Micro-generation

Power Your Own House!

Price 50p

Background

The notion that energy should be supplied to a dwelling from 'outside' through pipes and wires is relatively new. The first gas main was laid only in 1812 and gas is still not supplied to all homes (13% in England, more elsewhere). The widespread availability of electricity is barely 100 years old. For most of our history our ancestors collected wood for warmth and cooking and used candles for light. Many in the third world still do so today.

The gas and electricity utilities came to dominate supplies because they were more convenient as well as being reliable, cheap and relatively clean. Now the use of abundant cheap fossil fuel is causing global problems. Electricity generation at large remote power stations has received particular criticism because the steam turbine technology used ends up with large quantities of 'low grade' heat which have to be wastefully discarded to river, sea or air. Energy is also lost in transmission to users and, though this occurs with wind farms and other distant renewable sources, there is increasing interest in 'local' or 'micro' generation of electricity in or near homes.

Currently there is a ferment of ideas and, in economic terms, the market is 'chaotic', that is to say the best way forward is still not clear. Actually local generation is only one 'local' technology used to cut energy use.

This note draws on the expertise of Arup, the international consulting engineers, to point a way forward in reducing energy used in buildings, especially homes, and in generating the remainder locally, from renewable sources where possible

The available technologies can be split into 3 groups: micro-generation of both electricity and heat, the use of heat pumps, and greater efficiency of use.

Micro-generation

Solar hot water panels: The simplest and best proven technology is the simple solar hot water panel mounted (ideally) on a south facing sloping roof. Direct and indirect sunlight heats water (or another fluid) in the panel and the heated water passes through a coil in the house hot water tank. A 4 person household would need about 4 square metres (m^2) of panel and a hot water tank some 250 litres capacity. The pump is controlled by a thermostat which switches it off when the temperature in the panel is lower than in the tank, and when the tank temperature reaches an upper limit. The system may be drained in winter (or anti freeze added) but other maintenance should be limited to an annual check. Cost, including installation, will be between £1500-£3000 and this will typically provide 40-50% of annual hot water including nearly all needed in the summer. It will not provide central heating. About one third of the heat required in a house is used for hot water so a solar hot water panel would save about 15% of the heating bill. Payback would take at least 10 years with a gas fired boiler but much less with electricity. Technically there is no reason why hot water panels should not be installed on most new houses, particularly in the south of England. Worldwide this simple technology produces more renewable energy than wind.

Because the panels can not meet all demand the house hot water tank requires 2 heating coils (or a supplementary electric element). This means that in existing houses the hot water tank has to be replaced, adding a few £100s to the cost.

Small wind turbines: These are usually mounted on a pole fixed to a wall taking them above roof level. The 1 kW Windsave has gone out of business but 1.4 kW, 2.1 metre diameter Swift and 0.6 kW Ampair turbines remain on the market. The electricity produced is fed into a black box to synchronise the power with the mains and plugged into a 13 amp socket. When the wind is blowing and the householder is using electricity some power comes from wind.

An elegant, quiet 6 kW wind turbine suitable for an apartment block

Initially electricity savings of 30% were claimed but in practice output in towns has been poor. The wind is obstructed by houses and rarely as strong or steady as in rural areas. From April 2010 a feed-in tariff of 36.5p/kWh is paid for all electricity generated from micro turbines (and solar panels) plus 5p more for any electricity exported to the grid but only favourable sites in rural areas are likely to make much money. One advantage of wind turbines is that they can be retro fitted to properties.

Though imaginative, household turbines may not prove the best solution. There is an inevitable mismatch in a single household between demand and supply. The greater the number of houses the more the demand for electricity evens out. 50 kW wind turbines, supplying say 30-50

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This briefing note has been written by Richard Balmer and the opinions expressed are his own. It should be technically accurate but if you see errors or have comments, please contact him at richardbalmer162@btinternet.com

houses or apartment blocks, would have lower costs, greater utilisation, and better value for money if residents agree to accept them.

Solar photovoltaic (PV) panels: PV panels suffer in comparison to wind. They are more expensive and, in the UK's northern latitudes, inefficient. Average utilisation is barely 10% of the installed capacity and the panels give a direct current (DC), usually 12 volts, which has to be transformed to the 230 volt AC mains supply using an 'inverter'. Formerly performance tailed off with age but longevity is stretching out from 25 towards 50 years. Even so if PV panels are used instead of roof tiles in new housing the owner will have to replace the roof (or part of it) or forgo the solar electricity at some point in the future. This is less of a problem with commercial buildings which have shorter lives.

