slide 23).

Para 38. '...could mean expenditure of more than £ 20,000 per household'.
Hence look to measures of proven effectiveness – i.e. DH-CHP and renewables and PH with biomass heating.

Para 39. 'Electrical heating using decarbonised grid electricity'.

Electrical heating in new build is prohibited in Denmark, and there is funding for converting from electrical to gas and district heating. (Ref. http://www.elsparfonden.dk). Electricity has a much higher exergy than is required for space and water heating, so there would be exergy losses in such usage. Also generating electricity incurs energy losses. Although these can be largely recovered with CHP plant, the use of electricity should be confined to appliances and lighting, electric drives and traction, and industrial process heating at temperatures above about 1000 C or where extreme cleanliness is required. Moreover the upstream chain of generation, transmission and distribution is very costly in money and energy. Evidently the Danish government listens to professional engineers.

Para 39. '..but in most cases would involve a major departure from the way heat is delivered to communities now'. Anything would involve such a departure, because 'now' is unsustainable on climate and energy grounds. Also, every other service - water, sewage, electricity - comes from large off-site plant and for very good reasons, including scale and system effects. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction'). Most dwellings now have water- or air-based central heating, so switching to DH is easy. Moreover all owners and tenants would much prefer such a heat service, with far fewer maintenance and no gas safety requirements. In many countries district heat costs less than natural gas heat. (Ref. Werner S., 2006. 'EcoHeatCool Work Package 1: The European Heat Market', Figure 47. 'http://www.euroheat.org/ecoheatcool/documents/Ecoheatcool WP1 Web.pdf).

Table 2.1. 'CHP district heating'.
The Potential Carbon Saving is shown as 5-25%. Yet the document referenced in Footnote 14 gives it on p 7 as 'Energy savings (and therefore carbon savings) are typically 25% compared to gas boilers and up to 50% compared to electric heating'. The source of the value of 5% is not clear. However, from a recent major study of DH-CHP, it is clear that a carbon saving versus gas of only 25% is on an electricity plus heat basis. (Ref. Parsons Brinckerhoff et al, 2005, 'Comparison of CHP/DH'). When corrected to a heat only basis, the saving is 87%. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction'). More typically, it is about 80%. (Ref. Taylor G., 2002, 'Energy Solutions for 60% Carbon Reduction'. Section 3.9. http://www.energypolicy.co.uk/epolicy.htm).

Table 2.1. 'Lower savings as grid electricity decarbonises'.
Electricity gives very poor 'exergy matching' with space and water heating. This results in energy losses in conversion of fuels, and in the very high cost of plant for generation, transmission and distribution. The fact that some plant exists is immaterial, since continuing electrical loads would require that it be maintained and eventually replaced. In order to meet the carbon saving targets, measures must be chosen according to engineering criteria. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction').

Table 2.1. 'District heat with remote heat supply'.
The Potential Carbon Saving is shown as 'up to 80%', whereas for DH-CHP, 80% is typical. Also, when using renewable fuels and heat, the carbon saving can be 100%.

Table 2.1. 'Distance that heat is transported is a key determinant of cost..'.
However, if the amount of heat is large – as for CHP plants of hundreds of MWe – it is well worth transmitting it for several tens of kilometres, as with CTR and VEKS in Copenhagen. Harnessing the heat from such large CHP plants is essential for achieving the carbon savings of about 80%.

Table 2.1. 'Micro CHP'.
The Potential Carbon Saving is shown as '5-10%'. However, thermodynamic analysis, confirmed by the evidence from field trials, shows that for Stirling engine units of about 1 kWe, the 'Thermodynamic Heating Efficiency' is lower than the efficiency of a condensing gas boiler. Hence the carbon saving is negative.

Table 2.1. 'De-carbonised electricity'.
The typical capital cost/household is shown as '£ 3000 plus grid costs'. However, for a nuclear plant of 1.6 GW, costing 30 billion euros, with a peak heat load of 2.5 kW per household, and at 1 euro = £ 0.7, it would be 30 x 2500 x 0.7/1.6 = £ 32813 - i.e. 10 x as much. This is on a simplistic basis. For such loads on a large grid network there would be a diversity factor of around 0.5. Hence the capital cost would be 'only' five times as much at £ 16406. However, this puts it as the highest cost supply measure in the table.

This is only to be expected, due to electricity offering very poor 'exergy matching' to space and water heating, and hence incurring high energy losses. Moreover for safety reasons, nuclear plants have thermal efficiencies well below those of fossil plants, and they are rarely operated as CHP plants. Furthermore the possibility of the DH water carrying radioactivity into the connected buildings cannot be eliminated.

However, the typical capital cost/household would be even higher. Building new houses in the UK with a peak space heat load of 2.5 kW would probably take at least a decade to achieve. Meanwhile they may require not 2 but say 14 MWh/y to heat. (See under Para 35). Existing housing would require up to £ 20,000 per household to reduce the space heating load and energy, yet may only reach more like 4 kW and 10 MWh/y. Pre-2005 housing would still account for 93% of the total in 2020. (See Para 34). Hence the weighted average space heat load could be 3.9 kW, and the typical capital cost/household £ 20,000 + 16406 x 3.9/2.5 = £ 45,593.

In addition, the domestic water heating load would have major impacts on the electricity system. Modern houses are usually built with no hot water tank, since gas combi boilers are assumed, with outputs of 25 - 30 kW. Even electric showers have outputs of 7 - 10 kW. Moreover the usage would be concentrated on the morning and evening peaks and so add to them. Since the diversity factor would be high yet the load factor low, the peaks would be far higher than that of any plausible nuclear capacity. Hence they would require considerable fossil plant to be run, including some of the least fuel efficient. Thus the weighted carbon intensity for electrical space and water heating could well be higher than the current system annual average. In 2005, this was 0.527 kgCO2/kWh. (Ref. http://www.defra.gov.uk/environment/business/envrp/pdf/conversion-factors.pdf). For space heat of say 10 MWh/y and water heat of 5 MWh/y, the carbon emissions would be almost 8 tCO2/y. Natural gas has a carbon intensity of 0.194 kgCO2/kWh. For a gas heated dwelling using say 14 MWh/y for space and 6 MWh/y for water, they would be under 4 tCO2/y – only half as much. For the latter dwelling heated by DH from gas-fired CHP, they would be – assuming 80% saving – about 0.8 tCO2/y – only a tenth as much. Since this paper is considering heat, electrical appliances and lighting have been neglected. Hence the carbon 'saving' for electrical space and water heating relative to gas could be -100% and relative to DH-CHP -1000%.

