ECONOMICS

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Sustainability Domestic power

With wind turbines for sale at DIY shops and a stampede breaking out for renewables grants, has micro-power generation really arrived? **Simon Rawlinson** of **Davis Langdon** considers the options for domestic low and zero-carbon systems, and adds up the costs

01 Domestic low and zero-carbon energy

Barely a day goes by now without a policy announcement on sustainability. Although proposals for compulsory carbon emission targets in the forthcoming Climate Change Bill could give the carbon reduction lobby real teeth, it is the headline grabbing items – taxing 4 × 4s or the exemption of surplus domestically generated electricity from income tax – which dictate the tone of much of the sustainability debate.

Low and zero-carbon (LZC) technologies have received considerable attention, mostly focused on a few high-profile schemes in the commercial and public sectors. However, since all buildings must eventually reduce their carbon emissions, will small-scale renewables provide the most effective solution?

As a major energy consumer, the UK housing stock is challenging from many perspectives. First, a high-proportion are old and poorly-insulated, with low-efficiency heating and lighting. Second, consumption of energy in the home is increasing, as economic well-being results in the use of an ever-growing list of appliances and gadgets.

Third, the intensity of the UK's occupation of housing is falling, and as small households produce a disproportionately high carbon emissions, this is likely to place greater strain on our ability to meet our EU and domestic carbon reduction commitments.

Without question, the optimum strategy for cutting carbon emissions is reducing the need for energy in the first place. Changing occupant behaviour and improving the thermal performance of buildings are the most effective ways of reducing emissions, particularly as, in the case of building fabric, once an improvement is made, savings are continually accrued.

However, as carbon reductions of greater than 50% are needed to meet long-term targets, renewable energy sources are important too. Since the expectation is that technology will provide the solutions to global warming and as people want to be seen to be green, it is not surprising that some low-carbon pioneers have opted for more readily installable and recognisable sustainability investments such as solar panels or wind turbines.

These have been the most potent visual and technical symbols of sustainable development. Recent government measures, such as the DTI's Energy Saving Trust grant programme and the forthcoming Climate Change Bill, encourages investment in low-carbon fuels and technologies, and changes to make it easier for individuals to receive an income producing energy.

Rocketing demand for grant funding from the Energy Saving Trust illustrates the growing interest in LZC technologies. The DTI has allocated £12.5m this financial year to stimulate interest in domestic LZC. March's £500,000 allocation was taken up within an hour after the online application process opened. The wider availability of systems, such as B&Q's wind turbines and solar collectors, are increasing awareness and take up.

But before we all rush off to invest in renewables we need to ask whether current technology is able to provide effective solutions? And in adopting the low-carbon technology route, are householders investing their limited sustainability resources wisely?

02 The case for and against domestic LZC systems

The case for domestic LZC technologies goes beyond the reduction of carbon emissions to a wider case for diversifying the UK's energy supply market, based on abundant resources such as wind and solar.

Domestic systems are a deliberate shift away from large-scale generation, which achieves huge economies of scale, but often at the cost of low efficiency, such as the 50% energy conversion achieved by coal-fired power stations. While it is probably unrealistic to expect small-scale generation to be as cost effective as the national grid, it must be a reliable source of energy, and must produce energy when most needed.

Domestic renewables such as small-scale wind, PVs and solar water heating are promoted as being crucial to reaching the 10% carbon emissions reduction target set by government for 2010. However, as the UK is well supplied with wind resources, more effort is currently going into the development of large-scale plant in well-suited locations.

Setting aside large-scale wind power, the main policy priorities for investment in domestic LZC technologies are:

- **Encouraging the reduction of carbon emissions from housing**
- **Diversifying power sources for heating and electricity**
- **Developing more efficient technologies, such as CHP and biomass systems based on wood pellets**
- **Promoting local power generation to reduce transmission losses and load on the existing infrastructure**
- **Creating smaller-scale solutions for dwellings in remote locations, without access to most efficient sources of energy, such as those reliant on coal, oil or bottled gas.**

A zero-carbon, zero-waste development in Brighton, by BioRegional Quintain and Crest Nicholson

03 Available domestic LZC technologies

Sections four to nine outline the LZC technologies available and their current market positions. A summary table sets out the costs and outputs of typical systems. Here is a summary of the typical energy consumption figures for a modern family home as a benchmark for the contribution typical LZC systems need to make to have an impact on the carbon footprint of a household:

Heating and hot water = 21,500 KWh
Lighting and small power = 4,000 KWh

04 Biomass

Biomass is an emergent technology in the UK, particularly as there are limited reliable sources of feedstock. Most UK biomass is produced as a by-product of timber manufacturing and is consumed as woodchip. High efficiency combustion based on wood pellets can reach generation efficiencies of up to 92%, but volumes of biomass required can be large.

