Sustainable Construction

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Chapter 11
Renewable technology

In which we investigate current attempts to harness the ever-present renewable energy resources in the wind, water, earth, sun and biomass, and how, when applied alongside better conventional design, these can contribute to achieving sustainability objectives.

'In technology reality must take precedence over public relations, because nature won't be fooled.'

Richard Feynman

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Carbon sink
Photo: the author

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Wind Turbines, Shotts
Photo credit: Michael Wolshover

Renewable technology

Introduction

We are in an era of excitement again about renewable energy. This is welcome but caution is required to ensure that decision-making is sensible, and generates the most appropriate responses. Renewable energy technologies need to support good practice rather than substitute for it.

Simply adding technology to buildings does not demonstrate sustainable design. It is important to achieve the right balance of cost, functionality and lifetime benefits. Issues such as build quality and maintenance are crucial, and the basis for any renewable solution is better conventional design.

Savonius Rotor 1970s
(Photo permission: Centre for Alternative Technology)

Dulas Office, Machynlleth
(Photo: the author)

The need to develop renewable resources is undeniable. The benefits include:

- the opportunity to reduce pollution due to fossil fuels
- improved security of energy supply
- more predictable costs
- improved efficiency of generation and transmission compared to the grid
- development of a renewables industry
- real cost benefits in an environment of polluter pays.

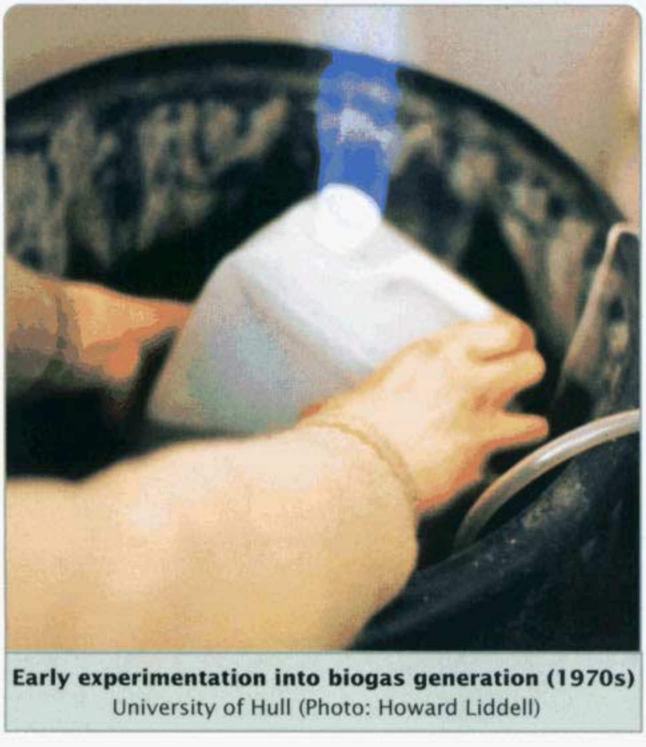
Extreme sensitivity is required to ensure that development is appropriate. Renewable technologies cannot and should not be the first choice in design. Some technologies are expensive and impractical, and are themselves the source of waste and pollution that can put pressure on ecosystems. Energy generated from renewables has to be used wisely to justify the investment. The term eco-minimalism has been coined to promote an approach that – in counterbalance to the contemporary excitement – looks at passive solutions first and foremost. It has much to recommend it.

Development

Sustainable development requires that we cultivate energy from natural processes in such a way as not to deplete them and not to result in social harm, environmental pollution, waste or short life. Environmental pollution, specifically climate change, is currently the principal motivation for interest in energy conservation and in renewable energy technologies as alternatives to fossil fuels.

Interest in renewable energies has waxed and waned for over 30 years. In the 1970s, the principal pollutants of concern associated with energy were oxides of nitrogen and sulphur (NOx and SOx) emitted from power stations. Predominant south-westerly winds in the UK gave rise to acid rain in Scandinavia and led to international interest in cleaner energy generation. International pressure during the 1970s' oil crisis was also a significant driving force. This led to concerns for the future availability and cost of oil. It coincided with some of the early experimentation in alternative 'green' lifestyles, as well as development of commercial opportunities for renewable energy. Sadly, some early research into economic viability was shamefully misleading.

Negawatts before Megawatts
In rural environments people hold very different views about renewable energy versus the alternatives. The only sensible solution is to make radical reductions in energy consumption so that the optimal use is made of whatever is generated (Photo: the author)



Early experimentation into biogas generation (1970s)
University of Hull (Photo: Howard Liddell)

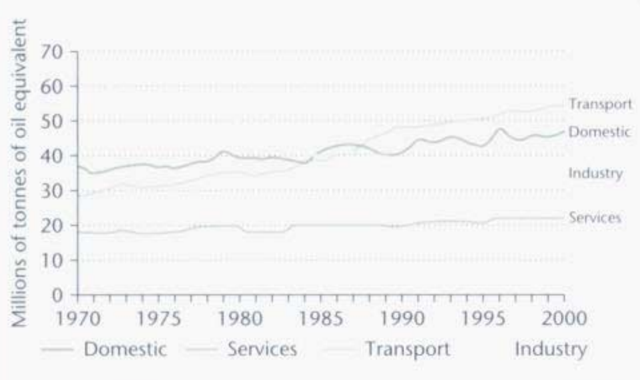
More recently, international concerns about global warming and security of supply have led to real commitment to increasing the contribution of renewables to our energy needs, which are increasing. The inherent dangers, unresolved waste management issues and sheer cost of nuclear power make its adoption unfeasible if common sense prevails.

The early experimental period led to the founding of institutions such as the Centre for Alternative Technology, where study of clean technologies has combined with experimentation in farming and alternative lifestyles.

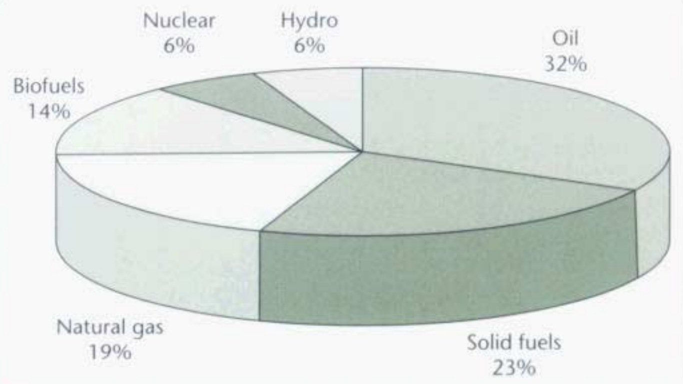
For a long time, renewable technologies in the UK were probably stigmatised by this linkage and unfounded assumptions about the lifestyle implications. These suggested that they were only relevant to those who wished to 'give up' on quality of life. In practice, some technical choices (low-tech solar panels or composting toilets) might impose lifestyle changes whilst others (grid connected wind) probably do not.

There remains a need to discuss the social, financial and environmental implications of different technologies within the framework of a wider understanding of sustainable development. It is important that technical responses are sensible and robust, manageable and affordable, and in particular that they are compatible with the user and management skills, needs and aspirations. Experience from exporting technologies to developing countries highlights many cases of waste and short life due to lack of basic skills and spares.