Para. 41. 'All of these figures are subject to change as technologies develop'.
This is not so. For most of these technologies, their performance and efficiency depends on thermodynamics, the laws of which are not subject to change. Also most of the technologies are mature, so as they approach the limits, changes in performance and efficiency would be small and slow.

Para. 43. '..some technologies, especially district heating, involve investment on an aggregate basis..'.
This is also true for water, sewage, gas, and electricity, each requiring both initial and ongoing investment.

Para. 43. 'A householder alone will be unable to choose between microgeneration, insulation or district heating..'.
Hence the choice should be left to an Energy Service Company (ESCO) subject to an absolute Carbon Emission Obligation. Towns and cities should carry out 'Heat Planning', as in Denmark, with areas of gas heating and district heating. For gas heated buildings, the ESCOs could offer additional insulation to save fuel and carbon. However, the areas of district heating would be progressively increased, to achieve much greater fuel and carbon savings. The cost of heat could be guaranteed to be less than that with gas heating, as is usual in Denmark. For buildings outside the actual or planned heat networks, they could offer insulation - potentially up to PH standard - and biomass heating.

Q. 1. See comments on Table 2.1 above.

Q. 2. The premise is wrong. Greater use of electrical heating would not reduce carbon emissions. For space and water heating, electricity is grossly mis-matched in exergy. (See under P 3). Yet generating it from fuels results in losses and a high carbon intensity. Also heat pumps have adverse system effects, due to peak resistance heating causing very low annual load factors. Moreover any increase in electricity use for space and water heating would require more (capital) energy investment in electricity generation, transmission and distribution. Furthermore electric heating could only be affordable in very low energy dwellings, such as those built to the PH standard. However it is impractical to tear down and rebuild or even refurbish all our towns, cities and heritage buildings to this standard. Yet DH-CHP would give carbon savings of about 80%, and with renewables, up to 100%.

For cooking and high temperature process heating, DH is not high enough in exergy, and natural gas is depleting, insecure, and dangerous due to the risk of explosions – especially with LNG. Moreover, biogas will always be limited, and must be reserved for end-uses that really need its exergy, such as high temperature process heat, large-scale CHP, transport – in gas-powered vehicles – and even chemical feedstock – e.g. for plastics.

Due to its high exergy, electrical heating is best suited to – and should be limited to - cooking and process heating at temperatures above about 1000 C or where extreme cleanliness is required. However the scope for savings should be explored beforehand. Electricity is extremely easy to measure and even best practice is unlikely to be anywhere near the limits. These are set by the science – e.g. chemistry and physics – and have not as yet been fully explored, save for lighting. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction').

Para. 44. '..the amount of energy used by appliances such as fridge-freezers is falling..'.
However the UK is very slow in adopting available A++ units, which – compared with A units - offer savings of 50%. Moreover the Energy Saving Trust web site shows products without even the energy ratings, never mind the power and (electric) energy consumptions. Yet all these are shown at www.topten.ch and www.topten.de.

Para. 45. 'Air conditioning is usually powered by electricity and in the UK is found mainly in offices'.
Most such offices are in towns and cities, and hence should be well within the reach of heat networks. This would enable the use of heat-driven (absorption) chillers which – compared with electric chillers – offer carbon savings of about 85%. (Ref. Wirgentius N., 2006, 'Primary Resource Factor – for systematic evaluation of heating and cooling options', http://www.euroheat.org/documents/Conference2006Presentations/8.Wirgentius.ppt Slides 4 and 9). For offices in city centres, District Cooling may be installed. By using 'free' cooling from lakes, rivers and seas at least part of the year, with heat-driven chillers for the remainder, the carbon saving is increased towards 100%.

Para. 45. 'It is possible that residential air conditioning will become more popular in the UK in the future..'.
However this can and should be avoided. Reducing building heat loss also reduces heat gain and increases the building 'Time Constant'. It then behaves in a more 'massive' fashion, with effectively more heat and cool storage capacity. This allows 'cool' to be stored at night and used in the following day. To approach and achieve the PH standard, excellent air tightness is required, which greatly reduces air infiltration. Moreover, Mechanical Ventilation with Heat Recovery is fitted, which allows the use of a Ground Tube to cool the incoming air, and for this 'cool' to be largely recovered. Finally all appliances and lighting have scope for reductions in electricity use of perhaps 50% or more relative to today's best – so reducing internal heat gains.

Chapter 3 Carbon Markets

Para. 47. 'The Climate Change Bill ... proposes to set a legally binding .. framework.. to cut carbon dioxide emissions'.
Such a 'legally binding' framework has to involve one or more contracts. This cannot be with individual citizens, since they have no access to low-cost, long term capital (save for mortgages on their own homes) nor the skills to design and deliver such measures. In any case, any such attempt would fail because they are voters. Therefore such contracts can only be with corporate entities, with access to low-cost, long term capital, and the skills to design and deliver such measures. These are known as Energy Service Companies (ESCOs), and are already active both on the Continent and in the UK. They are not voters, but need to be offered an attractive business proposition. Such measures require decades for delivery, so this requires that climate and energy policy be sustained for such periods. Hence it must be based on sound science and technology. (See under Para 4).

Para. 47. 'Emissions trading is seen as a key policy tool to meet fixed carbon budgets cost effectively'.
In the heat and transport sectors, the Government has decided that there is no role for 'markets' in 'carbon credits' in respect of 'carbon savings' made abroad. (Ref. DCCB, p 152 of 179, para. 5.1.30). JI and CDM measures implemented abroad cannot deliver heat (or transport fuel) and so increase energy security or alleviate fuel poverty.