Consultant XCO2 has calculated that a conventionally insulated house requires more than $10m^3$ of biomass a year – with significant implications for transport and storage. As a result, the technology is better suited to highly-insulated homes with lower heating requirements. As a feedstock, biomass is virtually carbon neutral: net emissions only relate to transport and pellet production. Consequently, the availability of local supplies is an important factor in minimising carbon impacts.

Advantages

- Carbon neutral technology owing to closed carbon cycle
- High conversion efficiency if based on pellets
- Potential to support local energy industries in rural areas.

Disadvantages

- Volume of fuel required
- Recurrent fuel cost, with no stable national pricing structure.
- Availability of local fuel supply determines carbon output and running costs
- Requires secondary heat source for low-season water heating
- Potential smoke and fumes from woodchip biomass.

Summary

While biomass has received much attention as a solution to the Greater London Authority's 10% renewable target, there has been less focus on rural markets where absence of networked gas and availability of farmland for cultivation makes it attractive. Owing to transport problems, biomass should only be considered for highly sealed and insulated buildings. Furthermore, its take-up may be held back by the lack of a diverse and secure supply industry.

05 Micro CHP

CHP in the UK is associated with large installations, such as in hospitals. Data from the end of 2005 recorded about 1,500 CHP engines in operation in the UK, producing 5,800MW, equivalent to 7.5% of the UK's total electricity requirements.

Micro CHP, defined as units with a total output of 50kW, is set to make a splash in 2007, with the mass-market launch of products specifically aimed at the domestic market by producers Microgen and Baxi. With a potential market of 12 million homes, drip-fed by the steady demand for replacement boilers, CHP has the potential to be a common, user-friendly aspect of LZC.

The latest CHP models are based on a 200 year old external combustion concept, the Stirling engine, which is particularly good at supplying steady output with low noise levels. CHP is of course not a renewable technology, and at a domestic scale, the attraction of the system is in higher levels of energy conversion efficiency, a reduction of transmission losses related to the electricity component and the creation of greater diversity in the supply infrastructure.

Given that electricity constitutes only 15% of CHP output, and that generation only occurs during the heating season, the opportunities to generate surplus electricity are limited. Manufacturers claim that domestic CHP will save about £200 a year in fuel bills and 1-2 tonnes of carbon, compared with existing (non Part L-compliant) heating systems. Units sized for a typical house will be offered to homeowners for about £3,000, and for as little as £1,400 for housebuilders.

Advantages

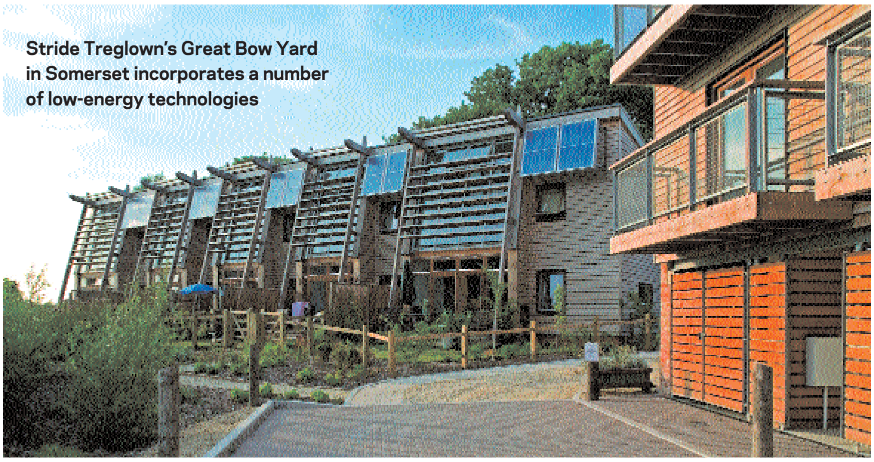
- Combustion efficiencies of up to 95%
- Low cost and simple installation
- Could directly replace existing central heating boilers
- Heating operation coincides with peak demand periods for electricity
- Ability to export excess electricity to National Grid

Disadvantages

- Inherent carbon emissions
- Seasonal patterns of electricity generation, restricted to heating season
- Continuing reliance on grid electricity to make up shortfalls
- Viability affected by fluctuating price of grid-generated electricity
- Only viable in dwellings with higher thermal requirements (large or less well insulated)
- Low ampere rating: typically 4-6A.