Highly intermittent attention to renewable energy means that it has been difficult to maintain any consistency in approach. It has taken a combined cognisance of environmental hazards, commercial opportunities of technology development and concerns about security of energy supply for serious attention to renewables to become an international issue. The present commercial climate, however, still gives largely unbridled support to the ongoing availability of cheap fossil fuels. Renewable technologies can rarely compete economically, especially as expectations of financial payback are generally very short. Dependence on subsidy, when it is unlinked to any issue of longevity, is notoriously unreliable.



Change in energy consumption by sector
Between 1970 and 2000 energy consumption by sector changed substantially, with rises of 96% in transport, 27% in the domestic and 17% in the service sectors. Industry use fell by 42%. Recently the rate of increase in transport has slowed and industrial use has increased. Overall energy use increased by 1% between 1999 and 2000



Total world energy use by fuel source

However, fossil fuels are increasingly recognised as generating costly and perhaps irreparable environmental damage. As a result, there is increasing attention to developing long-term fiscal policies which assist clean technology development. International agreements now oblige participating countries to make commitments to energy efficiencies. The Kyoto Agreement commits the UK to reduce greenhouse gases by 12.5% by 2012 from 1990 levels. At the time of going to press there is no agreement beyond Kyoto.

In Europe, there are now increasing efforts to stimulate renewable energy provision through tax incentives and political pressures to meet set targets. The UK strategy involves energy efficiency and fuel switching to less carbon-intensive fuels such as gas, renewables and 'sensible' CHP. Measures such as the Carbon Tax Levy – linked to environmental impact – dovetail with the Non-Fossil Fuel Obligation in encouraging expanding markets, widely seen as significant to reducing costs.

'Polluter pays' principle

Asserts that the full cost of controlling pollution should be carried by the polluter without subsidy or tax concessions. The cost of pollution is internalised and reflected in production costs.

Case Study 11.1:

Centre for Alternative Technology, Machynlleth

Founded in 1975, on the site of an old slate quarry, by Gerard Morgan-Grenville, the Centre for Alternative Technology (CAT) is Europe's leading environmental visitor attraction. The seven-acre visitor complex has a wide range of buildings which explore different building techniques, and a number of interactive exhibits to demonstrate a wide range of energy, small-scale farming, and water and waste management techniques.

A significant part of the ongoing exploration at CAT is the implementation of renewable energy technologies on the site.

Data collected from 2000 has been collated by the CAT and shows that 64% of their total consumption of 75.5 MWh of electricity was produced by renewables.

The centre has a 13.5 kW solar roof, two 3.5 kW hydro turbines, various wind turbines of up to 75 kW that were not monitored at this time, and a 600 kW wind turbine exporting directly to the grid. The remainder is supplied from a back-up diesel generator and the grid.

Consumption of non-renewable power was higher than normal due to the construction of a large building.

A water-powered cliff railway can take up to 14 adults at a time up or down the 60 m incline. It operates on the principle of 'water balancing'. The two carriages are connected by cable via a winding drum at the top. Water is run into a tank beneath the upper carriage until it is just heavier than the lower carriage and its passengers. The parking brakes are released and gravity does the rest.

It is one of the steepest cliff-railways in Britain, with a 35° slope and set at a velocity of about 1 m/s. The speed is controlled by a hydraulic pump combined with a regenerative braking system, allowing the surplus energy from the hydraulics to pump some of the water back to the top. This water can be seen from time to time spouting into the pool next to the Upper Station.

Photo credits: the author

Eco-minimalism

There is growing concern that the potential benefits from some renewable technologies are being oversold. Expensive technologies with short life, suspect manufacturing processes (often themselves energy and chemically intensive) and hence high embodied pollution are not evidently more sustainable than quality, conventional design based on a good understanding of buildability and scientific principles. Even basic calculations highlight that real priority areas for attention are design fundamentals, not technical add-ons. Certainly, the use of renewable energy technologies should never be considered in isolation from demand-side reduction. Both peak loads and run time of equipment should be considered.

Technical illiteracy is rife, leading to situations where buildings of so-called specialist organisations and even those boasting a demonstration of photovoltaic (PV) technology have toilets bearing handwritten notes: 'Beware very hot water'. It happens disturbingly often.

A thermostat plus spray taps would have been cheaper than the PV panel and a genuine contribution to energy efficiency. It will always be more cost-effective to use low-energy bulbs, good control, draught-proofing or more insulation than to install PVs or a wind turbine to an existing inefficient building. For new builds, the very best possible standards of energy efficiency and control should be prioritised before add-on technology.

Biofuels Compete With Food Production most biofuels in the UK would be imported (Photo: Howard Liddell)

Renewable technologies

Biomass

Energy is contained in plant matter and animal waste, and can be burnt to provide electricity, heat or steam. If the original product is free of chemical treatments, then the waste products can be returned to the land, as fertiliser. Plant matter can also be converted to a liquid or gaseous supply to produce alcohol fuel, biogas and plant-oil-derived diesel.

Biomass heating at Lyss, Timber College, Austria (Photo: Howard Liddell)

Use of organic waste for energy can be integrated into waste management strategies. Emissions from the combustion of biomass are cleaner than emissions from fossil fuels. Biomass is used extensively in developing countries, and in the developed countries large- and small-scale applications are becoming popular. The main sources in the UK are residues from pulp and paper operation, forests, agriculture, urban woodlands and animal waste. Some crops are grown specifically for energy. However, biomass energy is truly renewable (carbon neutral) only when the rate of planting equals or exceeds the rate of use. Landfill gas is a special case of biomass energy in that it is latent rather than renewable. It is formed from the natural breakdown of waste materials over time that generates methane, a particularly intense greenhouse gas.

Biofuels account for 82% of world renewable energy sources. Most of the hydro accounts for 15% and wind power 2.5%. Of the 3.0 Million Tonnes (MT) of oil equivalent of primary energy use accounted for by renewables, 2.2 MT was used to generate electricity and 0.8 MT to generate heat. Global renewable energy use grew by 8% in 2000 and has doubled in the last seven years. It accounted for 2.8% of electricity generated in the UK in 2000.

Case Study 11.2:

Ely Power Station

2002

Constructed by FLS Miljo, and located in Sutton near Ely, this £60 M, 36 MWe facility consumed around 200 000 tonnes of straw collected from farms within a 50-mile radius, and generated 270 GWh of electricity every year, which is sufficient to satisfy the needs of 80 000 dwellings.

The power was sold to NFPA under a NFFO3 contract. The plant was also capable of burning a range of other biofuels and up to 10% natural gas. It is claimed that this is the UK's first and the world's largest and most efficient straw-fired power station. The facility was opened in January 2002 by Brian Wilson, Minister for Energy.

In June 2004 ELY PCR took over the operation and maintenance of the plant allowing them to burn a wider range of fuels. This opened up the potential for reducing fuel costs and increasing security of supply.

