AECB strategic guidance - Carbon Lite programme

THE GREEN ELECTRICITY ILLUSION – technical paper Version 1.0.0

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1. SUMMARY

A growing number of new UK buildings, notably flats in London, are all-electric. They have no gas supply. Supporters defend this on the grounds that one can now purchase “green electricity”. This paper probes the reality which lies behind this claim.

The notion that once consumers are connected to a “green tariff” we should encourage their increased use of electric space and water heating appears to be severely flawed. Under today’s conditions, electric resistance heating gives rise to higher CO_2 emissions than any other method of space and water heating except an open coal fire. Friends of the Earth recently stopped recommending any “green electricity supplier” due to the doubt and uncertainty surrounding “green tariffs”.

The calculations in this report show that ***even in the year 2050***, the use of gas, oil or LPG for heating is unlikely to lead to markedly greater CO_2 emissions than electric resistance heating. In urban areas, even in 2050, the use of gas-fired combined heat and power (CHP) plant and district heating would give lower CO_2 emissions than electric resistance heating.

Electric resistance heating systems are inflexible and are incompatible with so-called future-proofing. They cannot be used to distribute an energy input from future renewable sources, if these sources happen to occur in the form of lukewarm or low-grade heat - as opposed to electricity, which is the highest grade of energy.

The AECB considers that the installation of electric resistance heating in new buildings should be banned by a clause in Part L of the Building Regulations. It should also be phased out of existing buildings which come under the control of Building Regulations - generally buildings which undergo major refurbishment.

The UK would not be the first country to bring in restrictions. Sweden and Denmark restricted the use of electric heating 15-20 years ago. Since 1980 they have also required new buildings to install heating systems which can utilise low-temperature heat; maximum water temperatures of 60 C supply and 40 C return (at design temperature) are standard. This policy preserves greater flexibility, because such a building can be connected up to almost any energy source which becomes available in the long term. This flexibility should also become part of our Building Regulations.

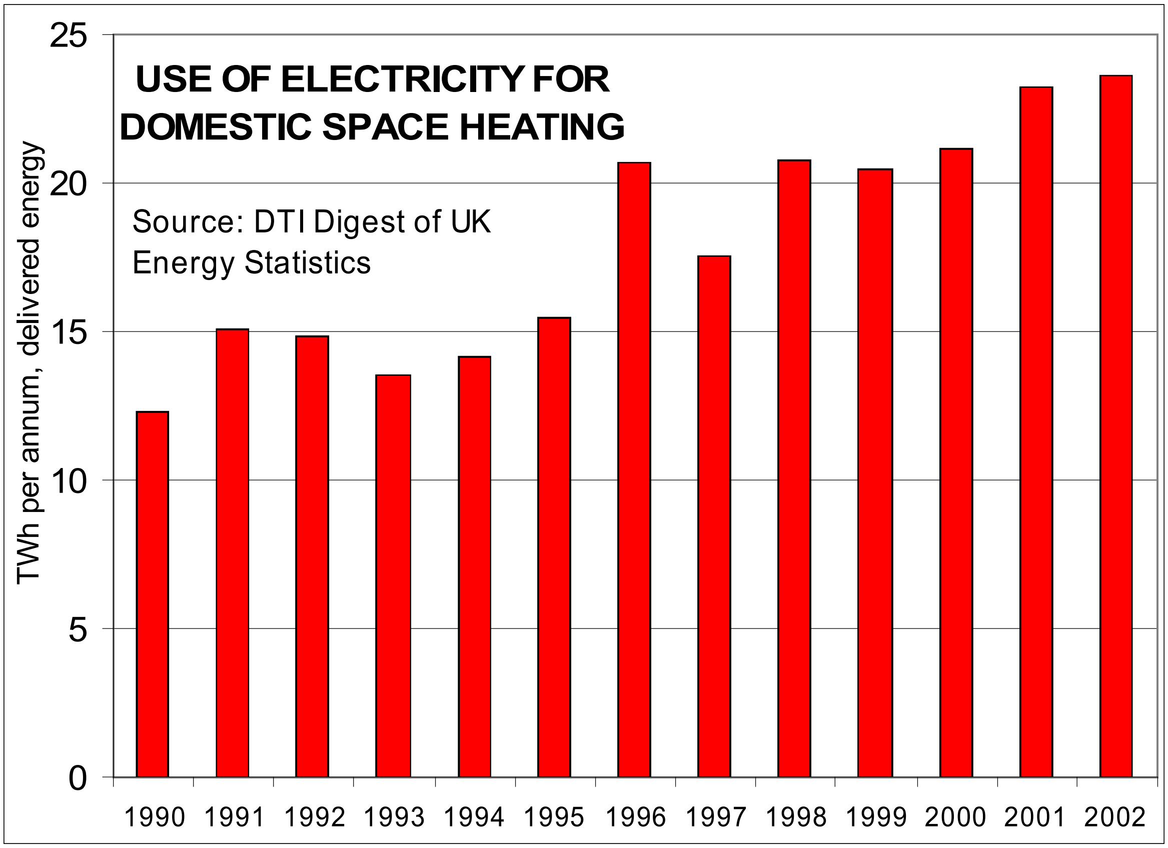
2. INTRODUCTION AND BACKGROUND

It has recently been said that to be more sustainable in our energy use we should sign up to a green tariff and use electric heating. Supporters of the increased use of electricity defend it by pointing out that one can buy "green" electricity from many suppliers. The belief that once one does this, electric resistance heating becomes "sustainable" and clean even found its way into the draft London Energy Strategy [1], albeit fortunately not the final one.

Many flats in London and other cities are being built with electric resistance wires for heating. There is no gas supply available for space or water heating, and not even a gas hob for cooking.

Figure 1 shows the dramatic increase since 1990 in the use of electricity for domestic space heating. *In the space of 12 years, the electricity use for this purpose doubled.* It is understood that this estimate by the DTI is subject to significant uncertainty, but it is the best available.

Figure 1. Growth of Domestic Electric Space Heating.



At the other extreme, some registered social landlords (RSLs) in rural areas installed electric storage heating in new dwellings which were outside the gas supply area. However, unlike the situation with urban flats, many of these RSLs changed their mind with the requirements of the 2002 Building Regulations, and are now fitting oil or LPG heating instead.

Can the new arguments for electric space and water heating, led by its use in urban flats, be justified by the way that the electricity supply system operates? No. We can see no way in which the situation has materially changed in recent years, except that about 150,000 consumers - 0.5% of the UK market - have signed up to buy "green electricity". But it is a fundamental error to believe that signing up to a "green tariff" instantly turns electricity from one of the most polluting and inefficiently-produced energy carriers into the cleanest one.

We think that the argument for all-electric buildings, allied to green tariffs, is based on serious misunderstanding of:

1. the physical reality behind green electricity;
2. the way electricity supply networks operate and;
3. the relative economics now and in the future of producing, storing and distributing energy in the form of electricity versus heat or fluid fuels.

