Building for the Future -
Sustainable Construction for Professionals

How to Conserve Energy in Further Education Colleges

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How to use the guide

The guide is designed to provide an overall strategy to include energy efficiency through various stages of planning and using a building.

The guide is divided into three broad sections.
- The first section deals with energy use in colleges and provides a general evaluation of where energy is used, and what are its cost implications.
- The second section explores design ideas to reduce energy use in buildings including building fabric, services and on-site energy generation technologies.
- The final section on operation and maintenance is targeted at building managers and explains various technologies associated with optimal energy consumption during use.

It is a basic guide and should be used with the sources of further information provided.

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Other Titles in the Series

This guide is one of a series of five. The others in the series are on:

- ***How to Commission Sustainable Construction in Further Education Colleges***
- ***How to Conserve Water in Further Education Colleges***
- ***A case study of an Academy building: City of London Academy***
- ***A case study of a FE building: Merton College, London***

The partnership would like to acknowledge the feedback received from GVA Grimley and King Sturge in preparing this report.

The images on the cover page are of Newbury College.

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Foreword

This guide is a product of Building for the Future - an inter-regional collaboration, part-funded by the GROW EU Interreg3C joint programme, which aims to achieve balanced and sustainable economic growth.

The purpose of this guide is to empower colleges to make informed decisions with regard to energy conservation.

By reviewing some of the issues around energy use and sustainable construction, we hope to assist colleges in the formulation of appropriate energy conservation strategies, and to justify the use of sustainable construction techniques.

Every construction project has its own challenges, but the impetus is towards reducing the environmental impact of buildings, both as they are built and as they are used.

AOSEC is very grateful to the partners that have been such an essential support to this project, and so it is with real appreciation that I thank the Environment Agency, the LSC and SEEDA.

Dr Anne Murdoch
Chair of Board of AOSEC
Principal & Chief Executive of Newbury College

Executive Summary

This guide provides information about energy conservation and reduction of energy-related carbon emissions in FE colleges, through design and construction of a building, as well as during its operation and maintenance. It explains the various principal end-uses of energy consumption in FE colleges, and provides key measures and strategies to reduce energy use.

The guide is about:
- Energy Use in Colleges – where and how much energy is used.
- Energy Conservation – how to reduce energy consumption effectively through design, appropriate technologies and operation and maintenance strategies.

This guide will help:
- **Colleges (construction clients)** to invest in energy efficiency by understanding the capital and operational costs, as well as associated benefits of each measure.
- **Design Teams** to address the range of issues while designing a sustainable and low energy college by passive measures, planning and appropriate technologies.
- **Building Managers** to understand design features and their functioning to effectively combine them with appropriate technology and management strategies to reduce energy consumption.

Contents

1 INTRODUCTION
Why conserve energy

Buildings in UK are responsible for nearly half of the total CO_2 emissions. Hence, there is an urgent need to reduce emissions resulting from the built environment.

Energy conservation and sustainability in buildings is therefore crucial and has a high priority on the government agenda. It is now necessary to consider the way we consume energy, especially for heating, lighting and cooling requirements within buildings.

Furthermore, fossil fuels release CO_2 on combustion, which is increasingly believed to be the primary cause for the increase in earth's temperatures resulting in sea levels rising and a changing climate.

Why consider energy efficiency in design and operation of buildings?

- It can save money by greatly reducing the cost of operation and maintenance of buildings.
- There are associated environmental benefits by decreasing carbon dioxide emissions.
- The government is actively promoting low energy buildings through stringent legislation like the building regulations and planning policies.
- They provide a healthier living and working environment, helping to improve general well-being and productivity of staff and students.
- Exemplar sustainable buildings can enhance an institution's image and reputation.

A holistic view to integrating energy efficiency and sustainability in the initial stages of commissioning a project can ensure that project opportunities and constraints are identified, and solutions providing maximum benefit are integrated.

1.1 Understanding Energy Use in Further Education colleges

It is important to consider the various uses of energy in colleges to understand energy consumption patterns.

How much energy is used by colleges?

The further and higher education (F&HE) sector, in England alone, consumes 5.2 billion kWh of energy and is responsible for releasing 3 million tonnes of CO_2 annually in the atmosphere (DEFRA, 2006). It is estimated, that over £200 million is spent on electricity and heating fuel requirements (HEEPI, 2005).

There is a lack of information available about energy consumption figures in FE colleges. Annual energy costs per institution in the F&HE sector range from £200,000 to over £3 million, and account for around 25% of building related expenditure (BRESCU, 1997a).

What affects energy consumption in colleges?

Energy consumption within the F&HE sector varies by great amounts depending on:

- the function and type of building
- the age of the building determining how it was built
- its location with respect to the climate
- its size and
- occupancy or number of users.

The following figure provides broadly representative data for energy consumption figures for further education colleges in England.

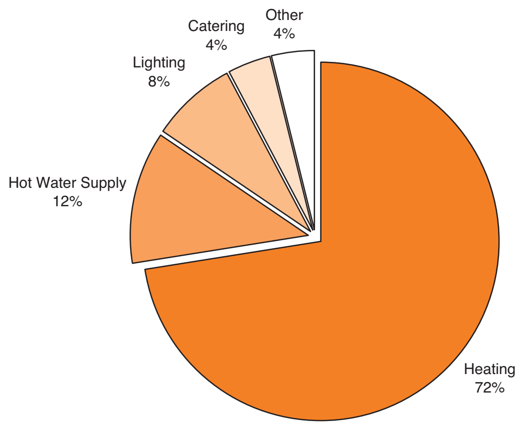


Figure 1. Typical energy consumption by End Use (kWh/m^2) Source: (Bordass)

- Space heating is the largest percentage of energy use.
- Hot water supply and lighting form the next important areas of energy use.
- The rest is accounted to catering and other miscellaneous uses.

Energy bills form a big part of the annual financial budgets of colleges. They can be reduced by integrating energy efficiency features. Although the initial capital cost may be higher for such buildings, it can significantly reduce the operational costs of the buildings over its lifetime.

Integrating sustainable features from the initial design stages has been found to be more cost-effective than adding them at a later stage during refurbishments. It is important for the colleges to have sustainable policies including benchmarks and energy monitoring procedures from the initial stages of a project.

Who is responsible for energy use and conservation within the sector?

Energy conservation within the colleges is a responsibility of not only the management and the architects. It is equally important to involve the actual users of the buildings i.e. the staff and students in energy saving measures and strategies.