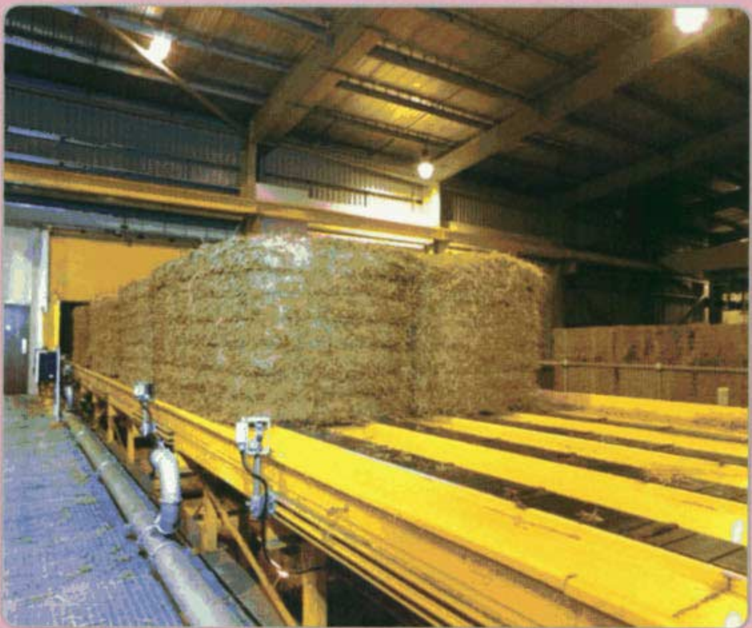


Photo: Energy Power Resources

Case Study 11.3:

Kinlochleven Community and Sports Centre, Argyll

Architects: Gaia Architects, 2001

The 964 m² single-storey building has a slate roof over a combination of masonry and timber-clad, timber-frame walls. It is highly insulated with dynamic insulation to the main hall and natural finishes throughout. A woodchip boiler was selected to provide a carbon-neutral development.

The space-heating requirement is met via underfloor heating, cast into the floor slab. The woodchips, sourced from a nearby sustainably managed forest, are stored in a 10 m³ hopper and feed a 120 kW boiler. The woodchips are supplied dried to 15–18% moisture content, and bought as measured heat and/or hot water at a competitive unit rate of 2.8 p per kWh.

The fuel is automatically fed to the biomass plant, where it is burnt at a temperature of 1350°C. A control panel modulates the fuel-to air ratio by monitoring the flue gases, to achieve maximum combustion efficiency. Once the heating has been satisfied, a 'slumber mode' kicks in, which maintains an ember bed on the burner, until more heat is called for. Temperature control works in the same way as that of a conventional boiler and supplies 82°C flow, 71°C return. The overall system efficiency is 85–90%, dependent upon the moisture content of the fuel. A 100kW standby LPG burner is in place in case of boiler shut-down during severe weather. Modem monitoring from the supplier's office enables flow and return temperatures to be checked, fault indication, and fuel monitoring to ensure accurate and timely fuel reordering.

Photo: Gaia Architects

Photovoltaic (PV)

PV cells convert solar radiation into DC electricity. It is adequate for 12/24-volt DC supply, but must be converted using an inverter to AC for most purposes, including export to the grid in the case of excess generation. Storage is required for use outside daylight hours. Systems are built up in arrays from modules to the required size. Principal applications until relatively recently were in remote locations, marine navigation, transmitters, water pumping or battery charging, where the alternatives of grid connection or local generation were unfeasible or expensive. They are now being heavily promoted to the building industry.

Costs have fallen rapidly, as take-up of photovoltaic technologies has increased, but they are difficult to justify unless there has been serious attention to reducing energy and power requirement by every possible means.

The cost of PV cells is presently £300–800/m^2 depending on efficiency. A high-efficiency array of 10 m^2 in southern England has a power output of about 1.5 kW and would generate around 4 kWh/day in midsummer and about one-third of that in midwinter. These seasonal variations generally necessitate that a back-up power supply is provided. It is rarely sensible to try to meet a peak load, and instead designs should seek to meet a base load that reduces the need for new or upgraded infrastructure. They can be utilised in conjunction with another energy source, usually wind.

Doxford Solar Office, Sunderland – the first speculative office building to incorporate building-integrated photovoltaics and, at the time, the largest ever constructed in Europe (Architects: Studio E Architects, 1995, photo: Studio E Architects)

The main advantages of PV systems are that they are silent, have no moving parts and require minimal maintenance. They produce no emissions in use. Cost has fallen and efficiency risen, but they are very expensive and cannot pay for themselves during their useful life. Most research and development is aimed at increasing the efficiency and reducing the cost, although there is also attention to cleaning up the manufacturing process, which controversially is reliant on solvents and heavy metals. Technical advances have significantly reduced the embodied energy.

Energy used to manufacture a crystalline silicon PV cell now equals four to five years of power generation from it. The expected lifetime is, on average, 20–30 years. Hence, each 1 kW panel is estimated to save 0.5–1 tonne of CO_2/year, or a net 5–25 tonnes in its lifetime.

Typically, PVs are roof mounted, in a domestic situation. More recently, in commercial buildings it has become popular to incorporate the PV cells into the building envelope. The argument is that by serving a dual purpose the net cost of photovoltaics or active solar collectors can be substantially reduced by replacing roof light-shelves, curtain walling or cladding systems that would otherwise need to be introduced. This depends on them having a comparable functional design life.

System	Approximate Installed Cost £/m
PV curtain walling, glass/glass crystalline	780
PV curtain walling, thin-film amorphous	280
Double glazing	350
Stone cladding	300
Polished stone	850–1500
PV rain-screen cladding	600
Steel rain-screen over-cladding	190
PV roofing tiles (housing)	500
PV modules on a pitched roof	650
Roofing tiles – clay or concrete	32
Timber roofing (larch)	34
Slate	less than 50

Table 11.1 Approximate costs of building cladding materials from Ralph Ogg & Co, Perth and BIPV projects, 2000, ETSU report S/P2/003 28/REP

Case Study 11.4:

The Eco House, Nottingham

Architect: David Wilson Homes, 2000

Located on the University campus, this four bedroom house was built to demonstrate the integration of existing renewable energy technologies such as evacuated tube solar water heaters, PV roof, lightpipes, solar chimney and rainwater collection.

Since then, ground source heating/cooling, PV extractor fan, PV trackers and wind turbines have been added.

Monocrystaline photovoltaic roof tiles cover 15.9 m^2 of the south-facing roof space, inclined at 52°. They are designed to produce 1250 kWh of electricity per year and supply a peak power output of 1580 W – 30% of the demand.

Two self-operated, sun-tracking PV arrays installed alongside the house operate with the roof array. Together, these systems result in approximately 75% of the building's electricity demand being satisfied by PV.

Mounted on the south-facing portion of the frame, a 3 m x 1 m solar collector provides adequate hot water during the summer months and pre-heats water during the winter.