The UK is committed by international agreements, such as Kyoto and 'burden-sharing' within the EU. These are expressed as percentage reductions from a given base year, which correspond to certain absolute carbon emissions by certain dates. The only way for the UK to ensure 'specific performance' is to express the contracts with ESCOs in the same way – as absolute Carbon Emission Obligations (CEOs). The 'framework' should involve dividing the heat (and electricity and transport fuel) markets into 'franchises' for specified markets - geographical areas for heat and electricity – for specified periods. The franchise periods must be long enough to cover at least the investment and return and possibly the lifetime of the assets. In the case of power and CHP plants and heat networks, this last is 30 to 50 years. However, the CEOs would be expressed as milestones for every five year period, and the performance would be subject to review. In the event of significant under-performance by any ESCO, the franchise would be withdrawn and put up again for bids.

Trading will never deliver any carbon saving. This can only be done on a sufficient scale by ESCOs and their engineers. However, carbon certificates could be sold by over-performing ESCOs to under-performing ESCOs. This would reward the former and penalise the latter, and so increase the probability of national milestones and targets being met. Hence, due to the above decision by Government and ESCOs being needed to ensure delivery, carbon trading can have only a marginal role in meeting fixed carbon budgets for heat (and transport fuels).

Para. 47. '..to meet fixed carbon budgets cost effectively'.
This would be ensured by a framework of franchises open for competitive bidding, then subject to periodic – e.g. five year – review. Thus the Government should trust the ESCOs and their professional engineers to deliver the

contracted carbon savings. Such performance contracts work very well on the Continent and between businesses in the UK. (See under P. 3).

Para. 51. ‘The Climate Change Bill proposes to establish an economically credible emissions pathway to 2050..’. The emissions pathway to 2050 cannot be defined only by the end point value. Both climate and energy policy depend on the total emissions between now and the end point, usually expressed in Gigatonnes (Gt) of carbon or carbon dioxide for the period. The Draft Climate Change Bill shows two cases. (See DCCB, p 136 of 179, Fig. 1). The UK emissions for 2010 to 2050 for the ‘-30% by 2030’ case are about 19.4 and for ‘linear’ case about 14.8 GtCO2. Since the former is 31% greater, the total emissions depend on the pathway and must therefore be defined. But even this is incomplete. Sustainability requires 100% carbon reduction, so climate and energy policy require that the pathway be defined by the total carbon emissions from say 2010 to the date when they become zero. Hence the planning end point should now be sustainability. (See under Para 4).

The Stern Review showed two emission paths to stabilisation - for 450 and 550 ppm CO2e. (Ref. http://www.hm-treasury.gov.uk/media/0/3/Slides_for_Launch.pdf Slide 4). The OCC Analytical Audit focuses on 550 ppm. (Ref. http://www.occ.gov.uk/activities/analytical_audit/FULL_REPORT.pdf Slide 15). For 450 ppm CO2, the total (global) emissions from 2000 to 2100, which is almost all the way to zero, is roughly 1800 GtCO2. (Ref. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf page 67).

Recent research has shown the need for even more drastic reduction paths. (Ref. Spratt D. et al, 2008, ‘Climate Code Red’. http://www.carbonequity.info/download.php?id=6). Indeed, to avoid serious climate change impacts, the GHG concentration will probably have to be reduced below present levels. (Ref. Hansen J., 2008, ‘Global Warming: The Perfect Storm’, http://www.columbia.edu/~jeh1/RoyalCollPhyscns_Jan08.pdf). Furthermore, we are now in the end-game, with the issue being survival of life on this planet. Therefore, as in war, the money cost – at least in comparison with today’s energy costs - is irrelevant. However, depletable fuels are all ‘zero sum’ resources - the more for us, the less for them - where most renewables are not. With the oil price passing $ 100/barrel and the world facing recession, all Governments should stop planning for unlimited growth. Already some countries – including NL, CH, DK, SE and DE - are planning and implementing their transitions to sustainability. The UK would have fewer enemies if it stopped competing in the ‘zero-sum’ game for the declining resources of fossil and nuclear fuels. This would in turn require far lower expenditures of money, energy, lives and limbs on military forces for fighting resource wars. This was evidently recognised long ago in those countries which are planning and implementing their transitions to a sustainable energy future – none of which have large military forces. Since like them, the UK cannot hope to win resource wars against the USA, Russia, China or India, a rapid transition to sustainability is not just prudent, but the only viable policy.

Para. 53. ‘The need to bring forward a range of low-carbon and high efficiency technologies to make deep emission cuts’.
This would incur delay which is neither permissible nor necessary. Thermodynamic analysis shows that for towns and cities, large-scale DH-CHP offers carbon savings for heat of about 80%, and with renewables, up to 100%. For buildings outside the heat networks, building or refurbishing to the PH standard offers fuel and carbon savings for space heat of about 90%. These best meet the engineering criteria – first energy savings to the ‘Point of Diminishing Returns’ then supply of renewables with ‘exergy-matching’. Furthermore they are confirmed by ample evidence on the Continent. (See under Q 21 and Para 35).

Para. 54. ‘Although insufficient by themselves, carbon markets have an important role to play in a combined response to the threat of climate change’.
Not so. (See under Para. 47).

Para. 54. ‘Disadvantages. Fuel poverty: Impacts on fuel prices of carbon trading will have a negative effect on fuel poverty’.
However, DH-CHP offers fuel and carbon savings of 80%, which allows charging a very low (marginal) price for heat. Moreover, this could be delivered by ESCOs, starting in town and city centres, which is where many of the ‘fuel poor’ live. (See under P. 3).

Para. 54. ‘Disadvantages. Transaction costs: The monitoring, recording and enforcement burden ..is a function of the number of parties..’.
Hence the only practical framework must involve ESCOs, who would be far fewer in number.

Para. 54. ‘Disadvantages. Price uncertainty: the reverse of the quantity limit’.
The UK is committed to ‘legally binding’ quantity limits under the Kyoto protocol. Moreover, the Heat Call for evidence says that the Climate Change Bill proposes ‘legally binding’ targets. (Ref. Para 5.1.11). However, the

essential condition for long term investment is a consistent climate and energy strategy all the way to sustainability and contracts of adequate duration. (See under Para. 47).

Para. 55. ‘However, abatement can take place outside Europe...’.
Not so. (See under Para. 47).

