APPLICATION NOTE

ENERGY EFFICIENCY SELF-ASSESSMENT IN BUILDINGS

James Parker

February 2012

ECI Publication No Cu0178

Available from www.leonardo-energy.org/node/156676

Document Issue Control Sheet

Document Title:	Energy Efficiency Self-assessment in Buildings
Publication No:	Cu0178
Issue:	01
Release:	February 2013
Author(s):	James Parker – BSRIA Ltd
Reviewer(s):	Bruno De Wachter

Document History

Issue	Date	Purpose
1	February 2013	First edition, in the framework of the Good Practice Guide
2		
3		

Disclaimer

While this publication has been prepared with care, European Copper Institute and other contributors provide no warranty with regards to the content and shall not be liable for any direct, incidental or consequential damages that may result from the use of the information or the data contained.

CONTENTS

SUMMARY

Energy efficiency has been a key topic for many years now, yet there still remain opportunities to reduce energy use in existing buildings. With existing buildings making up a significant proportion of Europe's building stock, reducing the energy they consume can help make inroads to meeting carbon reduction targets.

However, for most organisations the real driver for reducing energy consumption rests firmly in the accountant's office. With energy prices rising all the time, reducing the energy used in a building can give significant financial benefits.

Many issues relating to energy efficiency can be spotted by someone with limited technical knowledge. Things like non-optimised control of lighting or heating can be easily seen by examining the system in the correct way.

A systematic approach to analysing the data already held, gathering data needed, and looking at options for the future, should yield benefits.

INTRODUCTION

This guide presents a simple methodology for assessing the energy consumption of a building and identifying cost effective opportunities to improve energy efficiency, reduce operating costs, and minimise carbon emissions.

Assessing energy use in a building can be a small internal project looking at lowering costs or improving the internal environment. However, it can also be part of a more detailed strategic level assessment of the whole operation of an organisation. At this level of detail, the self-assessment would normally be the first step of a project, leading onto the appointment of external consultants.

This guide is aimed at building owners and facilities managers but can be applied by any person with minimal technical background.

ENERGY AUDIT

An energy audit is the key tool in understanding how a building consumes energy, identifying problem areas, and justifying solutions that may require investment. It is a study of energy uses and processes, from building to equipment level, over a given time period. A full detailed study of the building could be carried out over a year to highlight seasonal changes, but a shorter study over a month or two can be equally useful. The key thing is to have useful and meaningful data that is typical for the building. If there is an unexpected change in the weather, such as a cold period in summer, then an additional audit may be required to get a true picture of the building. An energy audit can be broken down into several stages, as shown in the flow chart below. Each will be explained in detail.

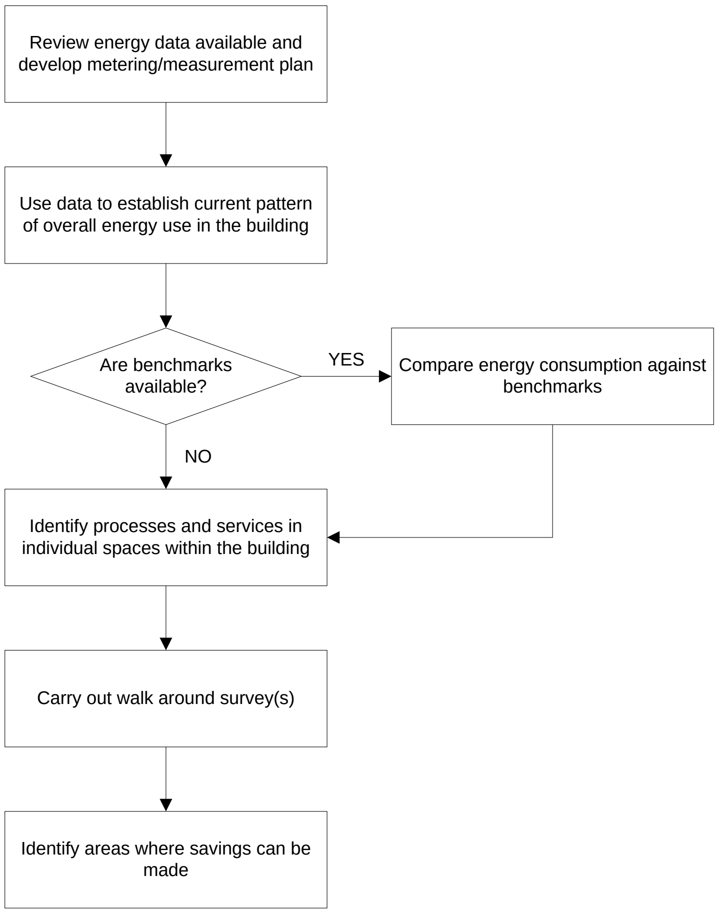

Figure 1 – Flowchart of an Energy Audit.

REVIEWING ENERGY DATA

The first step of any audit is to review what data is available and what data is needed. The review should identify what information already exists and any gaps.

Historical energy consumption data may be available from energy bills (copies may be held by the finance department), utility reports, manual meter readings and energy management system logs.

Building plans, system schematics and individual plant data are also important to understanding energy consumption and usually held with the Operating and Maintenance manuals.

A simple sketch of the position of the available meters will be very helpful in understanding energy flows and where additional meters may be needed to understand future energy usage.

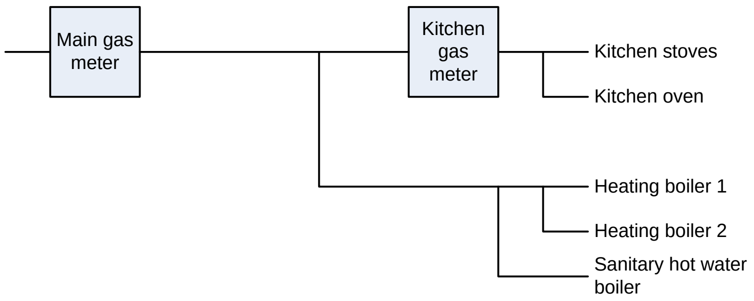

Figure 2 – Example sketch of gas distribution.

Plans and schematics of the building services are useful for the walk round part of the survey as well as later analysis. Where information is missing or incorrect, the walk around survey may be able to fill some of the gaps and resolve inconsistencies. If you can't easily read the schematics or are unfamiliar with plant room equipment, then arrange to be accompanied by the person responsible for maintenance. Above all, be safe and do not enter any hazardous area or operate any equipment except where you are qualified to do so.

It is also useful to look at what has been done before. Someone may have carried out an energy survey in the past. Have the issues identified in that survey been resolved? Have the changes resulting from that survey been successful?

ENERGY METERING

All buildings have one or more utility meters to measure the consumption of energy such as electricity and gas, or heat from a district heating scheme.