Relationship between the interested parties

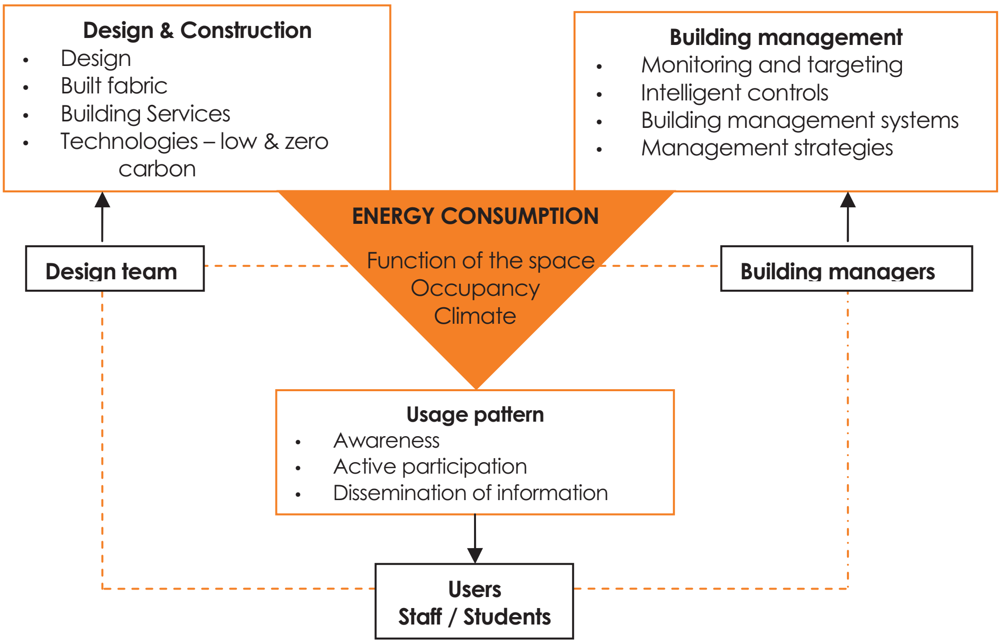


Figure 2. Diagram representing the relationship between different stakeholders and their roles

The stakeholders are inextricably linked to each other as well as their set of responsibilities.

For example, decisions made by the design team need to consider the way staff and students occupy and use spaces, and how the building management systems are to be run by the building managers. This will ensure that design intentions do not conflict with the way the building is actually used.

Another option would be to create awareness about the various energy efficiency measures amongst the users. The energy managers can do this by actively involving users to participate in energy conservation. Similarly, the design team can gain from the experience of energy and estate managers whilst setting targets for energy use.

1.2 Benchmarks for Energy and CO_2 Emissions

Energy benchmarks for fossil fuel (gas) and electricity consumption, along with the associated CO_2 emissions in colleges, as specified in the latest Chartered Institution of Building Services Engineers (CIBSE) guide F are listed below. Specific benchmarks for different building types within the FE sector are also included. These could be used to set targets depending upon the type of building being commissioned.

Space type/category	Good practice benchmarks			Typical practice benchmarks		
	Electricity (kWh/m²/yr)	Fossil fuel (kWh/m²/yr)	CO_2 (kgCO_2/m²/yr)	Electricity (kWh/m²/yr)	Fossil fuel (kWh/m²/yr)	CO_2 (kgCO_2/m²/yr)
Lecture room arts	67	100	50	76	120	58
Lecture room science	113	110	73	129	132	84
Science laboratory	155	110	92	175	132	106
Library air-conditioned	292	173	167	404	245	232
Library naturally ventilated	46	115	43	64	161	60
Catering bar/restaurant	137	182	98	149	257	117
Catering fast food	200	438	175	218	618	218
Further Education [1]	35	146	-	49	216	-

Table 1. Good-practice and typical benchmarks for fossil fuel use and associated CO_2 emissions for various building types in FE Colleges. (Source: CIBSE 2004)

1. The overall benchmark for further education represents a small sample collected from 49 colleges during 1992-1994, and may be unrepresentative of the whole sector.

Incorporating an understanding of the design, management and use of the building together would ensure that energy use in the building is minimised.

The following sections of the report discuss the energy conservation strategies in more detail.

2. DESIGN & CONSTRUCTION

Design and quality of construction are integral to the energy performance of a building when it is in use. Sustainable building design requires an understanding of how and where energy is used in a building with respect to its climate and location, building function, space types and occupancy or hours of use.

This section explains the strategies for the design and construction of energy-efficient buildings and the factors that need to be considered.

2.1 Built Form and Passive Design Strategies

Passive strategies are the first step towards designing any low-energy building. Essentially, passive measures exploit design strategies and the properties of building materials to heat or cool a building and provide natural light and ventilation. Passive strategies are used to reduce overall energy loads before mechanical services are put in.

Passive measures can greatly increase occupant comfort while at the same time are easy to maintain and mostly, require no mechanical intervention.

A new build project offers the maximum opportunity for incorporating passive measures by correct orientation and placement of functions in the new building.

2.1.1 **Site Planning and Selection**

Site selection influences many other environmental criteria such as the building's impact on the habitat and ecosystems, the energy that will be used by people commuting and the cost of setting up services and infrastructure.

Generally, there will be other overriding limitations when choosing a site such as cost and whether the site is owned by the institution or on a lease, as well as proximity to existing campus buildings. However, there are certain factors which should be adhered to as far as possible in selecting a site.

Location and Accessibility

- Consider the redevelopment of existing buildings and select previously developed brownfield sites for new construction. Construction on greenfield sites is environmentally damaging as it requires immense energy and economic capital to set up infrastructure, adversely affecting existing ecosystems and leading to pollution.

- Ensure the site has good access to public transport and services. This will enable a sustainable transport strategy to be incorporated in the early planning stages by providing space for cycle parking, and encouraging other alternative means of commuting such as car pools.

Landscaping

- Minimise environmental impact of development on site by protecting existing natural habitats. Incorporate sustainable urban drainage systems and appropriate landscaping strategies to promote local plants and wildlife.
- Consider strategies such as green roofs to reduce the urban heat island effect caused by excessive heat emitting properties of building surfaces. This will reduce the cooling loads by lowering temperatures. Green roofs also provide insulation.

2.1.2 **Orientation and Zoning of Spaces**

It is important to appropriately orient the building on the site with respect to its massing and zoning of spaces to maximise opportunities for natural light, ventilation and solar gain.

- Design buildings which are not more than 12-15 m deep in plan to allow natural light into spaces (Edwards B 2001). This is ideally suited to provide natural ventilation too.
- Daylight can be maximised by orientating a building within 30° of south (Carbon Trust 2005).
- South facing orientation also provides the maximum opportunity for solar gains in winter. Glazing on this side can be easily shaded to block direct sunlight in summer while allowing light in winter months.
- Functions should be placed such that those with heating requirements are south facing. Spaces with high internal heat gains due to high occupancy or equipment such as IT and computer rooms should be placed on the north facing side. North light is also free from direct glare and reflection, and hence is ideally suited for computer rooms where direct glare on the screen can be a problem.

2.1.3 **Day Light and Passive Solar Heating**

Apart from orientation and placing functions appropriately, other measures can be integrated into the design to maximise opportunities for natural day-lighting and solar gain.

Electric lights contribute substantially towards the building’s total energy costs which can be minimised by providing natural light in working spaces. Electric lights also contribute to internal heat gain in spaces. Minimising their use can lower the cooling loads in summer.

- South facing orientation and 12-15 metres depth of the building are ideal while designing for daylight in spaces and passive solar heat gain.

- Various design methods such as clerestories, light shelves, skylights and atria can be considered for maximising daylight penetration into the building.

- Worktops should be provided with diffused light to avoid glare and reflection. Spaces such as corridors and atria which are not constantly occupied can have more direct sunlight.

- Spaces on the east and west sides should be carefully designed as light from these sides have low sun angles and penetrate deeper into spaces. These are also more difficult to shade for the same reason.

- South-facing glazing can be easily shaded to block direct sunlight in summer while allowing light in winter months.

- Appropriate shading design can include fixed external building elements such as louvres, sun shades etc as well as internal blinds depending on the nature of light required. Other strategies can include staggering parts of the building to provide shade or using trees to shade parts of the building.

- It is important to provide appropriate glazing areas to maintain a balance between providing natural light and passive solar gain strategies. Excessive heat loss in winter and overheating in summer should be avoided.

- High performance double or triple glazed windows with low–e glass can reduce thermal losses from the windows while providing light.