Para. 57. ‘The Supplier Obligation’.
The ‘framework’ dividing all UK energy markets into franchises, held by ESCOs subject to CEOs, is a form of Supplier Obligation. It is an ‘outcome-based’ scheme of the ‘cap and trade’ type, but with a contractual obligation to deliver the ‘cap’, and hence minimal dependence on ‘trading’. ‘Outcome-based’ schemes have the huge advantage of being easy to monitor via the shipments of fossil fuels. Moreover, since it would be ‘legally binding’, it would replace all other schemes and initiatives. Indeed, since the investments and returns require decades, Government should set such a framework and leave the ESCOs and their professional engineers to deliver their choice of carbon saving measures and the contracted carbon emissions on time. (See under Para. 47).

A ‘measures-based’ or hybrid approach would be counter-productive. As competent professionals, the ESCOs would expect to choose and implement the measures that best met their contractual obligations. Also, by introducing constraints, a ‘measures-based’ approach would result in the objective costing more, or even being jeopardised altogether.

Q 3. Yes, but only indirectly through the suppliers – ESCOs. The carbon emissions from not just heat but all energy use should be included in a long term ‘framework’ within which ESCOs can deliver the carbon savings. This is competitive in that they would bid for the franchises that give access to all UK energy markets. However, they should then hold them for long periods so that large investments can be made and earn a return. There should be ‘milestones’ say every five years, and serious under-performance should result in the franchise being withdrawn and put up again for bids. There is no scope for ‘market’ activities on a timescale of minutes to months. The ‘framework’ must create an environment in which investments – of both money and energy - are made with near-certainty of return over timescales of decades to centuries. However, trading of carbon credits or certificates could reward over-performers and penalize under-performers.

Q 4. The ‘framework’ franchises should be open to any ESCO, which could be a utility, local authority, or partnerships thereof. In principle, these could be SMEs, but there is no case for preferring them. Indeed, larger entities would be better suited due to the long-lived assets and obligations, their access to low-cost financing for periods of up to 25 – 30 years, and the professional engineers on their staff, to identify, design, and deliver the measures and contracted carbon emissions. Nevertheless, the suppliers and contractors to the ESCOs could well be SMEs.

Para. 65. ‘a hybrid option that attempts to provide the certainty of outcome... while continuing to encourage investment in UK buildings...’.
A ‘framework’ based on franchises held by ESCOs contractually subject to certain carbon emissions by certain dates should allow the ESCOs to choose the measures that best met such objectives. These investments could be either in the buildings or the infrastructure. However, in delivering the carbon savings, they would increase security of service and reduce the cost of heat service, and thus fuel poverty. (See under Para. 57).

Q 5. (‘Hybrid SO’ is not in the Glossary). The only way to guarantee delivery of the carbon targets or budgets is via a pure SO, based on outcomes. For Government to specify the measures would be counter-productive, since they would introduce constraints which could increase costs and even jeopardise achieving the targets. Hence the ESCOs would be less likely to bid for franchises and accept the contractual obligations. The only way to abate carbon emissions is by investment in measures. However, the choice of measures should be left to the professional competence of the ESCOs and their engineers. (See under Para. 57).

Para. 70. '..a solely measures-based approach .. would lead to a significant increase in energy prices..'.
No-one wants energy as such, they want energy services. These can be delivered along with carbon reductions only by energy saving and renewable supply. For heat service, energy saving is likely to account for about 80% and renewable supply for about 20%. This is the case for both DH-CHP, then renewables and for PH with biomass heating. (See under Para. 53).

Q 6. Yes. The measures that are most effective for carbon saving would also best increase security of service and reduce fuel poverty. (See under P. 3 and Para. 54). There is no need to limit such favourable impacts.

Chapter 4 Renewable Heat

P 6. '..deploying renewable heat...'.
Large scale is needed for high performance and low cost, and DH is needed as the carrier which makes best use of the renewable sources. For example, the efficiency of solar heat arrays is – at say 50% - far higher than that of PV – at maybe 10%. This is a consequence of exergy and thermodynamics.

Para. 72. 'By using renewable energy to meet our heating (and cooling) needs, we would also diversify our energy systems with, potentially, a beneficial effect on the security of energy supply'.
The beneficial effect is not due to diversification but because – save for imported biomass - renewables are indigenous. Also, what is wanted is not security of energy supply, but of energy service, which can also be delivered by energy savings. (See under Para. 70).

Para. 80. 'Microgeneration...heat'.
There is adequate evidence on the performance of heat pumps and solar water heaters from field trials. Taken with the current costs, they are - relative to more effective measures for carbon saving - very far from cost-effective. For heat pumps, the cost of carbon saving is around £ 564 to 829/tC/y. For solar water heaters, the cost of carbon saving is £ 1316 to 2920/tC/y and the money payback time is 64 to 214 years. Also, no plausible reductions in specific cost (per unit output) could make them competitive. Moreover, both are subject to 'scale effects' and 'system effects'. All on-site renewable measures are intrinsically small and thus adversely affected by scale effects. These impact both the performance and the specific cost. Furthermore they do not benefit from 'diversity', which is about 0.5 for large networks. Where on-site measures have to be sized for the full demand, off-site measures connected via networks require only half the capacity per building. Also large units have low specific cost. (Ref. Taylor G. 2008, 'Carbon Savings in the Buildings Sector').

Heat pumps also have adverse system effects, particularly when using resistance peak heaters. Likewise, solar water heating would have adverse system effects if using electricity for backup heat. Again this is due to their low load factors, which require the electricity supplier to have generation, transmission and distribution capacity that is little used. For example, one heat pump system in the UK was reported as having an annual load factor of only 11% or less than 1000 full load hours per year. (Ref. BRE, 2000. 'Heat pumps in the UK – a monitoring report', Report GIR72. http://www.heatpumpnet.org.uk/files/gir72.pdf). Even with diversity, such loads would be very unattractive to the supplier. If such on-site systems were widely adopted, the electricity supplier would use a time of day and year tariff, or a maximum demand tariff, as already used for industry and commerce. This would compensate the central supplier, but increase considerably the costs to the site. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction').

