Energy Conservation in the home
– reducing the cost of energy.

A Guide for Rotarians and the Community on what can be done to address the Trilema of Climate Change, Energy Security and Affordability of Energy Supply.

by

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Background

The earth as a whole, and more specifically the UK is facing many environmental challenges particularly .those of the so-called Energy Trilema of Climate Change, Energy Security and Affordability of Energy. The subject area is vast and it is impossible to adequately do justice to the different aspects of the Trilema in a single paper, however this report attempts to explore ways in which Rotarians might specifically help address the direct issues associated with energy use in the home.

It opens up opportunities for Community Service to help, advise and support those struggling to meet their energy needs and some Rotary Clubs have used some of the information contained in this paper as the basis of Community Workshops. At the same time there are also opportunities for Rotarians to save money themselves by understanding where exactly opportunities lie. There are many myths about energy and this paper will also attempt to dispel many of these. In addition, this paper explores a number of newer opportunities now available to help individuals reduce their energy consumption, reduce carbon emissions, and in the long term save money by making use of the Renewable Heat Incentives and/or Feed in Tariffs now available.

Questions about energy use in the home and how energy bills might be reduced

This sections presents several common questions on every day use of energy, some of which are shown to be myths. It also summarises some of the key questions now being raised about new opportunities for reducing energy. These latter questions are answered in greater depth later in this paper. -

1) *When cooking vegetables how much energy (as a %) is saved by putting a lid on the saucepan.?*
2) *By time switching the heating in a house so that it is off from midnight until 8am the next morning (i.e. 8 hours off, 16 hours on), a saving of one third in energy will be possible. Is this correct?*
3) *With a well insulated hot water tank it does not matter if the heating source is left on. In what circumstances is this statement correct, and in what circumstances is it not?*
4) *Fluorescent lights use as much energy when switched on as they do in running for 15 minutes or is this a myth?.*
5) *You return home to your house at 16:30 to find the house feeling cold. (you have previously time-switched the heating to come on at 16:00). Which of the following would you do?:-*
   a) turn up the room thermostat;
   b) turn up the boiler thermostat;
   c) reset the time clock.
6) *The radiators in your room are fitted with thermostatic valves. The room temperature is comfortable but the radiators feel cold. What would you do? - adjust the valve or leave it as it is?*
7) *Other than space and water heating and cooking, which individual appliance is likely to use the most electricity in the home?*
8) *Why do energy tariffs vary across the UK?*
9) *What benefits are there from generating ones own electricity?*
10) *What is the Renewable Heat Incentive and what benefits are there for the householder?*

The answers to questions 1 – 7 will be covered at the end of the paper, while the remaining questions are covered in specific sections.

Contents

1. A question of units and the use of standby

- There is considerable confusion over units of energy and in particular the difference between kW and kWh. They are very different units and ***cannot*** be compared even though they are frequently used interchangeably in the media. Perhaps a good analogy is if a person asked the question of how far it was from London to Newcastle on Tyne. If the response was 60 mph, the person asking the question would be confused as the answer had been given as an average speed, not a distance. The speed is equivalent to kW whereas the distance in miles is equivalent to kWh. Travelling at 60 mph would for 4.5 hours would mean that one would indeed cover the 270 miles to Newcastle.

- Many people believe that a 1 kW electric kettle will consume much less energy than a 2 kW. This is ***not*** the case as to boil one litre of water requires just under $1/10^{th}$ of a kWh irrespective of the kW rating. The actual amount depends on the exact temperature of the tap water. For a 1 kW kettle it will take twice a long to boil the water, and the overall heat loss from the casing during the extra time may lead to a slightly higher consumption. Table 1 indicates the approximate time and cost to boil 1 litre of water in different size kettles.

  A key message is to avoid boiling more water than is absolutely necessary.

Table 1. Approximate time and cost to boil 1 litre of water in kettles of different ratings

Kettle rating	*Time (secs)*	*kWh*	*Cost (@13p/unit)*
3kW	***110***	***0.093***	***1.21p***
2kW	***170***	***0.094***	***1.22p***
1kw	***340***	***0.096***	***1.25p***

- Standby on appliances can be consuming 20% or more of total electricity in the house.
- Some standby systems can consume up to 10 - 20 W although there is a now move for all to be 1W or less and the very latest TVs achieve this.

  An example –
    - a television (~ 2 – 3 years old) average consumption 120 W standby consumption ~10 W
    - assume TV used 3hrs a day and then left of standby for rest of time.
    - total consumption in a year = 208 kWh per year costing around £27 of which 77kWh or 38% arises purely from standby.

- Boiling three kettle of water a day each with one litre will consume around 100 – 110 kWh per annum and cost about £13.

- A kettle will typically have a rating of 15 – 20 times that of a television, but as shown in the example above, the energy costs of the television over the year will be twice those of the kettle. It is not just the rating but the time for which each appliances is used that is important.

There are energy meters on the market which can measure the actual energy use of individual appliances such as a kettle, television, fridge etc. These can be purchased for around £15 and allow both the instantaneous electricity use of an appliance and the cumulative energy used to be measured. The cost per unit can be also entered and the running costs as opposed to cumulative energy may be measured. Furthermore, for the technically minded, the voltage, current and power factor can also be displayed. Figure1 shows examples of two such energy meters.

Figure 1. Examples of Energy Meters – the one on the right made by Brennenstuhl is less convenient as the cable can obscure the display. The one on the left is by ENERGENiE.

Standby electricity use on appliances can be significant and if running continuously can be a major component of energy bills. In some cases, 20% or more of the total household electricity may come from appliances left on standby. In many older television/cable box/DVD/video recorder set ups the standby consumption can be as high as 30W or more, although modern devices tend to be much lower. At 30W, a rough rule of thumb is that the annual cost of energy from standby will be around £30. To reduce this standby consumption it is convenient to use a remote device such as shown in Figure 2.

While these have a standby consumption of 1 – 1.5W, these are usually much less than a television/DVD/setup. Contrary to popular belief, settings on most DVDs/cable boxes etc purchased in last 10 years do not loose their settings. Furthermore with careful connections a single press of one button on the remote will automatically turns off all the connected appliances. The author has been using such a system each night for over 10 years and has never had an issue with his cable box over that time.

Figure 2. Remote switches for devices – these consume 1 – 1.5W which is often very much less than that from televisions etc on standby.

2. Reducing Energy bills

The use of lighting and appliances is very much under the short term control of the user unlike the case of space heating, where the dominant variables are largely constant over periods of time (i.e. the size, shape, of the property and also the insulation levels and the mean temperature difference between the inside and outside the property). It is true that the insulation levels may be changed as discussed in sections 3 and 5 and there may be short term preferences on the temperature, but largely if no physical changes are made, then the energy consumption from heating from one period to another will be similar provided that the external temperature is the same. On the other hand individual choices and attitudes in the use of appliances and whether or not they are left on standby can significantly affect the electricity consumption between identical properties.

2.1 Electricity - Lighting

Traditionally house in the UK had rooms lit with a single bulb usually of 60 – 120W although in larger rooms there may have been two or three such bulbs. Such illumination was often supplemented by decorative standard or table lamps and in some instances wall lights. The total wattage in a living room was rarely more than 250W and often less. However, with the advent of halogen spot lights up to 10 such spot lights were not uncommon, and with a typical wattage of 50W per bulb the total annual consumption per living room increased by up to 100%. As a rough rule of thumb, the average daily use of lighting in a living room will be around 5 hours a day – much less in summer, but much more in winter, although this figure will vary according to the specific life style of the inhabitants.

Using this approximate use information and assuming 10 halogen spots would result in an annual consumption of over 900kWh at a cost of over £100. There are replacement bulbs which are rated at 30W, and using these, though reducing the total light output slightly will normally be satisfactory and this change would save around £40 in running costs for that room. Going further, the new LED bulbs which have the same GU10 fittings as the original halogen are rated at just 5W each and the total running cost will reduce to around £10 or a 90% saving. While the LED bulbs are still noticeably more expensive, the reduced energy consumption and significantly longer life mean that they are cost effective, and strategies to say replace one room of bulbs at a time make sense.

2.2 Electricity - Appliances

Examples of how much appliances such as kettles and televisions consume have been covered in Section 1 as have opportunities to reduce standby use. Appliances such as fridges and freezers will tend to have a constant consumption throughout the year, but most other appliance energy consumption will depend on actual use. Most significant individual users of electricity in the home are washing machines and tumble dryers. What many people do not realise is that a washing machine will typically have a cycle rating of 0.8 – 1.2kWh, and used four times a week will consume around 200 kWh costing up to £27 per year. On the other hand a tumble dryer consumes around 4 times as much energy as the washing machine, and using that three times a week will result in a consumption of around 800 kWh costing over £100 a year in running costs.

Significant savings may be made by drying the clothes on a rack or in summer out of doors, and this strategy alone results in one of the more significant reductions in household energy bills.

2.3 Heating

The annual energy consumption for space heating in a home depends primarily on four main factors:

i). the size and shape of the property
ii). whether the property is detached, semi-detached, terraced of a flat
iii). the level of insulation in the roof, floor, walls, windows, and importantly the control of ventilation
iv). the mean temperature difference between inside and outside the property.

Other factors such as wind speed are much less significant except in exposed locations. To simplify estimates of energy use for space heating, the first three of the above factors are normally combined as a single factor (or heat loss coefficient - ***HLC***) for a given property. This ***HLC*** factor may be determined by multiplying the areas of individual components of the floor, walls, roof, windows by their respective U-values (a measure of their insulation) and adding on the impact of ventilation.

