Zero And Low Energy Buildings

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By

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Overview

Buildings make a large contribution to the energy consumption of a country. It is estimated that, of the total energy generated in the industrialised world, 40% is used in the construction and operation of residential, public and commercial buildings. Approximately one third of primary energy worldwide is consumed in non-industrial buildings such as dwellings, offices, hospitals and schools; it is utilised for space heating and cooling, lighting and the operation of appliances. In the European Union (EU), energy consumption for buildings-related services accounts for between 33% and 40% of total energy consumption. Energy used for heating, lighting and powering of buildings accounts for around half of the UK's total energy consumption. In an industrial economy, domestic water heating accounts for over 5% of total energy use, domestic space heating up to 20%, and appliances and lighting up to 30%. Total consumption of energy in the building sector is comparable to that used in the entire transport sector.

Shrinking reserves of natural gas and oil, insecurity of energy supply, and the fear that climate change is being caused by the burning of fossil fuels, are forcing governments around the world to consider ways in which the growth of building related energy use can be curtailed. For householders and businesses there are financial benefits, primarily smaller energy bills, associated with energy-efficient dwellings and workplaces.

The creation of an energy-efficient building starts with the design process itself. There are software packages on the market that not only assist in solving particular problems related to the building envelope, orientation, materials, and the design of heating, ventilation and air conditioning (HVAC) systems, etc., but also use artificial intelligence (AI) in helping the designer to reduce the energy consumption of a building.

Renewable energy sources such as solar, wind, and geothermal, can be used to reduce the carbon footprint of a building. Solar energy can be captured using hot water solar collectors, photovoltaic panels, or designing the building so that its structure acts as a solar collector. In some cases medium-scale wind turbines can be used to generate electricity for large buildings or groups of residential properties.

However perhaps the largest contribution that architects and builders can make to carbon emission reductions is to reduce a building's energy demand by increasing the efficiency of heating and cooling systems, lighting systems and appliances, and ensuring the building itself does not 'leak' energy.

This report examines a range of technologies and building techniques that could revolutionise the building industry worldwide and provide both architects and builders with a competitive edge as governments put in place legislation to reduce carbon emissions and energy dependency.

At a glance

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However perhaps the largest contribution that architects and builders can make to carbon emission reductions is to reduce a building's energy demand and ensure the building itself does not 'leak' energy.

This report examines a range of emission-reducing technologies and building techniques available to developers and architects.

Included are profiles of: The Peabody Trust; DENA; Clarum Homes; ZED Factory; Mazria; Monodraught; Seattle's Green Building programme; and Encraft

1 Introduction

The energy crises of the 1970s provided the motivation for research and development into low-energy building technologies such as advanced glazing technologies, passive solar systems, and natural cooling, ventilation and daylighting strategies. Several projects that were initiated in the late 1970s and early 1980s proved that energy consumption reductions of 50% or more could be achieved, at little or no extra cost, through improved design. Since then the construction of contemporary buildings in a range of climate zones has shown that the 50% target can be met by developers.

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The idea of reducing the energy consumption of buildings continued to develop, and has been formalised in the creation of low energy building standards such as the Canadian R-2000, the German Passivhaus, the Swiss Minergie-P and the American Leadership in Energy and Environmental Design (LEED) and ENERGY STAR standards.

The term 'passive house' refers to a specific construction standard. Houses built to this standard provide a high level of comfort in both winter and summer, are built using energy efficient components and construction techniques, and employ a whole-house ventilation system to keep running costs to a minimum. Properties built to this standard use approximately 85% less energy and produce 95% less carbon dioxide compared with properties built to prevailing standards.

A natural progression from the concept of a passive or low energy building is the development of buildings that are net zero, or near zero energy consumers. A 'zero energy building' has a net energy consumption of zero over a typical year; several sub-divisions of this class of building were created to describe how the energy is measured, for example based on the cost, amount of carbon emissions, use of on-site or off-site renewable energy, or the efficiency with which the energy is generated. Zero energy buildings are still rare, but the concept has been gaining ground and there are a number of projects throughout the world that are trying to make such buildings a reality. The concept of zero energy buildings is now finding its way into legislation.

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The adoption of low- and zero-energy building techniques, and the market for the software tools and services that provide a platform for a new approach to building design and construction, is heavily dependent on the health of the construction industry. Currently the construction sectors of most countries in the developed world are entering a period of decline. This slowdown in the construction of new homes and offices will pose a challenge for many of the companies that have developed services and technologies for the low energy building market.

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2 Energy Efficient Building

Creating low-energy buildings entails using some basic energy-saving techniques such as:

- Designing, locating and orientating the building to reduce energy loads
- Reducing cooling loads by eliminating undesirable solar heat gain
- Reducing heating loads by using desirable solar or geothermal heat gain
- Using natural light instead of electrical lighting wherever possible
- Using natural ventilation wherever possible
- Generating electricity through the use of renewable sources such as solar and wind
- Using more efficient heating and cooling equipment and appliances
- Using computerized building control systems

Ultimately the selection of techniques to be used will be influenced by the climate, the size of the building, lighting requirements, hours of operation, and the cost of electricity and other energy sources. Any low energy building design must include energy targets and lifecycle costs.

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2.1 Computer-Aided Design (CAD)

The first step in improving energy efficiency is to improve the building design process with advanced tools such as computer-aided building design software. Computer-aided design and analysis software that can generate finished drawings has been on the market for over two decades. Examples of commonly used packages include:

- AutoCAD www.autodesk.co.uk
- Intergraph www.intergraph.com
- VersaCAD www.versacad.com

There is also a range of building energy simulation software, which can be used to estimate the energy consumption of a building:

- BLAST www.bso.uiuc.edu/BLAST
- BSim www.bsim.dk
- EcoTECT www.ecotect.com
- Ener-Win www.members.cox.net/enerwin
- Energy Express www.ee.hearne.com.au
- Energy-10 www.nrel.gov/buildings/energy10
- EnergyPlus www.energyplus.gov
- eQUEST www.doe2.com/equest
- Encraft www.encraft.co.uk

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However, to obtain an integrated building design the use of artificial intelligence (AI) and expert (or knowledge-based) systems are required. These help the designer with the development of design alternatives, in verifying the proposed solutions against requirements in the standards, and in evaluating all design alternatives. Some AI and expert systems have been developed, but the majority are at the research stage. The Building Environment and Energy Performance System (BEEPS), based on EU procedure EPBD 2002/91/CE, is an expert system used to provide ratings for the energy performance of buildings.

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2.2 Site Considerations

The optimum orientation should be chosen to maximise daylight, minimise heat loss during cold or cool seasons, minimise heat gain during hot or warm seasons, and to avoid or minimise the need for air conditioning. Polar facing windows suffer very little solar gain. East or west-facing glazing is harder to shade from direct sunlight as the sun angles are low at some times of the year. Equator-facing facades receive both direct and diffuse radiation and are relatively easy to control.

2.3 Building structure

The shape of a building is significant, since it determines the surface of the external envelope. Compactness is expressed as a ratio of surface to volume. As losses are proportional to the surface area of the envelope, the more compact it is, the smaller the heat losses will be. For non-rectangular buildings, all the joints between the structural components which are not in the same plane could cause thermal bridges and losses. When possible, it is preferable to reduce the external surface by modifying the shape of the building rather than adding insulation or a layer of glazing. A compact design reduces not only energy consumption but also the cost of construction.

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The exterior walls, floors, roof, and windows are the components of the exterior envelope. How much they resist heat conduction, how airtight they are, and how they are oriented with respect to the sun and prevailing winds (particularly windows) all are major determinants of energy performance. Other structural considerations are room widths, the height and placement of windows, and strategies for shading to remove unwanted heat gain. The building design, the materials selected and the quality of installation must work together to achieve maximum efficiency.

Buildings in cold regions should be designed in such a way as to act as large solar collectors. This can be achieved by orientating the building on an east-west axis so that the longest sides of the house are facing north and south. This gives the largest surface areas access to the sun. The windows should be placed so that the largest and highest number of windows is on the equator side, and the smallest and lowest number is on the polar side. This means that the equator-facing windows behave like the glass face of a solar panel, trapping solar energy inside the house, while the loss through the polar-facing windows, which lose energy faster than a well-insulated wall, is minimised by their small size.

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Finally, some means of heat storage (such as water tanks or large masonry features, like walls or floors) could be added and placed such that the sun heats them during the day. Whatever medium is used, it must have a large capacity to store heat and then be able to release it slowly overnight.

Other structural features that can be used as solar collectors are Trombe walls, conservatories, and atria. A Trombe wall is built in front of a storage wall, separated by a thin air space, on the equator-facing side. Solar radiation warms the store and is radiated into the house in an even fashion from its inner side.

The difference in energy consumption between a solar- and a non-solar-heated house of the same insulation standard is of the order of 500kWh per year.

2.4 Insulation

Much of the energy consumed by buildings is lost through their fabric. High levels of insulation and air-tightness are therefore an absolutely critical element of low-energy buildings. The aim of insulation is to slow down heat transfer. The same materials are required to keep buildings cooler in hot climates, or warmer in cold climates. A well insulated and ventilated building offers comfort to its occupants and reduces the need for, and therefore the cost of, air conditioning equipment (heating, cooling, or ventilation).

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The insulation value of a building is its ability to allow or resist the passage of heat through it. This is known as the thermal conductance or resistance, depending on how it is measured; one is the reciprocal of the other. In some countries, including Great Britain, thermal conductance is known as the U-value. In others, for example North America, it is measured in resistance or the R-value.

Every material has a unique inherent value for thermal conductivity, and the insulation value varies in proportion to the thickness. Generally speaking, the more still air a material can trap in its makeup, the better it is as an insulator. The resistance of a material is found by dividing the thickness by the thermal conductivity. By adding the resistances of the different materials that make up a wall or a roof section and taking the reciprocal, the U-value is determined. In order to conserve heat, the building's U-value needs to be as low as possible. The New Building Regulations 2006 (England and Wales) gives the worst case U-value for walls as 0.35 W/m²K difference between the outside and inside temperatures.

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There are many different types of insulation to suit different tasks. Some are effective at blocking heat radiation or convection while others reduce heat transfer. The list below gives examples of insulating materials and techniques:

Mineral-based products such as mineral wool and glass fibre have a higher rate of thermal conductivity than plastics-based products and thus require 50% thicker insulation to achieve equivalent performance. They are air and vapour permeable, and as such require vapour and radiant barriers such as foil backing to ensure long term performance.

U-values of $0.2W/m^2K$ can be achieved with a mineral wool thickness of 125 mm in a standard cavity wall and 165 mm in a timber frame. Reducing U-values to $0.1W/m^2K$ requires 300 mm to 350 mm of insulation overall; this is equivalent to a total section thickness of just over 500 mm and represents a significant potential loss of floor area.