Older electricity and gas meters are manually recorded by the energy supplier, while modern meters may be linked to a remote monitoring system operated by the energy supplier or an energy management system installed by the building occupier or landlord. The new generation of smart meters now being installed by energy suppliers in many countries collect data more or less in real time and allow tracking of energy consumption by both the energy supplier and the building occupier. You should check what energy consumption reports and analysis tools are available from your energy supplier as these are often provided as a free service.

Other fuels such as oil, coal, biomass and liquid petroleum gas (LPG) may be delivered intermittently in bulk. Average fuel consumption can be estimated from records of deliveries, adjusted for variations in the residue of fuel from the previous delivery, or from level indicators in tanks and storage silos. It may also be possible to sub-meter the consumption of fuel from storage, particularly for oil and LPG (in gaseous form).

Other forms of energy distribution that are not normally considered as fuels may also be metered including heating and hot water, chilled water, steam and compressed air.

A sub-meter is an additional meter installed by the landlord or tenant to measure the consumption of energy by area, system or individual equipment. This is not normally used for billing purposes but allows the energy consumption of different users to be discriminated e.g. the electricity usage for lighting or gas usage for catering.

The major cost element of sub-metering is usually installation, particularly if that requires breaking into a pipe to fit the meter. The meter itself is usually inexpensive e.g. a small gas meter with pulse output can cost less than €100 (though they rapidly increase in price as they get bigger) but the installation cost could easily be five times the cost of the meter. For non-invasive ultrasonic flow meters used for heating and chilled water, the opposite is true with minimal installation cost but meters costing €2,000 and upwards.

It is not always necessary to install permanent sub-metering to understand the distribution of energy within the building. There are various non-invasive techniques for short term monitoring including clamp meters for electricity supplies, and portable ultrasonic flow meters for heat metering in heating and chilled water circuits. Where there is no easy option for short term sub-metering, it may still be possible to make an estimate of consumption for a specific consumer from a main meter by temporary isolating other consumers. A summary of metering options is shown in Table 1.

Form of energy	**Permanent metering options**	**Original measurement units**	**Temporary / short term metering options**
Electricity	Electricity meter	kWh or kVAh*	Current clamp and demand recorder
Natural gas & LPG	Gas meter	m^3 at standard conditions N.B. utility bills may be expressed in kWh	No easy options (non-invasive ultrasonic gas metering is possible but expensive)
Oil	Oil flow meter Tank level meter	litres	No easy options apart from recording the change in tank level
Biomass	Feed weighing system Silo load cell Silo storage level indicator	kg	Manual weighing/feeding
Heating and chilled water including district and community heating	Electromagnetic flow meter with heat flow integrator	kWh	Non-invasive ultrasonic flow meter with heat flow integrator
Steam	Steam meter (mechanical or Coriolis meter)	kg steam kWh	No easy options
Compressed air	Compressed air meter	m^3 at supply pressure	No easy options
Sanitary hot water	Water meter on cold supply to system	m^3	Non-invasive ultrasonic flow meter

Table 1 – Sub-metering options.

** kVAh meters are used for certain 3-phase industrial tariffs. kWh = kVAh multiplied by the average power factor.*

Many items of equipment, such as boilers, also have “hours run” meters or counters that can be used to assess how much or how frequently they operate. These can be useful in improving insight in where exactly energy is being consumed.

ENERGY CONVERSION

As energy can be supplied in different forms, and measured in different units, conversion to a common metric is required. This allows energy from all sources to be compared on a like for like basis. It is common to use kWh as the standard unit of energy consumed, as this is how electricity is measured. Gas and liquid fuels are normally measured in volume, and solid fuels in weight. These can be converted to the energy equivalent by multiplying by relevant calorific value (heat content). Although representative values of calorific value for typical fuels can be found in literature or on the web, these will vary according to the composition of the fuel and it is preferable to use the values indicated on the fuel supplier invoice. In the case of natural gas, the calorific value will vary by location and time of year. Note that where the calorific value is expressed in GJ per measured unit of fuel, you have to divide this figure by 3.6 to get the calorific value in kWh per measured unit of fuel.

It is recommended to gather the data for the fuels used in the building and arrange them in a table together with current costs and carbon emissions index to ensure that consistent values are used in all calculations.

Fuel	**Gross calorific value**	**Unit cost**	**Carbon dioxide emission***
Electricity	---	0.120 c/kWh	0.5246 $kgCO_2$/kWh
Natural gas	11.1 kWh/m³	0.055 c/kWh	0.1836 $kgCO_2$/kWh
Diesel & heating oil	10.6 kWh/litre	0.080 c/kWh	0.2517 $kgCO_2$/kWh
Wood pellets	5.0 kWh/kg	0.046 c/kWh	0 .039 $kgCO_2$/kWh

Table 2 - Example conversion factors for United Kingdom [1]

** Refer to energy invoices for more accurate values. The carbon emission listed here is direct emission from use of the fuel excluding indirection emissions from processing and delivery.*

Care should be taken with electricity carbon dioxide emission factors, as they vary up to a factor 10 from country to country, depending on the mix of generating technologies. The European average for consumed electricity in 2009 was 0.460 $kgCO_2$/kWh [2]. In most countries, the carbon dioxide emission factor for grid electricity is decreasing year on year, as more and more renewable energy generation systems are connected to the grid. Much of the significant energy consuming equipment installed in buildings, such as boilers or chillers, have life expectancies of 20 to 30 years. Therefore it is important to review the electricity carbon emission factor throughout the life of the component. It is equally important to take the expected future reduction in the electricity carbon emission factor into account when system replacement is considered and various systems consuming different fuel types are being compared. For example, an electric heating system might have higher carbon emissions compared to other systems today, but in 10 years from now, the opposite might be true.

ESTABLISH CONSUMPTION PROFILE AND PATTERNS

The most basic energy analysis is a breakdown by measured consumption though it is more useful to provide a breakdown by end use. For example, *Figure 3* shows gas consumption split into low temperature hot water (LTHW) for space heating and domestic hot water (DHW – also known as sanitary hot water). Electricity is split into lighting, process loads (in this case a data centre with servers and cooling equipment) and small power (distributed via power outlets for office equipment etc.).