For a property of average size built in the early post war years with no insulation improvements, the ***HLC*** factor may be as high as 600 W/ $^{o}C^{-1}$ or more, whereas a similarly sized well insulated property or one built in recent years will have a ***HLC*** of 150 W/ $^{o}C^{-1}$ or less.

Once the HLC is known, it is straight forward to estimate the energy required to heat the home, using the following simple equation provided that the mean temperature difference between the inside and out of the house is known:

Energy requirement = HLC x (temperature difference) / efficiency of heating appliance …..(1)

For an older gas or oiler boiler, the efficiency will be around 65% (or 0.65 for use in the above equation), while for modern condensing boilers, the efficiency may be as high as 92% (0.92). The seasonal efficiency of most UK boilers has been tested and information may be obtained from the Building Energy Performance Assessment Website (formerly known as the SEDBUK database). The temperature difference is the mean internal temperature in the house. The internal temperature is a matter for the individual to set, whereas the external temperature will depend on the prevailing climate at the location in question.

Most energy use within the home ends up as incidental gains reducing the amount of energy require to actually heat the property. In addition body heat and passive solar gain through windows can make useful contributions to reducing demand. For an average property with average insulation these incidental gains provide a "free" temperature rise of around 4.5^{o}C. Thus if the internal thermostat is set at 20 ^{o}C, no heating is required if the external temperature is above 15.5^{o}C (60F). This 15.5^{o}C temperature is known by a variety of names in the literature including "***balance temperature***", "***neutral temperature***", "***base temperature***" etc. and does vary depending on the exact incidental gains and the ***HLC***.

If the daily or weekly energy consumption for heating is plotted against the external temperature then a graph similar to Figure 3 will be produced. These data represent actual values for the house shown in Figure 4 for the year 2013. There are two parts to this graph – i.e. below and above the balance temperature. Above the balance temperature, no space heating is required and the only requirement in this case was for hot water. However, in this particular house, there is a solar hot water heater which means that the data for temperatures above 15.5^{o}C is rather more variable than would normally be the case. Nevertheless the two trend lines do indeed intersect at close to 15.5^{o}C. ….

The gradient of the line in Figure 3 is related to the HLC as follows:

Gradient (in kWh/^{o}C) = HLC / efficiency of heating appliance * 0.024 ……………………..(2)

The factor 0.024 arises from the fact that the data are presented in kWh per day and the Heat Loss coefficient is required in Watts. In the example shown the boiler efficiency is 90% and the ***HLC*** is 292 W $^{o}C^{-1}$. It is apparent that most data points are close to the trend lines, but points in region **B** relate to three days when the occupants were away and the internal thermostat was set at a low level, while in region **A** are the corresponding points on return when additional heating was temporarily required.

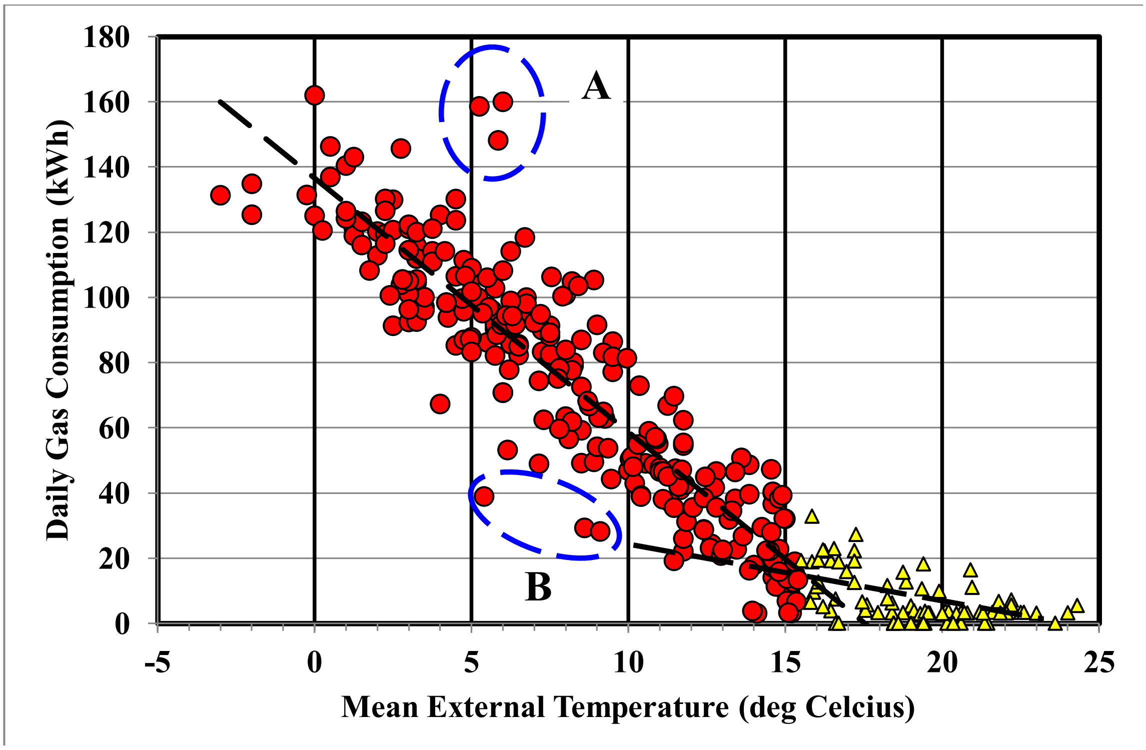

Figure 3. Variation of Heating Energy Consumption with external temperature for house shown in Figure.

Figure 4. The author's house showing both a solar PV and solar thermal array on the roof

The energy consumption thus varies according to the external temperature and Degree-Day Tables have been constructed allowing the annual heating energy requirement to be assessed. The relevant equation is:

Annual consumption = HLC x Degree-Days x 0.024 / efficiency of heating appliance ……….(3)

In East Anglia the number of Degree-Days in 2013 was 2504 and using data from the example shown in Figure 3 with a ***HLC*** of 292 W^oC^{-1} and a boiler efficiency of 90%, the annual consumption in 2013 is estimated to be 19500 kWh.

Further information on how the Degree-days vary across the different regions of the UK may be found in section while specific information of the Degree-days for any month since 1995 may be found on the VESMA website.

Equation 1 indicates that the temperature difference is an important aspect of energy consumption for space heating. In the UK, the mean external temperature is around 8.5°C and with a mean internal temperature of 20°C this indicates that a change in 1 °C in the thermostat setting will increase of decrease energy consumption for heating by around 8%. Studies of thermal comfort show that by always wearing a thick sweater in addition to a shirt or blouse would provide the same level of thermal comfort with the temperature set 3 °C lower implying a potential saving of 24% on energy bills. However, while such indoor clothing may have been more common a century ago, in modern day houses people are often less inclined to have thicker clothes indoors, but nevertheless the potential for saving is still there.

3. Different Tariff structures and why they vary across the UK with the same company?

3.1 Historical Background

Prior to privatisation of the Electricity Supply industry on 1st April 1990, all electricity in England and Wales was generated by the Central Electricity Generating Board (CEGB) who also operated the high voltage transmission network. In addition, there were 14 separate regional Electricity Boards who distributed the electricity at lower voltage, sold the electricity to the consumers in their area and also were responsible for meter reading.

There are thus five separate component parts to the supply of electricity: (1) Generation, (2) Transmission, (3) Distribution, (4) Sales, and (5) Meter reading. Prior to privatisation, there were effectively just two separate organisations involved. The CEGB were responsible for Generation and Transmission, and the local Area Board of Regional Electricity Company (REC) for the remainder.

In recent years following mergers and demergers, the companies responsible for the five components may be very different. For example, electricity supplied to East Anglia will come for a variety of generation sources including nuclear, coal, gas, renewable etc, while transmission is the responsibility of the National Grid Company. Thereafter, distribution is provided by UK Power Networks, a subsidiary of Hong Kong Electric while Sales to actual consumers depend on which of the electricity supply companies a consumer has chosen as his/her supplier. Finally, the meter reading company may be yet another company such as Siemens.

3.2 Different Tariff Structures

Traditionally, prior to privatisation, there were two separate parts to domestic electricity (and gas) tariffs. The first was a fixed charge which was made regardless on actual electricity consumed, and the second part was a unit rate for each unit of electricity used. This is shown as lines O – A – B in Figure 5. The logic behind the standing charge was the fact that the consumer had the ability to draw power at any time. However, this did mean that for those with lower consumption paid proportionally more for their electricity.

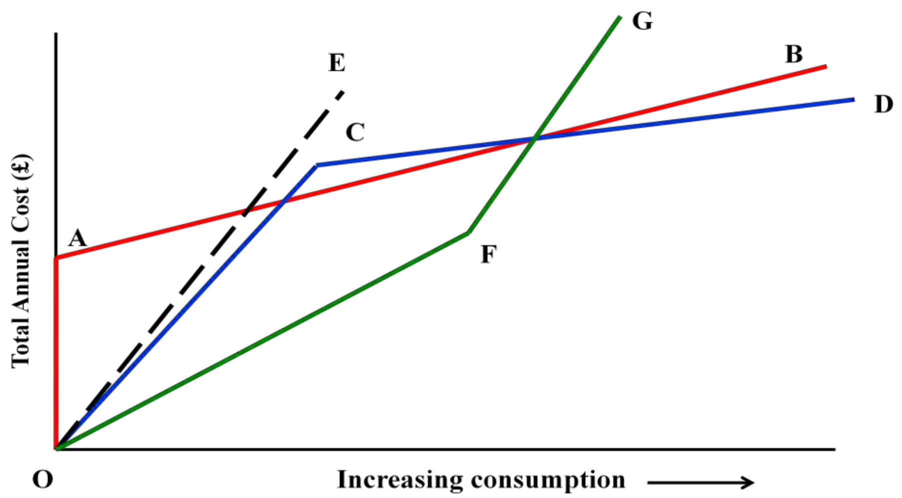

Figure 5. Simulation of different tariff structures. The approach simulated by O – F – G has been used by Irkutusk Energo in the Russian Supply Industry.