Regarding micro-chp of about 1 kWe, thermodynamic analysis shows that the Thermodynamic Heating Efficiency is worse than the thermal efficiency of a condensing boiler. (See Taylor, G., 2008, 'Carbon Savings in the Buildings Sector').

Only biomass boilers have a relatively low (capital) cost of carbon saving - though a significant running cost. However if located on-site, they too are small and thus subject to adverse scale and system effects. Hence their use on-site should be limited to buildings outside the heat networks. Biomass is better used in large scale plant connected to heat networks, especially as this can be not just boilers but CHP plant, and so make much better use of the exergy in the biomass fuel. Compared with those of Heat Only Boilers, the fuel and carbon costs of CHP heat would be reduced by about 80%. In either case, such heat sources would be almost zero carbon, and connecting them to the networks could increase the carbon saving of DH and fossil fuelled CHP from 80% towards 100%.

Para. 85. 'In theory solar PV and micro wind turbines could be used to provide electricity for electrical heating, but at present this would be a far from cost-effective heating option for buildings with access to mains electricity and the gas grid'.

Moreover, the efficiency of solar heat arrays is – at say 50% - far higher than that of PV – at maybe 10%. This is a consequence of exergy and thermodynamics.

Q 7. No. (See under Para. 80).
The renewable heat technologies are listed, and their magnitudes in Europe are shown in EcoHeatCool volume 4. (Ref. Werner S., 2006. 'Ecoheatcool Work Package 4: Possibilities with more district heating in Europe', p 40. http://www.euroheat.org/ecoheatcool/documents/Ecoheatcool WP4 Web.pdf). However, large scale solar heat should be added and is almost unlimited. (See under Para. 113).

Para. 91. 'Analysis suggests that ...at least 4% of UK heat demand could be met by biomass heat by 2020; further details...are set out in Annex II'.
Annex II is fundamentally flawed in that the BERR residential gas and electricity prices assumed for 2020 have already been exceeded in March 2008. The same is probably true for the commercial gas and electricity prices. Moreover, due to Peak Oil, Gas, Coal, and Uranium, they will certainly rise further by 2020. The world is entering the uncharted territory of resource depletion, so we must be prepared for endless increases in the prices of all depletable fuels – both fossil and nuclear.

Biomass may be used to fuel Heat Only Boilers (HOBs) or CHP plant. The thermal efficiency of non-condensing boilers is about 80%. Condensing biomass boilers are available, with thermal efficiencies of about 90% (on the Higher Heat Value), but are few and expensive. The Thermodynamic Heating Efficiency of co-generated heat from CHP plant at the plant boundary - as in industry - is about 300 to 400% and - after allowance for peaking boilers and DH network heat losses - about 250 to 330%. Comparing a CHP plant with a HOB, the total biomass consumed would be higher due to the co-generation of electricity. However, the heat delivered for the biomass attributable to heat would be at least three times as much. As a result, such heat could be much less expensive, and so gain a larger market share. This is a consequence of CHP making better use of the exergy of biomass. Therefore it should be used for CHP and - after gasification - for high temperature process heat, CHP, vehicle fuel and feedstock. (Ref. Gunnarsson I., 2005, 'Production and refining of biomethane: Some projects for the future', Slide 6. http://www.bioenergydays.com/pdf_file/lecturer_eng/pm_1_Biofuel/I_Gunnarsson_Biomethane.pdf).

Q. 8. I have not reviewed it in detail. No, but many studies have been published. (Ref. Faaij A., 2005, 'Global Potential for Biofuels'. http://www.iea.org/textbase/work/2005/Biofuels/Biofuels_Faaij_Presentation.pdf).
Several other EU countries – notably AT, DE, DK, NL, and SE - are making much more use of biomass, both home-grown and imported. Moreover, biomass – especially imported biomass – is the only renewable subject to 'zero-sum' considerations. Since others have built a heat infrastructure – DH - that enables them to enter into long term contracts, then late-comers like the UK would have to pay more. Furthermore logs, pellets and biofuels such as ethanol can be shipped worldwide, so there will be worldwide demand pressures,

Q. 9. No. The leading countries have been addressing these issues for decades. The UK should seek to make a significant contribution to the R&D effort, in partnership with them.

Para. 102. '..the lack of public support for the siting of energy-from-waste plants..'.
There are several large modern CHP plants burning waste in the centre of Copenhagen. One such - Amagerforbrænding - is well within sight of the Royal Palace. They have sufficient confidence in their operations that the stack emissions readings are published on the Web. (Ref. http://www.amfor.dk/on_line/).

Para. 108. '...biogas...could be injected into the gas grid.. avoiding the need for new heat distribution systems..'.
However, if biogas – whether from AD or gasification – were injected into the gas grid in the UK, almost all would be used in boilers. This would be a waste of exergy, and – since it could otherwise be used for CHP, producing co-generated heat at a very high thermodynamic efficiency - thus a waste of energy.

Moreover the electricity and Thermodynamic Heating Efficiencies (as well as the specific cost) depend strongly on the unit size, so the CHP units should be as large as possible. Hence they should supply large DH networks. Furthermore, due to the year-round supply of waste, such networks can supply heat for heat-driven chillers or District Cooling with energy savings of about 85% and – since the fuel is renewable - carbon savings approaching 100%. (See under Para. 45).

Q. 10. No. In Denmark, municipal waste accounts for 18% of the district heat. (Ref. http://www.ambwashington.um.dk/NR/rdonlyres/C47EF405-66C2-41CD-9F38-6D43A26DC232/0/EnergyEfficiency4Ramboell.pdf Slide 5). This is harnessed via DH. Since DH accounts for some 60% of all space and water heating in Denmark, municipal waste accounts for about 18% x 60% = 11%.

Q. 11. No. Injecting biogas into the gas grid would waste exergy and thus energy. (See under Para. 108). The supply of biomass, whether home-grown or imported, will always be limited by land area, water and nutrients. Hence biogas and biomethane are far too limited and too high in exergy to be used for space and water heating. Instead they should be reserved for high temperature process heat, larger CHP units, transport fuel and feedstocks (See under Q 7).