Fibreglass achieves a better seal around wires and pipes, and therefore reduces heat loss. High-density versions of fibreglass offer lower U-values per millimetre of insulation, but are more costly. Miraflex is a type of fibreglass formed from the fusion of two different types of glass. Because the two types of glass contract at different rates as they cool, the fibres curl and twist together, which means they can be held together in batts (slabs of material) without the need for a phenol formaldehyde binder. It is more flexible and has greater tensile strength than standard fibreglass so fibres do not break off and become airborne.

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Mineral wool is similar to fibreglass except that natural stone or iron-ore blast furnace slag are the raw materials. Mineral wool is used for commercial applications as it can withstand higher temperatures than fibreglass and has better acoustic insulation properties.

Mineral cellular products such as cellular glass and vermiculite have a higher thermal conductivity than mineral fibre products, requiring an additional 30% thickness to achieve an equivalent insulation performance. Cellular glass has a stable thermal conductivity in the long term. It is impervious to air and water vapour movement, making it suitable for exposed conditions. Cellular products are formed using recycled waste products such as glass, together with an aerating agent. Mineral cellular products can be recycled as building aggregates.

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Plastic cellular products range from extruded and expanded polystyrene to phenolic foam boards. The thermal conductivity of foam-based plastic cellular products is very low, enabling high levels of performance to be achieved using a significantly thinner section. These products are particularly suitable for super-insulation applications. Plastic cellular products are not affected by water.

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The production of plastic insulation has been associated with the use of ozone-depleting agents such as hydrochlorofluorocarbons (HCFCs). Hydrofluorocarbons (HFCs) are now used for production in Europe. They have no effect on ozone, but are still greenhouse gases. Over time, production is being switched to use neutral hydrocarbons or CO2 as blowing agents.

Aerogels are effective thermal insulators because they almost nullify three methods of heat transfer (convection, conduction, and radiation). Silica aerogel has the lowest thermal conductivity of any known substance, and carbon aerogels absorb heat while still allowing sunlight to enter. A combination of silica and carbon aerogel gives the best insulating properties of any known material, approximately twice the insulative protection of the next best material, closed-cell foam.

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Plant- and animal-sourced cellular and fibrous products made from renewable materials require chemical treatment to protect them

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Radiant barriers such as metal roofs (aluminium or copper), foil-faced polyurethane or polystyrene, light-coloured roof shingles and reflective paint reduce radiated heat rather than conducted heat. Radiant barriers are used in climates where the temperature difference between outside and inside is the greatest.

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Vacuum insulation panels (VIPs) use the insulating effects of a vacuum to produce low U-values. They consist of: membrane walls, used to prevent air from getting into the vacuum area; a core material, used to hold the vacuum inside the membrane while preventing the membrane walls from collapsing; and chemicals to collect gases which have leaked through the membrane or off-gasses from the membrane materials. The near-vacuum greatly reduces conduction and convection of heat. VIPs provide three to seven times more insulation than the equivalent thickness of rigid foam boards or foam beads, and have U-values of less than 0.015 W/m^2K

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2.5 Heating And Cooling

Apart from building design, the obvious way of minimising or eliminating the use of fossil fuels for heating is to use the energy that is naturally available on site, i.e. renewable energy in the form of solar and geothermal energy.

Once the building is completed, using the energy that is naturally available on site will reduce the use of fossil fuels for heating.

2.5.1 Solar Water Heating

Solar energy can be harnessed using solar collectors, which allow solar radiation in the form of visible light and short wave infrared to pass through but block the re-radiation of long-wave infrared which is lower in temperature and not so readily lost. They are usually mounted on roofs. Solar water heating, in its simplest form, consists of a glazed, insulated box with water-filled pipes running through it. Energy from the sun is trapped and concentrated in the box, thereby heating the water in the pipes. This water is then moved to an insulated tank where it is stored for use on demand. A system where the water is moved by means of a pump is known as an 'active' system, while one where the water is moved by a natural convection loop created while the sun is shining is known as a 'passive' system.

Solar energy can be harnessed by solar collectors and used to heat water or provide electricity for lighting.

A passive solar system uses a collector placed below a tank located at the highest point in a heating water circuit which is built in the form of a loop. If there is not sufficient sunlight to heat the water, the cycle stops of its own accord. As soon as there is sufficient temperature difference between the panel and the water in the rest of the loop, the warm water starts to flow again.

Energy saving can be increased by increasing the tank size, and the insulation around the tank. According to British Standards (BS5918), the hot water tank should have the capacity to store at least 80% of daily hot water needs, calculated on the basis of 30 to 40 litres per person per day.

In Northern Europe, under ideal conditions, one can expect to collect about 1000 kWh of energy per square metre per year. However, there are inefficiencies that make the actual amount collected lower than the ideal: the collector itself is not able to collect 100% of the available solar energy; there are energy losses in the pipes; there is heat loss when water sits in the tank losing energy to its surroundings; and there are inefficiencies in the heat exchangers that transfer heat between the panel and the tank.

In general, the overall system efficiency is approximately 40% for a three-bedroom family home with 3 to 4m^2 of solar collector. Insulating tanks to a higher standard, and avoiding long pipe runs can sometimes improve the efficiency. An annual saving in hot water bills of 50% can be expected with this type of system.

Approximately 50% of existing dwellings in the UK are suitable candidates for solar water heating. If this potential is to be exploited before 2025, it will require the deployment of approximately 12 million systems (allowing for a rise in housing stock). This could save an estimated 9.6 TWh per year of oil and gas and 3.4 TWh per year of electricity, giving a saving of 5.6 million tonnes of carbon dioxide emissions per year, or just under 1% of current UK carbon dioxide production.

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In southern Europe, where there is more solar energy, a system may produce twice as much energy per square meter as it would in the UK. The magnitude of the possible savings is illustrated by the fact that between 1972 and 1985 Denmark cut its national space heating energy consumption by 30%, despite the fact that the actual heated floor area rose by 30% over the same period.

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2.5.2 Geothermal Heating And Cooling

Geothermal energy is mainly used in temperate regions where the average ground temperature just below the surface is between 8ºC and 13ºC. In these regions the average ground temperature remains relatively constant throughout the year, while atmospheric temperature conditions vary throughout the year. In tropical regions, the atmospheric temperature is mainly stable throughout the year and underground temperatures are higher than atmospheric temperatures, so there is no merit in the use of geothermal heat pumps.

Geothermal heat is not always easily accessible, and where it is, it is usually used to heat buildings, greenhouses, swimming pools, and spas. Geothermal technology lends itself to both heating and cooling depending on the conditions at the surface and underground. Geothermal energy can be harnessed either directly, or through the use of geothermal heat pumps buried within the top 15m of the earth's surface. In both cases the geothermal water is integrated with the water system operating within the building.

Geothermal heat is not always easily accessible, and where it is, it is usually used to heat buildings, greenhouses, swimming pools, and spas. Geothermal technology lends itself to both heating and cooling depending on surface and underground conditions.

Geothermal energy can be used directly by pumping warm water from underground to the surface to be stored in tanks. Alternatively, a heat pump can be used; here a series of pipes in a closed loop circulate a mixture of water and refrigerant through the ground.

In winter when the ground is warmer than the buildings above, the liquid absorbs heat from the ground, and this heat is then concentrated and transferred to the building. In the summer when the ground is cooler, the pump transfers heat from the building back into the ground. In a similar fashion, water-source heat pumps can be used to tap the heat from water bodies such as hot spas or disused flooded mines.

Geothermal systems have a relatively low temperature output, and are therefore best suited to under-floor heating since the lower temperature is not a disadvantage here. When used with radiators, the radiators need to be significantly larger than for a boiler-based system. A typical geothermal system can provide up to 100% of a household's heating requirements.

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2.5.3 Boilers

Conventional boilers have a water jacket heat exchanger surrounding a combustion chamber where the fuel is burned. The water in the jacket heats up and is then circulated to where it is needed for space or hot water heating. The flue gases, which are the combustion products of air and the fuel, are vented out though a pipe (the flue) to the outside air. There is considerable heat contained in the gas, which can be as hot as 250°C, and it is normally wasted as it escapes out into the open air. The resulting loss means that the boiler efficiency is between 60% and 77%. More advanced boilers are now available that improve on the conventional boiler efficiencies. These are 'high efficiency' boilers and single and multiple 'condensing' boilers.

High efficiency boilers use a combination of a more efficient heat exchanger, a higher level of insulation in the casing, and an inverted 'U' flue to help reduce the flue gas temperatures and stack ventilation losses. The inverted 'U' forms a natural air lock and keeps air from being drawn up the flue when the boiler is not firing, which is the opposite situation to that in conventional boilers. Typically, these boilers have as high as 85% efficiency. High efficiency 'combination' boilers (sometimes called 'demand' boilers) operate on hot water demand and do not have hot water storage tanks, and therefore do not lose energy to the surroundings from the tank. These are suitable for use in small households with limited space for storage tanks and where a lower water flow is acceptable.

High efficiency boilers use a combination of a more efficient heat exchanger, a higher level of insulation in the casing, and an inverted 'U' flue to help reduce the flue gas temperatures and stack ventilation losses.

Condensing boilers also have better casing insulation and the inverted 'U' flue. In addition they also recover even more heat by condensing the flue gases from the combustion process, by putting a second and sometimes a third heat exchanger in the path of the flue gases. In this way, the final temperature of the exit gases can be reduced to between 50°C and 60°C. For the flue gas to condense, the return water must be below about 55°C. For this reason, condensing boilers are most suitable for low-temperature systems, such as radiant floor heating, swimming pool or spa, dedicated water heating, snow melt, and water-source heat pumps. Typically, single condensing boilers can achieve 90% efficiency while double condensing boilers can reach 98% efficiency. Generally, multiple condensing boiler systems are appropriate for system loads above 58.6 kWh.

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Biomass boilers can be used instead of gas- or oil-fired boilers, the advantage being that the fuel is renewable and carbon-neutral. A biomass boiler needs to be manually fed fuel in the form of wood pellets, wood chips, non-commercial timber or fuel crops - miscanthus, short rotation coppice - which has to be supplied from somewhere, ideally locally, thus requiring extra effort to store and load. As such, this option is less attractive to building inhabitants except for enthusiasts of green living. Biomass boilers are available in sizes to suit all applications from domestic (5 to 60 kW) to large commercial systems (300 kW to 200 MW).

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2.5.4 Heating Systems

A heating system carries the heat from the boiler to the various rooms that need heating. There are many types of heating systems. The two main ones are 'wet systems', where water is heated and then pumped round the building through various objects that release heat, and 'warm air systems' where the boiler heats air which is circulated through the building by means of air ducts. In the UK the wet system is most commonly used.