Following Privatisation and Deregulation many utility companies adopted a dual tariff approach where the first N units were charged at a higher rate and the remainder at a lower rate as shown as line O – C - D in Figure 5. This approach reduced the impact of the standing charge, but still meant that the lower consumer was paying proportionally more for their electricity.

For those with significant overnight use of electricity, particularly those with electric storage heaters, other tariffs such as Economy 7, Economy 10 etc were available, and generally, the unit rate over night was much lower, but compensated by a higher day time rate.

Prior to Privatisation and Deregulation, all domestic consumers were with the same company, but with the large number of options now available, the cheapest total cost to a consumer will vary depending on their actual annual consumption, and smaller changes here could mean that they are no longer on the cheapest. In recent years, most Utility Companies have reverted by to the ***standing charge*** approach for tariffs and an interesting situation arises in the NR (Norwich) postcode area where one company (July 2015) has no standing charge, but a standard unit rate of 15.84p/kWh, while another has a standing charge of £65.07 per annum but a lower unit rate of 12.95p/kWh. This means that households having a consumption below 2273 kWh per annum (well below average) will pay less on the tariff offered by the first company, but could pay significantly more if the consumption arises above this level.

Unfortunately, few utility companies now provide readily accessible tables to allow easy comparison, and even the comparison website require one to put in current usage before giving details of options – rather than giving the full range irrespective of usage.

3.3 Novel Tariff Structures used in other Countries

Some utilities, such as the Salt River Project in Arizona extended the number of tariffs from just two (i.e. day and night) to five or more separate tariffs reflecting the different costs of providing electricity at different times of the day. Other utility companies elsewhere in the world where there are significant summer time air-conditioning loads have been known to charge differential unit rates depending on mean temperature – i.e. when the temperature is below a given threshold, the rate is at one level, but at a higher level once the mean temperature is exceeded.

In 2004 and 2005 the present author gave numerous presentations to groups from the Russian Electricity Supply industry who were wrestling with the problems of tariffs, particularly since the tariffs in industry were often much higher that domestic ones in an attempt to subsidies the domestic tariffs at a very artificially low price. This was the original communist philosophy, but as markets opened up, Russian industry could not compete with counterparts in the West. On the other hand raising the tariffs to a realistic price would have been socially unacceptable. The present author was thus part of a group discussion which used the Irkukustk Energo Area (around Lake Baikal) as an example where a completely different tariff structure was used as shown but line O – F – G in Figure 5. The critical aspect is that the first N unit are at a cheaper rate – termed the "social" rate which was available to all, but thereafter the unit rate was much higher than normal such that an average consumer would pay the same regards, but the advantage of this approach would be that the poorer members of society and those who conserved energy would benefit by lower bills while the richer and more wasteful would pay more. Furthermore since the richer people using more were effectively on a higher tariff is would encourage then to invest in energy saving technology so as to reduce their consumption.

This type of tariff structure is much more in tune with elements of the Rotary "Four Way Test"

- Is it Fair to all concerned?
- Will it be beneficial to all concerned?

The author actually had a question on the above tariff raised in the House of Commons on this, but the response from the then Secretary of State for the Environment, Margaret Beckett, responded that she would not take the matter further and that things should be left solely to market forces, even though this would, unlike present tariffs be progressive for members of the community.

3.4 Reasons for Tariff variations across the UK

The wholesale price of electricity varies on a half-hour basis and in the first six months of 2015 was a high as £132.48/MWh (13.248p/kWh) and as low as -£9.00/MWh (- 0.9p/kWh), but averaged £41.86/MWh (4.186p/kWh). The daily weighted average wholesale prices are shown in Figure 6. At the peak price of 13.248p/kWh, this is higher than many retail prices and during these periods, the electricity companies would have been making a significant loss.

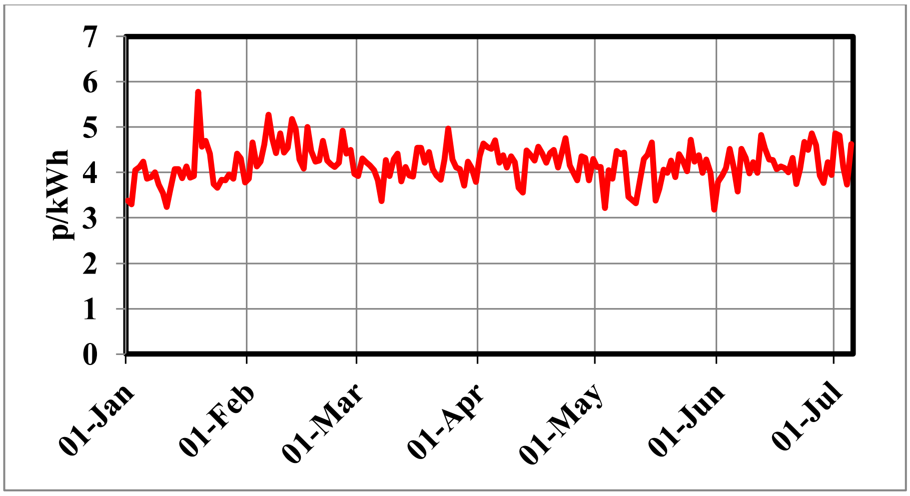

Figure 6. Daily Weighted average whole electricity prices in UK in first 6 months of 2015. The average price was 4.186p/kWh. Data abstracted from Elexon Website – 8th July 2015.

In 2013-14, the total support for renewable from the Renewable Obligation was the equivalent of 0.85p/kWh while the support for the Feed-in Tariffs amounted to a further 0.21p/kWh implying that the total cost of electricity generation (including support for renewable) was 5.25p/kWh compared to retail prices of around 13-14 p/kWh. The data for actual costs for support from renewable may be extracted from raw data from the ROC Register, the FIT Register, and relevant annual reports from OFGEM.

This cost will be similar for all suppliers of electricity, but differences occur in the cost of transmission and distribution depending on the geographic location within the UK. In 2015-16, these transmission costs vary from 3.39p/kWh for domestic consumers in the North of Scotland to 7.16p/kWh in the Southern Electric Area in England. This difference of nearly 4p/kWh is a consequence of there being greater generation capacity in comparison to demand in the north and the reverse in the south. These differences lead to greater or lesser losses in local transmission and distribution losses and to some extent, though not always reflect the differences in tariffs charged by the same company in different parts of the UK.

4. What specifically should the individual do to reduce their heating consumption and cut their bills in their own property?

There are many simple calculators available on the Internet allowing one to explore the energy consumption in domestic buildings, but most give a single summary and often recommendation as to what strategies should be adopted are generic rather than specific to the property involved. In addition, a large proportion of the general public do not know what their actual consumption of energy and instead have vague estimates which will often be inaccurate, particularly if they are paying by direct debit.

The author of this paper has been developing some software which is still very much under development, but which allows the user to play games such as "what if I do this or that strategy". Sometimes the recommended strategies are not the ones which might initially be thought. Figure 7 shows the heating section of the software, and shows and unimproved three-bedroom house built immediately after the war.

The figures shown here are approximate as the actual values are dependent on the actual size and shape of the property. Nevertheless by keeping these values constant, it is possible to explore the optimum strategies to reduce energy consumption.

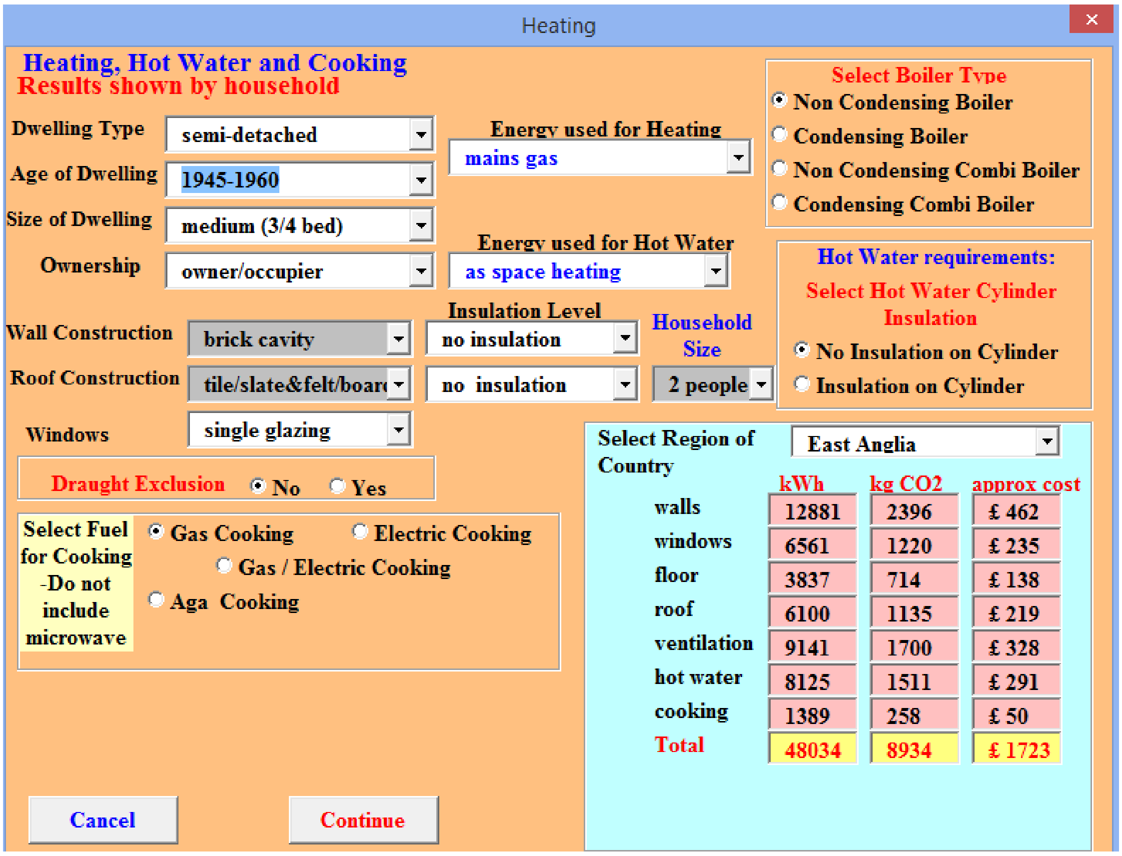

Figure 7. Energy consumption for the different components of an unimproved three-bedroom semi-detached in East Anglia house built immediately after WWII.