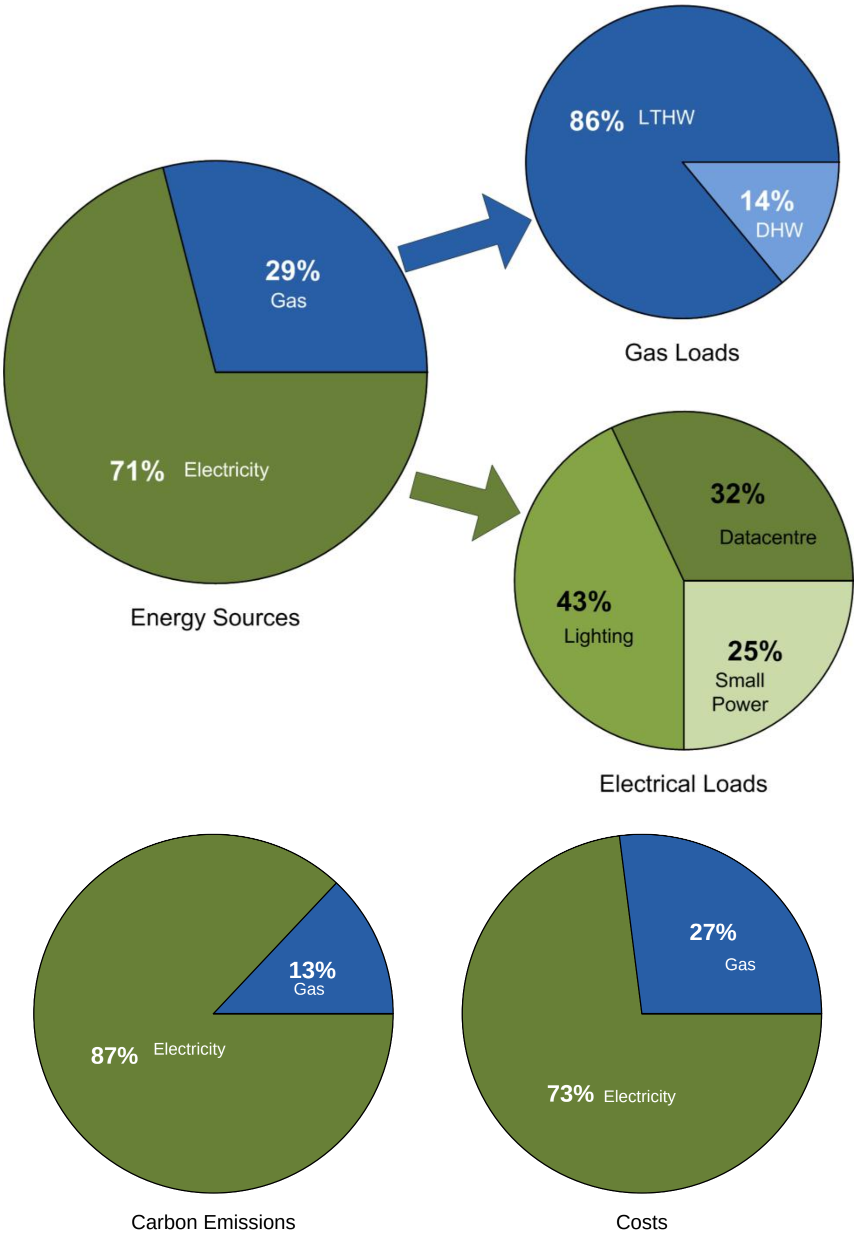

Figure 3 – Example of the Breakdown of measured energy uses.

In the example shown above, sub-metering allowed for the allocation of lighting and small power to each area of the building, and the allocation of gas between heating and hot water. This graph illustrates largest energy consumption over the monitoring period and this is often the area where most savings can be made. A similar chart can be created for cost and carbon emissions.

While cumulative energy consumption may answer the question of where energy is being used, the question of when and why it is being used depends on periodic data recording. Some energy usage will have consistent daily or weekly pattern while other energy usage will vary according to the season and weather conditions.

Figure 4 shows an example of electrical demand over the period of a week (Wednesday midday to Wednesday midday) for the same site, with the average demand (measured in kW) logged every five minutes.

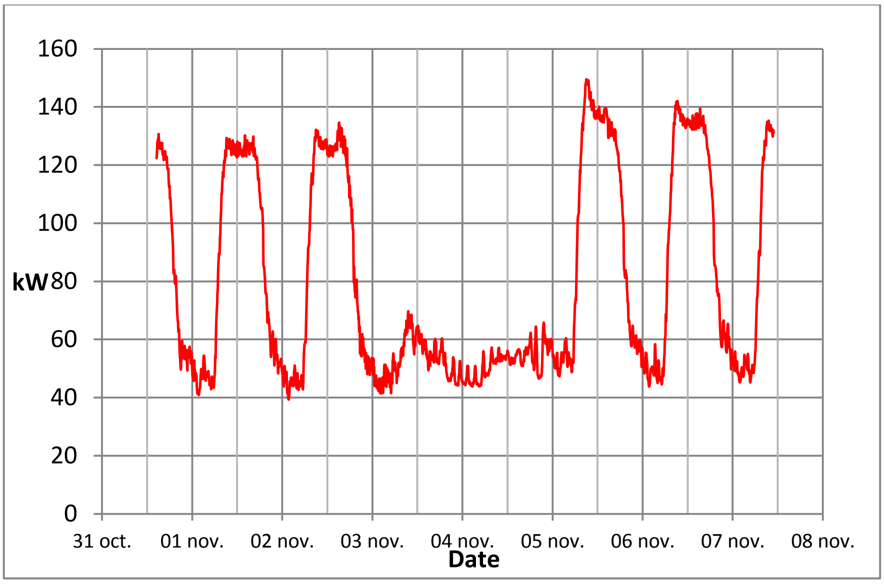

Figure 4 – Electrical demand profile.

This graph highlights the times of maximum and minimum demand. In this case there is a weekday load of over 130 kW and a night time and weekend load of 50 kW. The energy audit would attempt to find out what system or plant contributes to these loads and whether savings can be made. Visiting a site at night will often reveal a multitude of systems can be switched off to save energy.

Benchmarking

Once sufficient energy consumption data has been collected and collated, it can be analysed to see how well the building is performing. Benchmarking allows a comparison of the building against national or sector averages. Some benchmarks are overall consumption indices (typically quoted in kWh/m² per annum for certain space types, but can be linked as well to occupancy levels of the spaces) while others are broken down into specific uses such as lighting and heating. Bear in mind that even if your building is doing better than the sector benchmark, there may still be significant savings to be found.

Many public buildings have already been benchmarked for the display energy certificate required in all EU countries by the Energy Performance in Buildings Directive. This gives an overview, but not a detailed breakdown, per system.

An example is shown below, where actual data is compared against ECG 19. In the UK CIBSE has produced TM46 – Energy Benchmarks, which gives benchmarks for different uses of space in terms of kWh/m^2 per annum.