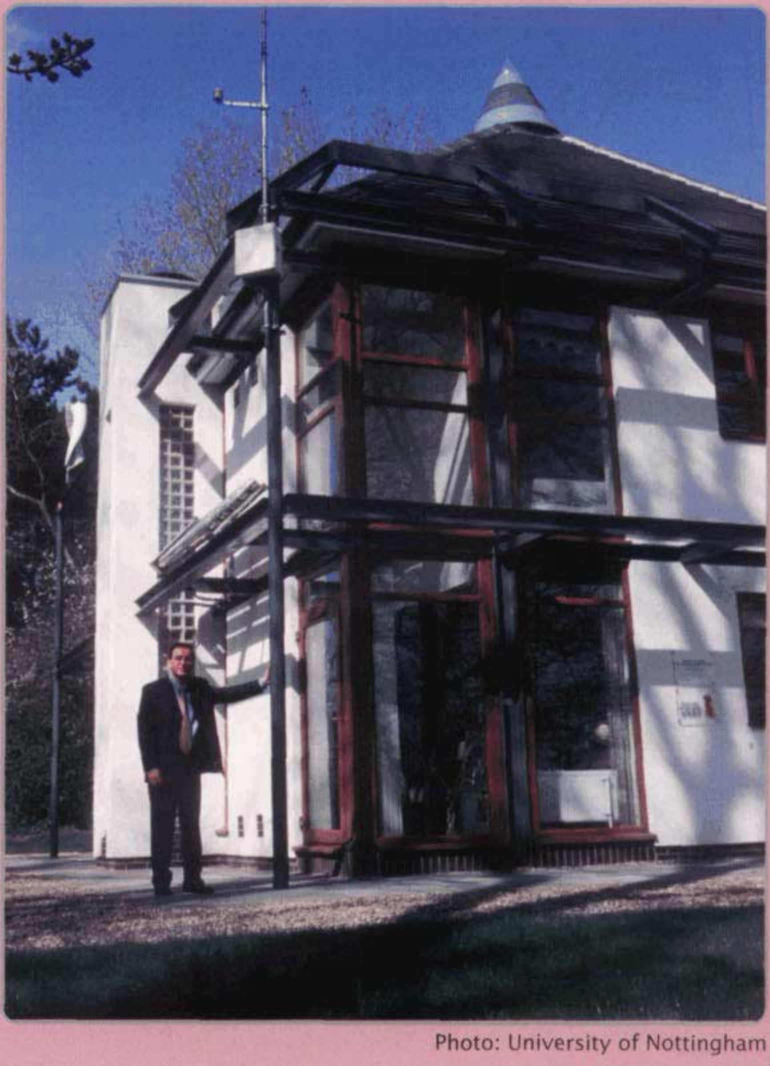


Photo: University of Nottingham

Case Study 11.5:

Sainsbury's petrol station, Greenwich

Architects: Chetwood Associates, 1999

The 57 m² roof of the petrol station at Sainsbury's Millennium store, Greenwich, London, contains 90 PV modules each rated at 75 W and wired together in 10 parallel rows.

The DC electrical output is converted through inverters providing the petrol station with its electricity needs, and any excess is exported to the grid via Sainsbury's on-site CHP generation unit.

The installation also has two wind turbines that provided power for a free plug-in port for charging electric cars, to encourage the use of cleaner transport options. These plug-in ports have now been removed.

Photo: the author

Case Study 11.6:

University of Northumbria

Refurbishment, 1994

The Northumberland building was used as a demonstration project for building integrated photovoltaic (BIPV) rain-screen cladding in 1994.

It has been extensively monitored to identify energy output and how it compares with durability of standard cladding systems.

Benefits of BIPV are the ability to offset some costs, but they are required to perform at least as well in traditional terms.

465 PV modules were used in a south-facing 286 m^2 array, tilted at 25° to vertical. Each has an 85 W output, giving maximum DC output of 39.5 kW. A peak monthly energy output, in August 1995, gave 3106 kWh DC converted into 2940 kWh AC.

The monitored figures predicted an annual output of 30MWh. Assuming a system lifetime of 25 years, the electricity cost is 42 p/kWh.

The building façade is shaded by surrounding buildings of similar size and by a chimney in front of the façade.

Shading occurs mainly in the morning and during the winter season, reducing the annual output, and increasing cost, by 25%.

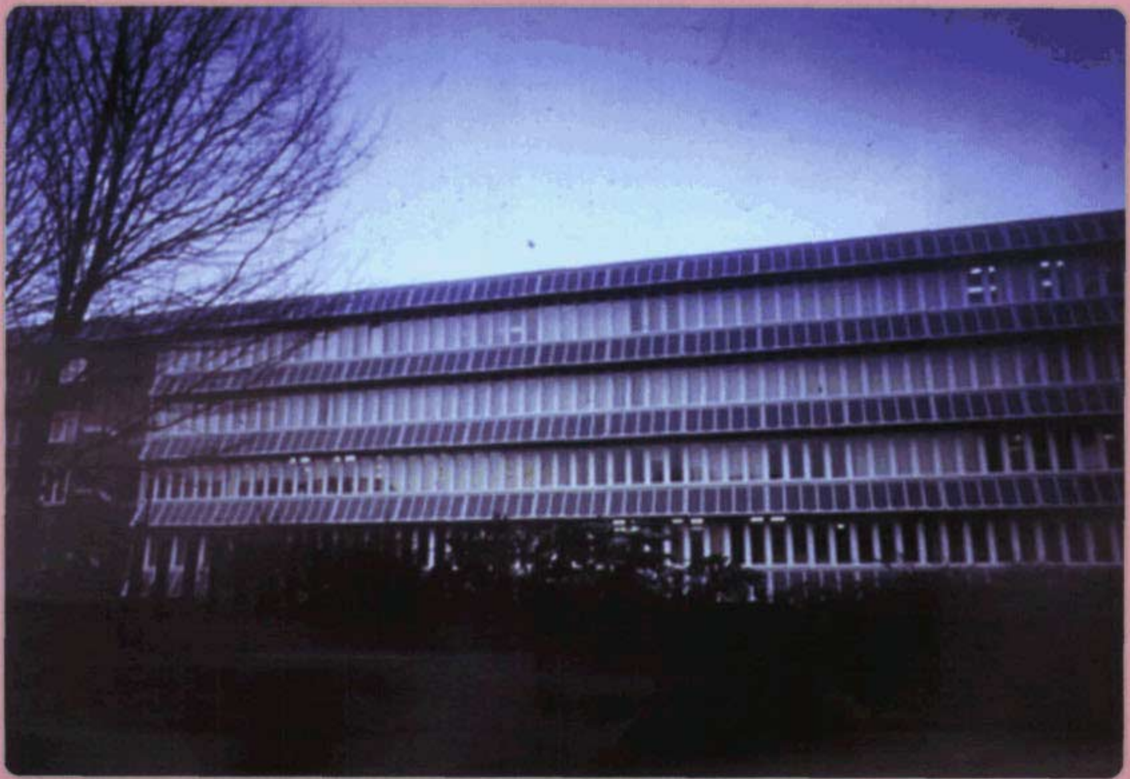


Photo: University of Northumbria

Solar thermal

Solar energy can be used for heating air or water. The solar energy available in the UK is around 900–1300 kWh/m^2/year. Climate data suggests that this is increasing in the south and decreasing in the north.

Evacuated tubes

Flat-plate collectors (FPC) consist of water-carrying pipes in contact with an absorber surface. Back and side insulation prevents heat losses, and a transparent cover has the effect of retaining the solar radiation, creating a greenhouse effect. Efficiency is influenced by the amount of insulation, outdoor temperature, fluid temperature and construction. Typical efficiencies are 40–50%, but 70% is possible; increasing levels of sophistication increase cost.