On the basis of the figures presented in this report, ***up to at least the year 2050*** and probably longer electric resistance heating will continue to be a waste of the earth's resources. We would be better off burning gas or LPG for heating. In towns, a better option still would be to use combined heat and power (CHP).

This paper seeks to point out some of the myths that have developed and to inject a note of realism into the situation. It also makes several recommendations for AECB policy.

3. GREEN ELECTRICITY TARIFFS

It is possible to buy electricity labelled "green" from a large number of suppliers. But the notion that once one does this, each kWh that one consumes comes from benign, non-polluting sources is an illusion; hence the title of this paper.

Some contracts for "green electricity" may mean that suppliers of renewable energy agree to put as much electrical energy into the national grid as a consumer uses, averaged over a certain period. Good Energy claims to fall into this category. But if the load profile of a "green" consumer differs from the supply profile of the renewable electricity which their supplier has contracted for then their building is *not* using 100% renewable electricity at all times. When their demand peaks, they are partly dependent on fossil fuel. When their demand is at a minimum, some of the renewable electricity which their supplier has generated or contracted for would be supplied to other consumers who are not on green tariffs.

Most suppliers undertake to invest a proportion of the revenue raised from your bills in renewable electricity generating plant which is not on stream yet. This is a weaker promise. Weaker still is a contract with suppliers who charge you more for your electricity but just invest the money which you pay them in general environmental projects.

What is usually forgotten in this discussion is that there was a major change in legislation in April 2002. Since April 2002 all UK electricity suppliers are legally obliged to increase the renewable proportion of their normal electricity supplies. The law said that renewables must reach a minimum of 5% of the electricity generated in 2005, 10% in 2010 and more thereafter. [2]

So all suppliers were required to deliver at least 5% of renewable electricity to all their consumers in 2005 and must do better still in 2006. As Friends of the Earth (FoE) say, there is a risk that well-meaning consumers will end up paying electricity suppliers extra money merely to help these companies fulfil their binding legal obligations [3].

FoE stopped recommending any green electricity supplier in July 2005. Their website highlights the risk of suppliers double- or even triple-counting a kWh of green electricity. This can arise because, confusingly, there are three different mechanisms by which producers can obtain or claim credit for the generation of renewable electricity. These mechanisms are as follows:

1. Green Electricity Tariffs - the subject of this paper;
2. Renewable Obligation Certificates (ROCs) - the official mechanism since 2002 by which the UK aims to reach 10% renewable electricity by 2010 and 20% by 2020; and
3. The Climate Change Levy (CCL) - which affects mainly non-domestic electricity users.

Also in July 2005, FoE asked OFGEM, the electricity and gas regulator, to act to clarify the legal situation. Action is awaited.

4. A FUNDAMENTAL FALLACY?

Given the way in which the electricity system operates, the output of any power station which is connected to the national grid is automatically fed into the UK's electricity transmission or distribution system. It is subsequently supplied to electricity consumers who are connected to and who impose a load on the transmission or distribution system. Roughly 99.5% of these consumers are not on "green tariffs".

In this situation, all electricity fed into the grid becomes indistinguishable, a mixture, and the notion of "green electricity" is a fallacy. There is really no such thing. The concept could only become meaningful on the day, hopefully later this century, when the UK finally retires its last non-renewable generating plant and the whole of the UK economy has been fully converted to the following seven renewable energy sources:

1. Wind,
2. Solar,
3. Wave,
4. Hydro,
5. Biomass (forestry waste, energy crops, etc),
6. Tidal;
7. Geothermal.

When that situation comes about, it would be correct to state that we are all receiving green electricity through the wires. Until then, it would not.

Swedish analysis shows that today there are small CO_2 emissions even associated with nuclear or hydro electricity, which supply most of Sweden's needs. These emissions are due to the fossil fuel inputs into construction of the generating plants. They amount to about 0.01 kg/kWh. This illustrates that even if all a country's electricity comes from CO_2-free sources, the emissions from using a kWh of electricity will not be zero until all the country's *energy* is provided by zero-CO_2 energy sources.

Some consumers may believe that "green electricity" means that enough electricity is generated from renewables somewhere on the national grid to match their consumption that second. But even if a supplier puts as much renewable electricity into the grid over a year as a consumer uses, there is probably a mismatch between the output of these renewables and the consumer's pattern of consumption.

Take a typical electric space heating customer who signs up to a green tariff. On cold, calm mid-winter days, he or she will probably be partly dependent on coal-generated electricity. This is because his/her rate of consumption at that time is very high but lesser amounts of renewable electricity are available. Today it is coal-fired plant which tends to be switched on and off to meet these irregular peaks.

At other times; e.g., 11 am on a warm, sunny, windy May morning, large amounts of renewable electricity may be generated from some renewable installations. But this consumer is using little of it, because he/she needs no space heating energy at that time of the year and relatively little water heating energy, since incoming mains water is warmer than in winter or early spring.

The supply profile of electricity from wind, solar or wave generating systems could never be matched to a consumer's actual load profile without new electricity storage systems. These have not yet been developed or installed. Few small hydro plants can meet a varying demand for electricity either - they have insufficient water storage behind the dam. The plants burning landfill gas, car tyres or animal remains could all in theory follow the load but there are doubts over the government's decision to define such plants as "renewable" - see section 5.

In this situation, it is almost meaningless to allocate one level of CO_2 emissions in kg/kWh to "green electricity" and a separate level to "normal electricity". It is safer to continue to quote an average for all UK electricity, having obtained proof of the proportion of electricity generated by "renewables" in that year. To avoid double-counting of green kWh, one should use a single mechanism; e.g. ROCs, to track the renewable output.

It is actually quite hard to ascertain the CO_2 emissions from one unit of normal electricity, in units of kg per kWh. The figures quoted in mid-2005 for electricity range from as low as 0.43 to as high as 0.58 kg/kWh, i.e., they vary **1.35-fold**. The true figure for 2003 is highly unlikely to have been less than 0.48 kg/kWh, a figure which is used in this paper [4], but it could possibly have been up to 0.51 kg/kWh [5]. The figure for 2005 may well rise again. This is due to some reversion from the use of gas to the use of coal in power stations and to a decline in the output of nuclear power stations since the late 1990s.

5. "RENEWABLE ELECTRICITY"?

Most "green electricity consumers" would take it for granted that their "renewable electricity" supply comes from small hydro, wind, solar and possibly biomass "energy crops". Actually in large parts of the country none of the "green electricity" entering the wires comes from these sources.

Department of Trade and Industry statistics show that most "green electricity" is generated by a number of very controversial and/or doubtful sources, which in some circles might not even be considered "renewable". Only a minority comes from the seven renewable energy sources listed in section 4.