The total cost for providing heating and cooking for this house will be around £1720, of which around £1400 will be associated with space heating. The dominant heat loss is through the walls. Table 2 shows the corresponding figures for the same house but with different levels of insulation improvement. Option (a) shows the basic house as in Figure 4, with options (b) – (k) representing different improvement strategies and result summarised in the table.

Table 2 shows different strategies for improving the performance of basic house+.

		Annual Energy (kWh)	CO_2 emissions (kg)	Approx. Annual Cost
a	Basic House Unimproved	48034	8934	£1723
b	Hot water cylinder jacket added	44123	8207	£1589
c	As (b) plus 100mm Loft Insulation	39234	7297	£1424
d	As (b) plus 300mm Loft Insulation	38488	7158	£1402
e	As (c) plus cavity Insulation	30475	6752	£1196
f	As (c) plus double glazing	32395	6025	£1196
g	As (f) plus double glazing	23636	4396	£901
h	As (g) but replacing non-condensing boiler with condensing one.	18692	3476	£735
i	As (g) but replacing boiler with a ground-source heat pump	5837	2616	£481
j	As (g) but replacing boiler with an air-source heat pump	7618	3560	£617
k	As (h) but using an oil rather than gas boiler	18692	5069	£1105
l	As (h) but using electric heating rather than a gas boiler	16960	8512	£1291
m	House built in last few years with gas boiler	14846	2762	£605

Note: costs are based on typical tariffs which are prone to variation

A cheap and easy first step (option (b)) is to fit a cylinder jacket which will reduce the total annual bill by around £130. The next most cost effective solution will usually be to add loft insulation. However, it is important to recognise that the cost benefits from fitting increasing thicknesses of loft insulation is highly non-linear and the greatest benefit is in the first layer put down. Thus if the house already has 100mm of loft insulation (c), raising the thickness to the current standard of 300mm (d) only makes a marginal impact, and there are other strategies which will reduce energy consumption more effectively. If on the other hand there is no loft insulation then it makes sense in time and money to install the full 300mm at the outset.

Options (e) and (f) explore the performance improvements by assuming there is 100 mm of loft insulation and then adding either cavity insulation (option (e)) or double glazing (option (f)). It is noticeable that cavity insulation provides a greater reduction than double glazing, and as the capital cost is usually much less it is a much more cost effective solution for reducing energy bills. The improved reduction in energy with option (e) occurs despite that fact that sealed double glazing units are also likely to reduce draughts and the ventilation rate. If both cavity wall insulation and double glazing are installed (option (g)), then the energy cost will be just over half of those of the unimproved house.

A further significant reduction may be achieved by replacing an older non-condensing boiler with a condensing one (option (h)) when the annual consumption will be 18692 kWh and the annual running costs in this case will be less than 45% of those of the original unimproved house. Some strategies are not possible for existing houses. Thus nothing can be done to improve the insulation standard of the solid ground floor of the unimproved house. However, recently constructed houses to the same size and shape as the original unimproved house used in the examples will have a lower overall consumption.

For a comparison using other heating sources, option (k) shows the equivalent values using oil for heating and option (l) using electricity, while option (m) shows the further reductions possible for a house built in recent years with the benefit of under floor insulation etc.

With the advent of the Renewable Heat Incentive (see section 8), options such as fitting a ground-source (option (i)) or air-source (option (j)) heat pump become relevant. In running cost terms, heat pumps in buildings are better suited to under floor heating rather than radiators (unless a sizeable storage tank is also fitted) and further reductions in energy and running costs are possible. The capital cost of installing a ground source heat pump can be significant but with the payments now available from the Renewable Heat Incentive, such schemes can make sense on a longer time scale basis.

5. How does energy consumption vary between households and in different parts of the UK?

5.1 Variation in electricity consumption with attitude of householder

Electricity consumption within a household varies considerably with attitudes of the occupants. Figure 8 shows the electricity consumed in over 100 houses in Norwich over a four month period.

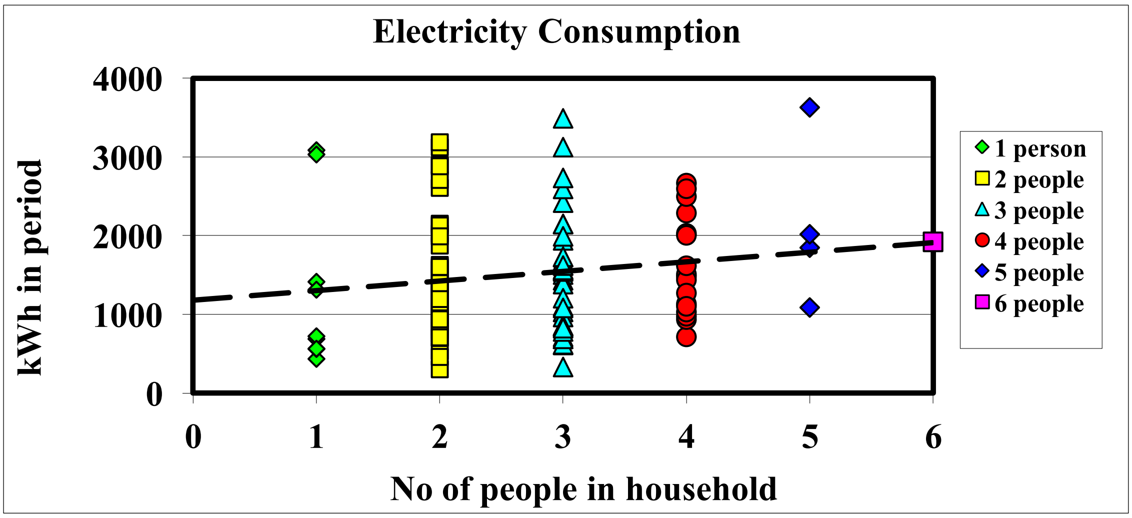

Figure 8 Electricity consumption in over 100 houses in Norwich over a four month period in 2009.

These houses were selected to be ones which had space and hot water heating by gas and also cooking by gas. Therefore any variation in consumption cannot be attributed to heating and to only a minor extent to the size of the property. The dominant use will be for lighting and appliances. It is apparent that there is a factor of 9 variation for any household size.

When the participants were questioned further it was found that those households who minimised the use of standby on appliances, those which minimised the use of tumble dryers, and those who had installed low energy lighting as opposed to using halogen spot lights had the lowest consumption for any household size. Furthermore even when income levels were examined, it was still found that the variation in consumption was as high as 6. This demonstrates the importance of raising awareness in attempts to reduce electricity bills. It also demonstrates that some households will be spending up to 9 times as much on their energy bills.

5.2 How does Actual Electricity Consumption by household vary across the UK?

In section 5.1 the way in which energy consumption in the home can vary significantly was discussed. Often this variation comes down to changes in attitudes. The majority of space heating and hot water in households is provided by fossil fuels, and as a consequence, the electricity consumption might be expected to be similar as its dominant use is for lighting, appliances and cooking. Since 2004, data on energy consumption has been available on a Regional and Local Authority basis. a regional. Table 3 shows that the consumption in the different regions varies by +/-10% about a mean value of 4085 kWh per annum, and that the ranking of the regions does not reflect the prevailing climate conditions with the warmest area (i.e. the south west) having the highest annual consumption.

Table 3. Regional differences in electricity consumption in 2013

Local Authority	kWh per annum	Local Authority	kWh per annum
North East	3,581	West Midlands	4,070
Yorkshire and the Humber	3,802	East of England	4,410
London	3,872	South East	4,414
Wales	3,928	Scotland	4,435
North West	3,931	South West	4,473
East Midlands	4,014		

The ten Local Authority areas out of 380 (excluding Northern Ireland) with the lowest annual household consumption of electricity are shown in Table 4. These areas reflect dominantly urban areas mostly in London and the North East. Such areas will have space heating and hot water normally provided by fossil fuels, with little electricity used for space heating. Table 5 on the other hand shows the ten Local Authority areas with the highest annual household electricity consumption. The annual consumption in these areas is typically twice that in the lowest ten. However, all but three of these areas are in Scotland and in areas where there is a relatively high level of electric heating (e.g. Orkney and Shetland).

Table 4. The ten Local Authorities with the lowest consumption per household (excluding Northern Ireland)

Local Authority	kWh per annum	Local Authority	kWh per annum
South Tyneside	3,261	North Tyneside	3,395
Islington	3,289	Gateshead	3,399
Hackney	3,333	Chesterfield	3,425
Lambeth	3,345	Hull	**3,433**
Norwich	3,351	Sunderland	3,437

Table 5. The ten Local Authorities with the highest consumption per household (excluding Northern Ireland).