Domestic hot water is required to be delivered at a temperature of around 60°C, to eliminate legionella, and some boost will be required at certain times of year. During winter antifreeze is required, or systems should be drained. The most advanced FPCs heat a little water at a time and store it. More sophisticated collectors absorb energy onto selectively coated black fins placed within evacuated tubes. These have higher operating temperatures.

All types collect direct and diffuse radiation, so operate under cloudy conditions. It is generally assumed that the more expensive the collector, the more efficiently it will perform.

However, controversial research to compare different collectors indicated that the cheaper FPCs outperform the more expensive evacuated tubes. The arguments appeared well founded but the results have not been confirmed.

In the UK, collectors should face south, inclined to the horizontal at an angle equal to the latitude to capture maximum solar energy. Typical installation costs are £300–750/m^2, providing 300 kWh/m^2.

A typical domestic installation is about 4 m^2, meets 20% of the demand and saves about one tonne of CO_2/year. Solar-warmed water can also be used in combination with the desiccant open-driven cycle to provide cool and dehumidified air in an environmentally benign alternative to traditional air-conditioning systems. The system requires heat to regenerate a desiccant material at temperatures readily achievable by solar energy.

As well as warming water, collectors can exploit the ability of any surface that is warmed by the sun to be a source of energy. Air moving passively or assisted mechanically across such surfaces and within designed channels can deliver pre-heated air directly or indirectly to top up heating systems. The low-tech, low-cost approach is being increasingly exploited for a range of applications, as it offers designers a variety of opportunities to provide a cost-effective alternative to commercial systems.

Solar thermal

The extension to Plymouth College of Further Education has domestic hot water provided by evacuated solar tube collectors that serve as both a canopy over the entrance area and absorb the solar energy to heat the building's domestic water requirements

The designers claim that the solar collectors supply hot water for the sanitary needs and approximately 60–80% of the catering domestic hot water needs. The pump is of a small domestic size and the system gives an overall good reliable performance

Hydro power

Hydroelectric plant enables potential energy present in water to be converted into kinetic energy with the use of turbines that drive generators. The amount of energy available is dependent on the flow of water and the head, which can be anything from 1 to 300 m. The technology is simple. Large-scale hydro power is a well-established form of renewable technology.

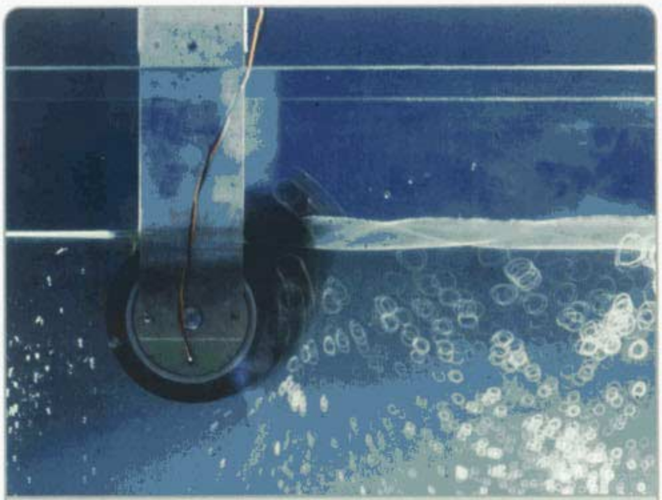
Small-scale hydro is occasionally worth considering for buildings close to rivers and streams. Technology improvements mean that previously unfeasible projects with low head and flow might be worth considering. As with all other renewable applications, the electricity produced is DC. In the UK, most of the hydroelectric potential is in Scotland.

Small-scale hydro
..is occasionally worth considering for buildings close to rivers and streams
(Photo: the author)

Wave and tidal energy

The main advantages of wave and tidal power are the large energy fluxes available and predictability of conditions. As a consequence, many devices have been designed to extract power from waves (kinetic energy) and tides (potential energy) and convert it into electricity. Two wave energy devices are described here.

The Salter Duck is designed such that a wave approaches the 'beak' of the device, making it oscillate. The rounded base prevents waves impinging from the side. A high conversion efficiency of the incident wave power is achieved by extracting the energy at the point where there is minimum reflected energy.



Salter Duck
A time exposure of a duck absorbing power from the waves. Around 90% of the energy was being captured
(Photo: Jamie Taylor, Edinburgh University)

The Oscillating Water Column exploits the amplitude of wave. These force the water level to rise and fall in a vertical cylinder, compressing and decompressing enclosed air. The oscillating stream of high-velocity air is fed to a special turbine, with unidirectional blades, that rotates regardless of the direction of the air. A 75 kW prototype operates on Islay, which feeds into the grid. The technique is being researched for use shallow waters.

Moon Power
Tidal energy exploits height to take the potential energy from water (Photo: the author)

Geothermal

Hot Rocks
The UK only has a few areas of mainly low-grade heat
(Photo: the author)

Geothermal energy is derived from heat deep within the earth. It can be used for heat or electricity generation. Geothermal energy has huge potential for a reliable power generator, with resources identified in over 80 countries and utilisation currently in 58. Of those countries, 21 are producing electricity from water at temperatures as high as 400°C, which is brought from underground reservoirs to the surface and flashed into steam. The best sites are those that correspond with fault lines in the earth, geysers and volcanic regions, but in many places it is possible to drill deep within the earth to reach high-temperature locations.

Throughout the UK, the ground maintains a constant year-round temperature of 11–13°C, with a few hotspots of largely low-grade heat. Ground source or geothermal heat pump systems have been developed to make use of this energy for heating of buildings (www.earthenergy.co.uk provides information on systems and a geothermal map). It is a viable option for single houses, especially new build with high insulation levels, where the capital costs are reduced. Systems are sized in the same way as any other performing the same function, heat losses, floor area and occupancy pattern.

A typical three-bedroom house will require an 8 kW system, comprising 250 m^2, 300-mm-diameter boreholes at £5900. The payback period could be in the region of five years. A typical smaller housing association development system might be closer to 4 kW at £4200. Larger commercial systems are more cost-effective (£1000/kW), as the same infrastructure can be used to meet heating and cooling loads. It becomes viable to use central plant with district heating when a group of houses is being built at the same time. (Trench systems in which the pipes are laid close to the surface cost less, as drilling equipment is not required. Problems of freezing ground have been experienced with this technique.) This will provide all of the space heating and provide DHW at 45°C. An immersion is required to boost water temperature to the required temperature and eliminate the risk of legionella.

Use of a heat pump means that an 8kW system uses only 2kW of electricity. However, as the price and environmental impact of electricity is three to four times that of gas, the benefits may be marginal. The heat pump is maintenance free and has a long lifespan. The pump warranty is supplier dependent, but usually around two years. However, parts are abundant and cheap. The systems are low maintenance and parts have standard warranty – there are no hidden maintenance costs. A ground loop has a 25-year guarantee and life expectancy is 50–75 years. Local skills can be employed to undertake installation. The local authority will need to be contacted, but no planning permission is required, because the pipe is installed underground, in a borehole or covered trench.