Here is a breakdown from the DTI [6] of how the UK's "renewable energy" was generated in 2003:

1. 87 % from biomass and wastes, subdivided into:
    i. 34% from burning landfill gas - mostly methane from domestic waste or restaurant waste;
    ii. 5% from burning methane from sewage works;
    iii. 19% from burning used car tyres;
    iv. 15% from the incineration of dead farm animals - traditional burial on farms has been banned - and other animal remains;
    v. 14% from wood;
2. 3% from wind;
3. 9% from hydro - of which "small hydro plants" make up one-thirtieth;
4. Less than 1% from solar, wave, tidal or geothermal.

All of sources 2 & 3, and most of source 1, were utilised for electricity generation. However, 67% of all "renewable energy" is produced by the combustion of car tyres, farm animals and the combustion of methane from putrefying domestic waste in landfills. As one researcher put it [7], most so-called "renewable electricity" is an elaborate system for management of wastes and its "renewable" nature should perhaps be questioned.

6. THE ELECTRICITY SUPPLY SYSTEM

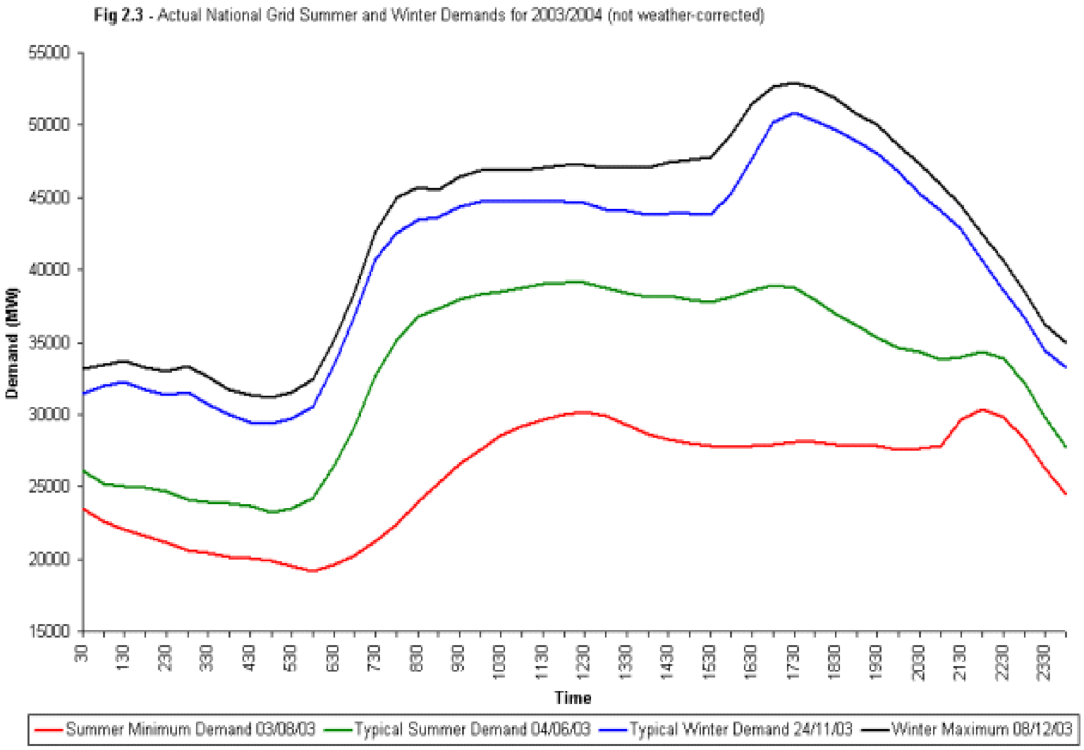
6.1. General

A critical factor to the discussion is that unlike traditional forms of energy, such as oil, gas, coal and biomass, electricity cannot be stored. Electricity supply system operators must produce exactly enough electricity when it is needed. *Power*, or energy consumed per unit time, becomes more critical to system planners than *energy* consumed over, say a year.

The load on the national grid is approximately *three* times greater late on a winter day than in the middle of a summer night. Figure 2 shows the situation in 2000-01. This partly reflects the increased use of electricity for lighting in winter but it also reflects the use of electric space heating and cooking. Although less than 10% of UK dwellings and less than 20% of non-domestic buildings are heated electrically, the peak demand is still appreciable.

Figure 2. Summer and Winter Electricity Consumption in England and Wales, 2003-04. Source: National Grid Company Seven Year Forecast (April 2004).

Please note that the y-axis origin is set at 15 GW, not at zero. This accentuates the apparent variation in demand. In fact the maximum demand in the whole of 2003-04 was less than three times the minimum demand.



If the rate at which electricity is being consumed rises to an exceptionally high level at any time, the rate of generation must rise to an equally high level. A match between supply and demand is usually secured by firing-up fossil fuel power stations whose turbines have been kept spinning slowly - a costly process in fuel - or by releasing stored water at hydroelectric power stations through the turbines to match surges in demand.

The second is an easier way to keep a grid stable, because water turbines can deliver large amounts of power with about ten seconds' notice, with little loss of efficiency, but the UK's hydropower capacity is tiny. Unlike Germany and Sweden, we never invested in hydropower plants on our major lowland rivers and even the development of high-head sites in Wales and Scotland has captured less of the available potential than in other European countries.

6.2. Space and Water Heating

Most UK buildings within the gas supply area, which covers most of our cities, towns and larger villages but very little of the countryside are heated by gas. 83% of all UK dwellings are connected to mains gas. In 2004, the peak gas demand estimated in a “design winter”, the severity which is expected to occur once every 20 years, was *245 GW*. The UK peak demand for electricity was *62 GW*; i.e., ***one quarter as much***.

Also, the majority of the electricity was used for lighting, ventilation, cooling, domestic appliances or office equipment. It was *not* used for heating. If the majority of UK buildings were heated electrically; i.e., if the bulk of the 245 GW peak load which is currently imposed on the gas supply system was transferred instead to the electricity system, and oil and LPG systems switched too, the UK’s peak electricity demand would soar from 62 GW to 250+ GW.

What could meet this increased and very variable demand? Biomass is a theoretical possibility, because like fossil fuels biofuels can be stored and the power stations concerned can follow the varying load. But the notion that biomass could ever meet all this demand is fanciful, given the many competing demands on the UK’s limited biofuel resources [8].

Also, it is as wasteful to burn biomass at 35-40% overall efficiency and use the electricity for heating or cooking as it is to burn fossil fuels in power stations and use that electricity for heating or cooking. A more appropriate way to use biofuels for space and water heating would be to burn them in CHP plant and use the heat output to heat buildings.

Another concern is whether such an increase in electricity consumption could be aesthetically acceptable. The peak load on all our transmission routes and underground distribution wires would rise sharply. This would almost certainly lead to a need for many more 275 kV and 415 kV pylons. These tend to be regarded as unwelcome features of the landscape and it seems unlikely that proposals to erect thousands more of them would be warmly accepted.