2.1.4 **Natural Ventilation and Passive Cooling**

Designing for naturally ventilated spaces reduces energy costs of air-conditioning and mechanical ventilation. Naturally ventilated buildings need to be designed to provide the required air change rate in winters while avoiding overheating in summer months. The design should provide for an air-tight building with controlled ventilation methods.

- Before designing for natural ventilation, consider the impact of noise and pollution, especially if the building is placed within inner city areas.

- Design windows that can be opened and provide for natural cross-ventilation wherever possible. Trickle ventilators should be incorporated to enable minimum ventilation rates even when the windows are closed.

- The stack effect can be used to naturally create a ventilation system in the building. During the summer, the hot air inside the building rises and can be let out through controllable vents or openings at a higher level. High ceilings of around 3m or atriums can be designed to achieve this.

Negative pressure due to the rise of warm air draws cooler air from outside through openings at the lower levels, thus creating an air flow. The system can be reversed in the winter by using ceiling mounted destratification fans to redirect warm air back into the spaces (Carbon Trust 2005).

- Night time cooling strategy combined with motorised vent openings can be used in high thermal mass buildings to provide comfortable temperatures inside spaces. Thermal mass helps the building to absorb heat during the day, while the internal temperatures remain lower. This heat is released at night, after a time lag. The internal spaces can then be cooled again by allowing ventilation in the night.

2.1.5 **Built Fabric**

Performance of a sustainable building to reduce its energy consumption is greatly dependent on what it is made up of or the thermal properties of the building elements and the materials.

Thermal Performance of a building defines its capacity to act as a climate modifier maintaining comfortable internal temperatures throughout the year and limiting dependence on building services to mechanically heat or cool the building.

A building loses substantial amount of heat (or gains heat in hotter weather) from its surfaces such as external walls, windows and roofs. This depends primarily on the thermal mass or the heat storing capacity of the building fabric, and the thermal transmittance i.e. the amount of heat it limits to pass through the fabric. This is expressed in U-values for each building element. For the climate in the UK, lower U-values ensure heat loss is minimised from walls and roofs.

It is important to design the fabric for achieving thermal performance.

- High thermal mass can help moderate temperatures in the internal spaces by storing heat when it is available and radiating it after a time difference. This is the reason why older buildings with heavy stone walls feel comfortable throughout the year maintaining stable temperatures inside even when outside temperatures are unfavourable.
- Adequate levels of insulation in the buildings act as a barrier and helps in limiting the loss of heat from the building.

Building regulations Part L specify minimum compliance U-values for new buildings as well as refurbishments.

Element	Area weighted average
Walls	0.35
Floors	0.25
Flat Roof	0.25
Pitched Roof	0.16
Windows/doors	2.20

Table 2. U-values of building elements for new non-domestic buildings Source: (Building Regulations part-L2A)

Air Tight Fabric is another essential criterion to ensure heat loss from the building is minimised. Benefits achieved from high levels of insulation are reduced greatly if the building loses heat from infiltration or leakages from gaps and junctions, especially around the openings. Air tight building envelope therefore, requires good design and close attention to detailing.

The revised building regulations Part-L requires mandatory air-pressure testing of all non-residential buildings.

Embodied Energy (EE) refers to the amount of energy used in the production and assembly of the building. Essentially, it is the energy required to extract, manufacture, process and transport building materials including the energy used during the building construction.

Since energy input in material processing can vary depending on the location of the plant to the source of the material, as well as the location of site, EE values are difficult to quantify. However, most materials fall between a range of values and can be classified as high, medium or low EE materials. Listed below are indicative embodied energy values for common construction materials.

Material	**Embodied Energy kWh/M³**
Aluminum	10,300
Steel	75600
Plastics	47000
Glass	23000
Timber (Imported softwood)	7540
Clay Tiles	1520
Bricks	1462
Plaster/plasterboard	900
Concrete tiles	630
Concrete 1:3:6	600
Local slates	540
Sand &cement render	400
Mineral wool (loose)	230
Timber (local air dried)	110

Figure 3.
Embodied Energy Values kWh/m^2
Source: (P. Borer 1998)

- Metals, plastics including PVC-based insulation and glass have **very high** embodied energy. Specifying recycled steel and aluminum can lower the embodied energy of the material over its lifetime.

- Specify recyclable and reclaimed materials such as reclaimed bricks and aggregates as far as possible.

- Using local materials for construction ensures less energy is spent on transportation of materials. It also enables the building to relate to the surrounding context.

- Use natural, low processed materials with lower embodied energy. They also tend to have fewer adverse environmental impacts.

- It is also important to consider the long-term environmental impacts of materials apart from embodied energy. The Green Guide to Specification (J. Anderson 2002) provides information on lifecycle impacts of materials and methods of construction.

Issues to consider when designing with passive strategies

- Windows provide access to daylight, views and solar gain, but are also responsible for heat loss, draughts and glare.
- A combination of day-lighting and ventilation strategies with appropriate thermal properties and glazing areas will ensure optimum light and temperatures are maintained in the space.
- It might be beneficial to support strategies with building simulation software and calculations at the design stage to appraise the feasibility of deploying different passive measures.

ACTION STEPS – Passive Design Strategies

✔ Design for the building's energy use based on **location, function and occupancy.**

✔ Use **building mass and zoning** to appropriately locate functions depending on their need to cool or heat.

✔ **Orient** the building to **maximise solar gain** in winter and reduce heating loads.

✔ Explore possibilities of **natural light** in spaces.

✔ Apply **shading strategies** to limit solar gain in summer.

✔ Use **natural ventilation** wherever possible to achieve required air-change rates in winter and cooling in summer.

✔ Design the building fabric to achieve the required **thermal performance**.

✔ Choose materials which are environmentally-friendly and have **low embodied energy**. Maintain a balance between durability, performance and the quantity of material required when measuring its energy impact. Detail buildings well to achieve an **air tight fabric** and prevent unnecessary energy loss.

2.2 Building Services

The design of services for space heating, cooling and lighting directly affect the energy end use in colleges and should therefore incorporate a high efficiency plant, with optimum sizing and appropriate controls. However, before deciding on the nature of the services, ensure that the following factors have been taken into account.

- The environmental policy of the institution
- Capital and operating costs
- Required temperatures and quality of the internal environment, keeping in mind the occupant expectations and provision of controls.

It must be also ensured that initial heating, lighting and cooling loads have been appropriately reduced by incorporating passive design measures before mechanical systems are introduced.

2.2.1 **Heating and Hot water**

The choice and type of heating system will depend on the requirements of each building type, based on its function and hours of use.

Heating Strategies

1. Use systems to manage demand effectively

- Several smaller boilers allow for a changing heat demand and provide more flexibility than one centralised system. This is especially beneficial when sites have more than one building.
- Systems should match the heat profiles of the spaces and can be thermally zoned for different time or temperature requirements based on occupancy. This will reduce energy consumption by providing heating where it is required.
- Time controls: Optimum start/stop control to meet the occupancy requirements of each building.
- Boiler controls: Sequence controls allow only required number of boilers to meet the heating load.
- Temperature controls: Weather compensation controls enable temperatures to be adjusted according to seasonal variations.

2. Invest in high efficiency systems and equipment

- Use high efficiency condensing boilers over conventional boilers.
- Ensure that pipe work, valves and other fittings are well insulated to reduce heat loss.

3. Provide control to users

- Provide simple controls for users such as room thermostats or thermostat radiator valves to enable them to control their internal environment.