The three main wet system types are wall-hung radiators, baseboard radiators, and under-floor heating. Wall-hung radiators give off their heat through both convection and radiation. Baseboard radiators are fitted near the floor around the perimeter of a room and work by convection. Under-floor heating works by means of pipes embedded in the floor in which hot water is circulated.

Under-floor heating is the best option, as it uses less energy because the required comfort level can be attained with a lower room temperature. It is also better suited for condensing boilers because of the lower temperatures of the return water. This can result in energy-savings of up to 26% over wall-hung radiators according to studies done by the British Research Establishment (BRE). Under-floor heating also happens to give the best temperature profile for human comfort, with a warm floor and cooler upper level.

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2.5.5 Glazing

The objective of glazing is the same as for solar collection, i.e. to allow solar radiation in the form of visible light and short wave infrared to pass through, but block the re-radiation of long-wave infrared.

Energy-wise, windows are extremely expensive. The U-values of single- and double-glazed windows are about 5.6 W/m²K and less than 2.0 W/m²K respectively, the latter being less than 1.0 W/m²K when high-technology materials are used. These values are very high when compared with walls which are required to have worst case U-values of 0.35 W/m²K (British Standard). In the UK, double-glazing is now required in all new buildings.

Energy ratings for windows vary from country to country. In the US, windows are rated according to their thermal resistivity. Canadian ratings consider air infiltration and solar gain in addition to insulation values.

A window with a negative energy rating (ER) loses energy, whereas one with a positive ER contributes energy and one with an ER of zero is neutral as it contributes as much energy through solar gain as it loses during a summer months.

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Advances in technology have improved insulating properties. Low emittance (low-e) glass has a special coating applied to one surface of a glazed unit that improves on the natural ability of the glass to hold the inside radiant heat.

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A range of low-e coatings have been designed to allow for high, moderate, or low solar gain. In heating-dominated climates with a modest amount of cooling, or in climates where both heating and cooling are required, low-e coatings with high, moderate or low solar gains may result in similar annual energy costs depending on the house design and operation. While high solar gain glazing performs better in winter, low solar gain glazing performs better in summer. Low solar gain low-e glazings are ideal for buildings located in cooling-dominated climates.

Gas-filled sealed units use argon, a better insulator than air, in the cavity between the glass panes. In double- and triple-sealed units, there is a hermetic seal applied to the edging around the unit to keep moisture out. The 'heat-mirror' glazing system has a thin heat-reflecting film suspended between two panes of glass and is seven or eight times more effective than normal double glazing.

One consideration when choosing high performance windows is the amount of solar energy coming in through the window as well as what might be going out. Triple-glazed windows do not let as much solar energy in as double-glazed windows because 10% to 15% of the available energy is lost through reflection, absorption, convection, or re-radiation in each pane of glass. Where maximum solar gain is required, as in conservatories, it might be better to use double-glazed windows, whereas triple-glazed windows could be more desirable in very windy or noisy areas. A key advantage of glass is that it is impervious to wind.

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2.6 Electricity Generation

Electricity for use in buildings can be generated using photovoltaic systems, micro-wind turbines or micro-Combined Heat and Power (micro-CHP) systems. These micro-generation systems can be off-grid or on-grid. Where a house, perhaps in a remote location, is not connected to the grid, the surplus electricity generated can be stored in batteries for use at peak times or when the wind speed or solar radiation is low. Where a house is grid-connected, the surplus can be fed back into the grid and, in some cases, sold back to the electricity supplier. A microgeneration system requires the installation of an inverter to convert the direct current (DC) current from the generator and battery into alternating current (AC) at the voltage and frequency of the mains supply. A typical home would require a 2.5 to 6 kW peak output system, depending on its location and size.

Where a house, perhaps in a remote location, is not connected to the grid, the surplus electricity generated can be stored in batteries for use at peak times or when the wind speed or solar radiation is low.

2.6.1 Photovoltaics

The photovoltaic (PV) cell is a device that converts solar energy into electricity. Assembled into modules, they are used to collect solar energy over a wide area, such as a roof top, or solar array. Solar cells are made from semiconductors such as silicon, germanium, and gallium arsenide. Silicon solar cells are more common due to the abundance of the raw material. Most PV cells available are made from monocrystalline silicon, polycrystalline silicon, and thin film silicon (using amorphous silicon). A typical crystalline cell might be 100 x 100mm.

Although they may appear to be an ideal way of generating electricity locally, silicon solar cells have a very low efficiency of 24% under laboratory test conditions and 16% in commercial applications. Theoretical maximum efficiencies are approximately 30%. Actual efficiencies are improving and materials that offer greater efficiencies such as copper indium diselenide (CIS) and cadmium telluride (CdTe), are being investigated. CdTe modules are in pilot production. Novel approaches such as producing multi-junction cells, which use a wider part of the solar spectrum, are seen as a possible route to increasing cell efficiency.

Although they may appear to be an ideal way of generating electricity locally, silicon solar cells have a very low efficiency of 24% under laboratory test conditions and 16% in commercial applications

The electricity demand for domestic applications such as lighting, radio, TV and hi-fi for a typical UK household is 1000 kWh. This would require PV rooftop systems of 10 m² in area and about 1kW in capacity.

There are three ways of integrating PVs into buildings: roof-based systems, façade systems, and sunshade and sunscreens. Building-integrated systems have the advantage of not requiring extra land on which to place a solar array. PV systems can be fully integrated into the roofs of residential and commercial buildings, and the walls of commercial buildings.

There is a significant financial advantage in using PV panels as they can replace some conventional wall cladding and roofing materials. In the UK PV systems on the walls and roofs of suitable commercial and industrial buildings could, with wide scale deployment, eventually supply around 360 TWh (120% of 1992 electricity demand).

There is a significant financial advantage in using PV panels as they can replace some conventional wall cladding and roofing materials that would otherwise be needed.

PV arrays have some visual impact on the environment. Rooftop arrays are clearly visible to neighbours, and may be regarded as either attractive or unattractive according to aesthetic tastes. Several companies including Solarcentury, Sharp, Biohaus, Sanyo and Solartechnik have produced PV modules in the form of special roof tiles that blend into roof structures more unobtrusively than current module designs.

Rooftop arrays are clearly visible to neighbours, and may be regarded as either attractive or unattractive according to aesthetic tastes.

PV installations have relatively long lifetimes and some have been in operation for over 15 years. The design life of standard glass/EVA (ethylene vinyl acetate) modules can exceed 20 years.

The resulting output from building integrated installations is the output of the PV array less the losses in the rest of the system. The output from the array depends on the daily variation (due to the rotation of the earth), the seasonal one (due to the orientation of the earth's axis and the movement of the earth about the sun), location (i.e. the solar radiation available at the site), tilt, azimuth, shadowing, and temperature. 1000 W/m² is a high level of solar radiation achieved only in very sunny conditions. Nonetheless, in London in clear sky conditions, a south-facing wall at noon in early December can receive approximately 650 W/m², and a south-facing surface tilted at 22.5

In London in clear sky conditions, a south-facing wall at noon in early December can receive approximately 650 W/m².

degrees from the horizontal at noon in late June can receive approximately 945 W/m².

The performance of PV modules decreases with temperature; building-integrated modules can reach 20 to 40 °C above ambient conditions. Designs for building-integrated PVs need to consider this from the outset in order to allow air to flow over the backs of the modules to maintain high performance.

It is important with all types of modules to avoid unwanted heat gain into the space which could cause discomfort and increase any cooling load. Possibilities for using waste heat exist; PV panels could incorporate water pipes, linked to space or domestic hot water systems. However such possibilities tend to carry greater cost and complexity.

2.6.2 Micro-Wind Turbines

Harnessing the power of the wind requires the installation of micro-wind turbines that can be mounted on poles, rooftops, masts, or towers. Wind turbines are only cost effective when the building is located off-grid, with average wind speeds of 5 m/s, where there are no obstructions such as tall buildings and trees to cause turbulence, and where turbines can be mounted at a height that takes maximum advantage of the fact that wind speeds increase significantly with height. Planning consent must be obtained before installation, in view of their height, visibility, and probable impact on wildlife. Consideration must also be given to neighbours who might object to the noise and visual impact of the turbine. Small-scale building integrated wind turbines that are silent and non-resonating with the building structure are now available from manufacturers such as Windsave and Renewable Devices. Turbines can have a life of up to 20 years but require service checks every few years to ensure they work efficiently.

Wind turbines are only cost effective when the building is located off-grid with average wind speeds of 5 m/s, where there are no obstructions such as tall buildings and trees.

2.6.3 Micro-CHP

Industrial CHP (Combined Heat and Power) systems primarily generate electricity, and use the heat generated as a by-product for applications such as district heating. Micro-CHP systems, which operate in homes or small commercial buildings, are usually driven by heat demand, and deliver electricity as the by-product although current systems can be made to operate in electricity- and/or heat-driven modes. Micro-CHP systems can provide the majority of a home's electricity needs, and often generate more electricity than the instantaneous demand. It is expected that micro-CHP units will replace conventional and condensing domestic gas boilers.

Micro-CHP systems, which operate in homes or small commercial buildings, are usually driven by heat demand, and deliver electricity as the by-product although current systems can be made to operate in electricity- and/or heat-driven modes.

In micro-CHP systems, the energy in the fuel (gas, oil) is converted into heat and electricity. A number of different conversion technologies have been developed for application in the domestic market. These include reciprocating engines, Stirling engines, low- and high-temperature fuel cells, micro-gas turbines, organic Rankine Cycle machines, modified steam engines, thermo photovoltaics, and thermoelectric devices.

In micro-CHP systems, the energy in the fuel (gas, oil) is converted into heat and electricity. A number of different conversion technologies have been developed for application in the domestic market.

Reciprocating engines are conventional internal combustion engines coupled to a generator,with a heat exchanger(s) to recover the heat of the exhaust gas and the cooling cycle. Internal combustion engines inject fuel and air into the cylinders where the combustion occurs. The resulting temperature and pressure changes of the fuel/air mixture (which is also the working gas) act on the piston to produce useful work. As the combustion process is cyclical, rather than continuous, it is more difficult to ensure complete combustion of the fuel, and noise and pollutant emissions tend to be higher.

Stirling engines are external combustion engines equipped with a generator and heat exchanger(s). The majority of true micro-CHP systems are currently based on external combustion technology as their characteristics are best suited to this stationary, constant running application. External combustion engines separate the combustion process (which is the energy input to the engine) from the working gas, which undergoes pressure fluctuations and hence does useful work. As the combustion process is used to provide a continuous heat input to the working gas, it is more controllable and generally more efficient, cleaner, and quieter than internal combustion engines.