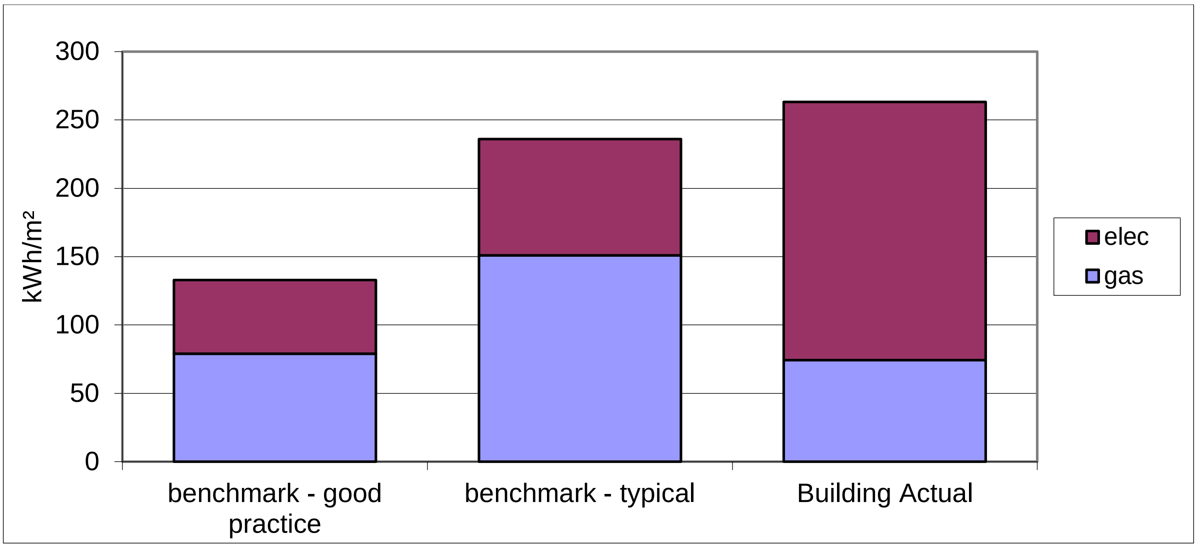

Figure 5 – Example of benchmarking annual energy consumption.

If no suitable benchmarks can be found, it may be possible to compare the actual consumption with the design predictions. This will highlight if the building is operating as intended and identify areas that need closer investigation. Another option could be to compare similar buildings in the same organisation or to join (or form) a benchmarking club with other building operators in the same sector.

Walk-around-survey

Walking around the building and observing how energy is actually used is essential to a full understanding of where savings can be made.

In preparation for the walk-around-survey it is advisable to spend some time studying the plans, schematics and other available documents (including any previous surveys) in order to understand the building. Depending on the size and usage of the building, departmental managers may need to be made aware of the intention to carry out the survey and should be asked to explain their processes and operating constraints. Simple checklists can then be produced and cross referenced to the floor plan to ensure that the key information is captured during the walk-around-survey. Locations for temporary monitoring equipment can also be identified and marked on the floor plan.

The survey may actually take place over several days or weeks in order to achieve a full understanding of the energy implications of all processes. It may also be useful to partially repeat the process at different times of the year as of heating, cooling and lighting all depend on weather conditions.

The survey will involve visiting every space in the building, noting how the space is used, how equipment is operated and if there are any obvious defects or room for improvement. The survey can also be used as an asset survey to confirm all types of equipment installed or fill gaps in the information held, such as technical data, critical to be able to judge savings potential.

As mentioned previously, checklists of the key information to be gathered can aid the survey. Examples of items that should be included on the checklists will be given in the following chapters.

Other tools that could be useful for the survey are:

- Notepad and pen or tablet PC to record findings
- Digital camera to capture images of faults or equipment
- Infra-red thermometer for measuring surface temperatures

- Tape measure
- Torch

The walk around should not be a passive viewing exercise. Useful insights can be gained from talking to the occupants and/or setting up an occupant satisfaction survey. Satisfaction surveys generally focus on occupant comfort and can be useful for identifying areas that are too cold, too hot, too light, etcetera. Occupants may be aware of issues that are not apparent at the time of the survey. Moreover, they can also be encouraged to take an active role in energy saving through improved behaviour.

Identifying Savings

The main aim of an energy audit is to understand energy usage and identify possible savings. Some of these savings will be obvious (such as switching off equipment when not in use) and others will result from a more detailed analysis (such as plant efficiency improvements).

Identified improvement measures should be split into one of three broad categories:

1. No-cost measures – such as good housekeeping or changes in behaviour
2. Low-cost measures – not requiring capital expenditure approval
3. High-cost measures – for which capital approval will be required

Measures in each category should be prioritised according to benefits and payback time.

Simple payback is the cost of the measure divided by the annual saving resulting from it, with the result expressed in years. Most commercial organisations have strict criteria for capital investment and are often looking for simple payback of less than 5 years. However, this may be unduly restrictive and a better option could be to look at the Internal or Economic Rate of Return (IRR), which gives a measure of payback and subsequent gains over a longer period. The most accurate instrument to make an economic evaluation of an investment decision is Life Cycle Costing. More information on Life Cycle Costing can be found in the Leonardo Energy Application Note available from http://www.leonardo-energy.org/life-cycle-costing-basics [3].

Also bear in mind that savings may not be mutually exclusive. Suppose there is a potential saving of 10% of heating energy from a boiler replacement and 20% from improved insulation. The combined saving from implementing both measures is not 30% but 28% of the existing heating bill.

Specific Services – What to look for

This section highlights some of the issues associated with particular systems that should be examined during the walk around survey.

Lighting

Reviewing systems

The three main types of lamps are:

- Incandescent – where electricity is passed through a wire that glows white hot to create the light – e.g. tungsten halogen
- Discharge – where light is generated by electrical discharge within a gas filled envelope – e.g. fluorescent tube
- Solid state – where light is created at the junction of a semi-conductor – e.g. light emitting diode (LED)

Advances in lighting over the last decade have significantly increased the variety and efficacy of lamps. Efficacy is expressed in lumens per watt. Control gear and electronics have also improved. This means that any light fitting (luminaire) over 20 years old should certainly be considered for replacement. Below is a checklist of issues that should be reviewed.

Issue	**Reason for change**	**How to recognise**
Luminaires with basic incandescent lamps	General light service (GLS) lamps are inefficient and recently prohibited for general use in several countries. Existing luminaires may be fitted with compact fluorescent or LED lamps	Traditional lamps that generate significant heat in use
Fluorescent luminaires over 20 years old	Luminaires deteriorate over time. Older control gear is less efficient and may be incompatible with high efficiency tubes. Modern luminaires can achieve a greater useful light output for less energy input	The luminaires may be contemporary with the building or records may exist of the last lighting change refurbishment.
Fluorescent luminaires with older magnetic ballast control gear	Much less efficient than modern high frequency control gear. Modern magnetic ballasts (class B1) can also provide efficiency savings. See http://www.leonardo-energy.org/files/root/pdf/2012/Ballasts.pdf for more detail.	Observe the tube via the camera display on a mobile phone. If the tube appears to flicker with light and dark bands the system has older magnetic control gear. If not then it probably has a high frequency ballast.
Less efficient fluorescent lamps	Old technology lamps are less efficient than new ones	T12 lamps are 38 mm in diameter and generally indicate older technology. Other common lamp types are T8 (25 mm diameter) and T5 (16 mm diameter)
Dirty fittings/diffusers	May reduce the amount of light emitted and cause additional lights to be used	Visual inspection.

Although it may be feasible to replace individual luminaires, any large scale lighting replacement should be done with the help of a qualified lighting designer who may be able to generate additional savings through re-design of the system.