4. Look for alternative technologies and systems

- Heat recovery systems combined with mechanical ventilation can help minimise heat losses in winter. Heat recovery systems work on the principle of preheating incoming fresh air by the heat extracted from outgoing stale air.
- Viability of combining conventional space heating systems with low carbon technologies such as a combined heat and power system or a ground source heat pump should be explored. (Low carbon technologies have been explained in a later section of the report).

Hot Water Strategies

- Combine efficient water fixtures with time controllers for intermittent hot water demand in college buildings.
- Provide localised heaters in areas of low demand like academic buildings and offices.

2.2.2 **Ventilation and Cooling**

If the entire building needs cannot be met by a natural ventilation strategy, it may be necessary to mechanically ventilate the building. Also, mechanical cooling or air-conditioning may be required in some specific spaces such as laboratories.

Cooling systems can be further subdivided into low energy cooling systems or those based primarily on mechanical cooling. (BRECSU 2001)

1 **Low energy cooling systems** require mechanical energy only for auxiliary equipment such as fans and pumps and should be considered before resorting to conventional cooling and air conditioning methods.

2 **Mechanical cooling systems** use a significant amount of energy to circulate the refrigerant or the cold medium through mechanical equipments.

Detailed information on various low energy and cooling systems and their application can be found in the good practice guide 290: Ventilation and Cooling option appraisal - a client's guide by BRECSU (2001).

Cooling Strategies

1. Use systems to manage demand effectively

While designing with minimal energy for cooling ventilation, consider zoning the building into smaller areas based on requirements such that the system works efficiently. (Laia)

Analyse required cooling loads based on:
- Solar gains due to orientation, and perimeter or internal spaces.
- Occupancy, working hours and function of the space, to assess heat gains for the occupants
- Equipment in spaces and associated heat load
- Rooms which require specific air quality such as laboratories with higher ventilation rates.

2. Invest in high efficiency systems and equipment

- Use high efficiency components such as fans, pumps and chillers.
- Ensure the system is correctly sized to meet the demand.
- Use refrigerants which are HCFC and CHF free.

3. Provide control to users

- Allow at least a partial control to occupants, such as through opening windows for a certain part of the year.

4. Look for alternative technologies and systems

- Appropriately define the required thermal comfort conditions. Mostly, comfort the conditions can be achieved using a combination of natural and mechanical ventilation. This is called mixed mode ventilation.

  Mixed Mode Systems combine natural ventilation with mechanical ventilation and cooling using sophisticated controls. The two systems alternate to provide comfortable conditions depending on the time of the day or the season. The dual system is based on a higher internal range of temperature than would exist if the space was entirely cooled mechanically. Limiting mechanical ventilation use helps in reducing energy costs associated with continuous cooling or air-conditioning of spaces. It also helps in providing more control to the occupant over their internal environment.

2.2.3 **Lighting**

Electric lighting costs are substantial for any institution. Daylight combined with energy efficient lights and appropriate controls can help in reducing costs.

Lighting strategies

1. Invest in high efficiency systems and equipment

Specify energy efficient lighting fixtures to provide appropriate luminance levels for sufficiently bright internal spaces.

Energy Efficient Lights

Low energy compact fluorescent lamps (CFLs) cost more to buy initially, but save money by using less electricity.

- To provide the same light level, the CFLs use almost one fifth of the energy required by an ordinary tungsten lamp.

Ordinary lamp	CFL
60 W	15-18W
100W	20-25W

- CFLs have a life of about 10,000 hours, which is 8 times of a normal lamp.
- A 20W CFL will save around £50 and 0.37 tonnes of CO_2.

2. Use systems to manage demand effectively

- Provide intelligent controls to minimise energy use while providing optimum light levels.

- Do not provide one control for the entire lights in an area. Rows of lights parallel to the windows can be wired together. This allows them to be switched off when sufficient daylight is available while the lights in the centre of the room can be switched on.
- This can be combined with daylight sensors or photoelectric switching and dimming controls, to adjust light levels relative to available natural light. Lights in areas with more natural light such as close to the windows or skylights are dimmed by the sensors as compared to areas with less daylight.
- Occupancy sensors in areas which are not constantly in use such as corridors and toilets bring on the light only when required saving considerable amount of energy. They are also used in external security lighting.

3. Provide control to users

- Provide desk lamps on work spaces in addition to room lights to meet the required light levels in offices and study areas in residential halls.
- Provide dimmers in rooms to control the amount of light in a room. This is especially beneficial in seminar rooms with data projection requirements.

ACTION STEPS – Building Services

✔ The **architect, M&E engineers and other services' consultants** should closely **work together** to design energy efficient services based on the sustainability principles defined in the brief.

✔ Incorporate the following principles while designing the system:
- **Invest in high efficiency systems and equipment**
- **Use systems to manage demand effectively**
- **Provide control to users**
- **Consider alternative technologies and systems**

✔ Explore the potential of combining building services with cleaner technologies such as **low carbon systems and renewable technologies** e.g. existing community heating systems.(Refer to heating strategies)

✔ Consider the overall requirements before detailing any individual services. Building services cannot be designed in isolation and should **complement the other services**. For example, an effective ventilation strategy will ensure that heat loss is minimised in winters, thereby reducing the heating load. Similarly, electric lighting controls minimise energy use as well as unwanted heat gain from lights.

2.3 Cost of Energy Efficiency Measures

This section gives costs of some energy efficiency measures for built fabric and building services. The costs are indicative and have been estimated for new building construction and would be different from costs of incorporating features during refurbishments.

Actual costs will be dependent on the function, and area of the space.

2.3.1 Costs for Commercial Measures (for Administrative and Institutional buildings)

Energy Efficiency Measure	Cost (£)	Additional Information
Built Fabric		
Fabric insulation in roof and walls	£2,940 (additional cost) Improvement over building regulations	2 storey naturally ventilated office. (BRE)
Air-tight construction	£10,000 for a fan pressurization test	Typical factory unit (DTI and Faber Maunsell 2006)
Building Services		
Energy efficient lighting	£4-12 for a single CFL (compact fluorescent lamps)	For 10,000 hours life, a CFL will save around £50.(DTI and Faber Maunsell 2006)
Lighting controls	£10-20/unit of control device	
Occupancy sensors Daylight sensors	£7,403 cost of daylight sensors in all areas	2 storey naturally ventilated office.(BRE)
Condensing boilers	£1,000 (additional cost above standard boilers)	Typical factory unit (DTI and Faber Maunsell 2006)
Heating/cooling zoned controls	£1,000 for thermostatic radiator valves and similar controls	Typical factory unit (DTI and Faber Maunsell 2006)
Energy sub-metering	£1,906 (sub-meters for major plant and both floors)	2 storey naturally ventilated office(BRE)
	£2,000	Typical factory unit (DTI and Faber Maunsell 2006)

Table 3. Costs for Commercial measures (for administrative and institutional buildings)

Note: All costs are indicative for new build and are derived from two sources.

1 DTI funded sustainable construction project- Industrial & commercial measures – costs for Typical factory unit (5000m^2 production &1000m^2 office)

2 BRE- putting a price to sustainability – costs for Building regulations compliant 'base case' 2 storey naturally ventilated office.

2.4 Low Carbon Technologies

Integration of low carbon technologies such as biomass as fuel, Combined Heat and Power systems (CHP) and Ground Source Heat Pump (GSHP) should be considered at the design stage.