The majority of true micro-CHP systems are currently based on external combustion technology as their characteristics are best suited to this stationary, constant running application.

Micro gas turbines are small gas turbines belonging to the group of turbo machines with electric power outputs of up to 300 kW equivalent. In order to raise the electrical output micro gas turbines are equipped with a recuperator (waste heat-heat exchanger). They are also equipped with a regular heat exchanger in order to use the waste heat from the exhaust gases.

Organic Rankine Cycle (ORC) machines have similar cycles to conventional steam turbines except that the fluid that drives an ORC turbine is a high molecular mass organic fluid such as pentane or butane instead of water or steam. This allows the use of low temperature heat sources such as solar ponds which typically operate at around 70 to 90 °C to produce electricity in a wide range of power outputs (from a few kW up to 3 MW equivalent per unit).

Fuel cells are electrochemical energy converters similar to primary batteries. In a fuel cell, the chemical energy within the fuel is converted directly into electricity (with by-products of heat and water) without any mechanical drive or generator. In theory this can result in high electrical conversion efficiencies and low emissions. However, numerous additional components are required to condition the fuel and to convert the DC electrical output into AC suitable for domestic installations. Fuel cells' theoretical potential has yet to be realised in any practical domestic product. Fuel cell micro-CHP systems are either based on the low temperature polymer electrolyte membrane fuel cells (PEFC or PEMFC) which operate at about 80 °C, or on high temperature solid oxide fuel cells (SOFC) working at 800 to 1000 °C.

In a fuel cell, the chemical energy within the fuel is converted directly into electricity (with by-products of heat and water) without any mechanical drive or generator. In theory this can result in high electrical conversion efficiencies and low emissions.

It is only recently that fuel cells have been developed specifically for micro-CHP applications and it is unlikely that commercially viable products will be available before 2010.

Fuel cells for use in micro-CHP applications are unlikely to be available commercially before 2010.

Various other technologies, such as steam cells and thermoelectric devices, are still under development. Thermo-ionic technologies use a temperature differential acting on metals to produce electricity. In a thermo-photovoltaic (TPV) unit, sunlight concentrated onto an absorber heats it to a high temperature of approximately 1200°C, and the thermal radiation emitted by the absorber is used as the energy source for a photovoltaic cell that is designed to maximize conversion efficiency at the wavelength of the thermal radiation. Although these are relatively inefficient and produce little power, there may be applications, for example in self-powered boilers, for which such concepts are of value.

Natural gas is consumed in a Stirling engine or any of the other prime movers described above to provide heat and electricity for use within the building. A total of around 70% to 80% (gross calorific value) of the energy value of the gas is converted into heat, which raises the temperature of water used for space and water heating in the same way as in a normal central heating system. Of the remainder, 10 to 25% is converted into electricity, and the residual 5% to 15% is lost in the flue gases. This compares with a conventional gas central heating boiler where 80% of the energy in the gas is converted into heat and the remaining 20% is lost in the flue gases. Domestic micro-CHP systems have the potential to be as much as 90% energy efficient. Although condensing boilers and micro-CHP systems operate at similar efficiency ratings, the advantage of micro-CHP systems over condensing boilers is the reduction in consumption of grid-supplied energy through the use of its own generating capability.

Domestic micro-CHP systems have the potential to be as much as 90% energy efficient.

Depending upon the requirements of a specific application, micro-CHP systems may be operated in different modes: electricity and/or heat-driven. Time-variant operation modes may be implemented by means of an energy management system which selects the optimum operating mode for specific requirements. It is also possible to apply combined operating modes such as heat driven with peak-electricity function, maximum electricity and/or heat demand, or minimum electricity and/or heat demand.

Micro-CHP units are similar in size to other household appliances. A 1 kWequivalent Stirling Engine micro-CHP, for example, is a third of the size of a typical fast-boiling electric kettle. Micro-CHP units require more servicing than gas boilers, however the auxiliary products fitted around the micro-CHP are common to existing heating systems.

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In the UK micro-CHP systems could eventually provide an installed generating capacity of 15 to 20 GW, which is roughly equivalent to the UK's nuclear generating capacity in 2001. The annual output is likely to be lower in reality, as micro-CHP is used for peak loading rather than covering base load. The capacity quoted above could also contribute an annual reduction of 16 MtC (Million tonnes of carbon).

2.7 Climate control: Ventilation And Air Conditioning

For the comfort and productivity of a building's occupants it is important that the building should have a good interior climate. A major factor affecting how well a building will 'hold' its heat is its rate of ventilation. Therefore to minimise heat loss, the building should be well-sealed around window and door frames, between floors and walls, roofs and walls, and other places where draughts could be a problem. The ventilation rate, measured in air changes per hour (AC/hr) for a well-sealed building is typically 0.5 to 1.0. The ventilation rate could be as much as 3.0 for a poorly-sealed or old building. The objective of ventilation is to have control over ventilation rates.

A major factor affecting how well a building will 'hold' its heat is its rate of ventilation.

While it is important to minimise heat loss by ensuring a well-sealed building, it is also important to minimise or remove unwanted heat gain, preferably without air conditioning. Computers and other office equipment increase the internal heat gains in most offices. It is therefore important to buy equipment that is energy efficient. Highly glazed facades, often with poor shading, have become very common. This, together with the extra heat gains from electrical lighting made necessary by deep floor plans, and the wider use of false ceilings, increases the risk of overheating. During very warm periods, it is important for the occupants' comfort to remove the heat emanating from lighting and body heat to avoid a temperature rise indoors. This is usually removed by convection (40%), radiation (35%), and evaporation (25%) depending air temperature, relative humidity and the activities of the occupants. Air conditioning units are usually needed if heat gains cannot be removed by natural means.

Computers and other office equipment increase the internal heat gains in most offices. It is therefore important to buy equipment that is energy efficient.

Thermal gains generated by human activity can be managed by grouping people with similar activities in the same area, and controlling the cooling or heating requirements of each area.

Natural ventilation minimises the need for air conditioning and can reduce the size of air-conditioning units required. Buildings which have a high solar gain, house industrial processing operations and are located in countries with a warm temperate climate usually suffer from heat gain. These buildings can be flushed of hot air by making use of the 'stack effect' which induces a convection cycle that dispels hot internal air through openings in the building envelope, replacing it with cooler external air. One application of the stack effect is the thermal chimney.

Buildings can be flushed of hot air by making use of the 'stack effect' which induces a convection cycle that dispels hot internal air through openings in the building envelope, replacing it with cooler external air.

A thermal chimney is created by forming an air corridor, usually alongside lift shafts, stairwells, and atria, to an opening above the roof. A rotating metal scoop at the top, which opens in a direction opposite to the wind, allows heated air to exhaust without being overcome by the prevailing wind. To assist the stack flow, siphonage can be added by locating long volume turbines (LVT) at the top of an air stack. The Science Building at the University of New South Wales is an example of a building that has applied LVTs.

2.8 Lighting

Close to 10% of the energy consumed in the UK is for lighting commercial and residential buildings. Domestic lighting amounts to around 6% of the total UK electricity consumption, while commercial buildings use the rest.

Close to 10% of the energy consumed in the UK is for lighting commercial and residential buildings.

During cold months, the heat from lights can usefully contribute to space heating. However, during the warmer months it can cause overheating.

Daylighting is the term used for making the best use of natural daylight through careful building design and the use of controls to switch off artificial lighting when there is sufficient natural light available. This saves on energy and the need for air conditioning. The daylighting performance of a building is often evaluated in terms of the daylight factor, defined as the ratio of the internal illumination to the illumination simultaneously available on a horizontal plane from the

Daylighting is the term used for making the best use of natural daylight through careful building design and the use of controls to switch off artificial lighting when there is sufficient natural light available.

whole of an unobstructed sky. It is estimated that the national potential for exploiting daylighting in the UK is worth between 0.7 and 1.3 MtC by 2020.

Traditional techniques for daylighting include:

- shallow-plan designs to allow daylight to penetrate all rooms and corridors
- light wells in the centre of buildings
- roof lights
- tall windows, which allow light to penetrate deep inside rooms
- task lighting directly over the workplace, rather than lighting the entire interior of the building
- deep window reveals and light room surfaces to cut the risk of glare
- conservatories
- locating windows on at least two sides of a room so that light comes in from more than one direction

More modern variants use optical fibres, light ducts, and steerable mirrors to direct light into light wells.

Light pipes

Vertical and horizontal light pipes can be used as a means of refracting and reflecting light into the depths of multi-storey buildings. Results from tests on horizontal light pipes (HLP) showed that on a bright sunny day, over one third of daylight (320 Lux required) at 3.5 m can be transmitted into a building. Vertical light pipes (VLPs) fitted with equator-facing reflectors can achieve a 40% improvement over VLPs without reflectors.

Vertical and horizontal light pipes can be used as a means of refracting and reflecting light into the depths of multi-storey buildings.

Energy-efficient light bulbs

When there is insufficient daylight to meet the needs of occupants, it must be supplemented through the use of artificial lighting. Usable light is measured in lumens, and the best way to rate the economy of lighting is through a measurement of lumens per Watt. The higher the number, the more efficiently is power being used to generate light.

Conventional tungsten filament incandescent bulbs convert only 10 to 15% of the power they consume into usable light. They actually generate more heat than light, and produce light by heating a filament until it glows.

Conventional tungsten filament incandescent bulbs create more heat than light.

The use of compact fluorescent lights can significantly improve the energy efficiency of a building. These bulbs produce light through a discharge process and have a fluorescent coating which extends their working life. An incandescent 100 W light bulb has a 1,000 hour life. A compact fluorescent bulb of equal light intensity has a normal life of over 8000 hours and is rated at only 20 W, therefore over its lifetime it will consume 160 kWh. An incandescent bulb burning over the same period of 8,000 hours will use 800 kWh. Fluorescent lighting should be used with electronic dimmable ballasts which consume less energy than magnetic ballasts. Operating lamps with electronic ballasts reduce electricity use by 10% to 15% over magnetic ballasts for the same light output. Electronic ballasts also offer reduced flicker, lower weight, less noise and longer life than do magnetic ballasts.

A compact fluorescent bulb of equal light intensity has a normal life of over 8000 hours and is rated at only 20 Watts. Therefore over the lifetime it will consume 160 KWh. An incandescent bulb burning over the same period of 8,000 hours will use 800 KWh.

Another type of bulb is the low-voltage mini-spot which has the advantage of low energy consumption as well as low voltage (12 V instead of 115 or 230 V). These bulbs generally have a tungsten element but with halogen added to the inert gas mixture that keeps soot from forming and lengthens the bulb life. They are not as energy efficient as compact fluorescent bulbs but use typically less than half the energy of an incandescent bulb. They supply a pleasant light, have a better spectrum, and can be used in specialist applications such as spot lighting.