Local Authority	kWh per annum	Local Authority	kWh per annum
South Bucks	5,497	Argyll & Bute	6,844
Aberdeenshire	5,566	Eilean Siar (Western Isles)	7,049
Perth & Kinross	5,577	Isles of Scilly	8,017
Cotswold	5,977	Orkney Islands	8,020
Highland	6,408	Shetland Islands	9,989

Table 6. shows the annual domestic consumption of selected local authorities in the East of England . What is noticeable is that though Norwich is the 5th best Local Authority in the UK, oth.er urban areas such as Watford have a much higher consumption. It is true that the more rural

areas such as Forest Heath and Norfolk area areas where there is more electric heating, and consumption would be expected to be higher.

Table 6. Selected Local Authority Areas in the East of England and the average domestic consumption and ranking in 2013

Local Authority	kWh per annum	Rank out of 380	Local Authority	kWh per annum	Rank out of 380
Norwich	3,351	5th	South Norfolk	4,867	325th
Harlow	3,703	62th	East Hertfordshire	4,911	334th
Stevenage	3,726	68th	Epping Forest	4,926	335th
Ipswich	3,766	78th	Forest Heath	5,007	341st
Luton	3,794	88th	Mid Suffolk	5,014	344th
Peterborough	3,887	113th	Maldon	5,154	356th
Cambridge	3,918	125th	King's Lynn and West Norfolk	5,263	362nd
Southend-on-Sea	4,079	175th	North Norfolk	5,276	363rd
Watford	4,099	184th	Uttlesford	5,338	366th

Since 2013, it has been possible to extract information on a Post Code area basis – the full table make be found on the DECC Website. Figure 4 shows the author's four bedroom house in NR4 6QA. On the roof are both a two panel solar thermal scheme installed in 2004 and also a 1.25 kW solar PV array installed in 2011. The house is gas centrally heated with gas cooking, but the total average annual electricity consumption over the last three years has been 1700 kWh – just over half of that for Norwich. Even allowing for the solar PV generation this would still only bring the total consumption to around 2300 kWh – just 70% of the average Norwich figure. On the other hand there are 21 four-bedroom houses in the NR4 6QA Postcode area, and the average consumption for all 21 is 3670 kWh so the author's house is performing very well and the electricity bills will be less than half of those of his neighbours.

5.3 Energy required for space heating

If identical properties with identical insulation in the South West of England and North East of Scotland are compared, Table 7 indicates that the heating energy consumption will be 45% higher in the latter area. The data shown are for twenty year averages, but data for individual months since 1995 are available for each of the 18 different regions on the Vesma Website.

Table 7. Twenty year average Degree-Day data for different regions of the UK

	Thames Valley	South East	South	South West	Severn Valley	Midland	West Penine	North West	Borders	North East	East Penine	East Anglia	W Scotland	E Scotland	NE Scotland	Wales	Northern Ireland	NW Scotland
January	313	334	306	269	309	346	345	351	326	353	343	351	338	353	347	299	327	311
February	274	297	274	247	272	302	298	312	289	306	298	308	296	308	312	270	287	286
March	242	263	257	237	247	276	280	297	287	288	273	280	289	294	302	261	279	286
April	165	187	189	182	181	205	206	226	231	217	200	201	218	231	242	205	212	227
May	99	118	115	116	110	133	135	158	171	153	131	130	158	177	186	142	150	185
June	42	53	54	55	48	66	73	89	95	84	66	67	87	97	109	73	80	115
July	20	27	28	25	24	34	39	51	51	46	34	34	50	56	62	38	45	71
August	19	25	25	21	21	31	38	52	46	46	29	29	51	55	60	30	45	60
September	42	55	49	42	49	64	70	85	77	78	59	58	85	87	96	55	74	91
October	106	126	106	90	117	145	148	164	150	160	137	135	162	170	182	117	151	167
November	215	233	206	181	216	247	250	256	239	262	246	248	251	265	265	205	241	237
December	313	330	299	262	311	347	350	358	328	364	350	350	347	361	361	287	325	313
Total	1850	2048	1908	1727	1905	2196	2232	2399	2290	2357	2166	2191	2332	2454	2524	1982	2216	2349

Caution must be exercised when comparing heating data for one year with another. Thus in East Anglia in 2013, there were 2504 degree-days compared to just 1907 in 2014. This means that the consumption in 2013 was 17% above average and 13% below average in 2014. Thus an unwary consumer might have thought that he/she had reduced energy bills attributable to space heating in 2014, but unless these were around 30% lower, the changes purely came from the differences in climate.

6. Supplying Energy to the home by unconventional means.

Traditionally houses in the UK have used fossil fuels such as coal, oil, gas and also wood to heat the buildings and provide hot water and cooking. In addition, electricity generated from central power stations is used for lighting, appliances and space and water heating and cooking. In the last decade there have been moves to use alternatives, particularly since the introduction of the Feed in Tariff scheme for domestic electricity generation on 1st April 2010, and more recently from the Renewable Heat Incentive (RHI) from 9th April 2014. Some householders installed devices long before those dates, and do not qualify for the financial benefits from these new schemes as described in section .

6.1 Electricity generation

By far the most popular method for generating electricity for households is by the use of solar photovoltaic (PV) cells, although in certain locations micro-wind and mini hydro schemes have been used.

The amount of electricity generated by a solar PV array depends on the installed capacity and the orientation of the collectors. Contrary to popular belief the optimum orientation is not necessarily due south and it depends on the probability of could cover in the morning and afternoon. Thus in East Anglia, the optimum orientation is around 10 – 15^o west of south such that collectors which are pointing south west will collect nearly as much energy as those pointing south. The actual optimum orientation at any location does depend on the local climate conditions. Figure 9 shows how the output varies for collectors at various tilt and azimuth angles in South East England.

Tilt

90	19	19	20	21	23	26	29	32	35	39	43	46	50	53	56	59	61	62	64	64	64	64	62	60	57	54	50	46	42	37	33	29	26	23	21	19
80	22	22	24	25	28	31	34	38	42	46	51	55	59	63	66	69	72	73	75	75	75	74	72	69	66	62	58	53	48	44	39	35	31	28	25	23
70	26	26	28	30	33	37	40	44	49	53	58	63	67	71	75	78	81	83	84	84	84	83	81	78	74	70	65	60	55	50	45	40	36	32	29	27
60	31	31	33	35	39	43	47	51	56	60	65	70	74	78	82	85	88	90	91	92	91	90	88	84	81	77	72	67	62	56	51	46	42	38	34	32
50	38	38	40	42	45	49	53	57	62	66	71	76	80	84	88	91	93	95	96	97	96	95	93	90	86	82	77	72	68	62	57	52	48	44	41	39
40	47	47	48	50	53	56	60	64	68	72	76	80	84	88	91	94	96	98	99	100	99	98	96	93	90	86	82	77	73	68	64	59	55	52	50	48
30	57	57	58	59	61	64	67	70	73	77	80	84	87	90	93	96	97	99	100	100	99	98	97	95	92	89	85	82	78	74	70	67	64	61	59	58
20	68	68	68	69	70	72	74	76	79	81	84	86	89	91	93	95	96	97	98	98	97	97	96	94	92	90	87	85	82	79	77	74	72	70	69	68
10	77	77	78	78	79	80	81	82	83	84	86	87	88	89	91	92	92	93	93	93	93	93	92	91	90	89	88	86	85	84	82	81	80	79	78	78
0	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350

Azimuth

Figure 9. Variation in total annual solar output as a percentage of maximum for different azimuth and tilt angles for solar collectors in South East England. This diagram has been constructed taking due account of differential cloud cover over the day

Figure 10 shows the variation in daily output for a 1.25kW PV array with month of the year. What is noticeable is the fact that the average output can vary significantly from one month to the corresponding month in a different year.

Solar PV generates electricity as direct current (DC) and this must be converted to alternating current (AC) for use in the home or for export to the local electricity grid. An estimate of the overall likely annual output in kWh for a PV array may be obtained by noting that there will be up to 7% loss in the conversion from DC to AC, that the capacity factor (load factor) for solar PV in an optimum orientation is approximately 11.5% and the number of hours in a year is 8760 - i.e. the total number of units generated will be approximately:

Installed capacity (in kW) x (1-0.07) * 8760 * 0.115 **……….(4)**

Or for simplicity ……….installed capacity x 937 **………..(5)**

Thus in the scheme for 1.25kW shown in Figure 4 which has a near optimum orientation, the annual output is estimated as 1171 kWh which is very close to the actual average recorded value of 1173.5kWh recorded over a three year period.. For collectors at other tilt and azimuth angles, the output should be modified by the percentage given in Figure 9. For a 1.25kW on a vertical south facing wall, the expected output would be 64% of the above figure or 752 kWh. If a scheme was installed after 1st April 2010, then, provided that it has been properly accredited it will potentially qualify for Feed in Tariff payments as indicated in section .