Shettleston Housing Association
Hot water is provided from combined geothermal/solar panel heating and cooled mine-water discharged from the heat pumps is used to feed the WCs
(Photo: John Gilbert Architects)

Wind

Wind turbines are now predominantly used for electrical generation. Offshore and onshore wind farms provide electricity for grid distribution and individual machines find good application in isolated places where they can offset infrastructure costs. Connection to the grid removes the requirement for battery storage, but it is often the prohibitively expensive cost of grid connection in rural locations that is the driver behind investigating wind or other options. Wind power tends to be available when required – at night and in cooler seasons – giving it significant advantages over solar energy in the UK.

Increase in use of specific renewable energy sources
(Photo: Howard Liddell)

Recent advances have lowered costs dramatically and increased performance, particularly of large turbines. Wind power is now a viable major contributor, and the fastest growing source of renewable energy. Power output of a wind turbine is dependent on the area swept by the blades. The UK is the windiest country in Europe, and for a while Scotland led the world in wind power technology and had some of the first developed wave turbines.

Although wind power can be utilised almost anywhere, the setting is critical due to the changes in wind speed with topography. Doubling wind speed results in eight times the power output, so optimum siting is important. Sites are selected on the mean velocity, which requires historical wind data related to height.

There are also restrictions based on birds' migratory paths. It is also important to consider the implications of space, visual intrusion and noise. Modern turbines also shut down in very high winds to reduce hazards. The efficiency with which energy can be extracted is about 30% and cost is £500–750/installed kW peak output. Professional maintenance is required and this should be considered in costings.

A source of some contention was the low rate paid out to small producers wishing to sell to the grid compared to the purchase price. This has changed dramatically with the increase in ethical suppliers of electricity and the availability of Renewable Obligation Credits.

Fuel cells

Fuel cells run on hydrogen – a colourless, odourless, tasteless gas that can be generated from water, natural gas, propane, methanol, ethanol or landfill gas. The fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water and heat. The fuel cell transfers chemical energy to DC by separating the proton and electron present in the hydrogen or in a hydrocarbon fuel. In the latter case, a 'fuel reformer' is used to extract the hydrogen.

Fuel cells can be combined as required and small demands can be catered for, whilst maintaining high efficiency. They have no moving parts, produce no noise and require minimal maintenance. As with all energy there is a cost of extraction, and in this case the production of hydrogen gas is energy intensive and therefore net gains are reduced, potentially with significant associated pollution, unless the hydrogen can be produced using clean energy.

A truly 'zero emissions' system is possible only if renewable energy is used to release the hydrogen molecule from hydrogen. In this case the output of the fuel cell operation is electricity, heat and water, with the water able to undergo electrolysis to repeat the hydrogen cycle.

Any other system has associated emissions. The major drawbacks are that fuel cells are heavy and very expensive. Technological advances or cost re-assessments are required if the fuel cell is to become a useful source of renewable energy.

Case Study 11.7:

Lerwick district heating scheme

Shetland Islands Council Charitable Trust, 1999

The Shetland Islands Council Charitable Trust decided, in 1977, to construct a district heating scheme in Lerwick to use the heat from the Council's proposed Waste to Energy Plant at Greenhead. It was not until 1999 that the scheme became operational and the first 10 km of mains were laid. The plant currently supplies about 280 houses and 70 non-domestic properties, including a hospital, two schools, a fish factory and two care centres, plus dairy, retail and commercial properties.

The incinerator burns domestic rubbish from Shetland and Orkney, which amounts to 26 000 tonnes of waste per year and gives an output of 6.8MW. The district heating uses a centralised boiler and distributes the heat via insulated underground pipes. Heat contained in the pipes is transferred to the buildings' internal wet heating system via a heat exchanger; no water is transferred to the buildings. Some of the advantages of the scheme to its customers are lower heating costs and reduced maintenance costs against a boiler system.

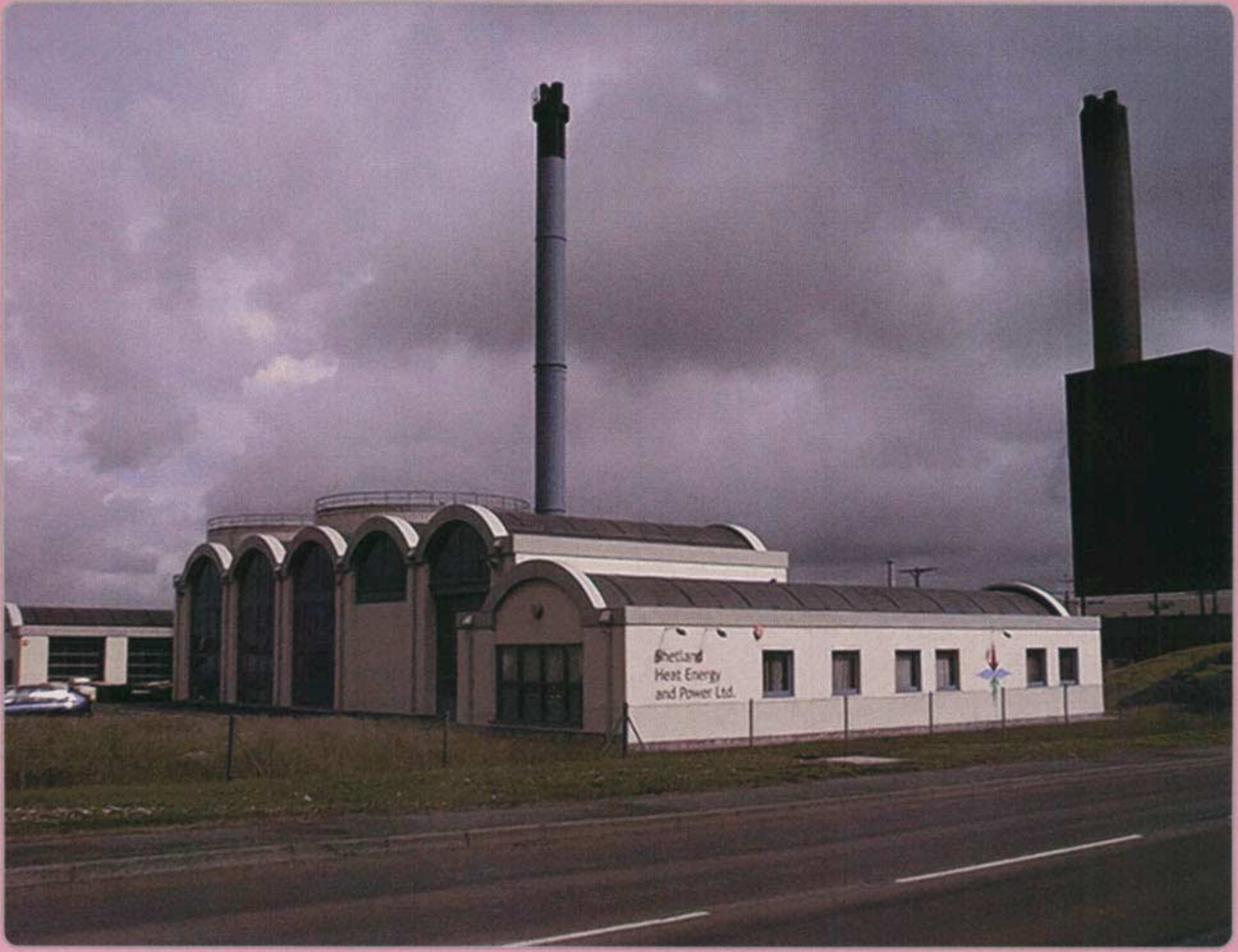


Photo: Shetland Island Council

Autonomy

Sustainable development requires that systems operate with minimal reliance on external inputs of energy or other resources. Indeed, the limits to growth are not the amount of people, cars or things, but the unrecyclable resources that they consume in manufacture and use, and the unmanageable waste or toxicity produced.