The Energy Savings Trust quotes £12,000 to install 2.2 kW of solar panels. On the south coast one might achieve an annual output equivalent to 900 hours use so at 10p/kWh the income would be about £200 a year, a mere 1.7% on the investment and insufficient to cover the capital cost. The latest feed in tariff of 36.5p + 5p for exports raises this to over £700 and perhaps 6% which is better. The economics get worse as one moves north or doesn't have a south facing roof or optimum tilt. Further south around the Mediterranean for example, there is much more sunshine and there is an argument for waiting for the market there to develop first.

Micro-CHP: Whereas wind turbines and solar panels can only supply energy when the wind blows or sun shines, a true micro-generator is like one's own small power station. Even so one must not be carried away. The advantage of generating electricity locally is to use the otherwise wasted low grade heat. Small may be beautiful but is invariably more expensive and less efficient. Here we are considering the provision of combined heat and power (CHP), not power alone.

Basically micro-CHP replaces the conventional hot water/central heating boiler with a unit the size of a washing machine. It uses a 2 stage process. The hottest gases from combustion generate electricity and the remaining 'low grade' heat used for hot water and central heating. Micro-CHP can use 'biomass' fuels such as wood pellets or chippings as easily as gas or solid fuels, though energy is saved even using gas.

Small machines cost more per unit of output than large ones so capital costs are high, around £4200/kW of electric output. The disadvantage with micro-CHP is, again, the mismatch between electricity and heat demand. The need for heat goes up and down with outside temperature whereas electricity varies by the hours of darkness and daytime household activities. Furthermore the efficiency of generating electricity is relatively low, barely half that achieved in big power stations. It is usual to run micro-CHP according to the heat demand and accept the electricity as a bonus. Though some electricity can be exported to the grid, the need for the national grid remains.

Even so electricity bills will be reduced. Also, where biomass can be employed instead of gas, CO_2 emissions will reduce from around 0.2 kg/kWh to an eighth of this. Biomass from forestry sources will cost about half that for gas and waste biomass even less, although there will be costs and complications in purchasing and storing fuel. Alternatively biomass can be grown in one's garden, though the garden needs to be about 4 times the area of the house.

The economics for CHP are similar to wind. One will achieve lower costs and greater utilisation with large units supplying apartment blocks or new estates than individual houses.

Fuel cells: Fuel cells produce electricity directly by burning hydrogen over a catalyst in air. There is great interest using fuel cells to power vehicles but they are costly and the holy grail of producing the fuel, hydrogen, renewably and cheaply is still being sought. Fuel cells for individual households would be an ideal solution because they could provide the 'back up' electricity currently needed from the national grid but commercial exploitation is 'over the horizon'.

Heat Pumps:

Heat pumps to air: Refrigerators and simple air conditioning units act as 'heat pumps'. Refrigerators are devices which move heat from inside an insulated 'box' to the outside at the back so the air behind a refrigerator will be warm. Heat pumps use the physical property that liquids need heat, not just to reach boiling point, but to boil off as gas (and vice versa). A kettle may boil quickly but takes a long time to boil dry. A heat pump comprises a compressor and evaporator. The compressor converts the gas to a liquid releasing heat. The evaporator reverses the process. In a fridge the first half of the cycle takes place outside and the second half inside the 'box'. The released heat dissipates into the surrounding air. The box type air conditioning units one sees in warmer countries operate on the same principle. Such units reverse in cold weather to provide heating.

All heat pumps use electricity but the energy gained can average 3-4 times the energy employed. Such pumps could be employed more in the UK. One drawback is that the pump operates at one point and the heat still needs to be distributed through-out the house, making retrofitting difficult. Another is that efficiency drops with outside temperature and the pump will eventually freeze so supplementary heating is still needed. Lastly, savings over gas are poor as electricity (to drive the pump) is about 3 times less energy efficient. On the other hand heat pumps are safe, need no maintenance and are relatively cheap

Heat pumps to ground: Heat pumps to air have obvious disadvantages where houses are close together. More recently the idea of drawing (and discharging) heat to the ground has come to prominence. A borehole is drilled and a plastic pipe loop installed. The loop runs into the house to a heat exchanger where the heat from the water/anti-freeze mixture in the pipes is abstracted for the house before the mixture returns, cooled, to the ground where it is warmed back to its original temperature. The borehole needs to be deep: 15 to 120 metres have been used. The depth depends on the ground conditions and in particular whether one can rely on the movement of water in the ground to continuously bring heat to the borehole. Costs amount to £800-1200/kW of heat, so a typical 6 kW system would cost around £6000. The temperature achieved with these systems struggles to exceed 40^{o} C so they are most suitable for under floor heating systems which require hot air at 30-35^{o} C. They can pre-heat but not fully heat hot water, nor feed central heating radiators which need water at 60-80° C. Electricity is also needed to power the pumps. Again there is a larger energy saving if the house is heated by electricity but not by gas. Although boreholes are preferred, because ground becomes warmer with depth, the pipe can be laid out in shallow trenches if land is available.