While lighting replacement can generate significant savings, simply switching the luminaires off when not required can often achieve the greatest saving. In large offices this may be inhibited by inflexible zoning particularly where the current layout of the space is not as the original lighting designer intended. For example, if an open plan space was split into cellular offices, switching the light on for one office may result in all offices being illuminated whether needed or not. Where the rational use of energy is prevented by the existing switching arrangements it may be possible to adapt luminaires to take advantage of wireless switching in virtual lighting zones controlled through the building management system or dedicated lighting controller. Luminaires can also be retrofitted with automatic daylight and/or presence sensors so as to automatically control the lighting when required.

An initial lighting review should be a simple walk around the building, inside and outside. This should be done at least twice; once during daylight hours and once at night. This will highlight problem areas with controls or operation. Here's what you should be looking for:

- Areas well lit by daylight with lights on
- External lights on during the day
- Internal lights remain on at night
- Unnecessary lighting in intermittently occupied areas such as toilets

A more detailed review should consider:

- Sufficiency and usability of controls: Are the light switches accessible and logically arranged:
- Automation: Are there opportunities for passive lighting controls and security sensors?
- Zoning: Do the lighting zones match work patterns and allow for energy saving in daylight hours?

Fans and Pumps

Fans and pumps use motors and drives. The electricity consumed by motors in buildings is significant. Globally electric motors are responsible for 40% of all electricity consumption [4]. Operational costs of motors far exceed the initial capital costs; therefore there is the potential for huge savings in energy through efficient use of motor drives.

Information about the installed motor can be found on the manufacturer's name plate (an example is shown below). This should cover the rated voltage, rated amps, rated power, power factor, mains supply frequency, nominal speed and efficiency class.

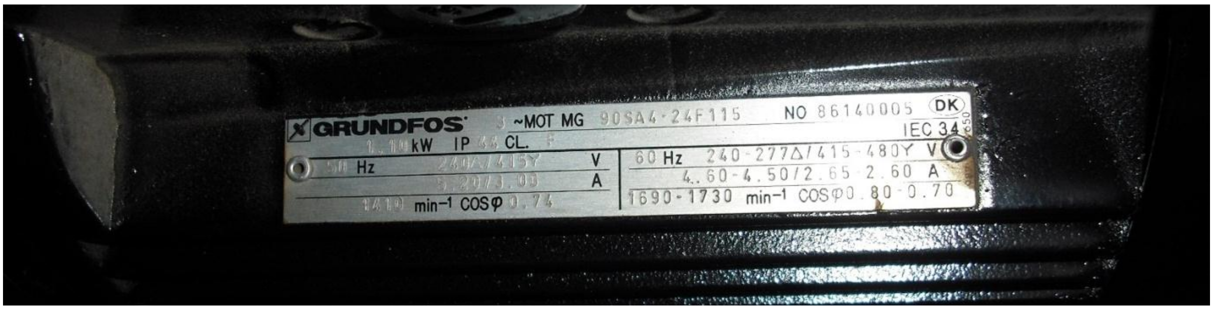

Figure 6 – Example of a pump motor name plate with data.

The amount of energy used by equipment can be affected by one of three factors;

- Run time / how it is operated
- Maintenance condition
- The system design/installation

The first two factors are the easiest to change, and so should be the focus of any survey. The run time of a fan or pump can be determined by one of the following:

1. Logging control signals via the building management system
2. “Hours run” meters attached to the equipment
3. Direct observation

Oversized motors are inefficient. It is relatively easy to measure the electrical current to the motor and compare this to the rated current, but this should only be done by a qualified person.

The survey should also look for issues related to operation and maintenance. Where the motor is connected to a fan or pump via a belt drive, the belt should be inspected for signs of wear or lack of tension. Misalignment of drive components can also cause problems.

Hot motors are usually a sign of problems. If the motor is overloaded then more heat will be produced. A useful tool for checking this is thermal imaging. Thermal imaging can also spot electrical problems such as poor cable connections. Rather than set specific temperature limits (unless this has been specified by the manufacturer) it is better to compare similar pumps on the same system. If one pump is running hotter than others, then there may be an issue.

There are several technologies that can produce significant energy savings for motors. For example, variable speed drives for pumps and fans can allow variable flow control without the energy losses associated with control valves and dampers. Alternating current (AC) motors can be retrofitted with a variable frequency inverter drive and/or replaced by high efficient models (the international motor efficiency label IE3 or IE4, or the European motor efficiency label Eff1). New applications of small motors (<1 kW) are increasingly using high efficiency direct current (DC) motors. More information on electric motor asset management can be found on the Leonardo Energy website - http://www.leonardo-energy.org/electric-motor-asset-management [5].

System related issues include:

- Excessive pressure losses in water and air systems, resulting in larger pumps/fans. Warning signs are lots of 90 degree bends and an excessive number of joints or fittings in the pipework system.
- Incorrectly sized pumps – pumps should be sized so that they run at between 50% and 90% of their peak load capacity. Undersized pumps may be running constantly at peak load which is not efficient, while oversized pumps will be running at reduced efficiency (i.e. below 40% rated capacity) all the time. Monitoring the motor current will enable the load to be estimated relative to the manufacturer’s specification.

Ventilation

Mechanical ventilation is driven by fans, so many of the issues are covered by the fans and pumps section of this guide. Mechanical ventilation comes in several forms including:

- Central air supply and/or extract systems using air handling units
- Local supply
- Local extract
- Special ventilation systems such as catering extracts

Central air supply systems incorporate air handling units with heating and cooling to temper the incoming air, possibly in association with energy recovery from the exhaust air. Local systems may be local air handling units or simple “fan in the wall” systems (with or without ducts) such as bathroom extract fans.

Things to look for are:

- Cleanliness – are the fans, grilles, filters and ductwork kept clean. Blockages or restrictions in airflow will increase system resistance and require the fan to work harder to deliver the same quantity of air.
- Is any heat recovery installed?

- Can the system be used for night purging or free cooling
- Is there any natural ventilation used? If so does mechanical ventilation operate simultaneously?

COOLING

Cooling can be energy intensive so reducing the amount of cooling required can give huge savings in energy and operating cost. Building regulations aim to reduce the need for heating and cooling by optimising the building fabric.

As with heating below, the first task should be to look for opportunities to reduce the cooling requirement by reducing the heat gains. Heat gains can come from several sources such as:

- Solar gain from direct sunlight through windows or through poorly insulated building fabric
- Internal equipment, particularly IT equipment, printers and copiers
- Lighting
- Building occupants

The Energy Performance of Buildings Directive requires periodic inspections of air conditioning systems and can provide useful information as to the current state and performance of the systems installed in the building being assessed.

Issues to be examined include:

- What are the control set point temperatures?
- Where are the sensors located?
- What is the control strategy?
- Are there manual overrides?
- Are windows open?
- Is the heating on at the same time?
- How are the occupants dressed?

The operation of the chiller or air conditioning unit should be monitored to observe operating patterns.

- Is it running during cool weather?
- Is it running excessively?
- Is it constantly cycling on and off?
- Is there conflict between the heating and cooling system?

