Low carbon buildings: from early concept studies to paying actual energy bills

Abstract

Optimising energy efficiency and tackling climate change are central themes to the economic, social and environmental dimensions of any sustainable development.

The aim of this article is to provide insight on what it takes to make a built environment sustainable, from undertaking a correct energy assessment at the very early stages of the design process, to prioritising the energy saving recommendations that would improve the carbon footprint of an existing building.

Best and bad practice standards and strategies are presented alongside key case studies from projects undertaken during the last couple of years by Ramboll Environ.

An overview of the current industry drivers and commercial tools available is also provided, including planning policies, energy and environmental certification, thermal modelling and ISO 50001 energy management systems.

Introduction

Urbanisation, social inequality and climate change represent three global megatrends that will put human kind to the test over the next decades. Under these increasingly challenging conditions, sustainability will be key to finding the solutions that enable humans to thrive. It is essential that the concept of sustainability permeate the way we build the framework around the lives we live. Our schools, hospitals, offices, homes and other buildings all need to positively contribute to the people who use them, their surroundings and to future generations: they have to be sustainable.

True sustainability can only be achieved in collaboration with the local community and the future building users by ensuring a balance between the building design and the environmental and climatic conditions of the particular site. Sustainable building design is a multidisciplinary method concerned with developing holistic strategies focusing on social, environmental and economic sustainability. As each project is different from the last with various socio-cultural, functional, environmental and economic preconditions, the term ‘sustainable building’ has as many different definitions as there are people.

For the purposes of this article, of the many aspects that make a built environment sustainable, we focus our attention on energy performance, from the very early stages of the design process to improving the carbon footprint of an existing building, and we use case studies from past projects undertaken to show best practice and less good examples of energy strategies and building management.

Specifically for the European scenario, it is worth mentioning the three main directives have been driving energy efficient investments and have raised energy awareness across the 28 EU Member States over the last few years:

- Energy Performance of Buildings Directive: 2002/91/EC and 2010/31/EU (recast), according to which each building that is going to be sold or let needs an Energy Performance Certificate

- Renewables Directive 2009/28/EC
- Energy Efficiency Directive 2012/27/EU, according to which (Article 8) all large enterprises need to undertake an energy audit of existing assets every four years

Based on these directives, the famous "20-20-20" target was set for 2020 (the 2020 climate and energy package), consisting of:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels
- Raising the share of EU energy consumption produced from renewable resources to 20%
- A 20% improvement in the EU's energy efficiency

We are currently running late with regards to meeting initial objectives and as a result the target has become 40-27-27 by 2030.

The EPBD directive also introduced minimum energy performances for new buildings where target carbon emissions have progressively reduced over the years. By the end of 2020 all new constructions should become ‘nearly zero-energy buildings’. For example, buildings with a high energy performance and low energy requirements should be covered to a significant extent by renewable sources, preferably installed on-site or nearby.

It is universally recognised that only a holistic approach involving competent energy consultants from the early stages of the design process and use of suitable energy modelling software would meet the rigorous energy efficiency requirements imposed by regulations. The bad practice of employing architects to design buildings before engaging with mechanical engineers, to understand how to condition the internal environment, has become the exception.

With regards to existing assets, only a strategic energy audit undertaken prior to implementing energy saving measures would maximise the associated return of investments and guarantee desired results within a given budget. However, it is not uncommon for a landlord, who has just replaced an existing heating system with like-for-like boilers, to then look at improving the thermal performance of the building envelope by adding cavity or external insulation. This would make the new boiler oversized (it could have costed less in first instance) and their operation inefficient as they are working at a partial load with higher running costs. Focusing on specific retrofitting projects before engaging with an energy manager who could advise on a suitable energy strategy is still a common mistake that many companies make.

Drafting a suitable energy strategy

This document is specifically for the real estate sector and is sometimes referred to as an ‘energy statement’ or ‘energy assessment’. The purpose of this study, which is often mandatory for major developments in Europe, is to demonstrate that climate change mitigation measures are integral to the proposed development’s design and evolution and that the measures are appropriate to the context of the development.