The use of dimming to adjust the amount of light used in any given application reduces the energy consumed and can in some cases increase bulb life.

Research is ongoing into means of producing a light emitting diode (LED) that emits pure white light. To achieve this goal, the light from a combination of LEDs emitting red, green and blue light is mixed to produce warm white light. One of the criteria for judging the quality of artificial light is the degree to which it approximates to sunlight. This is measured by a colour rendering index (CRI) in which 100 represents equivalence to daylight. Incandescent bulbs have a score of 95, against the best LED which achieves 85. However, in terms of efficiency, incandescent bulbs produce 10 to 20 lumens per Watt while LEDs emit 100 lumens per Watt. Furthermore LEDs have a life expectancy of up to 50,000 hours, meaning they could have a working life of several decades.

Light and occupancy sensors used in conjunction with dimmers and switches can automatically adjust or switch off artificial lighting. A photo-electric on-off control system can be deployed in such a way that artificial lighting is switched on and off automatically as the daylight level falls and rises through a predetermined level, with the desired luminance level being set by the occupant. According to the Chartered Institution of Building Services Engineers (CIBSE) code for interior lighting, an office should have a design illuminance level of 500 Lux.

> Light and occupancy sensors in conjunction with dimmers and switches can be used to automatically adjust or switch off artificial lighting.

The effect of incorporating daylighting in an office building in Japan resulted in a savings of 15.7 kWh/m²/year. It was found that the percentage of energy savings in electric lighting was up to 50%, and further electricity savings were realised due to a reduction in heat dissipation from artificial lighting, resulting in a lower cooling load.

> Daylighting in an office building in Japan resulted in a savings of 15.7 KWh/m²/year.

2.9 Future Technologies

There is a range of technologies that allow whole communities to exploit energy derived from low emission technology. Examples are:

- Active district solar heating: This development is a likely scale up of the solar heating technology discussed in this document to meet heating requirements at a district level, with a network of solar collectors sited on ground level rigs next to a central heating substation.

- Combined heat and power (CHP) fuel cell systems using a variety of options for fuel, e.g. natural gas, hydrogen and oxygen.

> Active district solar heating, CHP and the use of aquifers are examples of technologies that can be deployed community-wide rather than merely being built into a single property.

- The use of aquifers as thermal energy storage systems, using water from an underground well to cool a building or industrial process, and then using the heat gained to heat another well used to preheat ventilation air in winter.

3 Building Operation

3.1 Energy-efficient appliances

There is no point in designing energy-efficient buildings if, subsequently, energy is wasted through the use of appliances with poor energy ratings. It is therefore imperative that energy-efficient A-rated appliances are used whenever possible. Improvements in the standards of new household appliances and greater uptake of A-rated appliances could yield significant carbon savings and save around 0.4 million tonnes of carbon emissions by 2010, relative to the 'business as usual' baseline.

Energy savings of 10 to 20% can be realised by installing a BMS compared with independent controllers for each system.

3.2 Building Management Systems

A building management system (BMS) is a centralised computer-controlled system connected to all the monitoring equipment in a building, such as light sensors and energy meters. A building management system can significantly improve the overall energy management and performance of a building. Energy savings of 10 to 20% can be realised by installing a BMS compared with independent controllers for each system.

The monitoring itself allows plant status, environmental conditions, and energy to be monitored, providing the building operator with a real-time understanding of how the building is operating. This can often lead to the identification of a problem, such as excessively high energy use at certain times of the day, that would otherwise have gone unnoticed.

It is now possible to construct intelligent Building Management Systems, which incorporate expert systems that react to information fed from various control sensors in the building.

Energy meters connected to a BMS provide information on real time energy consumption patterns (and ultimately a historical record of the building's energy performance) which can be logged and analysed in a number of ways, both numerically and graphically. BMSs can therefore improve management information by trend-logging performance, benefiting forward planning and costing, and encouraging greater awareness of energy efficiency among building occupants.

It has been predicted by computer simulation that electricity savings of up to 20% could potentially be realised for lighting and heating by tuning the control of a BMS to the use of a building.

It is now possible to build an intelligent BMS with an expert system that reacts to information fed from various control sensors in the building. Energy savings can be achieved by incorporating a self-tuning occupancy predictor into a zone controller, using rules within the expert system to control the environment within the building for maximum occupant comfort at minimum cost. The optimal start and stop cycles can be tuned to fit the expected occupancy patterns using a mathematical thermal model for the area. Current energy saving schemes such as load control, load cycling and load balancing can easily be incorporated into the rule-based control methodology. If the model's prediction is incorrect, rules exist to modify the model. This means that at certain times of the day, heating, ventilating and air conditioning (HVAC), and lighting can be reduced in sparsely occupied areas of the building to save energy. It has been determined, using computer simulation, that electricity savings of up to 20% could be realised by tuning the control of a BMS to the use of a building.

4 Political And Legislative Environment

4.1 Building Regulations

Most OECD (Organisation for Economic Co-operation and Development) countries have set up energy efficiency standards for new buildings and service sector buildings; this includes all European countries, Australia, Canada, the USA, Japan, Korea, and New Zealand. Some non-OECD countries outside Europe have recently established mandatory or voluntary standards for service buildings; Singapore and the Philippines were among the first.

Most OECD (Organisation for Economic Co-operation and Development) countries have set up energy efficiency standards for new buildings and service sector buildings.

Over the last 20 to 25 years, standards have been reinforced on a number of occasions. Some countries have made three or four major revisions to their building code, each time setting standards higher, and in some cases looking for energy efficiency improvements of the order of 30% compared with the previous revision. Across the EU the average cumulative energy saving achieved for new dwellings, compared with dwellings built before the first oil shock, is approximately 60%. Aspirational targets that may find their way into future revisions range from 20% to 30% improvement on current standards.

Regulations for factories and offices are usually less severe than those applied to residential buildings, except in less developed countries and economies such as Chile, Hong Kong, The Philippines, Taiwan, and China where there are mandatory standards for large commercial buildings but not for flats, apartments and houses.

Regulations for commercial buildings are usually less severe than those applied to residential buildings.

The World Energy Council (WEC) has found it difficult to assess the impact of mandatory building standards over time. Firstly, in many countries these standards are continuously changing, moving from a component-based approach to a performance-based approach. Secondly, there is an absence of real field studies on their impact. Very few countries investigated by the WEC have really looked at the impact of their codes.

In most cases, compliance with the codes is only verified before the building is complete; if the building complies with the prescribed construction methods and materials then it is assumed that the thermal building code is fulfilled. However, in the future, it will be increasingly difficult to verify compliance due to the greater flexibility and complexity of new buildings and their low energy demand. Improper construction, such as thermal bridges, will influence results.

In some countries it is thought that 15 to 20% of buildings do not comply with the standards.

Retrospective evaluation of a certain number of buildings will come to be of primary importance in order to understand the impact of regulations. In some countries it is thought that 15 to 20% of buildings do not comply with current standards (even if they are tightly specified), and it is probable that this percentage will increase rather than decrease.

Some countries are monitoring compliance, particularly in the non-residential sector. In Hong Kong, for example, checks on a number of buildings revealed that buildings complied with the regulations. Over half of the high-rise buildings checked were more than 40% better than the standard. In the case of podiums (the lower and larger parts of high-rise buildings) 90% were approximately 50% better than the standard. This indicates that the standard was not set at a proper performance level.

The impact of air conditioning in developing countries is still uncertain. Air conditioning is particularly energy intensive and relies on electricity. Mandatory standards for this specific type of equipment may become necessary.

One of the quickest methods for reducing building-related energy consumption is to improve the energy efficiency of existing buildings. This can be achieved through using incentives, building codes and standards that specifically apply to existing buildings that are being extensively modernised and in cases where the developer has to obtain planning permission for these improvements. For this reason, alternative strategies, such as incentive programmes, have to be developed. One example of this is the UK's Low Carbon Buildings Programme for consumer based energy production, which offers grants to householders, community organisations, schools, the public sector, and businesses to install solar photovoltaics, wind turbines, small hydro, solar hot water, ground/water/air-source heat pumps, bio-energy, renewable CHP (CHP using waste heat from bio-fuel power generation), micro-CHP, and fuel cells in their buildings.

The renovation of existing buildings provides an opportunity to reduce building related energy consumption in the housing and commercial property sector.

Another example is the USA's Energy Policy Act 2005, which offers a variety of tax credits and grants to consumers and builders who install energy-efficient products and technologies in buildings, and tax deductions for energy-efficient commercial buildings. In Hong Kong, a scheme of accreditation for energy efficient buildings was introduced in 1998. Under this scheme, any building, new or old, that fully complies with the building energy codes is eligible for accreditation as an energy-efficient building. A certificate is issued to the building's owner and its name entered in a government register. This, together with an energy efficiency building award, serves to draw the attention of the public and building professionals to the issue of energy efficiency.

The future will see new requirements incorporated into building codes to mandate the integration of renewable and micro-generation systems (such as solar photovoltaics, fuel cells, micro-wind turbines, and micro-CHP systems) into buildings, and the consideration of energy consumption on a life-cycle basis. The trend towards performance-based building codes is also set to continue.

The future will see new requirements incorporated into building codes to mandate the integration of renewable and micro-generation systems.

4.2 Energy Efficiency Legislation

4.2.1 The European Union

As the construction and property sector accounts for 40% of the EU's energy requirements it offers the largest single target for any energy efficiency improvement programme. More than one-fifth of the present energy consumption and up to 30 to 45 million tonnes of carbon dioxide per year could be saved by 2010 by applying more ambitious standards to new buildings and buildings being refurbished. This would represent a significant contribution towards meeting the Kyoto targets.

> More than one-fifth of the EU's present energy consumption and up to 30 - 45 million tonnes of carbon dioxide per year could be saved by 2010 by applying more ambitious standards to new buildings and buildings being refurbished.

Significant legislation for the sector includes Directive 2002/91/EC on the energy performance of buildings, the Boiler Directive (92/42/EEC), the Construction Products Directive (89/106/EEC), and the buildings provisions in the SAVE Directive (93/76/EEC).

Directive 2002/91/EC on the energy performance of buildings

The objectives this directive are to promote the improvement of energy performance of buildings through cost-effective measures, taking into account outdoor climatic and local conditions, as well as indoor climate requirements, and to promote the convergence of building standards towards those of member states which already have ambitious levels. It lays down requirements as regards:

- the general framework for a methodology for calculating the integrated energy performance of buildings
- the application of minimum requirements on the energy performance of new buildings
- the application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation
- energy certification of buildings
- regular inspection of boilers and of air conditioning systems in buildings and an assessment of the heating installation in which the boilers are more than 15 years old
- the review of building standards at least every five years

Article 5 of the directive states that, for new buildings with a total useful floor area greater than 1000m², member states shall ensure that the technical, environmental and economic feasibility of alternative systems such as decentralised energy supply systems based on renewable energy, CHP, district or block heating or cooling (if available), and heat pumps, (under certain conditions) is considered and is taken into account before construction starts.