The system installation should be reviewed for maintenance issues, such as blocked pipes/ducts or grilles. Chilled water pipework and ducts carrying cool air should be insulated to stop heat gain and surface condensation. The use of portable cooling units should be discouraged as these will be much less effective than a properly designed fixed cooling system.

HEATING

For a large part of Europe, heating is a large proportion of the energy used in buildings. Reducing heat loads is achieved by

- Reducing heat losses through the building fabric, including heat losses caused by uncontrolled air leakage
- Improving the efficiency of the heating plant.

Extremely high levels of energy consumption for heating (when compared with benchmarks for similar buildings) may suggest a need for a major renovation of a building, or even moving to a new one. Heating is strongly linked to the thermal efficiency of the building fabric. Some improvements to the building fabric, such as improved air tightness, may reduce both heating and cooling loads.

Ideally any survey should take place during the heating season and the following should be noted:

- How are the occupants dressed?
  Short sleeves could indicate too much heat, jackets and thick jumpers, too little
- What is the set point of the thermostats/controls in the space?
- Are the windows open?
- Is there simultaneous heating and cooling of the same space?
- Note the positioning of the heat emitters (radiators, fan coils, etcetera)
  Are any blocked by furniture?
- Note the positions of thermostats/temperature sensors
  Could any be in a draught or direct sunlight?
- Note how the temperature is controlled
- Are any occupants using supplementary heaters?
- Is the heating on outside working hours?

If the building does not have a building management system, battery powered data loggers can be located at representative points to establish whether comfort temperatures are being achieved.

If heating pipes run through unheated or cooler spaces they should be insulated to reduce heat loss. Radiators should be checked for sludge build up, blockages or trapped air. This can be done by either thermal imaging or spot temperature checks. Radiators that are cold at the bottom indicate a build-up of sludge, cold at the top indicate trapped air, and cold patches in other locations may indicate blockages. These all naturally reduce the efficiency of the system and may indicate other problems.

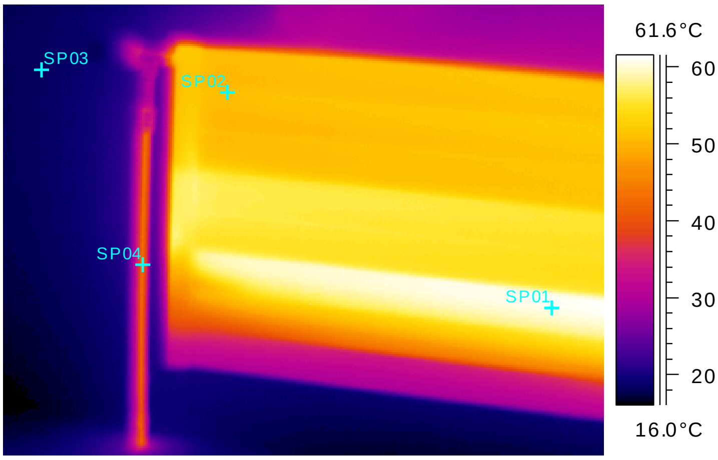

Figure 7 – A thermal image of a radiator showing uneven heating

With air heating systems, the filters should be checked for cleanliness. Again any blockages will affect the efficiency of the system in providing heat.

Areas with high ceilings, such as atria and warehousing, may be subject to thermal stratification (warm air collecting under the roof or ceiling). Spot temperature measurements may give some idea of the significance of this effect. An infra-red thermometer (around €100) allows easy remote measurement of the temperature on the surface of the ceiling. De-stratification fans can redistribute the warm air, or an alternative mode of heating can be considered e.g. radiant heating by gas fired radiant tubes or electric infrared heaters.

Control of heating is very important for efficiency use of energy. Heating an unoccupied building is wasting energy. Time clocks are the most common and simplest way of controlling the system, combined with thermostats to switch off the system once the demand has been met. As with lighting, zoning is a good way of reducing energy, having different rooms controlled separately, and separating the perimeter zone (which are usually cooler) from internal zones (usually warmer) are two common approaches. However, it is important not to forget about frost protection to protect the building fabric and contents.

Hot Water

Unless there are industrial processes within the building, hot water is used sanitary purposes (hand washing and showers) and possibly catering. Many buildings are over-provided with sanitary water and it is useful to compare the consumption with the hot water storage provision. As a rule of thumb it should not be necessary to keep more than one day of consumption in storage. Excessive storage increases energy losses and the risk of Legionnaires disease.

If the hot water is from a central system check:

- Are all the pipe runs insulated?
- What are the distribution and outlet temperatures?
- How long does it take to get hot water from the outlets?
- How is it controlled?
- How far are the points of use from the central hot water generating plant?

If the hot water is provided from point of use heaters:

- Temperature settings
- Storage capacity
- Operation

Consumption of hot water from centralised systems and gas fired water heaters can be monitored through installing a cold water meter on the inlet to the system. Point of use/instantaneous electric water heaters can be fitted with electricity meters.

Vertical Transportation Systems

Vertical transport systems in buildings are more commonly known as lifts (or elevators) and escalators. Most buildings of more than one storey will have a lift to allow compliance with disability access laws. Information on energy efficient lifts can be found in

http://www.e4project.eu/documenti/wp6/E4-WP6-Brochure.pdf [6]

Escalators (or moving walkways) will be motor driven, so many of the issues are common with fans and pumps, which are also motor driven. Lifts can be motor driven or hydraulic. The control system of the motors should be examined, particularly on escalators which may be operating continuously.

More complicated lift systems covering multiple floors will have a lift control system. These are important in saving energy, as they control the way the lift manages demand. Different algorithms can be used to minimise travelling distance, passenger waiting time etcetera. This should be noted, and possible combined with an energy monitoring exercise to get an overall picture.

Lift lighting and ventilation often provides an opportunity for minor energy savings but this should only be undertaken by the lift manufacturer or maintenance company.

Electrical Power

Small power is the term used to describe the electrical power supplied to office equipment and other appliances via conventional power sockets. Small power can account for around 15% of energy used in offices, and is an area that can yield significant savings through effective energy management.

Energy savings from small power can be made in two areas; technology and user behaviour. Notes should be made on:

- What technology is being used? Is it up to date?
- Is equipment in energy saving mode or switched off outside office hours
- What equipment needs to be left on continuously
- Energy labels equipment e.g. Energy star labels on computer monitors and EU Ecodesign labels on white goods (refrigerators, dishwashers, etcetera)

Certain equipment such as refrigerators, freezers and vending machines must be powered continuously so the energy efficiency of the appliance is more important. Manufacturing equipment should also be examined for savings opportunities.

If the building has sources of renewable or low carbon electricity then it is important that these are operating effectively. These could include photovoltaic (PV) panels, combined heat and Power (CHP) plants or wind turbines.

PV panel installations should be checked for:

- Sources of shading (other buildings, trees, etcetera that may have become a problem since installation)
- Cleanliness (surface dirt that could reduce efficiency)

Wind turbines installations should be checked for:

- Objects that could reduce the effect of the wind reaching the turbine, i.e. new buildings, trees, etcetera

CHP installations should be checked for:

- Correct sizing in relation to the building heat load so that it can run for long periods to maximise electrical generation.
- Is the CHP operating as the lead boiler

The tariff arrangements for import and export of electricity should also be checked.