An energy assessment takes relevant design, spatial, air quality, transport and climate change adaptation requirements into consideration, recognises the integrated nature of policies and ideally follows the energy hierarchy:

1. Be lean: use less energy by adopting high standards of sustainable design and construction measures for building fabric and building services
2. Be clean: supply energy efficiently by prioritising decentralised energy generation
3. Be green: use renewable energy

The purpose of initially targeting a ‘lean’ rather than ‘green’ building is to ensure that its thermal performance (low U-values), minimisation of thermal bridges and good air permeability has been optimised before installing any active solutions. This ‘fabric-first’ approach led Germany, Austria and North Italy to the development of so-called ‘passive-houses’ where annual heating demand is as low as 15 kWh/m^2.

When using ‘active’ cooling measures to guarantee thermal comfort in a built environment, natural and mixed-mode ventilation is preferential to comfort cooling. Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance to the cooling hierarchy:

- Minimise internal heat generation through energy efficient design
- Reduce the amount of heat entering a building in the summer through orientation, shading, albedo, fenestration, insulation and green roofs and walls
- Manage heat within a building through exposed internal thermal mass and high ceilings
- Passive ventilation
- Mechanical ventilation
- Active cooling systems, ensuring the lowest carbon options

Air conditioning systems are a resource-intensive form of active cooling, increasing carbon dioxide emissions and emitting large amounts of heat into surrounding areas. Adaptive comfort studies have demonstrated that within certain temperature and humidity thresholds, thermal mass, natural ventilation and night-time purging can guarantee thermal comfort in certain building types without any active air conditioning. By incorporating the cooling hierarchy into the design process, buildings will be better equipped to manage their cooling needs and to adapt to the changing climate.

Once the energy strategy has been identified, the applicant’s commitments in terms of CO_2 savings and best practice measures need to be presented and an energy model of the building needs to be prepared using approved simulation software. Any potential air quality impacts arising as a result of this should be considered separately in an air quality assessment.

Major development proposals should always include a detailed energy road map to demonstrate how desired targets for carbon dioxide emissions reduction are to be met within the framework of the energy hierarchy. A typical target in London is 35% better than the latest building regulations threshold.

As a minimum, energy assessments should include the following details:

- Calculation of the energy demand and carbon dioxide emissions covered by building regulations and the energy demand and carbon dioxide emissions from any other part of the development. This includes plant or equipment not covered by building regulations at each stage of the energy hierarchy, often referred to as 'non-regulated' carbon
- Proposals to reduce carbon dioxide emissions through the energy-efficient design of the site, buildings and services ('be lean')
- Proposals to further reduce carbon dioxide emissions through the use of decentralised energy where feasible, such as district heating and cooling and combined heat and power ('be clean')
- Proposals to further reduce carbon dioxide emissions through the use of on-site renewable energy technologies ('be green')

Ideally, carbon dioxide reduction targets should be met on-site. Where specific targets cannot be achieved on-site, any shortfall may be provided off-site or through a cash in lieu contribution to the relevant borough to be ring fenced to secure delivery of carbon dioxide savings elsewhere. Typical carbon costs are £60 per tonne.

Development proposals should demonstrate that sustainable design standards are integral to the proposal, including construction and operation and should be considered early on in the design process so that the following sustainable design principles are achieved:

- Minimising carbon dioxide emissions across the site, including the building and services (eg heating and cooling systems)
- Avoiding internal overheating and contributing to the urban heat island effect
- Efficient use of natural resources (including water) and making the most of natural systems both within and around buildings
- Minimising pollution (eg noise, air and urban runoff)
- Minimising the generation of waste and maximising reuse or recycling
- Avoiding impacts from natural hazards including flooding
- Ensuring developments are comfortable and secure for users, including avoiding the creation of adverse local climatic conditions
- Securing sustainable procurement of materials, using local supplies where feasible
- Promoting and protecting biodiversity and green infrastructure

Development proposals should evaluate the feasibility of combined heat and power (CHP) systems and examine opportunities to extend the system beyond the site boundary to adjacent sites where a new CHP system is appropriate. Major development proposals should select energy systems in accordance with the following hierarchy:

1. Connection to existing heating or cooling networks
2. Site wide CHP network
3. Communal heating and cooling

Innovative energy technologies to reduce fossil fuels and carbon dioxide emissions should be supported and encouraged where possible, particularly:

- The uptake of electric and hydrogen fuel cell vehicles
- Hydrogen supply and distribution infrastructure

- The uptake of advanced conversion technologies such as anaerobic digestion, gasification and pyrolysis for the treatment of waste

Case study 1 - non-domestic building

Ramboll Environ have been commissioned to provide guidance in preparing an energy assessment of the redevelopment proposal for a national college in London. In accordance with best practice, the design of the proposed development conforms to the principles of the energy hierarchy, providing a set of guiding principles to reduce energy consumption and associated carbon emissions to a minimum. Consequently, energy efficiency will be incorporated into the design of the building before the application of low and zero carbon (LZC) technologies.