The chances are high that quite a lot of the electricity which a “green” consumer uses for space heating would actually come from coal-fired plants. Many of these plants are pressed into service to meet the higher morning and evening loads, with oil-fired gas turbines meeting the extreme peaks and gas-fired and nuclear plant operating for longer hours to meet the base load. Part of the electricity used to heat an all-electric London flat on a “green tariff” would come from Didcot, one of southern England’s largest coal-fired power plants.

Should we encourage consumers to believe that their buildings are supplied 100% by renewable electricity when the reality is that some of the plants which will be switched on to meet their demand are coal-fired? We think not.

6.3. Cooking

The same criticism applies to consumers moving away from gas to electric cooking on green tariffs. If the electricity demands of UK households are aggregated, each household with electric cooking instead of gas or LPG imposes a high coincident peak demand on the national grid in the mornings and evenings, up to one kilowatt, but a fairly low demand at other times [9]. If all our 25 M households cooked electrically, rather than the present 50%, the peak demand on the national grid could increase by 12 GW, which is an increase of about 20%. Commercial cooking too can be provided by gas, electricity or LPG – today, most of it uses gas - and gives rise to this same dilemma.

Today, with 80% of electricity being generated from fossil fuels, one can meet peaks due to electric cooking by storing fuel at the power stations and firing the plant up to meet the peaks, or by running pumped storage plant. But with a grid based on renewables, meeting this kind of load is less easy. One could run gas turbine power stations on liquid biofuels, but as with other energy uses it would be more energy-efficient to cook with the biofuels themselves and not even convert them into electricity.

We could also use normal hydro or pumped storage plant to supply these peaks. But it seems a higher priority to use such versatile and responsive generating plants to balance the fluctuating output from wind, wave and solar power than to use them to compensate for a problematic load which was only created by using electricity for heating and cooking.

7. MORE RENEWABLE ELECTRICITY?

In 1982, the former Central Electricity Generating Board said that windpower could provide 20% of the UK's electricity without difficulty. This assumed that the other plant was as then a mixture of fossil, nuclear and the UK's very small hydro resources.

The UK hasn't yet reached 20% renewable electricity, but Denmark and the German state of Schleswig-Holstein have. As the CEGB predicted for this country, their experience is that the grid can be kept stable with this amount of windpower and other generating plant can be turned on and off to cope with the wind turbines' varying output.

A more recent report stated that if wind generates 20% of UK electricity some extra fossil fuel plant would have to be left on spinning reserve. However, the overall effect on fuel consumption would be small [10]. Generating 20% of electricity from wind power is definitely feasible.

But it will not always be possible to keep the grid stable just by turning other plants on or off according to how strongly the wind blows and by keeping the turbines of some gas-fired plants on spinning reserve. As a grid moves beyond 20% of wind-generated electricity, in most European countries the peak output of windpower starts to exceed the rate of electricity consumption on summer nights [11]. Beyond this point, any expansion of non-firm renewables needs further measures to keep the grid stable.

A possibility is diurnal electrical storage systems. These store the surplus electricity at night and release it again to meet normal peaks on the following day. The technologies are limited. In countries which have enough hydropower, the turbines can be uprated and operated in a more stop-start manner to balance the windpower output. New UK hydropower installations could also be used for this purpose. Some existing lakes and dams in mid-Wales which are not now used for water supply could probably be developed into pumped-storage plants. But if none of these options for using non-firm renewables are available, the surplus electricity would have to be dumped.

A report over 20 years ago suggested that an electricity supply system producing 60-65% of the UK's electricity from renewables would be feasible by around 2025 [12]. With slow progress since 1980, a more feasible date to reach this point is now 2050. But even to get 60-65% of the UK's electricity from renewables by 2050, many things would have to be done correctly, including:

1. *Very* extensive implementation of energy efficiency in preference to non-firm renewables, especially in the applications where energy efficiency is cheaper - in those cases it seems utterly perverse to build renewable generating capacity, in the face of all the attendant planning problems;
2. Virtual phasing-out of electric water heating, cooking and in particular space heating to reduce *both* the weather sensitivity of demand *and* the annual variation in demand. Large diurnal variations are far less of a problem since hydro, tidal or pumped storage plant are capable of dealing with them;
3. Extensive investment in firm renewable power; e.g., hydro and twin-basin tidal which can follow the load and compensate for the varying output of plant such as solar, wind and wave. In theory, tidal and hydro could be complemented or replaced by biomass-fired

plants, but as we said earlier the UK's biomass resources are small and the potential demands on them are vast;

4. All system capacity which is not matched GW for GW by firm sources such as hydro, tidal, biomass or geothermal plant would have to be dedicated to loads which could be regularly shed; the loss of load probability could be readily determined, in order to inform customers. Some loads are fully interruptible, including refrigerators, freezers and cold stores. The better-insulated they are, the longer their supply can safely be interrupted, so in this sense energy efficiency complements load management. Even fluorescent lighting loads can be reduced *in extremis* if the lamps have dimmable high-frequency ballasts.

Re. point 3, unless a sufficient proportion of the generating capacity can load-follow the grid would become unstable every time the demand for electricity rose or the output of intermittent sources fell. As we progress beyond 65% renewables towards 95-100%, it may become quite a challenge even to meet the loads due to essential uses of electricity; e.g., lighting, ventilation, computers and major and minor appliances. But it is clear that the higher the proportion of firm capacity, the lower the total load, and the more predictable the load, the easier it will be. In turn, the only means to raise the percentage of firm capacity, given that UK resources are pretty limited, will be to secure reduced consumption of electrical energy.

The only developed country whose national grid operates on near-100% renewables is Norway, which generates 99% of its average electricity consumption from hydropower. However, Norway has no intermittent renewables. Also, even Norway has invested in large undersea high-voltage cables to Denmark and beyond that the European mainland.

In periods when hydro is scarce; e.g., droughts, Norway now buys electricity from coal- or gas-fired CHP plants in Denmark. In periods when Norway has a hydropower surplus; e.g., during floods and after the regular spring thaw, it sells the excess to Denmark and northern Germany. Denmark now also depends on Norwegian hydropower to balance its varying windpower output.

The UK's hydro resources are nowhere near those of Norway, although our output could be expanded. Nor do we yet have high-capacity links to mainland European countries. This makes the goal of 100% renewable electricity technically fairly difficult [13]. If we continue to install electric heating and continue to add new winter peak load to the grid, the goal could continue to become more intractable.

8. SERIOUS FLAWS

Overall, the proponents of a large expansion in the use of electricity, allied to growing use of renewables, have not fully thought through their proposals. They have not considered the capital and recurrent costs of reinforcing the electricity transmission and distribution system and building enough power stations to supply the UK's buildings with electric space heating, water heating and cooking, to supply industrial process heat and to supply road transport from electricity. 30 years ago, the Atomic Energy Authority called their not dissimilar vision based on nuclear energy "the all-electric economy". That did not come about either, largely for economic reasons and the fact that future energy demand had been overestimated.