Building Fabric

The building fabric is the major determinant of the energy consumption of the building. The following should be considered:

- Is the building fabric compliant with current building regulations or can it be economically improved
- Are there any gaps around windows or doors when closed
- Are there any broken windows, or holes in walls/roof
- Are there areas of damp on walls or roofs
- Do automatic doors or windows/roof-lights operate correctly
- Are there large areas of un-shaded south facing glazing?

Specialist techniques that can be commissioned to assess the performance of the building fabric include:

- Air tightness tests, to measure the amount of air that can leak out of the building

- Smoke tests or smoke pencils to detect air movement or leakage paths.
- Thermal imaging to detect hot or cold spots
- U-value measurements to measure the thermal performance of a wall

Cooling loads can potentially be reduced by the installation of solar shading, particularly on buildings with large amounts of south facing glazing. However, the benefit of reducing solar heat gain has to be balanced against the potential reduction in daylight. Another factor to consider with fixed solar shading systems is the useful solar gain in wintertime, which can help to reduce heating loads. A compromise can be made through careful design based around the angle of the sun at different times of year. Another solution is the use of movable solar shading systems. These can be connected to the building management system, linking them to the heating and cooling controls.

The combined benefits/drawbacks of the system can be modelled using life cycle costing or life cycle analysis.

Environmental Controls

Controls range from simple switches to a complex Building Management System (BMS) providing fully automatic control of most systems in the building. Correct installation, set-up and operation of building controls is vital to keep energy bills under control. The figure below shows the effect of poor temperature control.

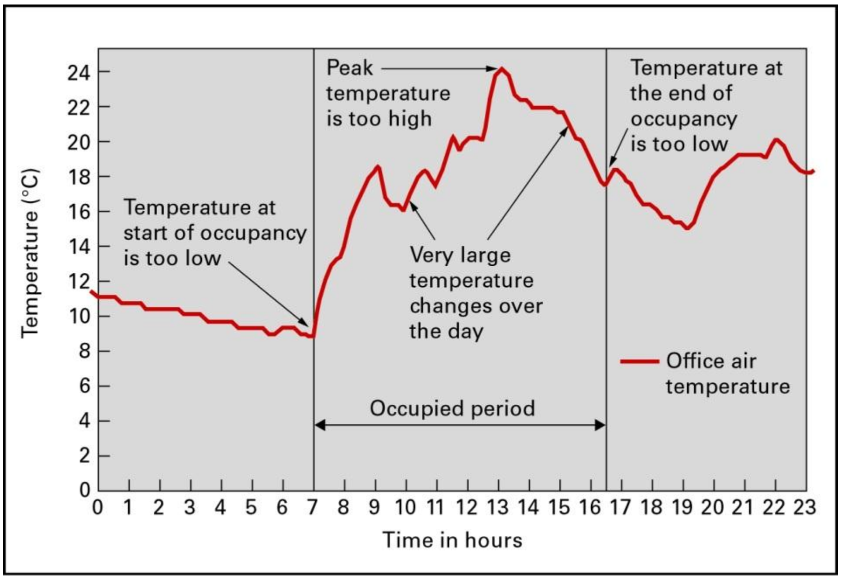

Figure 8 – Temperature profile of an office with poor temperature control [7].

General issues that may need to be checked:

- Are sensors providing reliable data?
- Are actuators working?
- Are automated schedules set correctly?
- Are the control functions and parameter optimised?
- How much influence do occupiers have on comfort settings?

Sensors

The most common sensor in a building is the temperature sensor, whether measuring the air temperature in a space or the fluid temperature in a pipe.

The location of space temperature sensors is important. They should be located to provide a representative indication of the temperature of the space and not be unduly influenced by draughts, solar gain or nearby heating appliances.

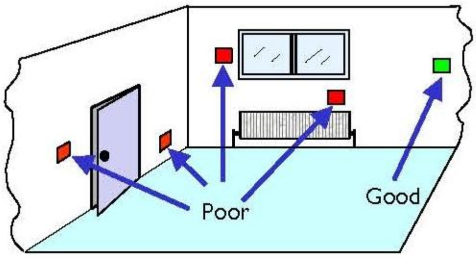

Figure 9 – Temperature Sensor locations [8].

Other sensors commonly used include humidity, carbon dioxide, movement sensors for the control of internal lighting, and daylight sensors, typically for switching off external lighting.

All sensors should be periodically checked and calibrated to make sure that they are still providing reliable data.

BMS

A building management system is usually more than just a control system. The BMS may be able to log (record) sensor data, control outputs, alarms and metered energy usage for future analysis. The caveat is that it can only record what it is connected to. If the existing energy meters (electricity and gas) are not yet connected to the BMS, it is well worth doing so to enable automated data collection. Where additional sensors or new metering connections are needed, it is increasingly cost effective to implement these by using wireless technology to simplify installation and minimise cabling costs.

The BMS is provided with an interface (increasingly web-based) that allows the operator to alter control parameters, set up logs and retrieve data. Unfortunately, this may not allow the operator to change or enhance the programme that was set up by the installer or add new hardware. Changes to the programme or hardware will usually require another visit from the installer, so the labour cost needs to be taken into account.

Opportunities for Change

When reviewing changes that can be made, the options should be split into three categories linked to the cost of implementation. These are:

- No cost – typically requiring changes in operation or user behaviour
- Low cost – minor repairs or small new items such as better lamps
- High cost – capital investment items such as new boilers

This section contains some ideas that can be implemented to produce energy savings. This list is not exhaustive.

Lighting

Option	When it should be considered
Retrofit with low energy compact fluorescent lamps	Useful replacement for incandescent bulbs
Retrofit with LED lighting	Useful replacement for halogen spot lights used for decorative effects
Install PIR movement sensors for control of lights	Good for areas with intermittent occupation during the day, such as corridors, toilets, break out spaces.
Upgrade fluorescent lighting to high frequency ballasts or a good magnetic ballast with an electronic starter	Where the lighting has older magnetic ballasts/control gear.
Add daylight sensors	For external lights that have no automatic control and for internal areas that are daylit for periods of the day.

Fans and Pumps

Option	When it should be considered
Install variable speed drives/controls	When the system need variable flow capability
Optimise control through time switching, auto start/stop, load sensing etcetera	When the pumps/fans are found to run unnecessarily
Fit more efficient motors	When the fans or pumps have old, inefficient or defective motors

Ventilation

Option	When it should be considered
Optimise controls – install time controls or adjust timers	Where fans are running when not required
Install CO_2 or occupancy detector sensors for control	For areas with variable occupancy
Install heat recovery	Where treated air (warm or cool) is extracted
Improved housekeeping, cleaning filters, block grilles, etcetera	Where problems exist. Should be part of a regular planned maintenance schedule

Cooling

Option	When it should be considered
Pre-cool the building overnight in the summer by ventilation	When the building can remain secure and is not occupied overnight.