Taking best practice guidance for passive energy-efficient design into account, the new building will exceed the 2013 Building Regulations Part L Target Emission Rate (TER) through the use of energy efficiency and passive design measures alone.

Based on discussions with the design team, the following key passive energy-efficient design measures have been included in development proposals:

- U-values [W/m^2K]
  - Ground and exposed floors: 0.10
  - External walls: 0.09
  - Basement walls: 0.10
  - Windows: 1.4 (g-value: 0.4)
  - Roof lights: 1.3
  - Doors: 1.4
  - Roofs: 0.09
- Air permeability at 50 Pa: 3.5 m^3/m^2h

The proposed development will install energy efficient LED (light emitting diode) lighting with occupancy sensors and dimmable photo sensors for all rooms with access to daylight. Lighting power levels of 1.5 $W/m^2$100 lux will be achieved in most of the zones except for very small zones where lighting power levels will be 1.75 $W/m^2$100 lux.

A very efficient VRV (variable refrigerant volume) system with heat recovery and a seasonal energy efficiency ratio (sEER) of 6.14 will be installed to supply heating and cooling to all large circulation areas, classrooms and academic offices. Balanced mechanical ventilation with heat recovery will supply fresh air to the building. As part of the energy strategy, condensing boilers with a high efficiency of 97.3% will be installed to supply heating to toilet and stairwell areas, as well as domestic hot water. Fans with a specific fan power (SFP) no greater than 1.6 W/ls will be selected for the balanced mechanical ventilation with heat recovery system.

The VRV system has the ability to recover heat rejected for use in spaces that require cooling and any surplus heat will be recovered to produce domestic hot water (DHW) or preheat hot water. For minimum fresh air provision, the majority of areas will be served by mechanical supply and extract air handling units (AHUs). All AHUs will be compliant with the Energy Related Products Directive and installed with heat recovery (plate heat exchanger). To optimise heat recovery, hydroboxes (capable of high-grade heat) will be installed on each floor to recuperate excess heat (when space heating isn't required) to a water based system via a heat recovery exchanger. This recovered heat will be fed down to the basement low-temperature hot water (LTHW) low loss header as the primary heating source, with top-up from the boilers as required.

In order to minimise overheating, the following measures have been proposed:

- Selection of low U-values (-50% compared to the notional building fabric parameters) and high levels of airtightness, stopping unwanted infiltration of heat and hot air. Good air tightness would be achieved by prefabrication of a number of key building components under factory conditions where possible, robust detailing of junctions and good building practices on-site
- Choice of high-performance glazing with low g-values (less than 0.4 in critical areas), which guarantee good levels of daylight penetration, limiting the amount of solar radiation through the glass, and the use of light coloured materials with high albedo surfaces to avoid the absorption of heat
- Blinds will be provided on all south-facing facades in occupied spaces (not transient spaces like corridors) to reduce glare and solar gain during peak summer periods
- Design of highly efficient artificial lighting systems with an installed capacity of less than 5 W/m2 (an average of 1.5W/m2100 lux across the building) with suitable lighting controls and the optimisation of natural daylight
- Criterion 3 of the Building Regulations Part L, which assesses whether the building has sufficient passive control measures to limit overheating as indicated in the BRUKL reports

Once demand for energy has been minimised, opportunities for suitable energy systems for the proposed development can be considered, as required by the second tier of the energy hierarchy. Connection to potential future district heating networks has also been considered to 'future-proof' the development. There is currently no heat network within the vicinity that is feasible to connect to. In order to facilitate a connection to a potential district heating network, plant space has been allocated within the basement of the new build and a layout of the plant room has been provided.

In response to the third tier of the energy hierarchy, a number of renewable technologies have been considered. High installation costs, technical challenges, poor wind speeds, visual concerns and air quality issues compromise installation of ground source heat pumps, wind turbines and biomass. Solar technologies (ie photovoltaics) have been identified as the most technically and commercially viable options for the proposed development.

The available roof space for the installation of solar photovoltaic (PV) panels is approximately 40m^2. A 6 kWp PV array (24no modules rated at 250 W each, with an azimuth of 0°=south) could be accommodated at roof level. There is no risk of overshadowing modules as there are no existing buildings located or planned south of the proposed site.