Planning Policy Statement PPS 22 on renewable energy encourages local and regional planning bodies to incorporate policies for on-site energy generation (ODPM 2004). Hence, a number of local authorities are now promoting new developments to generate part of their total energy use on site, usually 10-20%, through low and zero carbon technologies. Find out from your authority for more information on local priorities and available grants.

2.4.1 **Biomass Boilers**

Biomass comprises plants or organic waste from industrial, commercial, domestic and agricultural processes which can be used as fuel to produce energy. Biomass boilers can be linked to space heating and hot water systems in the building, like conventional boilers.

Biomass as a fuel source has potential environmental benefits. Unlike fossil fuels which are formed over millions of years, biomass can be replenished at a faster rate. Using biomass also reduces the amount of wood that goes to landfill as a waste. Although burning of biomass fuels releases CO_2, they are considered to be carbon neutral fuels due to the absorption of an equal amount of CO_2 whilst growing. (Energy Saving Trust 2007)

Application

Before installing a biomass boiler, it is essential to consider the following:

- The type of boiler and fuel - Boilers can be on manual or automatic feed. This also depends on the type of fuel used. Logs, pellets or wood chips are the common types of biomass fuels available.
- Fuel sourcing - A sufficient amount of storage space for the fuel is required for biomass boilers. Hence it is cheaper if fuel is sourced locally. It also saves carbon emissions resulting from transporting large quantities of fuel.
- They are especially beneficial to use in areas where gas is not readily available, such as rural areas with local availability of biofuels.

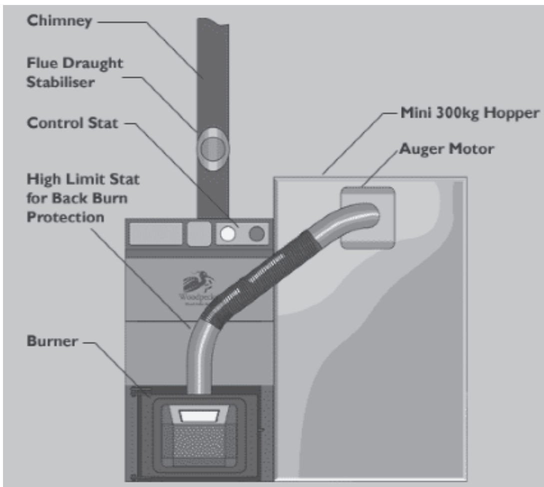


Figure 4. Pellet Boiler Diagram
Source: www.gerkros.ie

- Smoke from boilers – burning of wood releases smoke and requires a flue and chimney to carry this smoke. Certain areas are classified as smokeless zones and require only exempted appliances to be used. This should be checked with local authorities before a biomass boiler is proposed (Energy Saving Trust 2007).

2.4.2 **Combined Heat and Power Systems (CHP)**

Combined heat and power systems are stand alone systems which generate electricity and heat (thermal energy) in a single process. CHP plant may be powered by natural gas or bio-fuels to produce electricity. The excess heat lost during the electricity generation process is recovered, typically, to provide for local heating demands. It can also be used to provide cooling using absorption chillers.

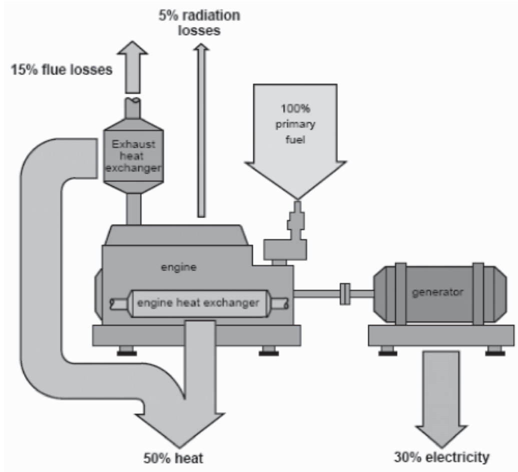


Figure 5. Heat and Power produced by a typical packaged CHP unit
Source: Small Scale CHP for buildings (BRECSU 1996)

CHP systems can have an efficiency of around 80% as compared to conventional power generation efficiency of 30-35%, as the heat lost in power generation is recovered and used nearby.

However, to maintain this efficiency, a constant heat load is required to utilise the recovered heat.

For best results, CHP should be sized to meet thermal base loads and electricity produced should be used locally with minimal load.

Application

They are best suited to multi –use sites with an operation of around 16 hours in a day and with constant heat requirements (Carbon Trust 2005). As a thumb rule, feasibility of building sites such as colleges with 4,000 hours of annual use for simultaneous heat and electricity should be investigated (BRECSU 1996). CHP can be a viable option for FE colleges with a large range of academic building types and sports facilities such as swimming pools.

CHP plant can ensure security of energy supply and can be used to partially account for standby generators found in most colleges or in some cases, even replace conventional boilers. This can also offset the cost of the plant against installation costs of CHP.

Higher efficiency per unit of fuel results in energy cost savings as well as lesser carbon emissions. The carbon intensity of energy produced from CHP can be further reduced by using wood chips as fuel or other locally-available bio-fuels.

2.4.3 **Ground Source Heat Pump (GSHP)**

Ground source heat pumps are used to provide both heating and cooling by transferring heat from a hotter to a colder body through circulating fluids.

GSHP utilise the earth's stable temperature of around 12 degrees centigrade at approximately 1.5 metres below the earth's surface. Pipe work containing heat transfer fluid is either laid in horizontal trenches or in a vertical borehole and transfers the heat from the ground to be used for space or water heating. The maximum temperature that is reached efficiently is around 50°C (DTI 2005). This can be further heated to a required higher temperature by electrically driven heat pumps.

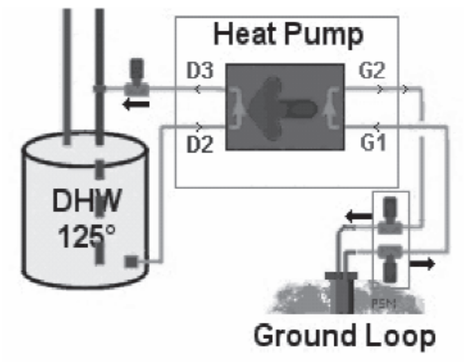


Figure 6. Schematic representation of a ground source heat pump.
Source: (DTI 2005)

Application

Heat pumps should be used continuously to be efficient and hence, should not be sized to meet full energy needs (Carbon Trust 2005). Instead, they should be sized to meet the load that is constantly present in the building at all times. A conventional connection to the grid is therefore required to provide for peak loads.

The technology can be used to effectively provide under floor heating which works at lower temperatures, hence increasing the efficiency of heat pumps.

GSHP is less carbon intensive than providing the entire heating or cooling demands through conventional fossil fuel based electricity. They are most cost- effective when replacing electrical heating systems or in areas where there is no gas supply.

2.5 Zero Carbon Technologies

Technologies such as solar thermal for hot water, photovoltaic panels and wind turbines are zero carbon technologies during operation and significantly contribute towards environmental benefits.

2.5.1 **Photovoltaic Panels (PV)**

Photovoltaic panels convert energy from the sun to electrical energy through semi-conductor cells. PV can provide electricity to be used locally in the building while excess can be exported back to the national grid.

PV generates energy during the day and the output increases with more brightness. Hence PV panels should remain unshaded throughout the day and ideally face south, at an elevation of about 30-40 degrees. A south facing array might generate around 100kWh/m^2/year. (Carbon Trust 2005).