This market is still developing but the technology is relatively simple and tall buildings which use concrete piled foundations are incorporating these loops in the piles during construction killing 2 birds, as it were, with one stone. Though more expensive, ground source heat pumps do not risk freezing in cold weather (a clear advantage) and, if 2 or more households can use the same borehole, costs can be shared.

Greater efficiency:

Appliance efficiency: Appliances are consistently being improved. An EU energy labelling scheme under directive 92/75/EEC has been in force since 1994 and is to be uprated under 2010/30/EU on 31st July 2011. This will bring in the familiar 7 colour A-G rankings for TVs for the first time and add A+++, A++ and A+ rankings to washing machines, fridge freezers and dishwashers (where, apparently 90% sold are already A), and make the E-G ones illegal. Remarkably an A+++ fridge freezers will be 60% more efficient than an A. Washing machines, tumble driers, dishwashers and so on tend to have working lives of less than 10 years so, unlike housing stock, efficiency improvements can be captured quickly. These and TVs use about 30% of household electricity. Halving this would be significant.

Unfortunately the number of appliances increases yearly. 50 years ago a typical home had a wireless and Hoover. Refrigerators, washing machines, televisions, dishwashers, freezers, microwave ovens, food mixers, waste disposal units, videos, CD recorders, computers and printers, security lights and so on have all increased demands for power. Many homes have several TVs and computers and the availability of the internet and computer games lead to many hours of use. Plasma TVs use 5 times the energy of conventional ones. The average fridge size went up by 15% between 1995-2001. Efficient lighting is widely available (though appropriate lampshades are still hard to find) and tungsten bulbs are going but lighting is now more creative and more bulbs are used. Whereas cooking used to be by gas, now it is electricity which is perceived to be cleaner though using 3 times the energy. In the future air conditioning is likely to become standard, if only in one room. In short, despite efficiency improvements, the use of electricity in the home goes on up.

Better insulation: Insulation standards have been improved steadily since they were first included in the building regulations in the 1970s. The 2006 regulations should reduce heat loss by 20% over 2002 ones and the 2010 and 2013 regs should improve the 2006 standards by a further 25 and 44% respectively. High quality insulating board containing air under partial vacuum is available and new buildings are now supposed to be tested for 'leakiness'. Two problems remain with retrofitting. First, though one can add insulation in the loft, double glaze windows, fill cavity walls with foam (no one seems to know how many cavity walls remain without foam) and reduce drafts, it is very difficult to add insulation under floors. Second, as the heat lost through the fabric decreases, the energy required to warm incoming cold air becomes more significant. Obviously a minimum quantity must enter so, if this heating is to be reduced, the outgoing warm 'fuggy' air needs to exit via a heat exchanger to warm the fresh air entering. The necessary ducting can be incorporated in new buildings but not cheaply in existing ones. There is also a reluctance by many to 'do anything' like clearing out the loft for the insulators. The Germans however have had programmes to do whole streets at a time and the coalition seems willing to do the same.

Summary:

New homes: It is technically possible to design a 'carbon neutral' house. Thus is not the same as 'self sufficiency' but one which, over a year, could have zero *net* energy demand. It could be self sufficient in heat but not, easily, in electricity and a national grid connection is still required to provide a dump and back up for the micro sources.

A carbon neutral house will require more technology and maintenance than people are used to. More items will go wrong and there will be consumer resistance until the technology is proven. Table 1 shows what would be needed and the estimated *additional* costs for a 3 storey 150 m² town house costing £360,000 (£1200/m² for building, £1200/m² for land). The extra costs will not reduce much with smaller, cheaper houses but the additional amount, 5% or even 10%, is remarkably small. In part this is because, though more expensive 'bits' are needed, labour costs are much the same.