The on-site predicted electricity production would be 5,591 kWh/annum and enable a further 1.9% carbon savings (2.90 tonnes of CO_2).

In the event that connection to a future district heating network does not come forward, the proposed development's hot water and space heating to ancillary areas would be provided by means of gas boilers and space heating and cooling to main areas via a VRV system supplemented by solar photovoltaic modules.

Overall, the proposed development has sought to prioritise the specification of energy efficiency measures and integration of low and zero carbon technologies, in accordance with principles of the energy hierarchy, to achieve a site-wide 37% reduction target of regulated emissions against the baseline.

Case study 2 - domestic building

The second case study is a residential development of over 300 apartments in London. The energy assessment submitted for the planning application demonstrated that the proposed development was designed to deliver significant CO_2 savings compared to Part L 2013 compliant buildings (-36%).

In response to the first tier of the energy hierarchy proposed by The London Plan, it was estimated that energy-efficient design measures were likely to exceed the baseline. It should be noted that Part L 2013 limits certain carbon emissions relating to the provision of heat and light to buildings (ie regulated emissions). Small power loads (eg electrical energy for domestic appliances such as televisions, refrigerators and washing machines) are not considered within the regulations but associated emissions can be significant compared to the overall emissions from a dwelling. This type of energy use is defined as 'unregulated emissions'; it occurs at buildings but is not considered within carbon emissions compliance calculation software. As baseline energy consumption should include regulated and unregulated energy use, CO_2 emissions were estimated for the proposed development using SAP calculations to predict the overall total carbon impact of the proposed development.

Based on qualitative analysis and research (eg Ewgeco, LCBT Gateway, Edinburgh Napier University, Institute for Sustainable Construction and Home Energy Display Trials), a 10% reduction was assessed for the proposed development from baseline unregulated emissions. A number of energy saving measures would be incorporated within the proposed development to raise the residents' environmental awareness, such as energy display devices, smart-metering and home user guides, to encourage occupants to utilise dwellings in a sustainable and energy-efficient manner.

The TER has been calculated using SAP 2012. Based on discussions with the design team, the following key passive energy efficient design measures have been included in the development proposals:

- U-values [W/m^{2}K]
  - Floors: 0.18
  - External walls: 0.16
  - Party walls: 0.18
  - Windows: 1.2
  - Doors: 1.4
  - Roofs: 0.13
- Thermal bridges: psi = 0.04 W/mK

- Air permeability at 50 Pa: 4.0 m^3/m^2h

These measures would improve upon the TER by 1.94%.

A number of measures have been adopted to avoid overheating:

- Use of smaller-south facing windows, deeply recessed to provide solar shading in a number of directions and kept to a minimum. On average, the glazed area of the proposed development would be 35% of the total
- A choice of high-performance glazing with low g-values (less than 0.4) which guarantee good levels of daylight penetration that limit the amount of solar radiation through the glass, and use of light coloured materials with high albedo surfaces to avoid the absorption of heat
- Minimisation of pipe lengths (particularly lateral pipework in the corridors of the apartment blocks) and high insulation of all 'twin' pipework (flow and return heat network pipes are enclosed in the same insulation) on the site-wide LTHW circuits to increase overall efficiency of the systems and avoid overheating
- Natural ventilation for communal lobbies wherever possible, opening windows provides the best solution to overheating
- Design of highly-efficient artificial lighting systems (installed capacity of less than 8 W/m^2) with suitable lighting controls and the optimisation of natural daylight; this is addressed in a separate report that accompanies the planning application
- Provision of green roofs to reduce the 'urban heat island' effect. A green roof not only acts as an insulation barrier but the combination of plant processes (photosynthesis and evapotranspiration) and soil processes (evapotransmission) reduce the amount of solar energy absorbed by the membrane, leading to cooler temperatures beneath the surface.

In response to the second tier of the energy hierarchy, connection to the proposed local district heating network is taken into consideration and the energy strategy focuses on interim solutions that achieve desired carbon savings whilst ensuring that the proposed development is 'future-proofed'.

