The rooftop power revolution

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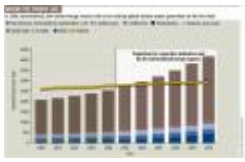

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Where the power lies

LATER this year, when Queen Elizabeth turns 80, she will see a dramatic drop in her electricity bills. This is not a special deal for the UK's senior citizens. The cut in the royal fuel bill will come thanks to a hydroelectric plant on the river Thames, which will start supplying power to Windsor Castle, one of her numerous homes.

The £1 million scheme, which will supply up to 200 kilowatts of electricity, is being developed by the electricity generating company Npower. The generators will be driven by four turbines now being built into Romney weir, about 800 metres from the castle. The generators will make a substantial dent in the royal electricity bill, supplying about a third of the castle's needs. And the cost of the upkeep will be minimal. "Once they're in you can pretty much leave them alone," says Patrick Spink of Npower Renewables, the company installing the turbines. "They are likely to be there for 100 years."

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Not everyone has a large river at the bottom of their garden. But almost all of us can trim our utility bills by generating our own energy. Photovoltaic tiles or a small wind turbine on the roofs of houses or apartment blocks are no longer a rarity. If these and similar small-scale generators were installed in large numbers they could have a significant impact on energy policy, helping to slash carbon emissions and taking the strain off overloaded distribution grids. A growing enthusiasm for renewable energy has also stimulated development of new small-scale energy generators that are reliable, simpler to install and, most importantly, capable of exporting the power they create onto the grid. "The potential is pretty significant," says Dave Sowden of the Micropower Council, the UK industry association that promotes small-scale power generation. "We are talking about turning power generation into consumer products that you can buy at a DIY store."

Faced with record oil prices and a desire to cut carbon emissions, most governments are looking at alternatives to fossil fuels. But can converting homes into power stations really turn conventional energy policy on its head? How much power can microgeneration contribute, and what technical issues must be solved before we can all begin to harvest and sell our own energy?

A single 1.5-kilowatt wind turbine seems insignificant compared to a 1000-megawatt nuclear power station, which some tout as the only hope of curbing greenhouse emissions. But according to a recent UK report prepared for the government-sponsored Energy Saving Trust (EST), home power generators of various kinds could provide 30 to 40 per cent of the country's electricity needs by 2050 - by comparison the UK's nuclear industry provides 20 per cent of current needs.

Microgeneration can bring several advantages. Energy from wind, water or the sun does not depend on gas or oil from countries whose governments can turn off the tap without warning or hike up the price. On top of that, the EST estimates that by 2050, microgeneration could cut the UK's carbon emissions by 15 per cent compared with the present mix of energy generation. And unlike large generating stations, which require a lead time of years, microgeneration capacity can be built up steadily - an incremental change that could, for example, remove the need for a new nuclear power programme.

The UK's liberalised energy market has helped to make it one of the world's leaders in microgeneration, says Jon Slowe of Delta Energy & Environment, a European consultancy specialising in small-scale

power generation. The UK also has a microgeneration strategy document due for delivery this spring. "It's quite a contrast to the rest of the world," Slowe says. "No one has really paid any attention to the household sector before."

So what qualifies as a microgenerator? In the UK the term is used to describe generators with an output of less than 50 kilowatts, but in other countries the term small-scale can apply to installations running into the megawatt range. And there is no single favoured way of generating power (see "Home-grown power"). Manufacturers of wind turbines and photovoltaic panels say global sales are growing by 20 to 40 per cent a year. Water power is gaining popularity too: in the south-west of England, for example, dozens of old water mills are being equipped with turbines capable of generating tens of kilowatts. Water wheels have returned, with a new generation of designs from German and US companies.

Cut out power cuts

Even the Archimedes screw has been transformed into a microgenerator, thanks to Ritz-Atro, a company based in Nuremberg, Germany. Its devices are capable of generating anything from 1 kilowatt upwards, from flows of just 70 litres per second. The company says they could be used in situations where the flow is too low for other microgenerators, such as small weirs or the waste outflows from small industrial plants. Two small screw generators have been installed in outflow pipes at water treatment plants near Tübingen in Germany, for instance.