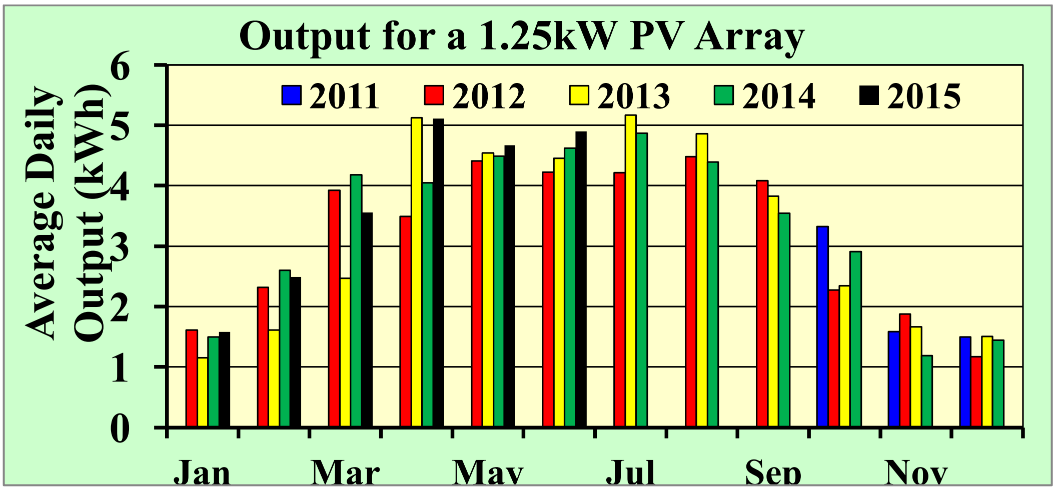

Figure 10. Average daily output for a 1.25kW PV array.

Whenever, electricity is generated by renewable methods such as PV at the domestic level, its ia done as DC and then converted to AC. This process is at best 93 – 95% so there is 5 - 7 % loss. Coupled with this, devices such a computers, televisions, DVD etc all run on DC and have power pack to convert back from AC to DC which is often much more wasteful. Indeed measurements taken at the University of East Anglia have shown conversion factors of less than 70% in the power packs for lap top computers, the waste going to heat. In the future buildings should be designed to have both local AC networks for large appliances such as kettles, washing machines, fridges etc, but the DC network for computing, entertainment, and LED lighting. This would also cut down on the waste heat and minimise air-conditioning in summer.

It might be argued that this waste heat can be beneficial in heating a house, but this logic is only valid if one heats the home entirely electrically, as the over heats both environmentally and in cost terms are much greater from this incident form of heating.

6.2 Unconventional Heat provision for the home.

There are four different unconventional methods for providing heat in the home, including biomass boilers, air-source heat pumps, ground source heat pumps and solar thermal (hot water) systems. Any such scheme which was accredited after 15th July 15th 2009 qualifies for Renewable Heat Incentive (RHI) payments (see section 8), however actual payments of RHI did not begin until 9th April 2014. The most popular scheme under the RHI has been biomass boilers where the conventional fossil fuelled boiler is replaced directly by one operating on wood chips.

6.2.1 Heat Pumps

Heat pumps, whether air-source or ground-source (the latter also including water-source) have been used to a limited extent in domestic properties since John Sumner installed one in 1953 in his bungalow in Norwich. Heat pumps are identical to a refrigerator and operated in exactly the same way. In a refrigerator or freezer, there is a cold box which in the case of a heat pump providing space heating is equivalent to a source of air or a coil in the ground outside the house.

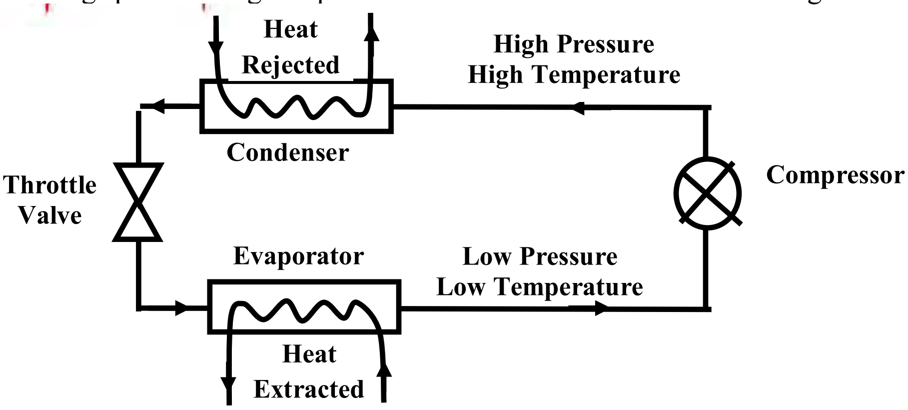

Figure 11. Schematic of a refrigerator/heat pump

This cold box or outside air source (Figure 11) is connected to an evaporator which causes the working fluid in the system to evaporate. Thereafter, as with the fridge or freezer, there is a compressor which compresses the working fluid to increases its pressure by approximately a factor of 10. Thereafter, the high pressure fluid is condensed at high pressure where heat is released in the grill in a fridge or freezer, or in a radiator or floor in a heat pump before the fluid is passed through a throttle valve to complete the circuit.

Unlike conventional fossil fuel boilers where the efficiency is less than 100% (see section 2,3), a heat pump effectively gains energy and in a well designed air-source heat pump up to 2.5 to 3 times as much heat is provided for each until of electricity consumed. In a well designed ground-source heat pump, the output can be as high as 4 times the electricity input. Heat pumps effectively work with thermodynamics to provide efficiency as opposed to fossil fuel boilers which, in effect, are limited in efficiency by the Laws of Thermodynamics.

To achieve the highest effective overall efficiency (or coefficient of performance - COP), a well designed heat pump scheme will have the external source temperature and internal heat supply temperature as close as possible. The best configurations will have under floor heating where heat is supplied to the house at around 35^{o}C as opposed to the 50 – 60^{o}C normally required in radiator systems. As such, heat pump schemes are best located in new build houses, although there is some scope available if in an existing house, single panel radiators are replaced by twin panel ones allowing the operating temperature to be reduced. Externally, a ground source heat pump which will have a coil buried in the soil will have a higher mean source temperature in winter and hence the COP will be higher than for an air-source heat pump.

Having under floor heating provides a degree of storage and allows the possibility of running the heat pumps at cheaper off peak electricity rates. However, a similar opportunity to reduce bills could be achieved if a buffer storage tank is provided in the system which could store heat over night for distribution during the day time. Some utility companies may have special heat pump tariff rates which would reduce the charges incurred if the heat pumps were run solely at peak rate day time tariffs.

One issue which arises if heat pumps is designed for optimum performance (i.e. operates at relative low temperatures of 35- 40^{o}C) also provides hot water. While 40 – 45^{O}C is adequate for hot water and to prevent scalding, it is too low to kill *legionella* bacteria. It is recommended that the storage temperature of hot water should be raised to 55^{o}C at least once a week and this may be achieved by running the heat pump sub-optimally once a week or alternatively having a top up immersion heater for occasional use.

6.2.2 Solar Thermal (Hot Water) systems

Historically hot water has been heated by the sun for over a thousand years, but the domestic type of installation now common has been around since 1880 when systems began to appear on houses in Baltimore.

Solar hot water systems are normally designed to work with a hot water storage tank and great care is needed if such a scheme is connected to a combi-boiler system as some combi boilers are unsuited to being connected to such a system. With a normal non –combi system there are two options:

i) for houses with a relatively low usage of hot water, a dual coil cylinder may be used where the upper coil is connected to the normal central heating system, and the low one to the solar circuit,
ii) a second additional cylinder connected to the solar circuit is inserted before the normal cylinder heated by the central heating system.

In the UK, solar thermal systems will typically have two or three panels depending on likely demand in the household. Figure 4 shows a two panel solar thermal system alongside a five panel solar PV system installed on the roof of the author’s house.

Unlike solar PV, the actual amount of solar thermal energy collected depends on other factors such as:

i). exactly when in the day hot water is drawn off,
ii). if a dual circuit cylinder is used, then the exact time when the normal fossil fuel hot water is timed to come on during the day.

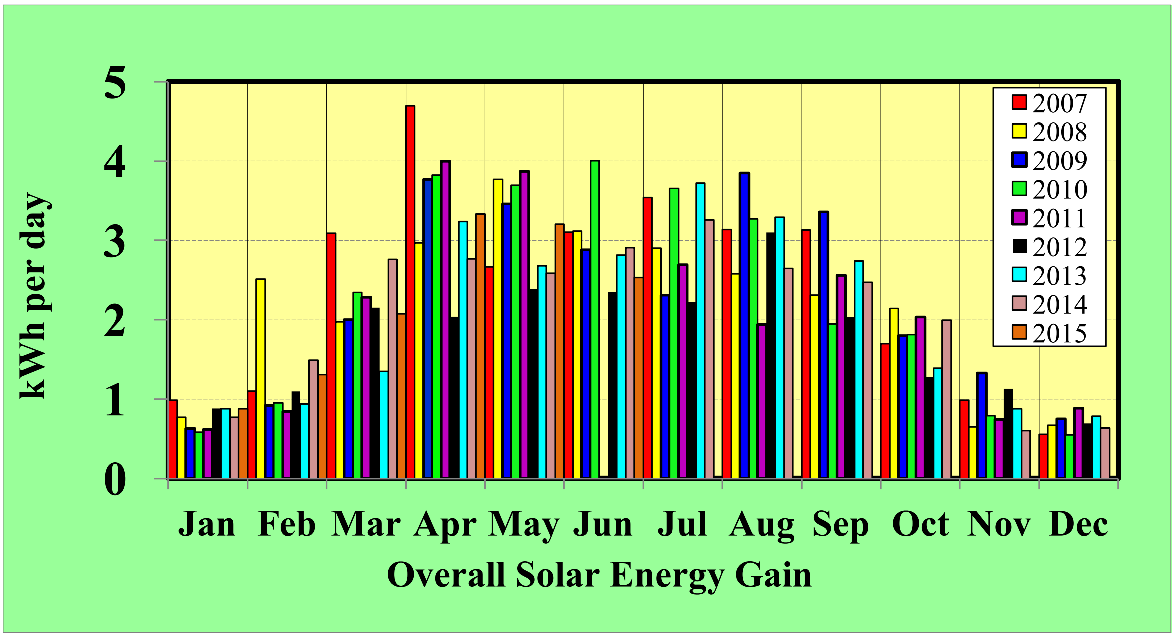

Figure 12. Output from a two panel solar thermal system.