The proposed site-wide heat network also allows the buildings to be supplied from CHP, a mini power station with heat reclaim and minimal distribution losses due to its close proximity to the load. CHP is considered a carbon-neutral technology when powered by biofuel but even when used in combination with fossil fuels, such as natural gas, it is still more energy-efficient than obtaining energy from the national grid. In fact, power stations that generate grid-supplied electricity are approximately only 40 % efficient. This is reduced by a further 5 % due to transmission losses arising from long distances between the power stations and the buildings that are served. This is a poor use of fossil fuel and has high carbon emissions per unit of electricity produced. CHP can increase the efficiency of power generation and fuel-use by making better use of waste heat, created as a by-product of producing electricity. Transmission losses are minimised by on-site generation and a gas-fired CHP can be seen as a relatively carbon-efficient means of energy supply.

In order to maximise efficiency, it is important that the CHP plant operates for as many hours as possible (ideally 4,500+ per year) and is sized to match base heat and power loads. As the CHP size increases so do the CO_2 savings and it would be more cost-effective to size the CHP to match electricity demand. This would require an unacceptable amount of heat dumping and therefore, in order to balance the requirements of the proposed development, it is assumed that temporary community boilers would provide circa 50% of the heat requirements. Due to the scale of the development (circa 300 units), the Greater London Authority's guidance on energy assessments suggests that the CHP should not be the lead source for a purely residential development. It complies with the 2013 Non-domestic Building Services Compliance Guide, which suggests that due to the size of the CHP plant, it should supply no less than 45% of the annual total heating demand.

Excess electricity generated on-site can be exported to the national grid but a much better use of it, which would also be in line with Policy 5.8A of the London Plan, would be to install a number of power points to charge electric cars for the use of residents or potentially at street level for the local community.

With regard to excess heat, thermal storage provides useful balancing throughout the day. Thermal stores consist of a cylindrical vessel of hot water, which would be installed at the proposed development between flow and return circuits and would remain full of water at all times. The use of a thermal store in association with a CHP system (and often with other low carbon heating technology, such as solar thermal) brings several potential advantages:

- It enables heat demands, either greater than the maximum output of the CHP or lower than the minimum turndown of the CHP, to be met. This reduces the use of community boilers and increased CHP running hours
- It enables the CHP plant to operate at full output rather than at part-load, thus improving efficiency
- It allows heat demands to be supplied outside the normal economic operating regime of the CHP (eg at night when electricity prices are low and it would not be economic to run the CHP)

The size of the thermal store depends on several parameters, such as the desired storage time and the temperature difference between flow and return, on the heating circuit. By using low return temperatures, and therefore a greater difference in density between flow and return, it is possible to reduce the size of the thermal store, which is predicted to be approximately 5,000 litres for a residential development such as the proposed development.

Based on the projected load profiles for the site and taking the design principles outlined above into account, the selected size of the proposed CHP plant is 35 kW electrical/ 62 kW thermal. The relevant technical datasheet has been submitted, as well as the cost-benefit analysis including carbon reduction benefits.

SAP calculations were undertaken based on the building services specifications in order to estimate predicted carbon reductions against the baseline. When taking the site's total CO_2 emissions into account, the chosen energy strategy will result in further carbon savings of 23.25%.

In response to the third tier of the energy hierarchy, solar PV is considered to be the most suitable technology.

For the site, a 73 kWp PV array could be integrated into the roof space on top of two tower blocks and, considering circa 8m^2 per kWp, the PV panels would require circa 585 m^2 of roof space. This could readily be accommodated within the proposed development, such as to avoid any shading and allow a safe periodic maintenance regime.

Solar thermal panels have not been considered any further as part of this feasibility study because solar PV has been prioritised, given the presence of CHP and the nature of the proposed development, which is 100% residential. There isn't a year-round demand for DHW or a high demand during the central hours of the day.

Owing to site constraints, wind turbines have not been considered as part of this feasibility study. Constraints include low wind speeds in an urban location and the turbulent flow regime across the site. Wind turbines are also likely to have an impact on the landscape and views, as well as health and safety implications for occupiers or users on-site and in adjacent areas, as a result of noise and shadow flicker.

Ground source heat pump (GSHP) systems are not suitable for satisfying high temperature hot water demands. Moreover, given the limited area available for horizontal collectors (which are typically installed in trenches 2m deep), the technical difficulty in drilling and excavating a well for vertical collectors (typically up to 100m deep) and minimum spacing between adjacent boreholes (that should be maintained at 5-15m to prevent thermal interference), GSHP have not been considered technically appropriate for the size of the proposed development or assessed further as part of this feasibility study.