Para. 113. 'Analysis of the potential for solar thermal water heating...'.
Like other on-site supply measures, this is subject to adverse scale and system effects. Small on-site solar arrays may use as back up heat electricity, with a high carbon intensity and a low annual load factor, making such loads very unattractive to suppliers. However in Denmark, arrays of above 250 m2 can produce heat that is competitive without subsidy. Compared with small on-site arrays of say 3 to 6 m2, large and very large arrays – of 1000 and 10,000 m2 have higher performance and lower specific cost, so increasing the overall cost-effectiveness by 6 times. (Ref. Steffensen H., 2007, 'EU aim at great expansion of large-scale solar thermal plants', DBDH Journal, 4/2007, p 15).

Para. 114. 'Analysis of the potential for heat pumps..'.
(See under Para. 80).

Para. 115. 'Most of the barriers to microgeneration heat...'.
Except for biomass heating, the promotion of microgeneration heat is misguided. There is ample evidence showing that the effectiveness in saving carbon is low – even negative in the case of micro-chp of around 1 kWe – and far less cost-effective than other measures. (See under Para. 80). If money and energy were invested in such on-site microgeneration measures, the carbon savings would be far lower than if invested in off-site measures such as large-scale, city-wide DH-CHP, which could give carbon savings for heat of 80%.

Q. 12. The adverse effects of small scale on performance and specific cost. The adverse effects of such units, with their low load factors, on the electricity system. Except for small biomass boilers for buildings outside the heat networks, on-site microgeneration of heat (as for electricity) is not cost-competitive with other measures. (See under Para 80). Government can do nothing about these consequences of the physical laws. Moreover the ESCO engineers would take them into account when choosing measures to meet their carbon obligations.

Q. 13. No. Save for small biomass boilers, their potential is zero, since other measures are far more cost-effective. (See under Para. 80). Therefore no national purpose would be served by addressing these barriers.

Microgeneration heat technologies fail the criteria of carbon saving and (energy) cost-effectiveness, due to adverse scale and system effects. These are intrinsic and insuperable, so these measures should be discarded – indeed discouraged – outright. The only exception with regard to carbon saving is biomass heating. Although this has potential problems with noxious emissions including particulates, small biomass boilers suitable for on-site use have greatly improved thanks to decades of research, mostly in Austria. As a result of this long-term investment, they have established an industry that now enjoys rapid growth. However, due to their high specific cost, their use should be confined to buildings located outside the heat networks. The adverse scale and system effects can be avoided with large biomass plants connected to the heat networks, even in the centres of towns and cities, since they are nowadays fitted with effective control of flue emissions, both gaseous and particulate.

Q. 14. No financial support is required for renewable heat, for all technologies and fuels. None save biomass heating are cost-effective at saving carbon or indeed, sufficiently effective by themselves. (See answer to Q 13).

Q. 15. As for Q. 14. The supporting evidence on renewable heat measures shows that they are either not effective or not cost-effective compared to large-scale off-site measures. This is based on thermodynamic analysis and evidence from field trials in the UK and on the Continent. (See under Para. 80).

Q. 16. As for Q. 14.

Q. 17. Heat meters are feasible and necessary for heat supply from DH-CHP and renewables, just as are meters for water, gas and electricity supply. They give feedback to the user and thus encourage economical behaviour. This has been shown repeatedly with water meters in the UK and with heat meters in Denmark and elsewhere. (Ref. Gullev L., News from DBDH, 3/2006, p 20). They would therefore be specified by the ESCOs.

Q. 18. The UK's climate and energy targets are expressed in carbon emissions. Hence the framework should be 'outcome-based', expressed also and only in carbon emissions. Any of the options in favour of renewable heat would constrain the solution, where carbon saving measures could be more attractive. This could increase the cost, or even prevent the targets being achieved.

Chapter 5 Heat Markets

P 7. '..in the same way that gas and electricity now is..'.
These days are over. There are no more low-cost fossil fuels to be had - witness oil at $ 100 a barrel and rising. The concept of a 'heat market' operating over timescales of minutes to months thus misguided. If we want continued energy service, we must invest in measures that are inherently long-term. Hence the ESCOs require long franchise periods. Since they are also inherently local monopolies, like water and sewage, it also requires 'Heat Planning' as in Denmark. This has long been accepted on the Continent, where there are over 1000 cities with DH-CHP. (See under Q 21). The 'business model' has to be based not on short term competition but on co-operation with trusted partners over periods of decades.

Para. 132. '..independently regulated, competitive energy markets are the most cost-effective...way of delivering...energy security and cleaner energy, as well as.. affordable energy'.
The objectives are wrong. What users want is energy services, which can result from saving as well as supply measures. Moreover as well as carbon savings, saving measures achieve increased security and affordability – i.e. lower cost of service. Of the 100% carbon reduction required for sustainability, energy saving measures could provide about 80% and renewable supply the remaining 20%. (See under P. 3). Heat services within towns and cities could come from DH-CHP and renewables and outside the heat networks, from building or refurbishing to the PH standard and biomass or biofuel heating. There can be no meaningful choice until these are made available.

Energy services are best delivered by a framework of franchises held by ESCOs subject to absolute Carbon Emission Obligations. Carbon targets – along with increased security and affordability - are delivered not by traders, but by engineers. Only ESCOs would have access to low cost, long term capital and the skills of professional engineers. With numerous ESCOs holding shares of the UK market, their professional engineers would find and implement the most cost-effective measures that delivered the contractual obligations. Regulation would be reduced to reviewing the ESCO outcomes at say five year intervals.

Para. 135. 'Use of this surplus heat... can be a low-carbon alternative... for low temperature users'.
For heat services, the franchises would be geographical areas. Since the cost of heat increases with the distance between source and load, the ESCO engineers would soon find every source within their area, and harness them as required to meet the contractual obligations.

Q 19. This is not the province of government save in 'planned economies', which have failed. Such information costs money to acquire and expertise to interpret, so is the province of professional consulting engineers, notably those working for the ESCOs.

Detailed information about the scale of surplus heat is not required for the studies by consulting engineering firms before the Government invites bids for the franchises. Evidence from other countries shows that there are ample sources that can be used via DH networks. In Gothenburg, such heat accounted for 58% of that produced for DH in 2005. (Ref. Gunnarsson I., 2005, 'Production and refining of biomethane: Some projects for the future', Slide 4. http://www.bioenergydays.com/pdf_file/lecturer_eng/pm_1_Biofuel/I_Gunnarsson_Biomethane.pdf).