Application

PV panels provide a highly visible public expression of the organisation's environmental commitment which can be beneficial for colleges. PV come as modular panels and have a wide variety of applications ranging from roof tops or stand alone panels.

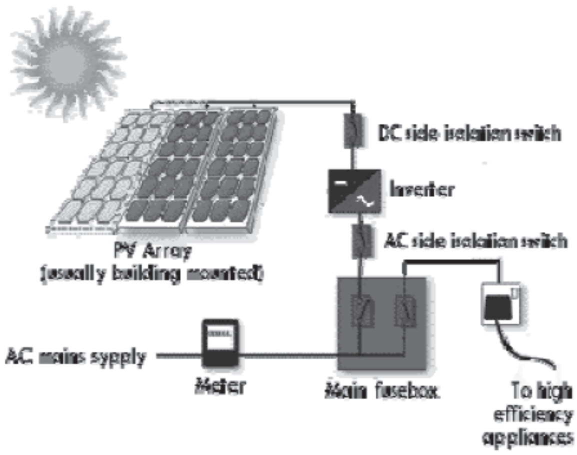


Figure 7. Components of a grid-connected PV system. (Source: BPVA, 2000)

They can be retrofitted on existing roofs or easily incorporated as part of the building envelope at construction stage on façades as cladding or rain screen or be incorporated in glass and used for atria roofs and walls. These are called building integrated photovoltaic panels (BIPV). Integrating PV during construction stage has the additional benefit of BiPV components displacing conventional building materials and therefore partial costs can be offset.

2.5.2 **Solar Thermal Panels**

Solar thermal panels convert energy from the sun to provide useful heat. The system comprises a collector with a heat transfer fluid mounted on the roof of the building. This fluid is heated by the sun and the heat is transferred by a heat exchanger to a separate water storage tank inside the building which is used to provide hot water.

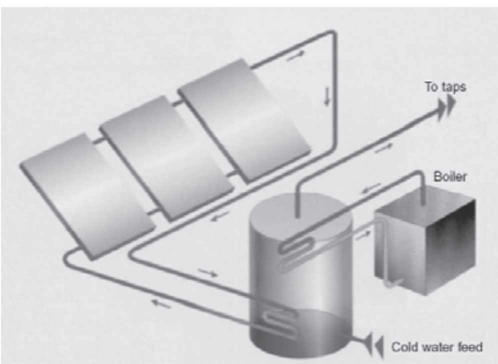


Figure 8. A typical active solar heating system (Source: HEEBPp 2002, p. 21)

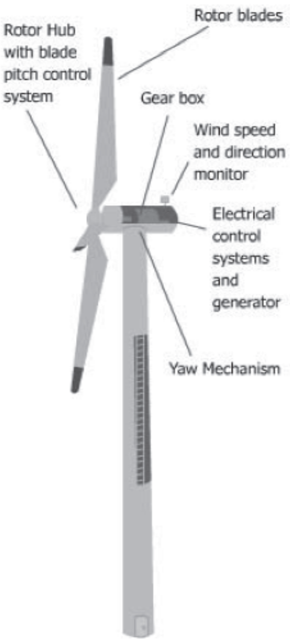
Like PV panels, their output depends on the available energy from the sun and should therefore be placed so as to maximise solar gain. South facing roofs which are not shaded by trees or surrounding buildings throughout the day are ideal locations.

Application

Their most common application is to provide hot water. However, a backup system should be provided to supply hot water when the solar hot water system cannot meet the entire demand, especially in winter months.

2.5.3 **Wind Turbines**

Wind turbines use energy from the wind to drive a generator. The electricity produced can provide for local needs and the excess energy can be fed into the national grid via an inverter. The output from a turbine is dependent on the size of the blades and the wind speed. Larger wind turbines providing for a group of buildings have a better output as compared to smaller turbines for individual buildings.



Application

Any site with a wind speed of over 5m/second can be considered for a wind turbine. Wind turbines can be mounted on buildings, or be stand alone turbines. However, they should be sited where the wind turbulence can be minimised. Wind turbines are hence mounted on high towers to take advantage of higher wind speeds with less turbulence.

Wind turbines are highly visible in the landscape and generate noise due to rotation of blades. The noise level will be dependent on where the turbine is sited. Hence, it is essential to undertake a feasibility study before installation. Planning permission is generally required before installation.

Figure 9. Diagram of a typical wind turbine. Source: BWEA

2.6 Cost of Low and Zero Carbon Technologies

The costs of various technologies including their carbon saving potential are compared in the following table.

Technology	Capital cost £/dwelling	Financial saving £/dwelling	Saving tonnesCO_2 over lifetime	Saving Kg CO_2 /£ over lifetime	Lifespan years
CHP	4600	6610	17808	3.9	15
GSHP	5000	4900	6533	1.3	pump - 15 coils - 30
Small wind	7400	11059	33080	4.5	25
Solar hot water	2500	1400	7600	3.0	20-25
Solar PV	8000	5175	19350	2.4	15-20

Table 4. Cost of Low and Zero Carbon Technologies. Source: (DTI, 2005)

ACTION STEPS – Low and Zero Carbon Technologies

- ✔ **Assess expected building energy loads in relation to pattern of use and occupancy to choose appropriate technology.**
  For example, certain systems like CHP are efficient only when there is a need for constant heat and electricity in the building. A sports centre with a swimming pool requiring hot water might provide a feasible option.

- ✔ **Evaluate the site for possibilities of integrating technologies.**
  Using low or zero carbon technology is dependent on the nature of the site. Solar technologies require non-shaded south facing surfaces, while GSHP requires sufficient land for embedding the pipes.

- ✔ **Research available funding options.**
  Grants are provided by the government for encouraging certain technologies. DTI micro generation grants of up to one million pounds are available to public sector organisations. The technologies supported are solar PV and thermal, wind turbines and ground source heat pumps, with support ranging from 30-50% depending on the technology.

- ✔ **Assess the total cost implications in terms of simple payback and whole life cost as well as environmental benefits.**
  Most systems require a supplementary grid-connected system to provide for peak loads or when the supply is intermittent. Costs of these should be evaluated against the potential benefits achieved in energy and cost savings and carbon emission reductions.

- ✔ **Consider any special requirements for planning permission.**
  Some Local Planning Authorities might require a certain percentage of total energy used on site to be generated from renewable or low carbon technologies. A combination of one or more technologies should be considered to achieve this.

  Certain technologies like wind turbine or the extraction of underground water for GSHP may require permission from planning and/or environmental authorities.

3. OPERATION & MAINTENANCE

Energy management and conservation measures built into day-to-day operation and maintenance of a college can significantly reduce the energy used, providing the dual benefit of monetary savings and environmental protection. An efficient building management team can help to achieve this in any institution.

This section describes the mechanisms for conserving energy during operation and maintenance and the role of the property management team in achieving these savings.

Energy used in the operation of colleges incurs huge amounts of expenditure. In the past few years, many colleges have experienced a rise in energy bills due to inflation and higher consumption standards related to changing comfort levels and in some cases, due to regulations such as increased ventilation rates in laboratories. Universities renewing their electricity and gas contract during 2004 faced a 30-50% increase in price (HEEPI 2005). However, energy costs remain one of the main items of controllable cost in the total operating expenditure of a college.

Key strategies to reduce energy during operation and maintenance are explained below.

3.1 Building Energy Management System (BEMS)

What is a BEMS?
A building management system or a building energy management system (BEMS) is a computer based system to efficiently manage and control building services such as heating, cooling, and lighting. They can also be combined with the functioning of other services such as security systems.