Biomass is a carbon-neutral alternative to renewables. Due to the constrained nature of the site, there is limited space to ensure appropriate storage of fuel on-site. The management burden of checking fuel quality, scheduling fuel deliveries and disposal of ash from a biomass system, further reduces its attractiveness. Also biomass could have implications for local air quality. For these reasons, the integration of biomass boilers has not been incorporated within the proposed development.

New SAP calculations were undertaken based on the LZC specifications in order to estimate predicted carbon reductions against the baseline. When taking into account the total site's CO_2 emissions, the chosen energy strategy will result in a further 11.54% carbon savings.

On this basis, and in the event that connection to the proposed local district heating network does not come forward, the proposed development's hot water, heating and electricity requirements would be provided by a combination of small-scale gas fired CHP units and gas-fired community boilers in each phase, supplemented by PV.
The renewable and low carbon energy generation would actually be monitored during the occupation of the proposed development. Electricity can easily be exported from LZC technologies. The new building would be fitted with a dual meter, capable of metering the energy exported to the local distribution network, as well as incoming electricity supplies. Some 'green-brand' electricity suppliers are very interested in buying the exported energy at a premium price that matches or exceeds the price paid by most consumers. In order to demonstrate that actual CO_2 savings achieved by the development are in line with the estimated figures, three years of post-construction monitoring will be undertaken. Appropriate equipment, compatible with monitoring data, will be fed to the Council's service provider on a daily basis to monitor LZC energy generation and submit the data to an automated energy and CO_2 monitoring platform.

Undertaking a suitable energy audit

There will always be a mismatch between the expected theoretical performance of a building and the reality of utility bills. The difference between the expected and realised energy performance is known as the ‘performance gap’. This is mainly due to the following two reasons:

- The method of calculating energy use for compliance purposes does not take all energy uses of a building into account, only ‘regulated emissions’. External lighting, lifts, small power, miscellanea and process energy including IT equipment are usually excluded
- The second reason for a performance gap is related to site practice. To deliver a building that uses an expected amount of energy, the design should be built as intended, the engineering systems commissioned effectively and the operators and occupiers of the building should understand how to operate and maintain the building to meet the expected performance. Very few buildings are operated as designed.

An energy audit is an ideal means of identifying ways to reduce a building’s energy consumption, ensuring that appropriate sources of energy are employed and promoting efficiencies that benefit the entire organisation. Depending on the company’s needs and whether previous audits have been undertaken, the energy audit could be:

- An initial opportunities assessment, in which overall quantities and costs are determined and annual and seasonal trends in energy use identified
- A screening survey covering major energy using plant and processes, identifying energy waste and inefficiencies, gaps in metering, correct reporting of energy use and priority areas for further investigation
- A detailed investigation and analysis in which one or more of the plant or processes identified by the screening survey are examined in more detail and advice is provided on options for achieving efficiency gains through technical or operational improvements

To profile and ascertain the true operations of a building energy performance and comply with the European technical standard EN 16247 that regulates energy audits, it is advisable to:

- Establish energy consumption at a site through the analysis of meter readings to determine the approximate use of each fuel
- Compare specific consumption with the target established for the property and published energy performance benchmarks for similar buildings
- Carry out a survey of the site to compile required data on key elements of the building
- Review energy initiatives being undertaken at site
- Identify opportunities for savings and devise proposals for further energy initiatives
- Compile a report to present the findings and recommendations arising from the study

From our experience as accredited energy auditors, the following three recommendations proved to be the most cost effective:

1) Implement an energy policy and strategy

Sites may not have a formal energy policy in place. Senior management and maintenance staff may have a proactive attitude to energy efficiency but to take the initiative a step further, it is recommended that a site-specific energy management policy and strategy is implemented to demonstrate an organisation's commitment to reducing energy consumption and their carbon footprint. Potential energy savings at the site will be highlighted through the creation of a formal framework, increasing awareness and improving the monitoring of energy consumption in all areas. We usually recommend the following:

- Draw up an energy policy and strategy. The policy should lay out the objectives, reduction targets and responsibility structure for reporting performance and be similar in procedure and structure to a health and safety policy. The policy should contain a simple mission statement from senior management and be highlighted on company notice boards in all areas to confirm their commitment.

- Appoint an energy manager and committee. It is required to appoint an energy manager to oversee all energy related issues, supported by an energy committee. This committee, consisting of a few key members of staff from various departments and chaired by the energy manager, should meet once a month to consider various matters and review energy performance. A well-managed committee can make sure that energy usage is monitored effectively and remains an important issue throughout the site. It can also bring forth ideas for improvement and monitor the results of trials, etc.