Para. 145, Figure 5.2.
Nuclear power plants (NPPs) are rarely operated as CHP plants. For safety reasons, NPPs operate with low top temperatures (steam conditions). Hence CHP operation – which reduces the electricity output for a given reactor and steam boiler – would increase the already very high capital cost per unit of electrical output. Moreover in the UK, all operating NPPs are located on coastal sites, chosen to be remote from major centres of population. Hence any such heat would have to be transmitted over long distances. Furthermore the possibility of radioactivity being carried by the DH into buildings cannot be eliminated.

Para. 147. '.. heat exchangers .. are used to adjust the temperature of delivered heat'.
This is wrong. Heat exchangers are used as pressure barriers between transmission and distribution and distribution and consumers.

Para. 147. 'Some energy is lost in the heat exchangers'.
This is wrong. The First Law of Thermodynamics (the conservation of energy) says that no energy is lost. However, the Second Law of Thermodynamics (the 'availability' of energy for conversion to work) says that some

exergy is lost. Hence heat exchangers are used only where necessary on engineering grounds, of which there are several.

Para. 149. '..in Copenhagen.. large centralised power plants far outside the city..'.
This is factually incorrect on two counts. All the plants that generate power also generate heat – i.e. are CHP plants. Power only plants are no longer permitted in Denmark. Moreover all said plants are located within the city and suburbs. The two transmission lines - CTR and VEKS - are used to link these plants to the various distribution networks supplying Copenhagen and its suburbs.

Para. 154. Large scale collection and interseasonal storage of solar heat is practised in Europe. The solar fractions range up to 90% or more. (Ref. European Large Scale Solar Heating Network. http://www.enerma.cit.chalmers.se/cshp/). However, solar fractions of up to 30% can be achieved with DH systems with only diurnal storage.

Q 20. A suitable 'framework'. (See under Para. 4). Also 'Heat Plans' for all towns and cities, as in Denmark. (See under P. 2).

Q 21. Such information is the province of professional engineers, notably those working for the ESCOs. (See answer to Q. 19). As for 'practical involvement in heat networks', there is ample evidence in the public domain. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction). Suffice to say that the case for DH carrying heat co-generated in CHP (for 80% carbon reduction) and then renewable heat (for 100% carbon reduction) is overwhelming. For example, West Copenhagen has already achieved a carbon saving of 90%. (See answer to Q. 29). Hence '1000 cities cannot be wrong'. (Ref. DHCAN, No Date. 'The Case for District Heating: 1000 Cities Cannot be Wrong!'. http://projects.bre.co.uk/DHCAN/pdf/PolicyGuide.pdf).

Para. 156. Figure 5.4.
The merit of CHP cannot be understood with this 'First Law' view, but only with a 'Second Law' view, where these refer to the Laws of Thermodynamics. The flaw in the First Law view is that it considers both electricity and heat – for which the 'energy efficiency gain' is indeed (1 – 100/133) = 0.25 or 25%.

However, CHP is not about electricity, nor even about electricity and heat, but only about co-generated heat. For the separate generation case, the electricity efficiency is 53/(38 + 53) = 58.5%. For the CHP case, the electricity efficiency is 53/100 = 53%. Assuming that the power plants are otherwise similar, the heat out over the loss of electricity (i.e. the COP of the Virtual Heat Pump) is 35%/(58.5% - 53%) = 35%/5.5% = 6.36. Assuming that there are only such CHP stations on the grid, the heat out over the fuel for heat in - i.e. the Thermodynamic Heating Efficiency (THE) - would be 6.36 x 53% = 3.37 or 337%. For CCGT CHP plants, the loss of electric output would be smaller, so the COP more like 8 and the THE about 4. In a real DH system, a few percent of the heat would coming from Heat Only Boilers (e.g. at peak demand) and there would be some heat losses from the DH network. This would be partially offset if the existing gas boilers had a thermal efficiency of only 65% (on average), as in UK housing. The final THE may be about 3.3. Compared with heat from existing boilers with an efficiency of 65%, the fuel saving would be (1 – 0.65/3.3) = 0.80 or 80%. Since both the CHP plants and the boilers use the same fuel, the carbon saving is also 80%. (Ref. Taylor G., 2002. 'Energy Solutions for 60% Carbon Reduction', Section 3.9. (http://www.energypolicy.co.uk/epolicy.htm).

Para. 159. '...Good Quality CHP faces a range of challenges and barriers'.
One reason is that the 'Good Quality' criterion is set very low. Indeed, analysis shows that – for natural gas - the 'Thermodynamic Heating Efficiency' of the co-generated heat is no higher than the thermal efficiency of a good condensing boiler. (See attached spreadsheet). Moreover all CHP plant exceeding this minimal criterion is granted full relief from the Climate Change Levy (CCL). This gives no incentive to improve the plant by refurbishment or replacement, and so increase the carbon savings. Clearly any relief from the CCL should be only proportionate to the carbon saving. (Ref. Taylor G., 2002, 'Energy Solutions for 60% Carbon Reduction', http://www.energypolicy.co.uk/epolicy.htm Section 3.11).

Furthermore the same 'Good Quality' criterion is applied to CHP plant using oil and coal as for natural gas, yet the carbon intensities are greater by 1.44 and 1.78 times. Hence in respect of the co-generated heat, CHP plants just meeting the criterion are emitting much more carbon than good condensing boilers. To correct this the required electricity efficiency should be increased from 20% for gas to 38% for oil and 43% for coal. (See attached spreadsheet). However 38% with oil would require engine-based CHP plant of around 1 MWe or more, while 43% with coal would require super-critical steam turbine plant of about 100 MWe or more. Yet these would only avoid the negative carbon savings relative to gas boilers. To achieve positive carbon savings would require the oil and coal plants to have even higher electricity – and hence Thermodynamic Heating – efficiencies, which would be impossible. Hence such plants should not be relieved of the CCL, but taxed even more to encourage a change.