Most colleges have a large number of departments spread across various buildings or sites. It is difficult to individually manage each of these, to suit their specific requirements. A building management system can efficiently manage the building services in each of these through a central control point.

How does it work?
A BEMS saves energy by providing effective control based on the input information. This is done by locating outstations or stand alone controllers to accurately pre-determine the requirements of the buildings based on changing external factors such as occupancy, time, lighting and temperature.

The data from each outstation can be seen from the central control point and can be adjusted to improve or change parameters. A system can initially have only one outstation point and more outstations can be linked at a later stage depending on the funds available and the requirements of the college.

BEMS are most efficient when the use is widespread. However, since the cost is more than for standard units, buildings with complex services or remote locations should get preference.

Use can also be restricted to only one or two kinds of energy using services such as heating or lighting. However, provision needs to be made earlier while choosing a central unit and software to allow additions.

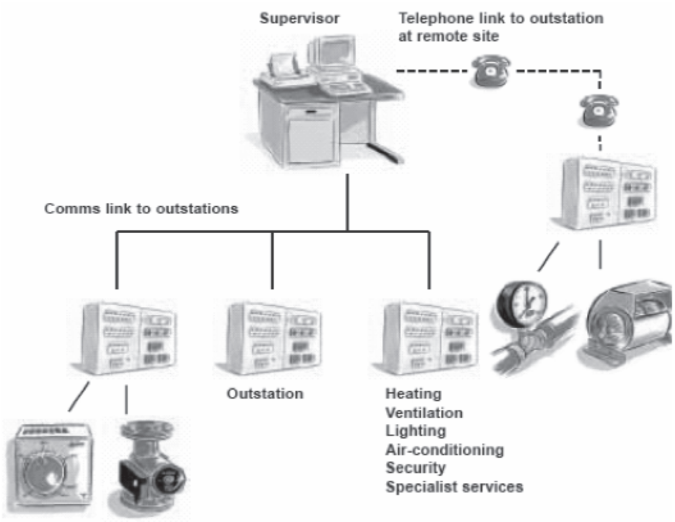


Figure 10. Diagrammatic representation of a BMS network
Source: (Carbon Trust)

Case Study

University of East Anglia (BRECSU 1998)

The university installed a BMS system over 10 years in two phases for heating, ventilation and air-conditioning.

- Cost of phase one was £95,000.
- Energy savings over three years £50,000
- Manpower savings over the same period £70,000
- 2-3 years payback period

Advantages of BEMS

- Ability to be programmed to respond to individual demands and requirements of services within each space to provide flexibility and comfortable conditions.
- Potential energy cost savings of 10-20% as compared to standard controls (BRECSU 1998).
- Ease of operation for buildings with complex services or remote locations.

3.2 Data Collection, Monitoring and Targeting (M&T)

To effectively reduce energy consumption and manage building services efficiently, it is essential that patterns of energy use are understood. A monitoring and targeting (M&T) system helps in identifying areas where energy is being wasted and employing appropriate energy saving measures.

What is a M&T System?
A monitoring and targeting system records data for energy use and provides a means of comparison against previous years of use and with benchmark buildings.

Essential feature of a monitoring and targeting system:

1. Record energy use to be assessed in relation to factors such as occupancy, weather, and function of the space.
2. Ability to highlight sudden energy use changes to identify areas of excessive use or faults that have developed within the system or malfunctioning of plant.

3 Provide a means of comparison for energy use.
- A building's energy performance over the years incorporating adjustment factors such as weather (degree days) and the number of hours the building is used for.
- Comparison with energy targets or benchmark buildings to evaluate how the building performs against these.

How does it work?
The monitoring system should record energy use through actual fuel bills to determine changes in energy consumption patterns. But this is only possible if the energy consumption is sub-metered for different buildings. This allows to distinguish energy use pattern and costs based on occupancy and to apply suitable measures.

Also, sub-metering different types of buildings allows the cost of energy to be transferred to a particular department, making it easier to target energy efficiency measures. For example, sub-metering can be a useful tool in determining prices for facilities when parts of the building are let out for community use or conferences etc.

Monitoring can be done by various methods depending on the complexity of the estate or site.
- A simple M&T system is to manually maintain log books with monthly fuel consumption data from meters which can then be transferred to a spreadsheet or commercially available software.
- Large estates might require computer based systems to monitor. These can be linked to the BEMS system as well.

Advantages of an M&T system
- Constant monitoring provides accurate and reliable information on energy use and fuel costs as against estimated bills.
- Spreadsheets help in analysing data to identify which buildings or services need to be targeted for energy efficiency improvements.

Case Study

University of Wales, Cardiff
(BRECSU 1996)

The main features of the monitoring & targeting system in the university were:
- The university was divided into a number of areas called energy accounting centres to measure fuel use separately by installing sub-meters.
- Meter readings were taken manually once a month and written into log books, which were then transferred to spreadsheets to sort and analyse the data.
- Targets were set and buildings identified for high energy use through the analysed data. Measures taken on the basis of these have resulted in savings of **£60,000/year**.

Whilst most spreadsheets or computer systems have an ability to assimilate all of the above data, it depends on the energy team to analyse and use the results for incorporating measures.

Reporting the findings from M&T systems periodically can be used to ensure that the benefits achieved from the system are acknowledged and sustained. A detailed post-occupancy evaluation can be instrumental in achieving this.

3.3 Post-Occupancy Evaluation (POE)

A key measure to evaluate and analyse building performance is to do periodic post-occupancy evaluations.

What is a POE?
A post–occupancy evaluation is primarily a method to analyse building performance while in use. It can account for a range of factors depending upon the purpose and the nature of the evaluation.

All buildings are designed to deliver a range of measures. However, the way a building is used by occupants is intricately linked to its performance. A POE essentially allows evaluating the energy performance of a building and relating it to occupant satisfaction within it, thus providing important clues to designers and estate managers equally.

Some of the common evaluation parameters are:
- Detailed energy audit analysing fuel use and cost.
- Occupant satisfaction survey for thermal comfort within the building and usability of controls provided.
- Environmental audit incorporating broader concerns like water consumption and costs, waste recycling potential, landscaping, transport policies, potential for renewable technologies etc.

How does it work?
A POE can be done periodically from time to time depending on the nature of the building. Essentially, a POE should be done within 1-2 years of occupying a building, when the building has reached its intended occupancy levels and allowing for a full seasonal cycle for the services to function.

A strategic POE can also be carried out every 3-5 years to assess how the building responds to the changing demands and what needs to be done to meet future needs.

There are various methodologies for carrying out a POE. Further information, about these can be obtained from 'A Guide to Post-Occupancy Evaluation' (University of Westminster).

Processes and Tools for a Typical POE

	PROCESSES	TOOLS
Energy / Utilities Audit	**Monitoring and Targeting** ▪ Separation of hot water and space heating ▪ Energy per unit of internal heated floor area ▪ Occupancy data, nature of use of buildings- residential/non-residential	
	Analyzing Trends ▪ Space heating and weather correction (degree days)	▪ Manual log books, ▪ Spreadsheets, software
	Benchmarking ▪ Normalised performance index and ▪ Environmental performance index	
Occupant Satisfaction Survey	**Thermal Comfort** ▪ Space temperature and light quality	Online or print questionnaires
	Usability of Controls ▪ Heating, lighting, window blinds etc.	
Environmental Audit	**Waste** sorting and recycling **Transport** policy and CO_2 emissions **Biodiversity** and landscaping	▪ Walk by surveys, ▪ Online or print questionnaires.