> The EU's article on new buildings with a total useful floor area greater than 1000 m² stipulates that member states shall ensure that the technical, environmental and economic feasibility of alternative energy systems is considered before construction starts.

Boiler Directive 92/42/EEC

This directive comes under the SAVE programme, and determines the efficiency requirements applicable to new hot-water boilers fired by liquid or gaseous fuels with a rated output of no less than 4 kW and no more than 400 kW.

Construction Products Directive 89/106/EEC

This directive on the drafting of laws, regulations and administrative provisions of the member states relating to construction products requires construction works and their heating, cooling and ventilation installations to be designated and built in such a way that the amount of energy required in use will be low, having regard to the climatic conditions of the location and the occupants.

SAVE Directive 93/76/EEC

This directive aims to limit carbon dioxide emissions by improving energy efficiency, and requires member states to develop, implement, and report on programmes in the field of energy efficiency in the building sector.

4.2.2 USA

The building sector is the largest consumer of energy in the United States in terms of combined end-use and loss estimates. In 2005, residential and commercial buildings consumed 21% of US total energy consumption. Most of this energy was in the form of electricity. With the associated power generation losses, the building sector is actually responsible for 40% of the country's energy use and approximately 40% of US carbon dioxide emissions.

In 2005, residential and commercial buildings consumed 21% of US total energy consumption.

Regulations for energy management in buildings are embodied in the building codes and in the Energy Policy Act of 2005. Apart from providing tax incentives for home owners, builders, and businesses that install energy conserving technologies, and for commercial buildings that are energy-efficient, the latter sets goals for the deployment of renewable energy technologies. It also sets targets for the reduction of energy consumption in federal buildings, and establishes energy efficiency standards for products such as HVAC and refrigeration. Individual states implement their own policy measures. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) has published a series of model codes for energy conservation in the building sector, the ASHRAE Standard 90 series, which are often referred to by the building regulations.

4.2.3 Japan

Japan sets standards (Evaluation Criteria) for residential and non-residential building under its Energy Conservation Law.

4.2.4 China

In terms of square metres, China has the largest construction sector in the world. Almost 2 billion square metres of new buildings are completed each year in urban and rural areas, of which more than 80% are categorised as high-energy consumption buildings. China has set a target of reducing the energy consumption of new buildings by 65% compared with that of existing buildings, and has set a tax and fees rebate system for low energy buildings. The energy consumption per square metre of floor space is at least two to three times higher in China than in industrialised countries. However, the absence of building standards and regulations has slowed down the implementation of energy-efficient building technologies.

China has set a target of reducing the energy consumption of new buildings by 65% compared with that of existing buildings, and has set a tax and fees rebate system for low energy buildings.

In Hong Kong, a labelling scheme for electrical appliances exists, and the government is examining the potential for the wider use of water-cooled air conditioning systems which could produce energy savings of 20% to 30%.

5 The Market

Throughout the developed world the property market is in a state of flux and it is widely believed that a prolonged period of growth, fuelled by aggressive lending by financial institutions and speculative property purchases by individuals, is coming to an end as interest rates rise. For almost a decade it has appeared that there has been a shortage of houses, especially houses that young couples who are just entering the property market and low wage earners, can afford. It is as yet unclear just how much of the demand for homes and resulting high prices have been caused by people purchasing second homes and by amateur landlords buying up small houses to rent out.

In some regions, for example Europe, a large number of aging baby boomers still live in large family houses, and during the coming decade this group of house owners will either be moving to small properties or managed residential care homes. This is a long term trend that will leave a surplus of large family homes on the market, some of which will not find a buyer until they are converted into smaller units or are themselves turned into care homes.

The impact of these trends, some of which have been responsible for the recent property market slide in the US, will be to limit the number of housing starts and reduce the scope for replacing existing energy inefficient buildings with zero or low emission ones. However there are other factors to take into consideration.

The property market slide in the US will limit the number of housing starts and reduce the scope for replacing existing energy inefficient buildings with zero or low emission ones.

5.1 Increased Regulation Within The Property Market

The building boom, which is now drawing to an end, has been driven by a high demand for new houses. Governments have been under pressure to relax any barriers, such as the requirement to use renewable energy in new buildings, that may inflate the cost of houses or cause building programmes to slow down. Planning authorities often give into developer's requests to 'opt out' of the requirement that new developments should include low emission technology.

Governments are under pressure to relax any barriers, for example the requirement that new developments should use low emission technology.

Developers argue that renewable-energy generation technology could add as much as $30,000 to the cost of a property and increase the construction costs of low cost housing by as much as 5%. This has created a situation within the housing market where the marketing departments of construction companies promote a small number of low emission housing projects while actively lobbying against the inclusion of renewable energy and low-emission construction techniques in large-scale projects.

The marketing departments of construction companies promote a small number of low emission housing projects while actively lobbying against the inclusion of renewable energy and low emission construction techniques in large-scale projects.

If an economic downturn forces the owners of second homes to release properties, and in so doing relieve the pressure on governments to stimulate new building, there will be less pressure on planners to rush through construction projects. At the same time, with less private homes being built, developers will be more reliant on public housing and other government-funded building projects. This will provide planners with greater leverage over developers and could stimulate the market for low- and zero-emission building technologies, services and materials.

In the absence of new housing starts, the building industry will become more reliant on projects involving the conversion of large properties into homes that are better suited to the elderly. These types of projects are usually small scale and here planners also have more leverage over architects and developers when it comes to the inclusion of zero emission building technology at the planning stage.

In the absence of new housing starts, the building industry could become more reliant on projects involving the conversion of large properties into homes that are better suited to the elderly.

5.2 Cost Of Technology And Materials

The argument that the cost of zero and low emission technology and materials can substantially increase the cost of houses is a valid one. If, during a property market collapse, the price of a typical house fell by 30% then the contribution that renewable energy technology made to the cost of the house would rise from 5% to 7%. There is much work that needs to be carried out to reduce the cost of new build low and zero emission technology and techniques. Renewable-energy technology vendors, builders and material suppliers will need to look at all aspects of their operations with a view to reducing energy use, as to date the construction industry has paid little attention to this aspect of their business.

The impact of rising energy prices on their cost base, and the pressure placed on their profit margins by increased energy- and emission-related planning regulation, will force construction companies to consider energy use at all stages of their operations. This change management process may be easier for a small new entrant to the construction market, with a disruptive business model, than for an incumbent player who, as a result of investment during the recent construction boom, has been left with a large amount of legacy infrastructure.

The impact of rising energy prices on their cost base, and the pressure placed on their profit margins by increased energy- and emission-related planning regulation, will force construction companies to consider energy use at all stages of their operations.

5.3 Potential Winners

Some small architects and specialist construction companies have already managed to significantly raise their profile, and gain new business by focussing on low and zero emission construction techniques. One example is house builder Baufritz who has developed what they refer to as a 'carbon positive house' that is claimed to reduce the total amount of carbon dioxide in the atmosphere.

The appearance of the buildings produced by these companies is unlikely to appeal to the typical householder, and most are aimed at purchasers who are making a statement about their 'green' credentials. However, given the success of some of these small companies, and the level of agility and innovation they are demonstrating, it is likely that larger players in the construction industry will attempt to mimic elements of these new entrants' business models. It is also possible that the new entrants themselves will take advantage of any property market collapse by combining elements of their low emission house designs with a new approach to low cost housing.

Architectural software companies are also capitalising on interest in zero and low emission construction, and have produced versions of their computer-aided design applications that address issues such as energy use. Building such features into their products has provided companies in a competitive market with an important differentiator. It has also created new marketing opportunities, such as software for building energy management and web-based applications to help householders assess the impact of renewable energy technology and insulation. These new technologies are important as they are also applicable in both the new build and retrofit markets.

Architectural software companies are also capitalising on interest in zero and low emission construction and have produced versions of their computer-aided design applications that address issues such as energy use.

6 Conclusions

Some of the technologies discussed in this report, such as PV systems and light pipes, are currently very expensive for the average family or business, with payback periods of several years. However, as demand increases prices are likely to fall as manufacturers benefit from economies of scale. The cost of a 20 W compact fluorescent bulb (equivalent in intensity to a 100 W tungsten filament bulb) has already fallen from $30 in 1997 to approximately $4 today. Although a full cost-benefit analysis has not been conducted, it could be argued that no price could be put on the benefits of eliminating the threat or consequences of global warming, having security of energy supplies, and extending the lifetime of the earth's fossil fuel reserves.

Technologies such as PV systems and light pipes, are currently very expensive with payback periods of several years. However prices are likely to fall with improved economies of scale.

A new generation of buildings will emerge with mandatory maximum energy requirements and producing their own electricity. It is likely there will be a shift away from centralised electricity generation towards distributed systems, which allow buildings to contribute to the energy available on the grid. Buildings will be constructed to tap into district- and community-based heating and power systems using solar heating, combined heat and power, geothermal energy, and aquifer storage. Computer technology will be used to ensure that buildings are designed to harness the maximum amount of energy from renewable sources, and that minimal energy is used during the lifetime of the building.

Computer technology will increasingly be used in ensuring that each building is designed to harness the maximum amount of energy from renewable sources, and that minimal energy is used during the lifetime of the building.

Work is needed to resolve a number of problems associated with microgeneration; for example, in connecting low voltage electricity generated from building-integrated renewable energy systems to the high voltage grid, and with the variation of wind, tidal, and solar energy.

Problems associated with grid connection and variability of natural energy sources will need to be resolved.

In the industrialised countries, there is the political will to reduce the energy consumption of buildings, as evidenced by legislative instruments, tax incentives, and the fact that energy efficiency standards for buildings are being raised. Standards, however, vary significantly from one country to another and it is unlikely that there will be a convergence in these standards given the different climatic conditions around the world.

It is unlikely that there will be a convergence of national standards and incentives given the different climatic conditions around the world.

Throughout the world, building standards will continue to evolve from being component- to being performance-based and will incorporate the potential for low energy use through the life of a building. Developing countries have begun to instigate energy efficiency standards in buildings. However, countries with hot climates are faced with the challenge of finding less energy-intensive options for air conditioning.

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New and improved technologies in building design, construction, and management, in conjunction with the continued improvements in legislative and fiscal instruments, will lead to higher standards in building codes and the removal of the least energy-efficient products from the market. This should ensure a significant reduction in the energy used in buildings.