The so-called essential uses of electricity, which include lighting, ventilation, pumps, heating controls, domestic appliances, computers, telecommunications, the internet and office electrical equipment, account for very little of the UK's total energy use. Less than 12% of the UK's delivered energy actually needs to be in the form of electricity. Around 88-90% of UK energy is needed as low- and high-temperature heat or transport fuels and it is much easier and cheaper to store heat or fuels than to store electricity. Given the high costs of distributing electricity, there is a question mark over a policy of increasing its use for all purposes, if 88% of energy does not need to be supplied in the form of electricity.

In fact, the most fundamental barrier to “an all-electric economy” is the capital intensity of electricity generation, transmission and distribution systems. It was shown decades ago that producing and transporting electricity *in any form* is 10-100 times more expensive than distributing solid fuels, oil or natural gas [14]. Table 1 is an abbreviated form and we have added some figures for energy efficiency measures and renewables. As pointed out at the time of the original work, if an all-electric economy was pursued, the level of investment in the expanded use of electrical energy supply systems - whether the electricity comes from nuclear or renewables - could actually starve the rest of the economy of capital. This ultimately makes such a policy self-defeating.

There are only three strategic post-fossil fuel, zero-CO_2 options to effectively provide society with energy: renewable energy (about seven sources), nuclear energy (fission or fusion) and energy efficiency. Combinations are also possible; e.g., the more attractive possibility on economic grounds seems to be a very dramatic increase in energy efficiency plus a rise in the use of renewables, at the expense of fossil fuels. The capital costs of individual technologies vary widely, but as a rule most energy efficiency measures are less capital-intensive than either nuclear or renewables. Most nuclear and renewable energy systems cost *one to two orders of magnitude more* than oil or gas extraction and distribution.

Table 1. Energy Whole System Costs.

Form of Energy		**Whole System Cost**
ENERGY SUPPLY SYSTEMS		£ per delivered kilowatt
FOSSIL FUELS		
Oil [15]		250
Natural gas [16]		400
NUCLEAR AND RENEWABLES		
Small-scale solar thermal	Water heating, no seasonal storage	5,200
Large-scale solar thermal	Swedish & German solar district heating systems with seasonal storage	5,000
Small-scale windpower	Rooftop 1 kW wind turbine	8,000
Large-scale windpower	Onshore 100 MW wind farm [17]	3,900
Tidal power, double Severn barrage		6,000
Nuclear fission, PWR [18]		5,200
Photovoltaics		40,000
ENERGY EFFICIENCY MEASURES		
Condensing boiler, small commercial or large domestic building		200
Compact fluorescent lamps replacing incandescent		110
More efficient refrigerator, A++ replacing D-G		220
Cavity wall insulation, new building		1420
Super-windows		2080

NOTES:

1. Illustrative only; intended to indicate relative priorities. Were a high degree of precision sought, one would need a major research project to update the pioneering work carried out by Lovins et al in the 1970s and 1980s.
2. Photovoltaics costs correspond to UK nominal installed prices of £6,000 per peak kW and an annual electricity output of 800 kWh per peak kW.
3. Energy efficiency costs are based on a few samples only. They can vary widely both up and down.
4. All the figures exclude operation and maintenance (O&M) or fuel costs. Energy efficiency measures usually have none but renewables with moving parts have significant O&M costs and nuclear energy has O&M costs, fuel and waste treatment or storage costs.

9. SPLIT INCENTIVES

One consequence of installing electric resistance heating in say a new block of flats is that the property developer saves a huge amount of money compared to the cost of providing central heating, which might be in the form of individual gas boilers or in the form of a central gas boiler or CHP plant. If one supposes that the saving might sometimes amount to £1,500 per dwelling, the capital cost saving in a large block of 300 flats would amount to £450,000.

A saving of £0.45M provides a very strong incentive to a developer to abandon all idea of providing a gas connection. After all, he/she can save on capital costs. Meanwhile the occupants are left to pay the higher running costs and the electricity supply companies are left to finance the costs of the extra power station capacity and grid reinforcement.

A development of 300 all-electric flats could need an investment in 2 MW worth of new power stations. This is calculated on the basis of a simultaneous maximum demand of 6 kW(e) per unit - very low for an all-electric dwelling - plus 10% T&D losses. On the basis of the investment costs of new nuclear plant, the share of the power station investment to heat and light these flats would be around £3,500/kW x 2,000 kW = **£7million** excluding grid reinforcement costs [19].By comparison, the construction cost of three hundred 67 m^2 flats at say a rate of £900 per m^2 is £18 M. So on that basis the construction cost of the power station needed to heat the flats would be 20-40% of what the buildings cost to construct!! This provides a graphic example of what is called a “split incentive”.

Clearly, if a developer fits electric cooking, space and water heating, it costs the power generators, distribution company and national grid company more. It needs more expensive switchgear and cables, investment in new power stations and often reinforcement of parts of the national grid so that they can convey electricity at a greater rate. For many decades, though, electricity companies charged property developers *less* to lay the thicker cables which were needed if the developer agreed not to allow gas into their development.

In effect, this was a prolonged cross-subsidy for electric space and water heating, funded by other electricity consumers. This discriminatory practice was eventually supposed to be phased out but it did have a lasting legacy of increased CO_2 emissions.

It is not surprising that all manner of vested interests; e.g., property developers and electricity supply companies, have lent their support to the increased use of electric heating; it is they who stand to profit most from it. Using these misleading arguments, a recent development of electrically-heated flats by the Berkeley Group was portrayed as “CO_2-neutral”. Support from private interests for such misleading statements does not mean that environmental bodies or government should automatically lend their support to them.

10. FOREIGN POLICY

Abroad, some jurisdictions in both Europe and North America have effectively banned electric resistance heating. Others have sharply restricted it.

Sweden restricted the use of electric resistance space and water heating 20 years ago. It did so on the grounds that resistance wires are inflexible and cannot easily be changed to use a different energy carrier in the future. In fact, to change an electric resistance heating system to a hydronic system, plumbing has to be installed and the cost of this - in Sweden - is £5,000-7,000 in a detached house.

Sweden permitted a few types of electric heating in detached houses, including electric boiler systems which are linked to hot water radiator, warm air or underfloor pipes. It decided to allow this because such systems can more easily be changed to another source of heat if necessary and at present electricity is relatively cheap in Sweden - it obtains over 90% of its supplies from hydro and nuclear, and unlike the UK it has no mains gas distribution system.

Denmark forbids the installation of electric space heating in new buildings. The only exception is a tiny minority of detached houses in rural areas - no mains heat or gas - where a design professional certifies that the dwelling will consume less than half the maximum amount of heat stipulated in the Danish Building Regulations.

Flats in Denmark never use electric heating. 60-65% of Denmark's space and water heating now comes from CHP plants and district heating systems and most flats are connected to the heat mains. Small towns which were never before considered feasible for DH are now being connected.