Advantages of POE

- Provides a method of assessing the energy and environmental performance of the building against design or intended criteria.
- Allows the building's performance to be benchmarked against best practice buildings to estimate the savings potential that can be achieved and allocating resources where they are required.
- Allows the designers and energy managers to understand how to address user needs more effectively and fine tune the systems to improve efficiency.
- Lessons learnt and feedback can be incorporated to inform the design of new buildings.

3.4 Role of Building Managers

Large sites with varied buildings and departments require the involvement of a number of people for managing energy, such as senior and departmental managers and facilities or estates managers. They play a pivotal role in conserving energy and ensuring energy efficiency at all levels in the college.

Some of the main responsibilities of the energy team are listed below to help the team identify opportunities for saving energy and costs at different stages of design, construction and operation.

1. **Involvement in major rebuilding or refurbishment decisions during design and procurement.**
   The estates manager should be involved in the design stage and maintain regular contact with all representatives including architects, environmental consultants and senior management to constructively contribute to the designing process.

- Informing the design process by past experience of energy management, and helping set energy targets based on understanding of requirements of specific departments.

- Engaging in procurement of services and commissioning of the building ensures an understanding of how systems operate and can help architects specify and design for appropriate technologies.

  Analysis of buildings designed to be energy efficient shows that problems can arise in the functioning of the building when the design intent and the operation of plant and controls do not match up. Moreover, these issues generally go unnoticed, and hence remain unresolved. This can lead to undermining the energy saving potential of measures employed. (Bordass, 2005)

2. **Efficient management systems during operation and maintenance.**
   The success of any energy management strategy depends on good management strategy and systems, and an efficient team.

- Allocating specific responsibility to each team member.

- Engaging other staff such as plant operators, security staff, maintenance contractors and hall wardens to be instrumental in energy saving strategies on the campus. Incentives and education can be provided to enable this.

  For example, cleaning staff can actively help in controlling energy use by switching off lights and equipment after use. Preferably, cleaning should be done soon after the hours of use or before the building is occupied. This also ensures that the entire building is not heated for a few people.

- Employing appropriate systems and plant controls such as time and temperature settings.

3. **Data collection, monitoring, targeting and reporting.**

- Choosing an appropriate data monitoring and targeting system.

- Periodic post occupancy evaluations to understand energy use relative to the way people use the building by incorporating user satisfaction surveys.

- Providing summary reports of results. It is important that savings and other benefits are reported to the senior management. This can enable future funding required for other environmental initiatives.

4. Dissemination of information amongst staff and students.

Generate awareness amongst staff and students to encourage participation in energy saving measures. Providing feedback on initiatives and results achieved also ensures co-operation and sustains interest in energy saving measures. There are various ways to achieve this:

- Posters in common areas can be used to provide information. The Energy Saving Trust provides posters, describing why it is important to conserve energy and reminding about simple measures such as switching off and not leaving equipment on standby.

- Student and staff magazines can be targeted to generate awareness and influence behaviour.

- Providing a simple building design user's guide can help people to understand and use systems appropriately.

- Savings from such measures should be monitored and publicised to motivate staff and to enable future investment in such measures.

ACTION STEPS – Low and Zero Carbon Technologies

✔ Understand the building's energy use by **regular monitoring and targeting processes**. These can vary from simple manual log books, sub-meters, computer programs or more sophisticated BEMS.

✔ Compare use with previous year's and **existing benchmarks** to identify spaces or services with higher energy use.

✔ Employ appropriate **systems and plant controls** such as time and temperature settings to counter the higher energy use.

✔ Combine effective management strategies such as regular **post-occupancy evaluations** and **reporting energy use** to generate awareness amongst users.

✔ Use the feedback to **complete the knowledge loop** during design and procurement of new buildings.

✔ Communicate messages about energy efficiency to staff, students and visitors to maximise energy savings. Money saved can be re-invested to their benefit.

4. FURTHER INFORMATION

Key Organisations

1 **Carbon Trust** advises business and the public sector to cut carbon emissions, and supports the development of low carbon technologies. http://www.carbontrust.co.uk
2 **Energy Saving Trust** provides guidance and funding for energy efficiency and low carbon technologies in buildings. http://www.est.org.uk/
3 **Building Research Establishment** provides a complete range of consultancy, testing and commissioned research services related to all aspects of the built environment. http://www.bre.co.uk
4 **Environment Agency** is the leading public body for protecting and improving the environment in England and Wales. www.environment-agency.gov.uk
5 **CABE**, the Commission for Architecture and the Built Environment, is the government's advisor on architecture, urban design and public space. It provides clients with hands-on advice on ways to get better value through better design. www.cabe.org.uk
6 **LSC**, the Learning and Skills Council. www.lsc.gov.uk
7 **Low carbon and renewable technologies**
British photovoltaic association; http://www.pv-uk.org.uk/
British wind energy association; www.bwea.com
The combined heat and power association; www.chpa.co.uk
The heat pump association; www.feta.co.uk/hpa/index.htm

Other Sources

1 **Higher Education Environmental Performance Improvement** is a project funded by HEFCE to create awareness and disseminate information related to energy and environment in the higher education sector. http://www.heepi.org.uk/

2 **Environment Association for Universities and Colleges, EAUC**, is the sector champion for sustainability in the UK. The EUAC network stimulates and supports all aspects of the sector to become more sustainable. http://www.eauc.org.uk

3 **Waste and Resources Action Programme, WRAP**, works in partnership, helping businesses and the general public to reduce and recycle waste. http://www.wrap.org.uk

5. REFERENCES

BRECSU (1996). Energy efficiency in further and higher education - monitoring and targeting, University of Wales, Cardiff. Watford, BRE.

BRECSU (1996). Small scale combined heat and power for buildings. Good practice guide 176. Watford, BRE.

BRECSU (2001). Ventilation and cooling option appraisal - a client's guide. Good practice guide 290. Watford, BRE.

BRECSU, D. (1998). Building management systems in further and higher education. Watford, BRE.

Carbon Trust (2005). Building a brighter future: a guide to low carbon design. London, The Carbon Trust.

CIBSE (2004). CIBSE Guide F: energy efficiency in buildings. London, The Chartered Institution of Building Services Engineers.

DTI and Faber Maunsell. (2006). "Sustainable construction: practical guidance for planners and developers." Retrieved 12 January, 2006, from www.sustainable-construction.org.uk/.

DTI, D., Future energy solutions (2005). Renewable heat and heat from combined heat and power plants - study and analysis.

Edwards B, H. P. (2001). Rough Guide to Sustainability. London, RIBA publications.

Energy Saving Trust (2007). Biomass Factsheet : Discover Renewable Energy. London.

HEEBP (2002). Domestic heating and hot water: choice of fuel and system type. Watford, Housing Energy Efficiency Best Practice Programme.

HEEPI (2005). Managing energy and water in higher and further education - the value of metering, monitoring and targeting in reducing environmental impacts and risks, and offsetting increased energy and water costs.

J. Anderson, D. S., M. Sinclair (2002). The green guide to specification, Blackwell Science Ltd.

Laia, C. Energy efficient active cooling systems. Vienna, CEETA, Austrian energy agency, Intelligent Energy Europe.

ODPM (2004). Planning Policy Statement 22 : Renewable Energy, HMSO.

P. Borer , C. H. (1998). The whole house book: ecological building design and materials. Centre for alternative technology.

University of Westminster, H., AUDE Guide to post occupany evaluation.

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