Summary

CHP is best suited for relatively large dwellings as a form of energy diversification. It is also easy to install and operate. While CHP achieves high levels of efficiency and some reductions in CO_2 emissions, it cannot realistically make a big contribution to large-scale reductions in carbon emissions.


Stride Treglown's Great Bow Yard in Somerset incorporates a number of low-energy technologies

06 Ground source heating and cooling

Ground source heating systems use the compressor technology of the refrigerator and the constant temperature of the below ground "heat sink" to provide a steady source of medium grade heat. Ground source heating is not strictly carbon-neutral as electricity is required to run pumps and compressors. However, the pump power conversion rate is around 4 or 5:1, making it an effective low carbon system.

Ground source heating is best suited to steady background heating loads such as under floor heating and as it cannot be modulated, should be sized to the base load of a building only. Supplementary heating is required for hot water and peak loads, although some of this load could be met with complementary technologies such as solar.

Advantages

- **Provides a constant and reliable source of heating energy**
- **Scalable, with the potential for a sizeable energy output in comparison to other on-site renewable technologies**
- **Competitive running costs when compared with electric heating but only if capital costs are excluded from consideration**

Disadvantages

- **System size: a 10m trench is required to generate 1kW of output.**
- **Civil works requirements: owing to the extent of trench works, the system is only feasible when combined with other works**
- **Need for mains electricity for operation**
- **Need for back-up systems for heating and hot water**
- **Low operating temperature of hot water means the system is unsuitable for radiator-based heating systems.**

In conclusion, ground source heating presents an opportunity for some new build development, although the land requirements and the need to specify under-floor heating rule the technology out for many domestic applications.

07 Wind power

Wind power is potentially the UK's most cost-effective renewable resource. The UK has an abundance of good-quality wind resource and although planning is still a major hurdle, large-scale wind power is the UK's preferred renewables option. The economics of wind are driven by two factors: wind speed and rotor diameter, with economies of scale acting strongly in favour of turbines of with a capacity of greater than 1MW. Micro-wind is defined as units of less than 4m diameter, having an output of up to 3.5kW.

Another performance factor particularly relevant to micro wind power is quality of wind flow. Poor wind flow can have a detrimental effect on output levels, efficiency and unit longevity. Poor wind quality is often experienced in urban locations, where neighbouring buildings disrupt turbine operation. The height of the turbine installation relative to neighbouring buildings will help to determine efficiency – ideally they should be 9m above other obstructions within 100m, which is impractical for a domestic installation.

Owing to the site-specific nature of wind, results are uncertain. The B&Q 2.7m diameter micro-turbine for example has a peak output of 1kW, achieved only at speeds between 28 and 34mph, which is rare, even in an increasingly volatile UK climate.

Given the uncertainties involved and the greater efficiency of large generators, large turbines are a better option, although few people will have the site or finances for a turbine this size. A 6kW turbine will generate about 10,000 kWh per annum, saving 4 tonnes of CO_2.

Advantages

- Wind is free and unlimited
- Low cost, relative to output
- No motive power required once installed
- Correlation between availability of wind and demand for power.
- Long operating life and low maintenance requirements

Disadvantages

- Problems with visual impact and operational noise
- Requires a long-term wind survey and planning consent
- Substantial pylon structures required
- Vulnerability to changes to neighbouring development that could disrupt wind flow

Summary

Although wind has great potential in the UK, micro-wind is in many cases a high-risk option that should be considered only in locations with a reliable prevailing wind supply.

Wind turbines at ZEDfactory's RuralZed in Upton, Northamptonshire

08 Photovoltaic cells

PVs are another well known and established technology. Having been in production for 40 years there is only a limited prospect of further efficiency improvements to panels. BP's most recent product achieved a 4% improvement in conversion rates.

As a result, cost reductions can only come from an increase in market size. Cost is a real barrier. In Germany the market has been sustained through a large subsidy paid in the price of electricity exported to the grid.

Although PVs do not face the economy of scale issues of wind, there is a constraint on PV output related to available roof area with a suitable aspect and pitch. Even for the most efficient monocrystalline panels, 8m^2 of PVs are required to generate 1kWp – an output that will typically contribute about a fifth of annual household electricity consumption, and will reduce carbon emissions by about 0.3 tonnes a year. Panels have a life of 25 years so full payback is uncertain at current electricity prices.