It should be noted that some of the technologies described above are mutually exclusive. For example there is no advantage in installing solar hot water panels if one is heating hot water with a biomass fired CHP unit. There are 2 other cautionary notes. The maximum amount of installed wind capacity that can be deployed in the UK is limited. If house

Technology	Extra cost £
Mechanical ventilation via heat exchanger	1,800
Low energy light fittings throughout	300
All white goods class A rated	-
Visible displays of current power + water use	-
Water efficient toilets	300
Spray taps in hand basins	300
Low carbon CHP with biomass + gas backup	1,800
Insulation to U = 0.11W/m² (c. 300 mm thick) for walls, roof, ground floor	4,200
Triple glazed, Argon gas filled windows	900
Solar PV panels over 20% of roof	5,250
1.5 kW wind turbine	3450
Total	£18,300

Table 1 Extra cost of energy reduction technologies for 150m² 3 storey town house. 2006 prices

mounted wind turbines are erected in their millions, that capacity will eventually be at the expense of large wind farms which currently produce electricity at least 2 or 3 times more cheaply. A similar reservation applies to the use of biomass in micro-CHP. There is insufficient spare land for the UK to be self sufficient in biomass. We can either use that land for bio-fuels or biomass power stations or micro-CHP, but not all of them and not even all of one. For true sustainability the country actually needs fewer people.

Existing homes: Not all the technologies listed in Table 1 can be introduced into existing dwellings at any kind of sensible cost. On the other hand much, besides simple good housekeeping, can be done. In order of priority this is:

1. If an appliance can not be repaired, replace with a Class A++ alternative at least. Similarly replace conventional lights with low energy ones.
2. Invest in insulation up to 300 mm in the roof, foam in the walls, double glazing in windows and draft excluders, where not already in place.
3. If heating uses electricity investigate an air or ground source heat pump and a solar hot water panel. In southern counties consider solar PV.
4. In rural areas consider a wind turbine if the neighbours don't mind and micro-CHP using locally grown biomass.

Conclusions

Micro or local generation of power can only make a small contribution to CO_2 reduction because the potential gains are constrained by the slow turnover of the country's energy inefficient housing stock. If it is assumed that buildings use 50% of all energy and that they last on average 100 years; that carbon neutral buildings arrive as early as 2016; but that gains in efficiency in existing buildings are offset by the increased numbers of buildings and equipment used within them; then UK CO_2 emissions would only reduce by 2% by 2020 and 17% by 2050 from improvements in building technology.

However, another route is opening up. Underlying the possible changes described above is the fact that it is relatively easy to reduce heat demand, first by better insulation and then by displacing gas with electricity, for example using heat pumps. Gas demand should go down whilst electricity increases. If that electricity is provided by low carbon electricity - renewables, nuclear and fossil with carbon capture and sequestration - we would have a near zero carbon house without needing to rely on micro or local generation. In truth it seems as though the plan for zero carbon housing by 2016 is being quietly dropped. It is thought developers will be offered the option of paying for an equivalent tranche of zero carbon energy if they can not make their development zero carbon itself.

The pressure to make housing zero carbon however must remain and every support given to the dry sounding, but absolutely critical, 'Building Regulations'. Section L of these regulations determines minimum standards for insulation and energy use. The Building Regulations 2006, in force since 6th April 2006, should be reducing CO_2 emissions by an average of 20% from the standards introduced in 2002 which themselves aimed to reduce emissions by 20% from Building Regulations 2000 (mainly by setting much higher standards for the efficiency of central heating boilers). The 2006 regulations provided, for the first time, for a pressure test of the property (to check for drafts and leaks through poor design or construction) and allowed architects the welcome opportunity to achieve the set TER (Target Energy Rating) in various ways to encourage innovation, rather than by prescription. The standards however remain far short of those achievable in Table 1.

The second, linked, initiative is to get as many of the emerging technologies as possible into houses (or apartment blocks or estates where the economics may be better) *as soon as possible* and in as large a number as possible, and *tried, tested and 'tuned'* so that by 2015 at least architects, builders, house buyers and legislators have the confidence (and the supporting evidence) to introduce them in all new properties.

So, the strategy should be first to reduce the energy demand of all new houses as far as possible and only then choose the optimum way to manage the import and export of electricity to and from the grid and, second, to find ways to improve the energy efficiency of existing housing as far and fast as possible.

This country is full of innovative people and innovative ideas. What we lacked until the coalition was a government with technical know how and foresight. Planned programmes and sound research are needed to test the technologies, including such things as cutting the energy cost of making housing materials such as bricks. The critical point is that the sooner this is done, the sooner ideas can be either be rejected or, hopefully, cross the bridge to commercial market.

The feed in tariffs for micro wind and solar PV sound good but will not be enough.

PROFESSIONAL ADVICE

As noted on the first page, the majority of the material for this briefing note has been drawn from a presentation given by Chris Trott, of consulting engineers Arup, at Harrogate in March 2006. More advice can be obtained from Chris at:

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A further source of useful information is the Energy Savings Trust