A study last year by Amory Lovins of the Rocky Mountain Institute in Snowmass, Colorado, showed that the output of small-scale unconventional power sources is starting to outstrip that of the world's nuclear power industry (see Graph). Even Lovins was surprised. "I knew things were big but nobody had ever added them up before," he says.

Part of the attraction of small-scale generation is that it is well suited to renewable sources of energy such as wind, water and solar. These can be used in conjunction with micro-combined heat and power (micro-CHP) units, in which some of the heat output of a gas boiler is used to make electricity. "One of the beauties of microgeneration is that the technologies are complementary," says Walt Patterson, an energy specialist with the London-based think tank Chatham House. "If the sun isn't shining, it's often windy." Just as usefully, the electrical output of a micro-CHP unit follows a consumer's demand for heat. So while photovoltaic cells produce electricity during daylight hours, micro-CHP can kick in when people come home in the evening and switch on their heating.

Small-scale power generation has other advantages, too. Producing power locally avoids distribution losses, which account for about 10 per cent of the electricity fed into the grid. This also helps ensure security of supply, says Lovins, by avoiding the power cuts that arise when the grid fails - the main reason for power failures in the US.

According to Mike Bergey, president of Bergey Windpower of Norman, Oklahoma, after the power cuts that hit California in 2001, sales of the company's 10-kilowatt wind turbines went up by 400 per cent. "They would have grown three to four times that if there had not been the huge problem with getting building permits," he adds.

One problem with small-scale generators is that their power output fluctuates. If you have a wind turbine on your roof, you'll need electricity from some other source when the wind dies. And if you're away from home when it's windy, you'll generate more electricity than you can use. The obvious answer is to buy in extra power from the grid when needed, and sell power back to the grid at times when you are generating a surplus. But the electricity grid was built to distribute power, not receive it. As a result there are a number of obstacles, both technical and commercial, to doing this. Power companies in many countries prefer not to let smaller generators connect to their grids as they fear technical problems could arise. There is often no system for paying microgenerators either. In the US, for example, only 34 states have regulations that provide a mechanism for paying people who supply electricity.

Power companies are frequently obstructive, says Lovins, and may demand exhaustive engineering studies before allowing a connection. "I think the basic problem is that most US utilities do not understand that distributed generation is in their financial interests, so they fight it." Power companies often fail to see that microgeneration can help them avoid expensive upgrades to the grid, for instance. As a result, says Lovins, the US is lagging far behind Europe.

There also needs to be a fair system to pay people for the electricity they generate. But what price is fair? There is general agreement that households should be paid less for the power they sell than they are charged for the power they buy, to cover the cost of installing and maintaining the distribution network. It's just how much the difference should be that is in dispute.

Such commercial problems are mirrored by technical ones. Electricity meters were designed to monitor how much power a household consumes, not how much it produces. A survey by the UK's energy industry regulator Ofgem in October 2004 found that about two-thirds of the country's 26 million meters had a reverse stop, preventing them registering any power fed back into the grid. Anyone else who connects a generator such as the Windsave wind turbine (which simply plugs into the mains) will see their

electricity meter running backwards on windy days - dismaying power companies, which expect customers to help pay the cost of maintaining the network.

The simplest solution would be to wire in a separate meter to measure electricity exports, so that they can be paid at the appropriate rate. Alternatively, smart meter systems that use processors and software can record energy flow accurately, calculate the exact costs of power usage and automate energy export.

The electricity industry has voiced fears that microgeneration on a large scale would create unacceptable voltage fluctuations on the distribution grid. The UK's grid, for instance, consists of networks linked by transformers: the high-voltage network is used for energy transmission, a medium-voltage network supplies power-hungry industrial users and a low-voltage network supplies homes and small businesses. Anything attached to the network - be it phone charger or electric furnace - creates voltage fluctuations when it is switched on or off. If large numbers of wind turbines or solar cells attached to the low-voltage network start to generate power simultaneously, it is possible they could create voltage fluctuations capable of damaging equipment or even causing blackouts.