Review controls and set points, time clocks etcetera	Where simultaneous heating and cooling occurs, excessive running time and running out of hours
Reduce heat gains - e.g. fit blinds to reduce solar gain, reduce the number of lights or electrical appliances left on	When cooling is required for more days/hours than expected, e.g. out of season

HEATING

Also see cooling and building fabric for associated issues

Option	**When it should be considered**
Review set points and dead bands	If heating and cooling are operating simultaneously or if temperatures are excessive
Review schedules. Improve controls e.g. fit thermostatic radiator valves, additional sensors, improve zoning etcetera	If the heating is on outside working hours If the heating is controlled in a large zone basis which has differing temperatures
Install de-stratification fans or consider radiant heating system	Where high ceilings cause the heat to collect at high level.
Install optimum start/stop control (or equivalent function in BMS)	If the boiler is runs excessively, particularly before occupancy. The optimiser is linked to external and internal temperature sensors and calculates exactly the right time to operate the boilers to reach the required temperature at occupation
Install time-clocks and a zoning system for controlling heating.	When parts of the building often remain heated while unoccupied.
Install weather compensation control	If water temperature is too hot, this could cause boiler cycling. The compensator regulates the water temperature from the boiler according to the outside temperature.
Install a more efficient boiler or low carbon technology such as a heat pump	If old inefficient boilers are being used.

HOT WATER

Option	**When it should be considered**
Install point of use heaters	Where small sporadic quantities of hot water are required at points spread across the building
Insulate pipework	Especially for central systems with longer runs of pipe to the outlets

BUILDING TRANSPORTATION SYSTEMS

Option	**When it should be considered**
Low energy lighting	Where it is acceptable to lower the light levels in the lift car
Escalator/moving walkway load sensor control	When the demand/use is variable during the day including periods of no passengers
Regenerative lift drive systems	Good for systems that run often during the day

Electrical Power

Option	When it should be considered
Educate staff to switch off equipment out of hours. Some equipment may be able to be switched off remotely or via timers	When equipment is left on overnight unnecessarily.
Replace old equipment	Modern IT equipment is more efficient. Switching from desktop PCs to laptops can save significant amounts of energy.
Power factor correction	If power factor is too high or low. This is mainly a cost saving measure
Voltage optimisation	May have some benefits to efficiency if mains supply voltage is erratic

Building Fabric

Option	When it should be considered
Adding insulation	Where walls or roofs are not insulated or have low levels of insulation
Draught-proofing	Where air leakage paths have been identified or there are holes or gaps in the fabric that need repairing.
Adding solar shading	Where there is significant solar heat gain through glazed areas. However, the potential reduction in daylight and useful winter solar gain should be taken into account to ensure energy savings are maximised.

Calculating Costs and Benefits

The financial case

To get any project approved, the business case will need to be put forward to the appropriate budget holders for the building. This will involve calculating the costs and benefits of the project. Benefits can be in the form of cash savings, energy and therefore carbon savings, and reduction of the environmental impact of the building or the organisation. The latter can be important in the modern world where corporate social responsibility is high on the agenda of large multinational organisations.

Saving money is always a good selling point for any project. Energy efficiency measures normally have reasonable payback, some within a matter of months. Typically most companies are looking for a payback within a five year period. Some may accept a longer payback period if other benefits are apparent. To calculate savings, you must first have good understanding of the operating costs associated with the system to be upgraded. This can be done by gathering information such as:

- Energy consumption
  - Power rating
  - Hours run
- Maintenance costs
  - Costs of parts and consumables
  - Labour costs
- Residual life

For a single item, the operating costs calculations for a set period of time could be put in a simple form:

Energy consumption + Maintenance + replacement costs (if required in timeframe)

(Power x hours run) + (parts + Labour) + *Replacement* = operating costs

Bear in mind that improving the efficiency of one system may have an effect on another. This effect can be beneficial e.g. improving lighting efficiency may also reduce cooling loads in summer. However, it can also be counterproductive, e.g. shading to reduce cooling loads may increase the need for lighting.

The next step is to calculate the investment costs for the project. This may involve capital spend for buying new equipment, or mainly labour costs if implementing a strategy change such as an employee education programme. Make sure that all the investment costs are covered. For example, installing a new boiler may require design work as well as the cost of the equipment itself. On the other hand there may be tax or financial incentives available.

Next calculate the running costs. Many of the costs and savings will be estimates and it is important to document all assumptions made to allow adjustments to be made if these change or more accurate information becomes available.

Also look beyond the energy savings. New equipment may bring significant additional benefits in terms of reduced maintenance costs, increased reliability and an improved working environment.

Other benefits

Non-financial benefits can be more difficult to quantify. Typically the benefits a project might bring are things such as improved occupant comfort, improved productivity, or reduced environmental impact. The latter can be measured using a technique called Life Cycle Analysis (LCA). LCA gives a measure of the impact of an item over its lifetime. This includes manufacture, in use and end of life impacts. Impacts include emissions such as CO_2 as well as less obvious impacts on marine ecology. The methodologies are included in the ISO 14040 standard as well as PAS 2050 available in the UK. There are several database sets available for the EU, which are included as part of software packages such as SimaPro™ [9] and GaBi™ [10].

A full LCA analysis can be very complicated, but a simplified variant just looking at CO_2 can be just as useful in judging environmental impacts of a proposed scheme.

Some producers may provide environmental product declarations, where some of the calculations have already been done for you.

REFERENCES

[1] The Carbon Trust, “Conversion factors - 2011 update,” 2011. [Online]. Available: http://www.carbontrust.com/media/18223/ctl153_conversion_factors.pdf.

[2] Covenant of Mayors, “How to Develop a Sustainable Energy Action Plan -Guidebook - Part 2,” 2010. [Online]. Available: http://www.covenantofmayors.eu/IMG/pdf/004_Part_II.pdf.

[3] B. De Wachter, “Life Cycle Costing - The Basics,” 2012. [Online]. Available: http://www.leonardo-energy.org/life-cycle-costing-basics.

[4] The Carbon Trust, Motors and Drives, CTL 156, London: The Carbon Trust, 2011.

[5] B. De Wachter, “White Paper - Electric Motor Asset Management,” European Copper Institute, 2011.

[6] ISR-University of Coimbra, “E4 Energy Efficient Elevators and Escalators,” March 2010. [Online]. Available: http://www.e4project.eu/documenti/wp6/E4-WP6-Brochure.pdf.

[7] A. Martin, BMS Maintenance Guide, BG4/2003, Bracknell: BSRIA, 2003.

[8] K. Pennycook, Design Checks for HVAC - A quality control framework (2nd Edition), BG4/2007, Bracknell: BSRIA, 2007.

[9] Pre Sustainability, “About SimaPro,” [Online]. Available: http://www.pre-sustainability.com/simapro-lca-software.

[10] “Gabi Software,” [Online]. Available: http://www.gabi-software.com.