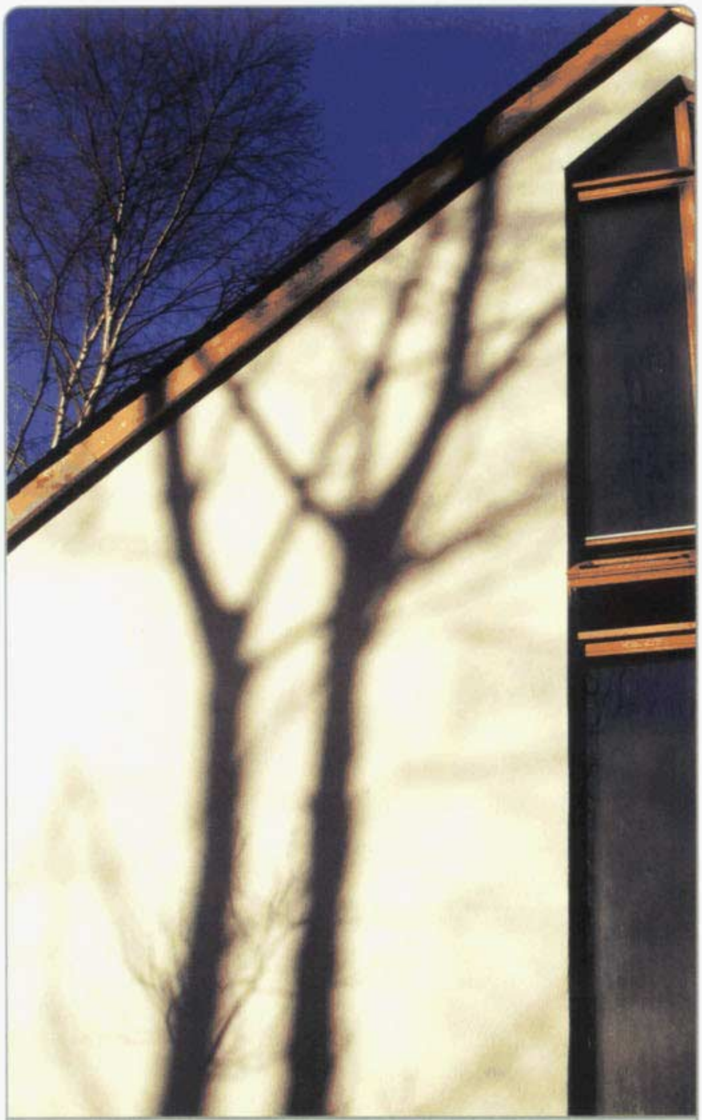
To this end there have been a number of studies of individual houses and also developments at a larger scale to investigate the resource throughputs and the potential to develop such autonomous systems with independence from grid-based systems. They extend beyond energy use to other forms of resource management. This implies the need to develop feedback loops in which resources form cyclic systems, rather than the linear ones which characterise our present unsustainable systems.

Future potential

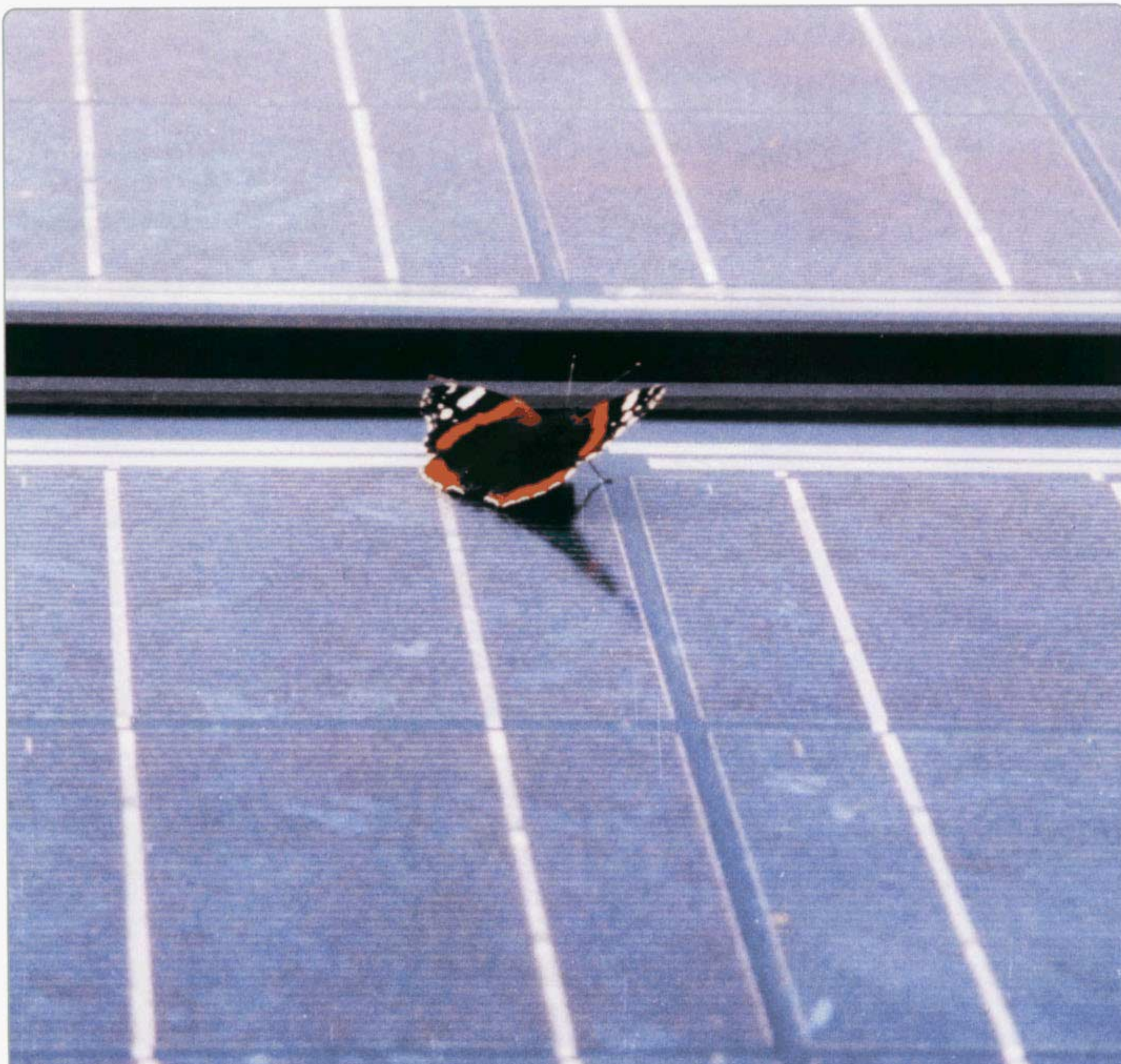
Shell UK predict growth in all the major technologies, with the fastest growth anticipated in solar, PV and wind. The UK government is committed to achieving 10% of the UK's electricity from renewables by 2010. Presently, the figure stands at 2.5%. New and Renewable Energy – Prospects for the 21st Century summarises much current strategy. To assist the uptake of renewables, the UK government has undertaken research into funding needs, and its Performance and Innovation Unit's 2002 report recommended:

- £25 m for offshore wind
- £15 m to help farmers and foresters establish energy crops
- £10 m dedicated to innovative PV schemes
- £10 m for PV and other technologies utilised directly on homes, business and community buildings
- £10 m for fundamental research on the next generation of renewable energy technologies
- £5 m for demonstration and testing of wave and tidal technologies (UK research leads the world)
- £4 m for advanced metering and control technology so electricity grids can best harvest PV and other small-scale technologies
- £18 m for development and demonstration of advanced energy crop technologies for clean and efficient production of heat and electricity.

A study commissioned by the Scottish Executive reported a total renewable energy resource in Scotland equal to 59 GW, three-quarters of the UK's current installed generation capacity. All of it, including relatively expensive offshore capacity, could be produced at less than 7 p per unit by 2010 (excluding grid strengthening costs). Wind accounts for more than half of the renewable energy potential, followed by wave and then tidal power. The Executive's current target for renewables is 18% by 2010.



Glencoe Visitor Centre
Built from and heated by local trees
(Architects: Gaia Architects Photo: Michael Wolshover)



Solar panels at The Autonomous House, Southwell, Nottinghamshire (Photo: Robert & Brenda Vale)

Bibliography

Historic and general

There is an extensive range of guidance on renewable energies going back over three decades. Some of the early materials on specific technologies remains very relevant to the non-specialist and there are a number of good general text books.

Frequent policy shifts mean that technical and commercial advances have been haphazard. This is reflected in the lack of coherence in the information and it is easy for designers to get out of touch. Funding regimes are volatile.

There is an abundance of case study publications from government agencies and the technical press has contemporary project literature that is often ahead of books. A number of publishers now specialise in renewables.

Historic and general

Dickson, D. (1974) *Alternative Technology and the Politics of Technical Change*. Fontana.

Boyle, G. (1975) *Living on the Sun – Harnessing Renewable Energy for an Equitable Society*. Calder & Boyars.

Chapman, P. (1975) *Fuel's Paradise – Energy Options for Britain*. Penguin.

Lucas, T. (1975) *How to Build a Solar Heater*. Mentor.

Vale B. and R. (1975) *The Autonomous House* Thames and Hudson

Boyle, G. (1996) *Renewable Energy – Power for a Sustainable Future*. Open University.

BSRIA (1996) *Sustainable Housing*. BSRIA. A study of energy/water supply and drainage/sewerage technologies and their application at scales from a single house to a cluster, village or town.

BSRIA (1997) *Sustainable Housing - options for independent energy, water supply and Sewerage* BSRIA

Twidell, J. and Weir, T. (1998) *Renewable Energy Resources*. E. & F. N. Spon. Undergraduate study, including fluid mechanics and heat transfer, but also detailed applications.

EUREC Agency (2002) *The Future for Renewable Energy 2 – Prospects and Directions*. A useful summary of the available technologies, with refreshing honesty about issues like costs and the secondary effects of manufacture and disposal, such as pollution. An in-depth review of why renewables are not yet truly sustainable technologies and the life-cycle issues that need to be tackled in order to get there.

Web Sites

Department of Trade & Industry – The DTI New and Renewables programme is a source of policy guidance. The website is the source of information on contemporary policy. www.dti.gov.uk/energy/sources/renewables/index.html

Centre for Alternative Technology (CAT) – extensive experience and a large range of publications are available at www.cat.org. including comprehensive guidance with good references to journals and suppliers.

Energy Saving Trust. www.energysavingtrust.org.uk/

The European Renewable Energy Research Centres Agency. www.eurec.be/

Future Energy Solutions (was ETSU) Extensive publications lists are readily available on all the different technologies, including a vast record of commissioned reports, fact sheets, demonstration projects and case studies, categorised under energy from waste, biomass, wind, tidal, solar, fuel cells, small-scale hydro. There are hundreds of titles. www.aea-energy-andenvironment.co.uk/

Wind energy

McGuigan, D. (1978) *Small Scale Wind Power*. Prism Press.

Piggott, H. (1978) *It's a Breeze: A guide to choosing wind power*. CAT.

Winddirections, Journal of the European Wind Energy Association.

Hydro, wave, tidal

McGuigan, D. (1978) *Small Scale Water Power*. Prism Press.

DoE (1990) *Taking Power from Water*. HMSO. Review of tide, hydro and wave power technologies, programmes and UK potential.

Solar thermal

Halliday, S. P. (1998) *Solar Air Conditioning – Technical Assessment & Demonstration*. Gaia Research

Duffie, J. A. and Beckman, W. A. (2001) *Solar Engineering of Thermal Processes*. John Wiley.

Gordon, J. (2001) *Solar Energy – The State of the Art*. ISES.

Halliday, S. P. (2002) *Solar Desiccant Cooling*. Applied Thermal Engineering.

Andren, L (2003) *Solar Installations*. James & James.

Santamouris M. (ed.) (2003) *Solar Thermal Technologies for Buildings*. James & James.

Weiss, W (2003) *Solar Heating Systems for Houses*. James & James.

Solar PVs

Thomas, R. (ed.) (2001) *Photovoltaics and Architecture*. E. & F. N. Spon. An overview of how PVs work, and a useful guide for architects and engineers to assess feasibility.

Geothermal

Armstead, H. C. V. (1983) *Geothermal Energy* – Its past, present and future contribution. E. & F. N. Spon.

Fuel cells

Bockris, J. O'M. (1991) *Solar Hydrogen Energy*. Optima.

Biofuels

Kovarik, B. (1981) *Fuel Alcohol*. IIED.

Horne, B. (1996) *Power Plants*. CAT. Comprehensive guide and a useful contacts list.

El Bassam, N. (1998) *Energy Plant Species*. James & James. Explains how biomass works, harvesting and storage, conversion and economics.

Sims R. E. H. (2002) *The Brilliance of Bioenergy*. James & James.

Royal Commission on Environmental Pollution (2004) *Biomass as a Renewable Energy Source* RCEP

Biomass and BioEnergy Monthly. Pergamon Press.

District heating

Renewable energy in district heating. DBDH Journal 4/2000 (www.dbdh.dk).

Heat Pumps

McGuigan, D. (1981) *Heat Pumps*. Garden Way.

Renewables design tools

Design of PV systems – CD from Construction Resources (info@ecoconstruct.com).

EUREC Agency – *Photovoltaic Information Strategy to Architects (PISA)*. A useful, free, CD.