New and improved technologies in building design, construction, and management may reduce the threats of climate change, insecurity of supply, and depletion of fossil fuel reserves.

Key beneficiaries within a housing market that is in a state of flux will be innovative companies with business models that work with a regulatory system designed to reduce building-related emissions and at the same time reduce the amount of energy required to construct the building itself. Such business models are likely to prove highly disruptive within the construction industry.

Business models based on low energy use building are likely to prove highly disruptive within the construction industry.

A slowdown in the construction industry in countries that have recently experienced a speculative boom will reduce the market for low and zero emission building technology and materials in the new-build market. Vendors should therefore turn their attention to the building, retrofitting and renovation market.

Vendors should turn their attention to the building retrofitting and renovation market as growth in the construction sector slows.

7 Vendors

7.1 Peabody Trust - BedZED

A consortium consisting of the designers Bill Dunster Architects, the developer Peabody Trust, and the environmental consultancy The BioRegional Development Group, has developed BedZED. Arup who are a design and business consulting firm, and Gardner and Theobald, the cost consultants, also worked on the project. The development was completed in 2002 and is managed by the Peabody Trust.

The consortium aimed to create a carbon-neutral development, one that would produce at least as much energy from renewable sources as it consumed.

BedZED is a mixed-use, mixed-tenure development. BedZED comprises 82 residential homes with a mixture of tenures: 34 for sale, 23 for shared ownership, 10 for key workers, and 15 at affordable rent for social housing.

Natural, renewable, recycled, or reclaimed materials were used where possible in the construction of BedZED. Building materials were selected from within a 35 mile radius of the site to minimize the energy required for transportation. Heat from the sun and that generated by the occupants provides space heating to a comfortable temperature, thus reducing its energy demand. The houses face south to take advantage of solar gain, are triple-glazed, and have high thermal insulation. The homes and offices are installed with low energy lighting and energy efficient appliances. Most rain water falling on the site is collected and reused. Appliances are chosen to be water efficient and use recycled water where possible.

The homes and offices are powered by a small scale CHP plant. It is fuelled by off-cuts from tree surgery waste that would otherwise go to landfill. The waste heat produced from generating electricity provides hot water which is distributed around the site using a district heating system of super-insulated pipes. Each dwelling is provided with a domestic hot water tank that doubles as a radiator when more heat is required.

Natural ventilation is provided through a wind-driven passive stack principle. Non-mechanical wind cowls, with heat exchangers below, rotate to catch the slightest breeze and pull stale air out of buildings.

At peak times PV cells generate 309 kW of clean electricity, saving over 200 tonnes of carbon dioxide emissions a year.

BedZED also reduces fossil fuel energy consumption through its legally binding Green Transport Plan, which provides an onsite Car Club, ZEDcars, and on-site charging points for electric cars.

The results of monitoring conducted in 2003 and based on the UK averages showed that space heating requirements were 88% less, hot water consumption was down by 57%, the electricity used, at 3 kWh,

Peabody Trust

BedZED at a Glance

The project, located in Wallington, Surrey, is the UK's largest eco-village. It was designed to address environmental, social, and economic needs. It brings together a number of proven methods of reducing energy, water, and car use.

www.peabody.org.uk

was 25% less, mains water consumption was reduced by 50%, or 67% compared with a power shower household.

The BedZED project has won seven awards to date. These include the International Energy Globe 2002 Award for the foremost example of sustainable energy in building and housing, and the Housing Design Award for Sustainability 2001.

The BedZed development has experienced a number of problems. The biomass fuelled CHP system failed in 2005 and BedZed was put back on the national grid, although 11% of its electricity is still supplied by the photovoltaic system. The 'Living Machine' reed bed sewage filter system has also been out of operation, as it produced more water than the site could use and was closed due to its prohibitive operational costs.

Analysis

The number of zero energy buildings in the world is on the increase. Other zero energy developments, such as the Solar Row, a 13-home community being built by the Wonderland Hill Development Company Colorado, USA have been built using a similar model to the one employed by Peabody. Stimulation is being provided mainly through government incentives and research programmes. In the USA, the US Department of Energy's 'Building America' programme is supporting BedZED type zero-energy research programmes. The government-owned Canada Mortgage and Housing Corporation sponsored a public competition that would see the construction of 12 to 16 zero-energy demonstration projects across the country by the end of 2007. However the construction industry needs to see more companies in the private sector taking the initiative to build zero energy buildings without having to be coerced by legislation.

7.2 DENA

In Germany, low energy houses are defined as new buildings or modernised older houses with a maximum energy requirement that is compatible with the Energy Conservation Regulations (EnEV). Priority is given to reducing energy needs, efficient energy conversion, and the integration of renewable energy resources. At least one pilot project is being implemented in each federal state to reduce the need for primary energy to no more than 60 kWh/m², which is 30% to 50% less than the EnEV requirements for new buildings. As part of this initiative, 143 buildings have been, or are being, modernised to improve their energy efficiency. Results show that the houses are on average 50% more energy efficient than comparable new buildings. The pilot phase showed that transmission heat loss was cut by 80%, and that thermal insulation is 45% more effective than standard new EnEV buildings.

Innovative building insulation, double and triple glazing, PV systems, high-efficiency heating systems (solar thermal installations, condensing boilers, wood pellet boilers, and ground-source heat pumps), district heating from centralised CHP systems as well as small-scale CHP systems are among the technologies used in the project.

The second phase of the programme began in 2005 with 2,230 housing units. On completion, these homes were found to consume only 50% of the energy required to heat comparable new buildings. The project also demonstrated that energy efficient construction and modernisation are significant factors in ensuring that properties retain their value and attractiveness irrespective of rising energy costs.

In June 2007 changes were put in place regarding the introduction of energy certification for existing buildings in addition to new buildings. Now there is an obligation to present an energy certificate when dwellings and buildings are being let for the first time or sold. These measures will be introduced from July 2008.

DENA at a Glance

The German Energy Agency initiated the 'Existing Low-Energy Houses' project in 2002. The pilot phase started in 2003 with 19 housing companies renovating around 880 apartments in 33 buildings.

www.dene.de

Analysis

Throughout Europe there is a drive to reduce building-related energy use as part of a long-term initiative to reduce emissions within the EU by 20%. In the UK there are plans to incorporate energy efficiency certificates in "Household Information Packs", which are provided to the purchasers of a property. In Germany most houses and flats are rented rather than purchased so the plan is to certify the energy efficiency of the property when a new tenant enters into a rental agreement. While issues regarding the cost of certification and the availability of inspectors have forced governments to delay the schemes there will, if targets for the reduction of building-related energy use are to be met, have to be some mechanism in place that encourages developers and property owners to upgrade existing properties.

7.3 Clarum Homes

In 2005 Clarum built the Vista Montana apartment community in Watsonville, California, and based the heating system for this development on building-integrated solar electric technology. GE Energy supplied the 60 kW system for the complex, which produces approximately 90 MWh of electricity annually.

GE's roof-integrated system replaced the flat cement roof tiles and blends with the roofline. The integrated system provides a combination of functionality and attractiveness that Clarum says is designed to add value to the community.

In addition to the solar electric system, the Vista Montana apartment community was designed to incorporate a range other energy efficient and renewable building features. As part of the Department of Energy's 'Building America' programme, Vista Montana was one of Building America's first near-zero energy homes communities.

ConSol, Clarum's energy consultant and one of Building America's team leaders, used a systems engineering approach to produce homes on a community scale that used 40% less energy. The homes were engineered to minimize each home's energy load through ConSol's ComfortWise programme so that most of the electrical needs could be met by the solar system. The ComfortWise programme includes the installation of tightly sealed duct work, a high-efficiency heating and ventilation system, smart glass (low-e windows), and third party testing and certification.

The Vista Montana Apartments community also included affordable housing, and many of the buildings were designed for larger families.

The project was financed with California Statewide Communities Development Authority tax exempt bonds, federal and state tax credits and City of Watsonville HOME Programme funds. The community offered apartments to residents earning incomes at 50%-60% of Santa Cruz County area median income levels.

CLARUM HOMES
Environmental Innovations in Homebuilding

The company was founded in 1994 and is based in California, USA. It is a family-owned property developer whose mission is to build sustainable communities.

www.clarum.com

Other developers providing zero or near-zero energy homes in the USA include:

Pardee Homes
(www.pardeehomes.com)

Morrison Homes
(www.morrisonhomes.com)

John Wesley Miller, Arizona
(www.armoryparkdelsol.com)

SheaHomes, California
(www.sheahomes.com)

Centex Corporation, California
(www.centexhomes.com)

Analysis

There is a wide range of developers and builders that claim they are able to build zero or near-zero energy homes. However there may be a shortfall in the number of individuals and private companies that are willing to pay extra to reduce their building's carbon footprint. More research needs to be carried out by the building industry, housing associations and government agencies to quantify, in simple terms, the financial benefits of constructing low-energy buildings and educating the general public so that the house buyer can make informed decisions as to whether or not they can afford to opt for the low-carbon option when purchasing a property.

7.4 ZEDfactory

The company offers the full range of architectural services: design (large scale eco-villages to one-off building commissions), master planning, urban design, landscaping, eco-refurbishment, the arrangement of project financing, procurement and supply chain management, and marketing and sales. It also has a development arm that competes in the volume house-building market, and partners with land owners who wish to develop their land.

It has developed a range of house-types which it uses to obtain economies of scale and for which it employs off-site construction methods. This means that it can build carbon-neutral communities at prices comparable with those of conventional volume housing. House types include the RuralZED, so named because it embodies the qualities that are associated with rural living, light, air and space and the ZED-in-a-box house type designed as a high-density urban block of terraced houses with green space for all. The company's ZED-in-a-box town house can be built in a terrace, as a semi-detached or as a detached house. The mini solar block house type designed for small urban sites has each block being defined separately as an apartment or living/working area, or combined as a single home, and the urban solar block is designed as a high-density combination of apartments and duplex units over five storeys. These house types are also provided as DIY kits.

The features typical of these house-types are super insulation with internal linings of dense concrete for thermal mass giving low energy performance without the need for mechanical cooling, arrays of PV panels on the roofs, natural ventilation using wind-driven cowls with heat recovery, double glazed windows, and wood pellet boilers for heating and hot water

Clients are offered the choice of building full ZED specification buildings, or low energy buildings which can be upgraded to full ZED specification over time with the addition of micro-generation technologies such as solar collectors and wind turbines.

In 2004 ZEDfactory set up a supply arm called the ZEDfabric Company Ltd. in conjunction with suppliers in China and the UK. This business unit supplies components used in zero energy development construction, one of its aims being to close the gap that currently prevents the wider use of renewable resources.