Such plant could be converted to or replaced with plant to burn some biomass or only gas. However to reduce the carbon emissions of coal to those of gas, the biomass - even assuming it to have a carbon intensity of zero - would have to provide 44% of the energy. This is far higher than the usual co-firing range of 5 to 10%, so would probably require a specially designed boiler. Interestingly, just such a boiler is included in the latest Avedore 2 CHP plant in Copenhagen. (Ref. Ottosen P., News from DBDH, 4/2001, p 6).

The chart in the attached spreadsheet shows the huge difference in electricity efficiency between the CHP QA and GQ criteria and the best current practice versus unit size. Some qualifying CHP units will have electricity efficiencies higher than the criterion. Yet with full, rather than only proportionate, relief from the CCL, there is no incentive to exploit this to the full and thus achieve the large carbon savings that should result from CHP.

Q 22. These schemes cannot deliver the required carbon saving and are thus insufficient. The only requirement is a suitable ‘framework’, to enable ESCOs to deliver the carbon saving.

Q 23. No. See answer to Q. 15.

Q 24. See answer to Q 19.

Q 25. See answer to Q 19.

Q 26. See answer to Q 19.

Q 27. Yes. The heat (and electricity and transport fuel) markets should be divided into franchises, and ESCOs under Carbon Emission Obligations should be left to deliver the contractual carbon savings. (See under Para. 4).

Chapter 6 and district heating.

P 8. ‘..attempts to estimate its potential to deliver cost effective low carbon heat..’.
I and others have estimated that DH with large scale CHP and renewables can deliver carbon savings rates of 80 to 100%. (Ref. Taylor G., 2008, ‘Criteria and Heat Measures for Carbon Reduction’). Hence relative to heat related emissions of 220 MtCO2/y in 2020 (HCE, p 14, Fig. 1.5), these measures could save 121 then 154 MtCO2/y. Thus even the long-term estimate of 19 MtCO2/y (HCE para 258) is low by factors of 6 to 8.

In order to be cost-effective, measures must first be effective. Since the engineering criteria result in the choice of DH-CHP for existing towns, cities and heritage buildings, no other measures can be as effective, hence cost-effective. Buildings outside the heat networks should use PH and biomass heating. Whitehall is already heated by DH-CHP, delivered by an ESCO. Moreover, the system is fitted with heat meters. (Ref. Anon, 1999, ‘Elyo Cofreth Wins Top Energy Award for Delivering CHP to Whitehall’, http://www.chpa.co.uk/news/press_releases/1999/021299 (Elyo Cofreth).pdf).

The Heat Call for Evidence gives the heat emissions for 2005 as 267 MtCO2/y, which are some 47% of the total. (Ref. HCE, Figure 1.5 and Para 16). Hence the UK total for 2005 is about 568 MtCO2/y. Allowing for reduced heat emissions of 220 in 2020 and assuming no change in emissions for the transport and electricity sectors, the UK total for 2020 would be about 568 – (267 – 220) = 521 MtCO2/y. Compared with this, the above carbon savings of 121 would be 23% and that of 154 30%. These would certainly be significant. Moreover, such savings may be easier to make in the heat sector than in the transport and electricity sectors. DH-CHP can be implemented without delay, whereas new nuclear can have no impact before 2020 and Carbon Capture and Sequestration is not even ready for deployment. In the event of rapid climate change or resource wars, if the transport and electricity sectors were not sufficiently decarbonised, their usage could be cut drastically. Yet the heat sector could be unaffected.

Q 28. Huge – i.e. a carbon saving rate of up to 100% for buildings connected to District Heating. (See under P. 2).

Q 29. In order to be cost-effective, measures must first be effective. For Western Copenhagen, with DH-CHP fuelled by fossil fuels, municipal waste and biomass, the Primary Resource Factor is already only 0.13. (Ref. Gullev L., 2007, ‘The Chairman’s Column’, DBDH Journal 4/2007, p 2). Assuming a pre-existing boiler efficiency of say 75%, giving a PRF of 1/0.75 = 1.3, the carbon saving is already (1 – 0.13/1.3) = 90%. No other measure can achieve this with existing towns, cities and heritage buildings.

Q 30. See answer to Q. 27.

Q 31. The deployment of DH should be accelerated to achieve major carbon savings, increased energy security and the alleviation of fuel poverty. The ever-rising cost of fossil energy will make such investments more difficult so it is vital to do so while we still can. Moreover we must not make investments that do not compare in effectiveness or cost-effectiveness.

Only DH-CHP and renewables for existing towns and cities and PH and biomass heating for buildings outside the heat networks meet the engineering criteria. Hence no other technologies are worthy of being given priority for space and water heating. However biogas and renewable electricity are needed for high temperature process heat.

Q 32. Facilitate and co-operate or even participate in ESCOs, as is common on the Continent – especially in smaller towns. These often have a single CHP plant, with just a single chimney as in e.g. Enkoping, Sweden.

Q 33. ESCOs based on what were utilities, as well as local authorities, possibly in partnership. The essential difference is that they would be in the business of selling energy services - i.e. savings as well as supply - and be contractually subject to meeting their Carbon Emission Obligations. The expanded answer is set out in an accompanying document. (Ref. Taylor G., 2008, 'Criteria and Heat Measures for Carbon Reduction').

Q 34. No. There is no role for Government beyond creating the framework of franchises for all UK energy markets and setting the national targets and milestones on the way to sustainability.

For example, the so-called 'Good Quality' CHP scheme has two major flaws. The criterion is set very low yet qualifying CHP plants are given full relief from the Climate Change Levy. Moreover, the same criterion is applied to CHP plants using oil and coal as for natural gas, despite their much higher carbon intensities. Hence all such plants give negative carbon savings. (See Para. 159).

Reliance should be placed on the 'framework' of franchises to be held by ESCOs, the competence of the consulting engineering firms who provide the initial studies, and that of the ESCO engineers who would deliver the solutions to meet their contractual obligations. These last would provide enough incentive to ensure 'specific performance'. Therefore the engineers would choose equipment with a long life and low maintenance costs.

Q. 35. See answer to Q 33.

Appendix II

The Marginal Abatement Cost curve is of no real value, since the supporting evidence and data is not included. Moreover, such checking as allowed by the data provided shows it to be full of errors and inconsistencies. (See the attached spreadsheet and the embedded comments).

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