A *1981* report showed that similar district heating systems would be an economic and feasible method of heating buildings in London [20]. This was before we started to worry about CO_2. However, as in 1980, UK power stations continue to waste more heat than the domestic sector consumes.

Since 1980, Sweden and Denmark have required central heating systems to be designed for maximum supply and return temperatures of 60 C and 40 C at design ambient temperatures. This increases future fuel flexibility compared to UK heating systems, which are normally designed for supply and return temperatures of 80 C and 70 C. It also reduces pumping costs.

For instance, active solar heating systems with seasonal storage, as developed in Sweden and Germany since 1977, can produce heat at 60 C more easily and cheaply than at 80 C. Ditto with CHP/DH systems; heat at 60 C costs less in fuel than heat at 80 C. The doubled temperature drop also halves the pumping costs.

Southampton illustrates the significance of this discussion. The whole city centre is heated by geothermal hot water at 71 C from under the city, a resource which was discovered during research on geothermal energy 25 years ago. Hot water at 71 C can be used by buildings which have radiators for heating but it is incompatible with buildings which are heated by resistance wires. Had the buildings in central Southampton not had radiator systems, £Ms would have had to be spent on totally re-plumbing them before geothermal energy could even be utilised. As it was, most buildings were able to utilise the renewable energy source immediately - albeit with the help of a French engineering company and a Scandinavian bank, as the UK government was uninterested.

In other developed countries, such as the USA, France, Germany and Italy, the installation of electric heating in flats is rare. More common is a single boiler or preferably a CHP plant in the basement or in a roof plant room. This gives central heating to the whole block with no need for expensive individual maintenance or gas safety inspections.

So far as we are aware, the only exceptions to this rule are Norway and western Canada. These both face unusual circumstances. In those two regions, hydroelectricity is so cheap that many flats are heated electrically.

Individual heat metering is possible in older blocks of flats but it is unattractive in modern low-energy buildings. The Swiss have published data showing that the transmission of heat between flats makes individual metering hard to organise. Occupants who maintain their dwelling 2 K cooler than the average of other flats may gain 80% of the heat which they consume by conduction from neighbouring flats. They may utilise £20/yr worth of heat which they paid for and £100/yr worth of heat which their neighbours paid for! Individual hot water consumption can easily be billed, though, using water meters in every flat. This is now recommended practice in several European countries.

11. ELECTRICAL ENERGY EFFICIENCY?

There seems to be agreement that energy efficiency should form a large part of the solution to climate change, but UK consumption of electricity is rising by 1.5% per year. This is because the UK's implementation of energy efficiency is not keeping up with economic growth and the demand for services based on electricity. These include mobile telecommunications, new domestic electrical appliances including digital TV, the internet and so on.

If we maintain a 1.5%/yr growth rate, we shall need 16% more electricity in 2010 than we did in 2000 and we shall need 35% more in 2020 than in 2000. In turn, the targets which the UK has set of 10% renewable electricity by 2010 and 20% by 2020 will be outweighed by the growth in electricity consumption. Generation of electricity from fossil fuel-fired and/or nuclear plant ***will have to increase.***

Table 2 shows what will happen to CO_2 emissions from the electricity sector in 2020 relative to 2003 if current trends continue. *CO_2 emissions from the electricity supply system will rise by over 5%, not fall*. If similar developments are seen in other sectors of the economy, the UK will fail to meet its Kyoto commitments which oblige the UK to reduce emissions by 12.5% between 1990 and 2012.

Table 2. Projected CO_2 Emissions from the Electricity Sector.

Fuel	**Proportion of Elec. Generation**			**Specific CO_2 Emissions** (kg per kWh)		
	2003	2020	2050	2003	2020	2050
Gas	38	54	27	0.43	0.41	0.41
Coal	35	18	7	0.97	0.94	0.94
Oil	1	1	1	1.17	1.13	1.13
Nuclear	23	7	0	0.01	0.01	0.01
Renewables	3	20	65	0.01	0.01	0.01
Weighted average	100%	100%	100%	0.52	0.41	0.20
Consumption (relative scale)				1.00	1.29	(Spec-ulative)
Overall CO2 emissions (relative scale)				**1.00**	**1.07**	

NOTES:

1. Net imports from France, amounting to 2% in 2003, are assumed to be all nuclear or hydro electricity. However, it is possible that some of this electricity may be from coal-fired plants.
2. The assumed overall efficiencies of coal, oil and gas power stations are 36%, 25% and 49% respectively in 2003, rising marginally by a further one percentage point in 2020 and 2050; i.e., it is assumed that rising plant efficiencies from 2020-2050 are offset by a growing need to run plants at part load to balance the output from non-firm renewables;
3. The average transmission and distribution efficiency is assumed to remain at 92%;
4. The nuclear output in 2020 is based on the assumption in the report from the Downing Street Performance and Innovation Unit in 2002 that it will decline to one third of current levels.

The more positive aspect of this situation is that thousands of energy efficiency technologies have still not been implemented in the UK and could dramatically reduce electricity consumption without any effect on standards of living. There have been successful energy efficiency programs in many countries especially in Switzerland, Germany, USA, parts of Canada and to an extent Denmark.

The west coast of the USA has seen particularly dramatic and imaginative efforts to persuade people to use electricity more efficiently. The programs included:

1. Subsidies to manufacturers of energy-efficient lighting equipment et al to reflect a percentage of the cost of the electricity saved - this can be ***far more effective*** per £ spent and more easily-implemented than subsidies to *retail* purchasers of electrical equipment;
2. Education of architects and others in how to daylight new buildings;
3. Programs to retrofit office buildings to a standard justified by the cost of the electricity saved, usually saving 50-75+% of their previous electricity consumption;
4. Novel programs to bring compact fluorescent lamps, energy-efficient motors and so on more quickly into use;
5. Recently, mandatory state-wide energy efficiency standards even for tiny domestic appliances such as electric toothbrushes, mobile phones, digital TV boxes, hi-fi systems et al.

Despite 30 years of steady economic growth, California's per capita electricity consumption is no more than it was in 1975. For some periods, especially from 1985 to 1995, the state benefited from inspired policies which encouraged investment in energy efficiency throughout its buildings and factories *as a strategic alternative to building new power stations*.

The state utility regulator has just announced plans to require all the privately-owned gas and electric utilities to spend another **$2 billion** on energy efficiency. They will invest in a long set of energy efficiency measures, in preference to investing in any form of energy supply, since energy efficiency is cheaper.

Other US states such as Oregon, Washington, New York and others also took energy efficiency seriously and managed to decouple electricity consumption from GDP growth. In US states which did less to implement energy efficiency, electricity use continued to grow at the historic rate of 1.5 to 2% per year. This happened in most European countries, including the UK.