In the case of solar thermal systems, the more hot water that is used the more solar energy will be captured and for optimum performance, it makes sense to adjust the timing of the hot water provision from the central heating system periodically throughout the year. As with solar PV systems, there can be considerable variation in the solar energy captured from one month to the corresponding month in a different year (Figure 12). Compared to solar PV systems, the actual predicted output from a solar hot water system is less easy to determine with any precision for the reasons given above, and particularly how the water is actually used. However, for a two panel solar thermal system an annual estimate in the range 600 – 800 kWh is likely, although under optimum water use during the day the figure could be higher.

7. The Domestic Feed in Tariff Scheme

The Feed in Tariff Scheme was introduced on 1st April 2010 for smaller renewable energy schemes as opposed to the larger capacity schemes which come under the Renewable Obligation Scheme, the latter is being phased out and will be replaced by the Electricity Market Reform with Feed in Tariffs – Contracts for Difference (FIT-CfD) on 1st April 2017. These FIT-CfD differ from the Domestic Scheme and are not covered in this paper. Furthermore, the majority of the domestic installations are for solar PV, and the associated tables are relevant for the scale of such schemes likely to be used by householders. For larger schemes and for non-PV schemes there are separate tables of the relevant tariffs which may be accessed on the OFGEM Website. .

By 31st March 2014 around 1.5% of houses in the UK had been fitted with solar PV panels and of the domestic FIT schemes over 95% were solar PV as opposed to approximately 60% in commercial, industrial, and community schemes.

7.1 The Feed in Tariff Payments

Each unit of electricity generated receives a Feed in Tariff payment according to Table 8. In addition, any electricity exported also receives a payment relating to the relevant Export Tariff. In most domestic situations, unlike commercial installations, the export electricity is not metered and it is thus "deemed" that 50% of that electricity generated is actually exported. Thus the effective current tariff (July 1st 2015) for an installation on an existing house which was installed before 3rd March 2012 is 48.84p + 0.5 x 3.44p or 50.56p.

The cost of the payments is borne by an effective surcharge on domestic tariffs, and in late 2011, when it was realised that the scheme was becoming very popular, but furthermore the capital cost had fallen by over 50%, a degression mechanism was instituted from 3rd March 2012 to periodically reduce the tariff rate for new installations in line with the new uptake and the capital cost of new installations. Despite this reduction, investment in solar PV through the FIT scheme is still an attractive option for the householder, with returns on capital being achieved in 8 – 12 years, and thereafter there will be a steady income to the end of the 25 year period.

The total cost of the Feed in Tariff Scheme for all generation including domestic, and non domestic in 2013-14 was £691m (OFGEM, 2015) which was borne by an effective levy on all electricity bills. During that period 317 874 GWh (DUKES 2014) was consumed by final users which means that the additional cost of a unit electricity was 0.21p/kWh and with a typical unit price of 12p/kWh, this indicates that the cost of the FIT scheme was just 1.67% on household bills.

The amount of electricity generated by a given PV array is estimated in Section 6.1. .

7.2 Accreditation

All schemes to qualify for Feed in Tariff payments must be installed by an installer accredited under the Microgeneration Certification Scheme and to qualify for payments the relevant MCS certificate must be submitted to a FIT Licensee. With potential degression taking place every 3 months, it is important to ensure that all the paperwork is in place before the deadline of the next degression (see Table 8 for examples how the tariff has degressed since 2012).

As part of the accreditation an Energy Efficiency Rating was introduced from 1st April 2012. From that date, houses had to demonstrate an energy efficiency rating of D or better to qualify for the high tariff rate, otherwise the medium rate would be paid. This requirement was to ensure that money was being used in the cheapest and most cost effective way to reduce carbon emissions. This requirement has meant that many houses have had their thermal performance improved as a pre-requisite to installing solar PV. The lower tariff rate paid for schemes installed after 1st April 2012 relates to community based schemes.

Table 8. Feed in Tariffs for PV installations which are less than 4kW maximum capacity in pence per kWh

	Installation accredited before													
	3rd Mar 2012	1st Apr 2012		1st Aug 2012	1st Nov 2012	1st May 2013	1st Jul 2013	1st Jan 2014	1st Apr 2014	1st Jul 2014	1st Jan 2015	1st Apr 2015	1st Jul 2015	1st Oct 2015
Installed on a new building	42.6	22.59	Higher	22.59	17.22	16.11	16.11	15.54	15.14	14.61	14.61	13.88	13.39	12.92
			Medium	18.07	15.49	14.51	14.51	13.99	13.62	13.15	13.15	12.49	12.05	11.63
			Lower	9.68	7.64	7.41	7.14	7.14	6.72	6.72	6.48	6.38	6.16	5.94
Installed on an existing building	48.84	22.59	Higher	22.59	17.22	16.11	16.11	15.54	15.14	14.61	14.61	13.88	13.39	12.92
			Medium	18.07	15.49	14.51	14.51	13.99	13.62	13.15	13.15	12.49	12.05	11.63
			Lower	9.68	7.64	7.41	7.14	7.14	6.72	6.72	6.48	6.38	6.16	5.94
Export Tariff	3.44	3.44		3.44	4.85	4.85	4.85	4.85	4.85	4.85	4.85	4.85	4.85	4.85

The figures shown in Table 8 are those valid as of 1st July 2015. These tariffs run for 25 years and the rate is increased by RPI on 1st April each year. Tariffs for other generating devices – e.g. solar PV larger than 4 kW or small wind, hydro etc may be found on the OFGEM Website.

7.3 PV schemes offering "Free" Electricity

Some PV companies are offering "Free" electricity if a householder allows the company to install PV on the roof of their house. In essence the company pays for the capital cost meaning that the householder does not have to pay up front costs and the company is effectively paying for the scheme by claiming the FIT payments which the householder would not get in this case.

However, while such schemes may seem attractive, it is important that the householder is fully aware of the implications, and in indeed exactly what does "***Free***" electricity actual mean. There are at least three ways in which this might be interpreted, and it is important to carefully read the smaller print in any agreement to find out exactly what it meant. The three different approaches may be summarised as:

a. All electricity used by the household is "***Free***". Bearing in mind that for any PV system, electricity is only generated during the day time and electricity used in the evening or at night time will still be obtained from the Electricity Supply Company. Depending on the actual size of the PV array and the distribution of electricity use between daylight and other hours, this could be an attractive option for the householder, but this in many cases is NOT what the PV Company will expect to support.
b. All electricity that is generated during daylight hours as registered on the generation meter is "***Free***". However, if a household is out during most of the day (particularly in winter), electricity use will be mostly in the evening and will thus have to be imported and will thus NOT be "***Free***"
c. If an export meter is fitted then, it is possible to work out how much is actually exported during the middle of the day, even if the use is low. In this interpretation of "***Free***" it will be the net amount electricity generated which will be "***Free***" and the amount of "***Free***" electricity accredited would be between that implied in (a) and (b) above.

A further consideration is the question of insurance. What happens if, for instance there is a fire and the PV cells are damaged/destroyed. For a normal householder paying for a scheme him/herself, the normal insurance company will normally cover such losses, but in the case of a company installing on a house roof, the situation is far from clear, and this needs to be fully understood by the householder before entering in to any agreement.

8. Domestic Renewable Heat Incentive.

The Domestic Renewable Heat Incentive came into force on 9th April 2014 and applies to any accredited scheme which was installed after 15th July 2009, the date on which the first version of the scheme was announced. Because of the delay in starting the scheme the Government offered a Renewable Heat Premium Payment (RHPP) grant to offset the capital cost. In a similar way to the Feed in Tariff scheme for electricity generation, the scheme pays the householder for energy generated and thus after 9th April 2014, the capital costs will be recouped by the RHI payments over a number of years.

There are two important differences in the Domestic (RHI) from the Domestic Feed in Tariff:

i). The payments come from general taxation rather than from an effective surcharge on consumer bills,
ii). The amount of heat energy produced is "deemed" rather than actually measured as in the case of the Feed in Tariff.

However, like the Feed in Tariff, the amount paid for each unit of energy generated varies each year on the 1st April according to the Retail Price Index, and since late 2014 a degression mechanism is in force which means that for new installations the tariff paid may be less than that paid to early adopted of the scheme.

Table 9 Domestic Renewable Heat Incentive Tariffs

	Installation Accredited before			
	31/12/2014	31/03/2015	30/06/2015	30/09/2015
Biomass Boilers	12.20p	10.98p	8.93p	7.14p
Air Source Heat Pumps	7.30p	7.30p	7.42p	7.42p
Ground Source Heat Pumps	18.80p	18.80p	19;10p	19.10
Solar Thermal (Hot Water)	19.20p	19.20p	19.51p	19.51p

Existing Tariffs are incremented by RPI on 1st April each year

9. Answers to questions posed in Introduction

1. ***When cooking vegetables how much energy (as a %) is saved by putting a lid on the saucepan.?***

   The answer is 85% - 90%. The majority of the heat is lost through evaporation to the atmosphere and trapping the evaporated water vapour and stem under the lid retains the heat.

2. ***By time switching the heating in a house so that it is off from midnight until 8am the next morning (i.e. 8 hours off, 16 hours on), a saving of one third in energy will be possible. Is this correct?***

   There will always be a saving, but never anything like the 33% implied and often assumed.