Other variables affecting cost and complexity of the installation include the location and orientation of the panels, shading, temperature control, framing and controls and inverters. Once in use, panel cleaning and monitoring of performance to ensure the system is operating efficiently are important.

Advantages

- Free energy once the system is installed
- Scalable system based on modular panels
- Potential for substitution of other cladding or roofing materials
- Complementary with wind power.

Disadvantages

- High initial cost and extended payback
- Must be integrated into the new-build construction programme
- Power generation is not synchronised with peak demand which necessitates export to the National Grid.
- Potential for underperformance, so in-use monitoring required.

a Areas required for the production of 1kWp

	Efficiency	Area required
Monocrystalline	15%	8m^2
Multicrystaline	13%	10m^2
Amorphous	7%	20m^2

09 Solar hot water

Solar collectors are used to generate higher levels of heat from solar energy than can be achieved by passive measures. The main objective is to heat domestic hot water, although heating systems can also be supplemented. A typical domestic solar hot water system of 1,000 to 2,000kWh can provide about 70% of annual hot water needs, saving about 0.2 to 0.4 tonnes of carbon per annum.

Systems based on the circulation of liquids and air are both available, with the most efficient and expensive, based on an evacuated tube system, similar to vacuum flask technology.

Recent developments include systems compatible with combi-boilers – preheating water before it flows through the boiler.

Apart from their greater thermal efficiency, evacuated tube systems are more effective at capturing energy from the sun as it moves across the sky, but have a deeper section and can be visually obtrusive. Most solar hot water systems require electrical power for pump operation and some panels incorporate PVs to provide this energy. Retrofitting solar collectors may also require changes to the existing hot water system.

Advantages.

- Most systems provide all hot water requirements during summer months
- Simple, self contained system
- Relatively short payback period.

Disadvantages

- Effectiveness reduced in winter and by shading.

Connecting to the national grid

Although the government is introducing measures to encourage export to the local grid by small scale generators, the process is quite complex and there is little incentive for supply companies to engage with the domestic sector when they can fulfil their existing renewables obligations with large-scale suppliers.

Issues that need to be dealt with include:

- Notification under Building Regulations Part P in connection with the micro-generator
- Planning consents associated with external features such as turbines or PV panels
- Compliance with electricity safety, quality and continuity regulations, with requirements for additional switchgear at the network connection
- Revised supply agreements to cover reverse power flows
- Updated meters that permit the measurement of reverse flow.

Previously ...

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16 March	The tracker Germany profile
23 March	Cost update

Data **toolkit**

Building's database of cost data is an essential for anyone procuring buildings. There is an archive of cost models, market forecasts, whole-life costings, specialist costs, procurement and sustainability articles and many more besides.To gain access to all this information, see www.building.co.uk/datatoolkit

Cost of Going Zero Carbon

Building is hosting a one-day conference called the Cost of Going Zero Carbon, exploring how to meet the challenge of delivering zero-carbon buildings. Topics include costs, planning issues and the value of buildings. It will cover different responses to the challenge, from completed projects to future zero-carbon communities. The event will be on Wednesday 13 June 2007 at The Commonwealth Club, 25 Northumberland Avenue, London WC2. For details contact Catherine Moore on 07771-704844 or email catherine@moorestyle.co.uk

10 Comparative cost and performance

LZC System	Typical output	Capital cost (£)	Carbon reduction (Kg CO_2/pa)	Payback period (years)
Micro CHP	heating: 18,000kWh, electricity: 2,400kWh	1,000-3,000	600/kWp	3-4*
Biomass	20kW	5,000-6000	0.3/kWh	na
Ground source heating	8kW	800-1,400**	0.1/kWh	na
Wind (very small scale)	1kW	1,500-3,000	0.41/kWh	30+
Wind (small scale)	1.5-6kW	4,000-18,000	0.4/kWh	20-30
Photovoltaic cells	1.5-2.0kWp	4,000-9,000/kWp	300/kWp	Up to 120
Solar panels, flat plate	3kW	2,000-3,000	0.2/kWh	10+
Solar panels, evacuated tube	3kW	3,500-4,500	0.2/kWh	10+