The grid was, after all, designed to transmit electricity from power stations through substations to the low-voltage cables that connect homes. It was not designed to receive power from a large number of small sources.

Yet according to a report in 2004 by consultants Mott MacDonald, such fears are unfounded, in the UK at least. It found that most of the country's low-voltage networks wouldn't have any problems, even if every home was capable of generating power. Only on rural networks, where there are lengthy cable runs, is there expected to be a problem. And even this can be remedied by reducing the output from the transformers that control the voltages on these lines, something the report says can be done during normal maintenance. On the plus side, microgeneration could avoid expensive upgrades to the distribution grid which would be needed if predicted growth in demand is met solely by centralised generators.

Most microgenerators are not yet the simple-to-install consumer products that advocates hope they will become. Micro-CHP must show that it is reliable, for instance. And the manufacturers of small wind generators will have to convince the public that they have eliminated the noise that many people still see as a problem with wind turbines.

Crucially, the prospects for microgeneration depend on how quickly the cost of installing the equipment can be recouped. Utility bills tend to track the price of oil, so last year's sharp rise in the oil price should improve the economics of microgeneration. A micro-CHP system will now pay for itself in about 12 years, a small wind or water turbine in slightly less. But it still takes around 50 years for most photovoltaic systems to pay for themselves.

At the root of the problem is the obstacle that often faces new technologies: production runs for domestic power generators are still small, so individual units are expensive. The EST report suggests that governments could help by subsidising the cost to consumers, and introducing a requirement that all new buildings should include microgenerators. Yet Japan and the UK have restricted subsidies for renewables and the 2005 US Energy act contained little encouraging news for microgeneration. If the queen of England can have her personal power station, shouldn't we all?

Home-grown power

Microgenerators can harness energy from sources ranging from natural gas to the sun's rays. But in the UK at least, one of the primary sources is wind power.

Two of the rooftop wind turbines undergoing trials in the UK come from companies in Scotland: Renewable Devices of Edinburgh and Windsave of Glasgow. Renewable Devices' Swift turbine produces 1.5 kilowatts in a 10.5-metre-per-second wind. This year the company signed an agreement with the Perth-based company Scottish and Southern Energy to supply turbines to customers.

The 1.75-metre Windsave turbine produces 1 kilowatt in winds of 12 metres per second, and trials of it are being backed by British Gas. Key to the design is that it simply plugs into a standard mains socket. An inverter converts the output from the turbine into 230 volts AC, and a sensor adjusts the phase of the output to match that of the mains. "It's counter-intuitive," says Walt Patterson of Chatham House. "You plug it in to generate electricity." Both turbines are expected to cost about £1 per watt to install and could pay for themselves in eight years or so.

The outlook is less bright for photovoltaic panels. Global PV capacity is doubling every two years, but less than a quarter of existing PV installations are economic, and only pay off where there is no mains electricity. The Eddystone lighthouse off the coast of south-west England, for example, replaced diesel generators with photovoltaic cells in 2000.

In Germany and Japan, PV generation has been encouraged by subsidies to grid-connected households that put solar cells on their roofs, and these two countries have about two-thirds of the

world's PV generating capacity. The breakthrough will come when the cost of solar electricity matches that of mains power - most likely a result of mass production rather than improved efficiency. By 2020 PV electricity should cost roughly the same as the forecast level of peak electricity tariffs.

Microgeneration is not just about generating electricity: you can make your own heat too. One option is to extract heat from the ground using a heat pump that pulls heat out of a mixture of water and antifreeze flowing through a closed loop of pipes laid in the ground. Ideal for underfloor heating, heat pump systems are already as cheap as oil-fired central heating. Solar heating is also widely used to provide hot water - and not just in sunny locations like the Mediterranean and southern California. Some 70,000 houses in the UK use solar water heating, for instance, and the government estimates that by 2010 some 50,000 households a year could be installing the technology.

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