Other ZEDfactory developments include the BowZED residential units in East London, UK, the Conference and Arrivals Buildings of the Earth Centre in Doncaster, UK, the Jubilee Wharf in Cornwall, UK, and the Changsha ZEDquarter demonstration building in the Hunan province in China.

ZED Factory at a Glance

An architect's practice established in 1998 specialising in the design of zero (fossil) energy developments.

www.zedfactory.com

Analysis

ZEDfactory is not the only ‘ecological architect’ exploiting interest in energy sufficiency and marketing their services to developers keen to be seen as taking the issue of climate change seriously. However, few of these companies have attempted to build an industry for low energy buildings, providing not only architect’s services but also property development and component supply. The increasing popularity of zero-energy buildings could be an invitation to building and construction conglomerates around the world to extend their portfolios to include research into, and development of, low energy building components.

7.5 Mazria

The practice is led by its founding member Edward Mazria, and Principle Architect Sandra Odems. It majors in environmental design and daylighting within architecture, both of which are applied to all of their projects. The company's projects range from small single-family residences to large scale commercial and public buildings. Mazria has won the American Solar Energy Society's Design Award for the Stockebrand and Woods Residences in Virginia and the Department of Energy's Institutional Building Design Award for the Mount Airy Public Library in North Carolina,

The design of the Mt. Airy Library applies renewable energy technologies in a facility that calls for high illumination levels and humidity control in a region with hot, humid summers and cool winters. The library plan is organized around a circulation spine and main lending desk, from which the librarian can have visual control of the building. A saw-tooth clerestory above the structural bays provides daylight over the circulation desk, reading areas and reference stacks. A butterfly roof configuration with glazed ends and a central elongated light well provides illumination for the open stacks area.

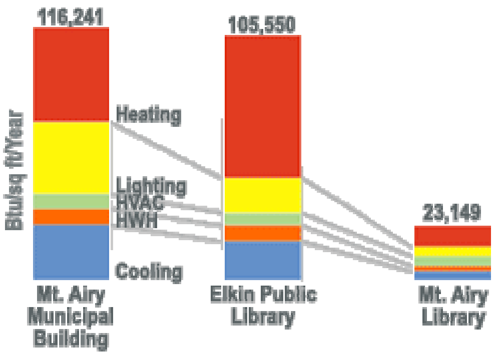
Passive cooling in the building is achieved in a number of ways. Shade trees and a light-coloured roof membrane reduce the impact of solar radiation in summer. Operable windows allow for natural ventilation when the weather permits, and thick white masonry exterior walls provide the thermal lag necessary to delay the effect of the summer sun on the interior until the evening hours when the library is closed. Passive heating in winter is accomplished by storing the heat gained through south facing windows and clerestories in CMU walls, the concrete structural elements and the tiled concrete floor slab.

Computerized monitoring equipment has shown that the total energy use of the library is 23,149 Btu/sq ft/year. Mazria claim that the library uses about one sixth as much energy per square foot as a nearby municipal building. A typical commercial building uses approximately 20,000 Btu/sq ft annually for lighting. Mt. Airy used only 2,691 Btu/sq ft, a reduction of over 86 percent.

Mazria at a Glance

An architectural practice based in Santa Fe, USA that was established in 1978 by Edward Mazria and specialises in the use of daylighting within buildings.

www.mazria.com



Analysis

Architects who have mastered the art of incorporating renewable and low emission technology into the designs of new buildings, and can market that technology as a feature, are carving out an important niche for themselves in the construction market. These architects are attracting valuable publicity and in some cases are winning contracts from clients who want buildings that are both different and make a statement. At some point low emission technology will lose its value as a differentiator and low emission designs will have to be sold on the basis that the resulting building is cheap to run in a world where fossil fuel prices are rising. Mazria will need to hone its skills in the use of concepts such as daylighting to ensure it can successfully incorporate low emission technology as a standard feature in all buildings as opposed to an added value feature in specialised projects.

7.6 Monodraught

The company's 'Sunpipe' is a mirror-finish aluminium sun pipe which brings natural daylight into a building, producing the equivalent of up to 1200 W of natural light, and is supplied in residential and commercial versions.

The 'Windcatcher' is a natural ventilation system that eliminates the need for air conditioning in boiler houses and in commercial buildings for combustion ventilation. It is a vertical balanced flue system that captures the prevailing wind from any direction and directs it into the boiler room. It uses compartmentalised vents to bring fresh air into a room, and stale air is expelled using the natural effects of the wind. The system uses the stack effect where warm air rises and decreases the air pressure within a room so that cooler air falls into the room. This subtle change in air pressure produces only enough air flow to make a room comfortably fresh. Stale and stagnant air is extracted by the wind blowing onto the wind-ward side of the Windcatcher, with the stuffy air going out through the leeward side of the ventilation stack. Monodraught systems are fitted with insulated volume control dampers that control the rate of ventilation and are themselves controlled by temperature and carbon dioxide sensors.

The 'Suncatcher' is a combination of the Sunpipe and Windcatcher. Other products include the 'Sola-boost', 'SolaVents', 'Monovents', and 'Vertical Balanced Flues'. The Sola-boost is an extension of the Windcatcher and is aimed at providing additional ventilation on sunny days with its solar-driven internal fan. The 'Heat Harvester' is a device that is suspended from just below roof level where it sucks the heat that is otherwise wasted and blows it 15m to 20m back down to the floor level using a 35 W motor.

Monodraught's products are being used in schools, hospitals, and prisons. 70% of Monodraught's business comes from schools and universities. Clients include the Centurion Vocational Centre in Somerset, the Blackberry Hill Hospital in Bristol, and the Lewisham Police Station in London.

Monodraught has seen a consistent and steady increase in turnover of 35% for the last five years and now has a turnover of £12million per annum.

Monodraught

Monodraught at a Glance

The company, which was founded in 1974 and is based in the UK, develops products that maximise the use of the wind and sun to provide power for buildings.

www.monodraught.com

Analysis

Manufacturers of solar PV systems, solar thermal systems, and wind turbines are usually regarded as the principle suppliers of renewable energy used in buildings. Providers of other renewable energy components such as light pipes and natural ventilation systems are very seldom mentioned and this may explain why their public profile is low. However Monodraught should be able to capitalise on a growing awareness of the limitations of small-scale wind turbines and the high cost of photovoltaic devices and position its technology as a relatively low-cost energy technology for the zero-emission building market.

7.7 Seattle – Green Building Programme

The Seattle state government's City Green Building programme aims to make green building the standard practice in Seattle through education, technical assistance, and incentives. In February 2000, the City of Seattle adopted the 'Leadership in Energy and Environmental Design' (LEED) standard as part of a Sustainable Building Policy via a City Council resolution, and thus became the first city in USA to formally adopt a sustainable building policy. In October 2005, the City of Seattle had 38 capital improvement projects either completed, under construction, or planned, and was aiming to achieve the Silver level of LEED, the US Green Building Council's rating system. 13 of these projects are completed. Some projects have not been able to meet the goal, and some have exceeded it. By 2013, when all 38 are complete, the city is expected to be one of the largest single owners of LEED accredited facilities.

In 2005, Seattle ranked number one in the country for LEED projects and professional expertise, with 808 LEED-accredited professionals. As a result, Seattle firms are benefiting from exploiting their expertise and services. The city has provided support to green buildings with incentives of over $2 million for energy conservation, over $2 million for natural drainage/water conservation, and over $300,000 for design and consulting fees for LEED projects. Among these projects are the Carkeek Park Environmental Learning Centre, Seattle City Hall, the Central Library, and the Seattle Justice Centre.

In order to encourage more green building, the City launched the 'Built Green' and 'SeaGreen' programmes. The 'Built Green Multifamily Incentive Programme', co-funded by Seattle City Light and Seattle Public Utilities, provides financial assistance to building owners and developers to incorporate cost-effective sustainable building goals early in residential multifamily-building design decisions. SeaGreen is a set of guidelines tailored to affordable housing projects.

Preliminary plans covering the period up to 2009 include the construction of over 13 million square feet of residential properties (single and multifamily), and over 5 million square feet of commercial and industrial properties. Other USA government jurisdictions that have committed to LEED for public construction are the Cities of Boston, Los Angeles, Chicago, Austin, Portland, and San Francisco.

SEATTLE.GOV

Seattle at a Glance

Seattle's state government has put in place a City Green Building programme and provides a range of incentives and resources, such as design tools, for architects and developers.

www.seattle.gov/dpd/GreenBuilding

Analysis

Currently there are a large number of city- and state-wide energy efficiency drives that are focussed on building-related energy use. However there is often little coordination between individual schemes. It would be timely and useful to have an international agency such as the World Energy Council develop international energy efficiency building codes which would be accessible to and could be adopted by national and local governments that are in the early stages of developing their own building codes. It would also be helpful if such an agency could provide guidance and resources to developing countries and emerging economies so that energy efficient housing programmes in these regions could benefit from the lessons learned in industrialised countries

7.8 Encraft

Encraft has developed a software tool that enables an architect, developer or homeowner to cost and measure the impact of a range of renewable energy technologies. The information is impartial, unique to each property and based on engineering specifications and energy models for each building and household. As the web-based service is automated, the cost of a design session is low.

The software is designed to reduce the time spent in researching low- and zero-emission building technologies and also help the user avoid making costly mistakes when selecting materials and technologies.

Companies can host and rebrand Encraft's design tools and calculators on their own website.

Encraft also provides specialist consulting engineering services to optimise the use of low carbon technologies in building projects, developments, and existing property portfolios. To support this service the company employs chartered mechanical, electrical and manufacturing engineers and low carbon technology specialists.

Encraft at a Glance

The company, which was established in 2003, works on low carbon projects in the construction sector and also supplies software tools that help designers and households to evaluate the impact of house design decisions and renewable energy technology selection.

www.encraft.co.uk

Analysis

Information technology companies already supplying design software to architects and construction companies have been quick to enhance and reposition their products as tools to help reduce building-related emissions and energy costs. One high profile example is AutoCad, a well established supplier of PC based CAD software. Encraft, a relatively new player, is approaching the market from a different direction. It is already providing consultancy to a range of organisations in the construction sector and has now decided to encapsulate its knowledge and skills and market them as an online software service.

Compared with the revenue Encraft earns from a single consultancy assignment, the revenue from its online service is small. However if the company can recruit a significant number of resellers who are willing and able to promote the service, Encraft should be able to expand its market reach and increase revenues without adding to its cost base. As other consultants could do the same, Encraft will need to exploit its first mover advantage to the full.

Encraft should also be able to expand its consultancy business on the back of new leads it generates with its online service, something that is not necessarily an option for software suppliers without a consultancy division.

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