- Appoint energy champions. Appointing an energy champion for each area / shift will ensure that energy efficient objectives are carried out and will demonstrate the company's commitment to reducing energy consumption. They can also communicate ideas on energy saving from the workforce back to the management.

- Draw up a formal action plan. The findings of the energy audit report should be incorporated into the action plan to ensure that energy saving measures are implemented. A member of staff should be assigned to each action plan priority which will ensure that implementation can take place.

- Set consumption reduction targets. Consumption reduction targets need to be in place to provide a goal to work to. A simple reduction target (eg 10%) for the first year would be a start and the reduction target value should be measured in either consumption (kWh), financial cost or in CO_2 emissions.

Provision for monitoring and evaluation. This activity needs ongoing monitoring and an evaluation system in place to determine success, as well as the full support and interest of senior management. Depending on the company and the effort put in, savings between 5% and 15% have been achieved. Additional management time is required, which may be seen as a distraction unless benefits have been realised. Monitoring and management of energy will only realise savings if the information provided is acted upon and working practices amended accordingly. The recommendations made in the energy audit report should be used as a basis for developing policy and targeting areas that need the most attention.

For an energy strategy/policy to be successful, it should have the following ingredients:

- Get senior management committed to drawing up an energy policy
- Appoint energy manager and form a committee
- Make all employees aware of the policy
- Commitment to annual reporting (public or to all employees)
- Should contain commitment to the development/deployment of improvement targets
- This policy is to be reviewed/upgraded on a regular basis

2) Implement an energy 'switch off' programme.

For certain buildings, the nature of activities carried out on-site is highly automated, once set up by the local operator. However, there are a number of opportunities to reduce in-direct energy consumption (ie heating, chilled water, etc). It is vital that all staff become actively involved in the energy waste reduction initiative. It is recommended that the client develops and instigates a programme for raising staff awareness for all energy issues. This can be done by implementing a switch-off campaign. The implementation of many small measures has a beneficial cumulative effect and helps to develop a culture of energy saving within the organisation. It should be standard practice to conduct regular reviews of energy usage by monitoring consumption and identifying potential areas for savings. Having identified these areas of unnecessary consumption, it is recommended that the following be carried out:

- Conduct a detailed walk-round survey with key members of staff (managers/security guard, etc) and identify all equipment/plant/services which could be switched off when not needed
- Label all non-essential services/plant/equipment which can be switched off outside of production hours, during nightshifts and at weekends
- Either consider automating the switching or nominate members of staff to manually switch off equipment/plant/services
- Nominate members of management to check that the system is working
- Introduce a series of presentations to staff on energy awareness matters. Obtain energy efficiency posters and stickers (doors, windows and light switches) and put them in prominent positions around the site

There are a number of improvements that can be carried out to improve day-to-day energy efficiency on-site.

Overnight or weekend operation – overnight there are often several hours where no activities take place. Any reduction in operating times will result in energy savings. Energy consumption savings can be achieved by exploiting a simple questionnaire, such as:

- Is the compressed air, chilled water or heating systems left on during this period and is it necessary?
- Are all lighting systems switched off in areas where light is not required?
- Are heating systems switched off in areas when no activities are taking place?

A walk-around during this time would determine whether plant and machinery is in operation and identify where energy can be optimised. Instruction should be given to staff on the importance of switching off plant during this period.

General – staff should be encouraged to switch off all tools, portable fans and localised lighting when not at work stations. Staff should isolate the compressed air supply to an area when not in use (eg end of shift, lunch breaks) as this will stop any air leaks in the area. Staff should be encouraged to report compressed air leaks and make suggestions on improving efficiency.

Heating systems - when heating systems are in operation, staff should close external loading doors and windows. Staff are encouraged to reduce temperature settings in the area, rather than open external doors or windows.

General lights - lighting systems are left on unnecessarily across some areas (eg toilets and plant room areas). Instructions are to be given to all staff to switch off lights when areas are not in use.

Office staff – switch off or enable ‘energy saver’ facilities on all computers, photocopiers, fax machines and printers when not in use. Staff should be encouraged to switch on ‘energy saver’ mode when photocopying is complete and ensure that all portable fans, workstation lights and coffee machines are switched off when not needed. Office staff should not open windows when the heating systems are operating and adjust temperature controls on radiators instead.