** excludes civil works and underfloor distribution

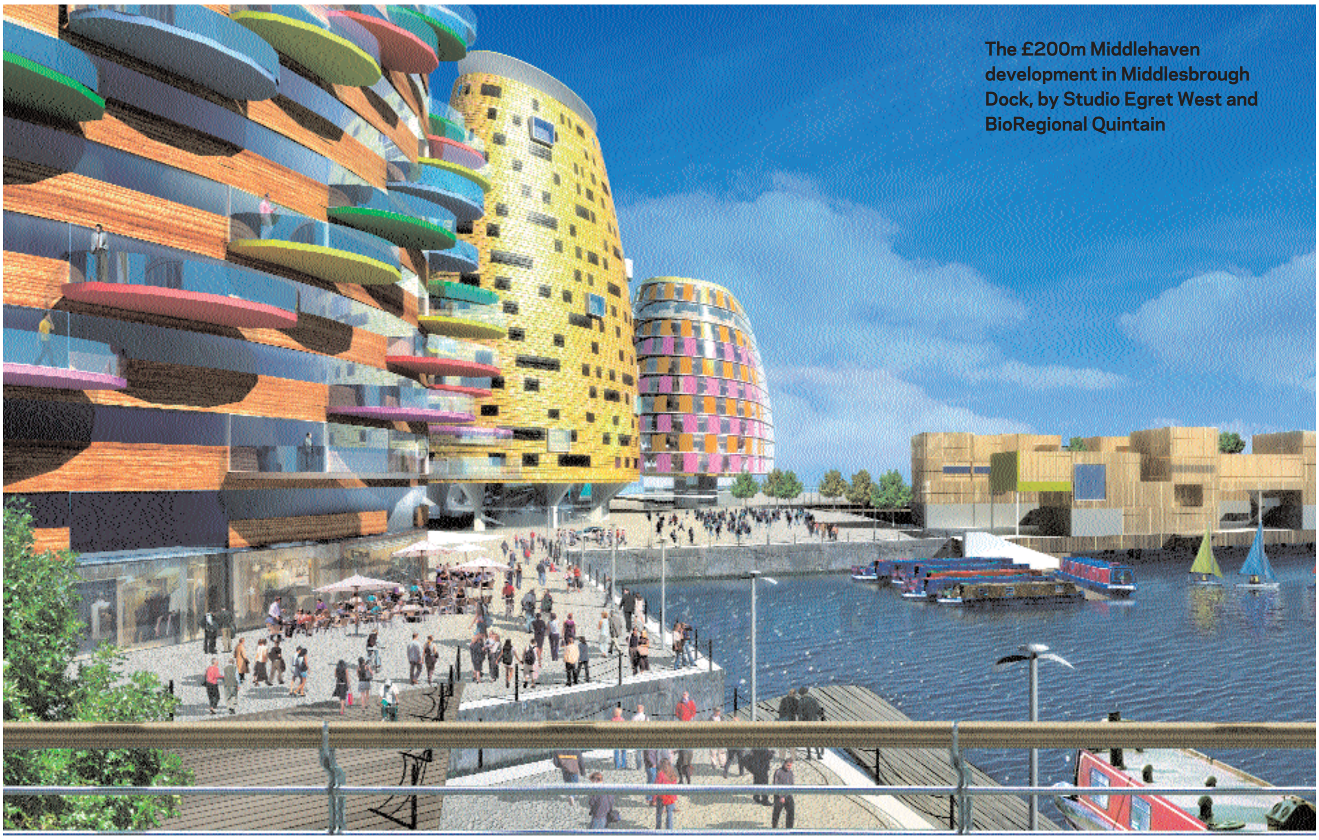
* payback based on extra cost compared to conventional boiler

11 Overview

This analysis has shown that no single technology can substitute conventional energy sources.

Issues associated with zero-carbon technologies include relatively low output, lack of diversity, and uncertainty with respect to performance in situ. Given the small scale and fragmented nature of the renewables industry, the profusion of products and the difficulties associated with predicting performance, investors should be encouraged to see domestic-scale renewables as being a secondary step in reducing carbon emissions rather than the first option. Low carbon technologies such as CHP present a different challenge in that they continue to give occupants security of supply and complete elasticity with respect to energy use. While they contribute to a marginal reduction in emissions, they may not promote large cuts in carbon emissions. Low and zero carbon technologies have a place in the reduced carbon agenda, but are probably more effective at a commercial scale.

At the domestic scale, the owner or developer's priority should be to eliminate carbon consumption through significant improvements over Part L in thermal performance, either through the application of passive design principles to new-build, or through extensive retrofit of thermal insulation and draught-stopping to existing buildings.



The £200m Middlehaven development in Middlesbrough Dock, by Studio Egret West and BioRegional Quintain