   Figure 13 demonstrated the temperature profile within a house following the switching off of heating at midnight. Stored heat in the fabric will slow down the temperature loss and in a well insulated house the internal temperature will only fall by a few degrees, while for a poorly insulated house the temperature may drop below 10°C.

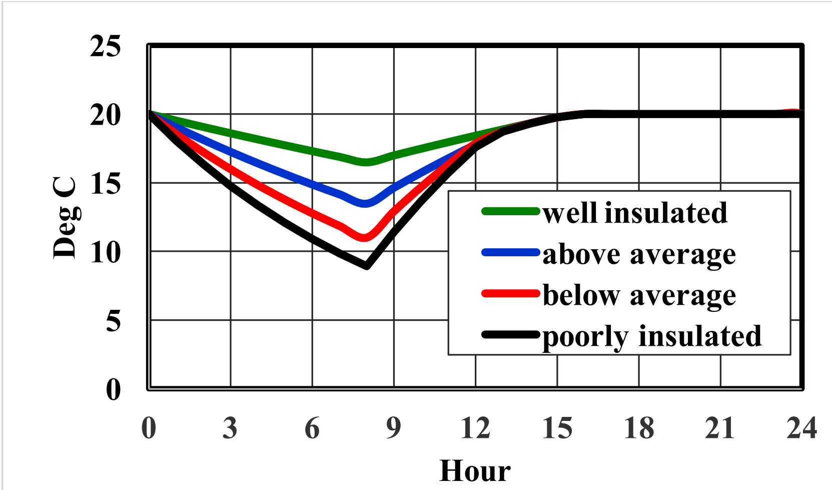

Fig … it and on again at 08:00 when the external temperature is 0°C.

The critical point is what is the mean temperature over the day and how does it relate to the external temperature? – see equation 1 in section 2.3. In this example, the saving for a well insulated house will be only 5.6% of total energy costs whereas for a poorly insulated house where overnight temperatures drop significantly the percentage saving will be around 16%.

3. ***With a well insulated hot water tank it does not matter if the heating source is left on. In what circumstances is this statement correct, and in what circumstances is it not?***

The answer to this is very similar to that for question 2, and time switching will always save energy but it may only be by a limited amount.

4. ***Fluorescent lights use as much energy when switched on as they do in running for 15 minutes or is this a myth?.***

This is a complete myth, but it is often propagated as fact. A typical fluorescent tube consumes around 60 – 80W. Using the upper figure an assuming that it takes 5 seconds to come on what must be the power drawn to consume more energy that running for 15 minutes. In fifteen minutes, the 80W tube would consume 0.02kWh. For the lamp to consume the same amount in 5 seconds the power would have to be over 14 kW which on 240 Volt mains would be a current of 60 amps well above the fuse rating of the circuit in the house – so the fuse would blow. Where this myth originated is not known but it is far from helpful in rational debate on energy.

5. ***You return home to your house at 16:30 to find the house feeling cold. (you have previously time-switched the heating to come on at 16:00). Which of the following would you do?:-***
   - ***a) turn up the room thermostat;***
   - ***b) turn up the boiler thermostat;***
   - ***c) reset the time clock.***

Neither option (a) or (b) are entirely sensible. If the thermostats have been previously set for comfort then they will automatically adjust to the correct temperature, and turning them up will not speed up the warming of the house. Indeed there is a danger that the temperature will overshoot before the occupants realise and in the meantime energy will be wasted. The problem that many people fail to realise that once a building has cooled it will take some time to come up to temperature anyway (see figure 13). If the occupants regularly return at 16:30 then the times witch should be set to come on earlier than 16:00 in future. Turning up the thermostat does not help

6. ***The radiators in your room are fitted with thermostatic valves. The room temperature is comfortable but the radiators feel cold. What would you do? - adjust the valve or leave it as it is?***

The answer is, of course, to leave the valve as it is. If one is comfortable does it matter that the radiator is cold. Indeed if it is then one is saving energy. This appears to be a physiological issue rather than a rational approach to what is going on.

7. ***Other than space and water heating and cooking, which individual appliance is likely to use the most electricity in the home?***

   The answer to this is given in section 2.2, and for most houses it will be the tumble drier. The greatest savings in electricity costs will be to minimise the use of the tumble dryer. Thus when it is possible it is better to use solar drying outside, or in a drying room if it is available.

8. ***Why** do **energy tariffs vary across the UK?***

   This has been covered in section 5.2

9. ***What benefits are there from generating ones own electricity?***

   This has been covered in section 7

10. ***What is the Renewable Heat Incentive and what benefits are there for the householder?***

    This has been covered in section 8

10. Conclusions

This paper has focussed on issues related to the costs of energy in the domestic sector. As implied there are many other aspects, many which are controversial in the whole energy debate, and it is not possible to cover all adequately. Instead, a moderately comprehensive attempt has been made to answer potential questions which have arisen when presentations about domestic energy use have been given. These issues are changing all the time, and in this respect the topics covered cannot be considered final and definitive. In particular the opportunities now provided by the Feed in Tariffs and the Renewable Heat incentive were not even considered 10 years ago, but they are strategies which can help to reduce energy bills in the future and also tackle the other aspects not covered here of Energy Security and Climate Change mitigation.

There are many myths surrounding energy use, and the questions posed at the beginning and the answers will help to dispel many of these. Equally, there is considerable confusion of unit particularly kW and kWh. Remember that kW are analogous to miles per hour whereas kWh are analogous to miles and the two cannot be interchanged. Thus an electric kettle which consumes 20+ times power as a television actually consumes much less over the year as it is used for much less a time in the year.

An attempt has been made to explain the different tariffs (section 3) used by various Utility Companies and how these have varied over the years and in addition why they vary from different regions of the UK to another. Furthermore reference has been made to the approaches taken in some other countries including a novel approach being explored in Russia which would appear to meet the tenets of the Rotary "Four Way Test" more correctly than traditional tariffs.

In reducing energy used for heating, cavity wall insulation will always be more effective and much more cost effective than double glazing, but it is surprising how many people choose the latter in place of the former. Section 4 also demonstrates that even with an unimproved house from the 1950s it is possible to achieve significant savings, although not quite reaching the standards of house built in recent years which will have insulation beneath the floors etc (compare options h and m).

Section 5 has clearly demonstrated that attitudes among different householder even with the same type of property can significantly affect their energy bills by as much as a factor of 9, and it is here that Rotarians might be able to provide objective information for the community to help them reduce their bills, particularly if combined with the measures outlined in section 4.

Section 6 gives background information on the newer technologies now available to reduce energy bills by generating electricity or heat for the house directly. In previous years there were small grants for installing such, but these have been replaced by the Feed in Tariff for electricity generation (section 7) and the Renewable Heat incentive (section 8) for heat generation and will provide a pay back in around 8 – 12 years and thereafter provide an income for those installing. There are some schemes apparently offering "free electricity", many of these must be treated with caution as outlined in section 7.3.

11. References and further sources of information

Most of the figures quoted in this report have been abstracted from, and processed from, statistical information contained in many of the following sources. In some cases, information has also been abstracted from Annual reports etc. To ensure most up to date information, all data used for analysis were abstracted between July 1st and July 10th 2015 from the relevant Website. Where data from annual reports was cited, these data were compared with recent data from raw data sources

Building Energy Performance Assessment Support Website: http://www.ncm-pcdb.org.uk/sap/index.jsp

In particular the following sub-page

- http://www.ncm-pcdb.org.uk/sap/searchpod.jsp?id=17

Department of Energy and Climate Change (DECC). Website:
https://www.gov.uk/government/organisations/department-of-energy-climate-change

In particular the following sub-pages

- ***Sub-National Energy Consumption Statistics***
  https://www.gov.uk/government/organisations/department-of-energy-climate-change/about/statistics#sub-national-energy-consumption-statistics
- ***Renewable Heat Incentive (RHI): Quarterly Statistics – published 23rd April 2015***
  https://www.gov.uk/government/statistics/renewable-heat-incentive-rhi-quarterly-statistics-march-2015

Elexon Website https://www.elexonportal.co.uk/news/latest?cachebust=ai1h3187v6
(it is necessary to register to use this site on first access)

National Grid Website. http://www2.nationalgrid.com/uk/

In particular the following sub-page

- http://www2.nationalgrid.com/UK/Industry-information/System-charges/Electricity-transmission/Approval-conditions/Condition-5/

OFGEM Website: https://www.ofgem.gov.uk/

In particular the following sub-pages

- https://www.ofgem.gov.uk/environmental-programmes/feed-tariff-fit-scheme/tariff-tables
- https://www.ofgem.gov.uk/environmental-programmes/feed-tariff-fit-scheme/feed-tariff-fit-reports-and-statistics
- https://www.ofgem.gov.uk/publications-and-updates/renewables-obligation-ro-annual-report-2013-14

ROC Register Website: https://www.renewablesandchp.ofgem.gov.uk/Default.aspx

In particular the following sub-pages

- ***ROC Certificates issued***
  https://www.renewablesandchp.ofgem.gov.uk/Public/ReportViewer.aspx?ReportPath=/DatawarehouseReports/CertificatesExternalPublicDataWarehouse&ReportVisibility=1&ReportCategory=2
- ***FIT Summary Reports***
  https://www.renewablesandchp.ofgem.gov.uk/Public/ReportViewer.aspx?ReportPath=/Fit/FIT Installations Statistical Report_ExtPriv&ReportVisibility=1&ReportCategory=9

Vesma Degree Data Website http://www.vesma.com/

In particular the following sub-page

- http://vesma.com/ddd/index.htm