12. CO_2 EMISSIONS FROM ELECTRIC HEATING VERSUS OTHER SYSTEMS

The emissions of CO_2 associated with consuming 1 kWh of different forms of energy today, and a possible long-term figure for 1 kWh of electricity in 2050, are shown in Table 2.

Table 2. CO_2 Emissions from Different Forms of Energy.

Form of Energy		**Specific CO_2 Emissions**
		kg per delivered kWh
Gas		0.19
LPG		0.23
Oil		0.27
Coal		0.32
Electricity	2003 actual	0.48
	2050 projected	0.20

NOTES:

1. The figures for oil are approximate, reflecting variations in crude oil composition and in refinery output.
2. The figure for electricity is higher than it was in the late 1990s; there has been a small net move from gas and nuclear to coal;
3. The figure for electricity in 2050 is based on a system in which 65% of electricity is supplied from renewables, 20% from gas, 5% from oil and 10% from coal. The assumed overall average generating efficiencies, before adding a 92% transmission and distribution efficiency, which is assumed to stay unchanged from today, are gas 51%, coal 38% and oil 27%.
4. In line with Swedish findings, we assume that even the 65% of electricity in 2050 which is renewable has CO_2 emissions of 0.01 kg/kWh, reflecting the continuing use of some fossil fuels to construct the associated plant and switchgear. In a 100% renewables situation, this figure would fall to zero.

The UK is using incorrect numbers for the amount of CO_2 emitted by consuming 1 kWh of electricity. The government's widely-quoted figure of 0.42 kg/kWh is highly misleading. As Table 2 indicates, the figure was *at least 0.48 kg/kWh* in 2003 and was possibly as high as 0.51 kg/kWh.

Taking account of the differing seasonal efficiency of heating systems, Table 3 shows the relative CO_2 emissions from different methods of producing low-grade heat, including electric resistance heating and others.

Table 3. Relative CO_2 Emissions from Producing 1 kWh of Low-Grade Heat.

Heating System	**Specific CO_2 Emissions**	**Relative to Elec. Resistance Heating= 1.00**	**Relative to Elec. Resistance Heating = 1.00**
	kg/kWh	2003 actual	2050 projected
Gas condensing boiler	0.21	**0.43**	*1.03*
Gas-fired large-scale CHP	0.03	**0.07**	**0.17**
Gas-fired micro CHP	0.17	**0.36**	**0.87**
LPG condensing boiler	0.25	**0.52**	*1.25*
Oil condensing boiler	0.27	**0.57**	*1.36*
Coal-fired boiler	0.49	*1.03*	*2.46*

Electric resistance heating	2003	0.48	1.00	
	2050	0.20		1.00
Electric heat pump	2003	0.16	**0.33**	
	2050	0.05		**0.25**

NOTES:

1. Condensing gas, LPG or oil boilers are assumed to have a seasonal efficiency of 92%.
2. Coal-fired boilers are assumed to have a seasonal efficiency of 65%.
3. Emissions for large-scale CHP are based on the marginal CO_2 emissions per kWh from a combined cycle power station which is re-designed to reject heat at 70 C instead of normal cooling water temperatures of 25 C, crediting the lost electricity at the 2003 rate of emissions; i.e., 0.48 kg/kWh.
4. Emissions for small-scale CHP are based on the published typical electricity generation efficiency of 12% and thermal efficiency of 80% for Powergen's Whispergen unit, see Its part-load efficiencies are unpublished and may be lower. We then calculated the marginal emissions per unit of heat after crediting the electricity output at the 2003 level of CO_2 emissions; see note 3.
5. Heat pumps are assumed to have a COP of 3.0 in 2003 and 4.0 in 2050.
6. Heating systems which have higher CO_2 emissions than electric resistance heating in 2003 or 2050 are in *italics*. Those which have lower emissions are in **bold.**

All the heating systems listed bar one do much better than electric resistance heating in 2003. The exception is a coal-fired boiler which emits about as much CO_2 per kWh as electric resistance heating. Electric resistance heating produces **14X** as much CO_2 per kWh of low-temperature heat as the least polluting option - townwide gas-fired CHP and district heating.

Even in 2050, the only system which produces distinctly worse emissions than electric resistance heating is a coal-fired boiler. Gas and LPG boilers are roughly level with electric resistance heating. If 65% of electricity is generated by renewables in 2050, the use of electricity for heating would still emit as much CO_2 as a natural gas condensing boiler and nearly as much as an LPG condensing boiler. The least polluting of the options listed in 2050; i.e., district heating from a gas-fired CHP plant, would still far outperform electric resistance heating.

If the comparison is so unfavourable *in 2050*, a potent question is: "Why should anyone promote electric resistance heating now?" Indeed, why should they?

No similar analysis has been made for cooking. But if it were, it would show lower CO_2 emissions from gas or LPG cooking than from electric cooking, rather as an analysis shows lower emissions from gas space and water heating than from electric resistance heating.

If we presume that the UK's policy goal is to save CO_2 to the maximum possible extent, the most effective use of its supplies of renewable electricity are to ensure that they only go to customers who use electricity for "essential uses" - lights, ventilation and appliances. The most effective way to achieve this goal is by:

1. Persuading existing users of electric space heating to change to gas- or LPG-fired condensing boilers - or in towns, preferably to CHP,
2. Persuading existing users of electric cooking to shift to gas or LPG, and
3. Preventing developers of new buildings from installing electric resistance heating in the first place.

This strategy would increase the proportion of electricity which comes from renewables, and *reduce CO_2 emissions*, faster than would happen by installing renewables at the same rate and encouraging electric heating. As long as the national grid is partly supplied by fossil fuel electricity - a situation which may last for another 60 years or more - this would be a valid strategy to reduce the UK's CO_2 emissions.

13. CONCLUSIONS

The way that green tariffs are marketed has led a few consumers to think that when they sign up to a green supplier they receive renewable electricity through the wires at all times. This is not so. Due to the way that electric grids operate, until the UK obtains 100% of its electricity from renewables it could never be so.

It would, however, be reasonable for a consumer to believe that once he/she signs up to a green tariff, the supplier contracts for enough new renewable electricity generation to match all of his/her annual consumption. Not even this is always true.

With the advent of the Renewables Obligation, and faced with the above issues, the significance of Green Electricity Tariffs has been called into question. There is certainly widespread confusion and a serious risk of multiple counting. FoE has called for action by OFGEM to clarify the situation; such action is still awaited.

Unless there is stronger action to increase energy efficiency, and thereby halt the growth in electricity consumption, CO_2 emissions from the electricity sector will be higher in 2010 than they were in 2003 *even if* the electricity sector meets the government's target of 10% renewables by 2010. The last achievement is now widely considered to be pretty unlikely.

The UK appears to need not so much a renewables obligation as an efficiency obligation. This would require electricity and gas companies to report annually how their sales in kWh are decreasing in relation to the growth in floorspace, growth in the economy, etc. To implement this needs political will, especially a willingness need to learn fast from the more effective implementation of energy efficiency in regions such as California. Their static per capita electricity consumption for the last 30 years is a remarkable achievement, given that the UK's per capita consumption has risen by nearly 2%/year.

14. RECOMMENDATIONS

The installation of all types of electric resistance space and water heating system should be banned in new buildings, pending a full review of the UK's future energy needs and of the feasibility of an electricity supply system based on 90-100% renewables. It should also be removed from existing buildings when work is done which brings them under the control of Part L of the Building Regulations.

The availability of grant aid for electric heat pumps should be reviewed. Under some circumstances, the overall net CO2 saving is nil versus a gas or LPG condensing boiler system, making the use of public funds for this purpose questionable [21].

The next Part L should include a "future-proofing" requirement that the heating systems in new and existing buildings use supply and return water temperatures of no more than 60/40ºC. This has been Swedish and Danish practice since 1980.

Electric earth source heat pumps should be allowed for the time being but should be restricted to buildings which lie outside the gas supply area. These areas offer less scope for the use of the much more fuel-efficient CHP/district heating systems, and there is in theory a slight CO2 saving when compared to LPG; even this is in doubt relative to mains gas. In this attempt to look at the most appropriate heating systems for different areas of our towns or cities, we would be merely following the practice of our European neighbour, Denmark. Driven to act by their over-dependence on imported oil, they began this process over 26 years ago [22].

A separate program is needed to encourage the use of gas or LPG for cooking in preference to electricity. This is a small but easy way to reduce CO_2 emissions for this purpose by about 50%.

The UK should abandon the confusing notion that there are two separate commodities, green and non-green electricity. Given the way in which the national grid works, this concept diverges from reality. Instead, we should quote a single figure for the CO_2 intensity of electricity, in kg/kWh, which hopefully should fall from year to year, and we should use the Renewables Obligation to track the contribution from renewables in any one year.

Some companies who currently offer so-called green tariffs and are working hard to increase the proportion of renewable electricity should be rewarded by being accredited by OFGEM. This should, however, be conditional on their proving that on behalf of their customers they generate - or contract for - a higher percentage of renewable electricity than the minimum legal requirement in that year.

This accreditation must *not* be at the expense of allowing other companies to fall below the minimum. For instance, the legal requirement in 2005 for all companies was 5% and a reasonable interpretation of the law was that all electricity consumers were entitled to receive this 5%.

All renewable electricity should be certified using the same mechanism, namely ROCs. Having three different and independent mechanisms seems a good way to cause confusion.

Programs to increase the generation of electricity from renewables should be maintained, but a much higher priority is to increase the rate of implementation of the more efficient use of electricity. Highly successful methods have been demonstrated overseas for many years.

[1] Greater London Authority, *GREEN LIGHT TO CLEAN POWER: THE MAYOR'S ENERGY STRATEGY.* (February 2004).

[2] Regrettably not even the supposedly binding legal target of 5% in 2005 was met. 3-4% of UK electricity in 2005 was "renewable" as defined by the government.

[3] *GREEN ELECTRICITY TARIFFS.* Briefing issued by FoE (July 2005). See the following website: http://www.foe.co.uk/campaigns/climate/press_for_change/choose_green_energy/

[4] House of Lords Science and Technology Committee, 2nd Report, Appendix 4 (2005).

[5] Dr. Bob Everett, Lecturer, Open University Energy and Environment Research Unit, personal communication (July 2005).

[6] DTI, *UK Energy in Brief* (2004).

[7] Paul Mobbs, *Energy Beyond Oil*. Published by Matador Books, distributed by Troubador. ISBN 1-905237-006. See also the following website: http://www.fraw.org.uk/ebo/tour_info/ebo_introduction.html

[8] Competing demands on biomass after fossil fuels are depleted and the UK economy is powered by renewables include: (a) chemical feedstocks; (b) transport fuels; (c) fuel for mid-merit order, peaking and standby electricity generating plants, (d) fuel for CHP plants; (e) fuel for backup to solar space and water heating systems; (f) fuel for very high-temperature industrial processes, such as steelmaking (g) fuel for backup to industrial solar process heating systems at lower temperatures (h) other considerably lower priority uses; e.g., burning wood for space heating.

[9] Peter Chapman et al, *THE ELECTRICITY INDUSTRY*. Report from Open University Energy Research Group (1977).

[10] David Milborrow et al, *POWER UK 109* (March 2003).

[11] Ironically, if the UK used electricity more efficiently and used less of it for heating, although one would expect the *annual* variation in demand to decrease the *diurnal* variation in consumption would probably increase. Much of today's summer night demand is due to appliances with high standby power consumption, and ICT equipment in non-domestic buildings, being left on at night and at weekends.

[12] David Olivier, Hugh Miall, Francois Nectoux, Mark Opperman, *ENERGY-EFFICIENT FUTURES: OPENING THE SOLAR OPTION*. Earth Resources Research Ltd., London (1983).

[13] David Olivier, "100% Renewables?" *RENEW* 145. Published by EERU, Faculty of Technology, Open University (Summer 2003).

[14] Amory B Lovins and L Hunter Lovins, *BRITTLE POWER*. Brick House Publishing Company, Mass., USA (April 1983).

[15] Ref. 10, op. cit. Further data on typical oil well costs is contained in Australian government papers; see the website www.ga.gov.au/servlet/BigObjFileManager?bigobjid=GA6117.

[16] Ibid.

[17] Enviros Consulting, *THE COSTS OF SUPPLYING RENEWABLE ENERGY.* DTI, London (2005).

[18] The nuclear costs of £3,500 per kW(e) are based on the actual costs of the PWR built at Sizewell B updated to 2005 money values, including an addition of 16% for interest during construction. Source: Dr. David Toke, Senior Research Fellow in Environmental Policy, Univ. of Birmingham, personal communication (July 2005).

[19] The figure should also include the grid reinforcement costs associated with the sustained increase in load from building these flats. We have been unable to find any published UK figures, but several estimates from the USA state that their typical grid reinforcement cost associated with new power stations is $1,000 per kW(e). At the current exchange rate of $1.75 per £, *if* UK costs were of a similar magnitude they would equal £550-600 per kW(e). This

would give a further cost of £3-4,000 per flat; i.e., in addition to the cost of *£21,000 per flat* to build the power station capacity to heat it.

[20] Orchard Partners, *COMBINED HEAT AND POWER IN THE LONDON BOROUGH OF SOUTHWARK: A Preliminary Study*. Commissioned by Southwark Borough Council (1981).

[21] In new buildings, faced with the higher capital cost of the heat pump system, usually £2,000+, it can turn out to be more cost-effective to spend the available budget on *further* improvements in insulation and airtightness plus a gas or LPG condensing boiler system. On the basis of the COPs given on OFGEM's web site, heat pumps achieve minimal CO2 savings if they are used in the gas supply area instead of an "A" grade condensing boiler system.

[22] See the website of the Danish Board of District Heating, www.dbdh.dk.