Depending on the effort that is put in, savings between 5% and 15% have been achieved.

Meeting a client’s needs and ensuring staff safety remains the main priority on-site and therefore all energy savings measures should be thoroughly assessed to ensure implementation does not infringe on production levels. Additional management time is required, which may be seen as a distraction unless benefits have been realised. Implementing any awareness programme requires monitoring and reminders to ensure that staff maintain good housekeeping.

3) Improve energy monitoring and include key performance indicators (KPIs)

Energy consumption information is usually collected on a monthly basis for review and the analysis is normally for reporting and cost purposes only. This information is not usually compared against previous consumption readings or used to identify out of hours energy wastage. The data is seldom compared to similar sites within the corporate group, consumption to each area or to individual plant (eg air compressors). Companies do not usually monitor KPIs, such as energy consumption (kWh) against volume (kg) per raw materials, or output volume (tons) to monitor productivity or consumption. There is often one electricity meter and one gas meter on site, no sub metering of areas or any support services (eg compressed air, chilled water).

Energy management uses monitoring and targeting (M&T) as a practical way to measure performance and the effectiveness of their energy savings effort. There are a number of benefits, including:

- Providing live monitoring of energy consumption that can be managed from a central location
- Monitoring plant performance on an hour/day/week/ month basis if desired or necessary
- Recording progress against targets to identify poor performance and quantifying both savings and waste (eg out of hour usage and air leakage)
- Helping management to control energy use by setting target consumption limits
- Allowing energy savings from the report recommendations to be quantified

This is a fundamental first step toward energy and utilities management for the site. The usual method of monitoring energy consumption consists of one collective reading on a weekly/monthly basis for the whole site. This method of monitoring is considered to be reactive, rather than proactive, and generally leads to mismanagement because the client has no idea when or where any abnormality has taken place.

KPIs are used to measure productivity and identify exceptions to normal performance. The site's KPIs can be used for comparison against sector benchmarks, internal data generated by other facilities or sourced from external sources where possible. When site KPIs increase, this should be acted upon and rectified by management.

Install automatic meters with 'smart' metering capabilities in accordance with the principles set by CIBSE TM39 'Building energy metering'. The client should consider automatic meter reading (AMR) of the main incoming meter, further sub-metering of main areas and an extension to some or all production lines/processes. Further consideration should be given to meter-direct and indirect energy consumption (eg vessel heating) and metering main support services (eg compressed air and chilled water systems).

There are monitoring and targeting systems on the market that can automatically record consumption every 30 minutes and store it on a PC or the web for live or future reference. This 'live' data can be accessed at any time. A number of different types of reports (energy vs product units) can be set up automatically for analysis at suitable time intervals and alarms set to highlight exceptions to normal performance.

Case studies have shown that effective M&T is likely to achieve a 2-5% saving on energy costs. Additional management time is required, which may be seen as a distraction unless benefits have been realised. M&T will only realise savings if the information provided is acted upon and working practices amended accordingly. A suitable strategy would be as follows:

- Identify a competent and suitably qualified professional
- Identify systems to be monitored and install smart metering of electricity supplies to each area
- Obtain quotes for any proposed work
- Determine what KPIs are necessary, how to be measured and monitored
- Ensure local area managers are aware of the importance of collecting the data necessary for producing performance KPIs
- Review site KPI performance on a regular basis
- Appoint a member of staff to oversee the management of this system

Case study 1 – Commercial building

Ramboll Environ have been commissioned to undertake an energy audit of a 21,300m^2 multi-storey office building in London in terms of existing energy use and identifying ways to reduce future energy consumption at the site and delivering a sustainable future.
The aim of the energy audit is to identify opportunities to reduce energy use, costs and associated carbon emissions. The auditor was also given access to the building's plant rooms and roof area, this access gave a useful insight into the quality and arrangements of the building services equipment.
The following sections of this report detail the analysis of energy consumption and existing systems, provides a summary of energy saving opportunities, including projected costs and savings that can be taken to minimise energy consumption and environmental impact.

The building provides Grade A office accommodation and was originally designed in the 1980s for large dealing floors and financial uses. It was comprehensively refurbished in 2006 with a landscaped roof terrace on the 4th floor.

The premises are occupied by circa 1,150 staff and the standard working hours are 09:00 to 17:30, Monday to Friday. The building is occasionally occupied at weekends and security staff (three people) and cleaners are present at night.

The outside air temperature on the day of the survey was approximately 19°C and the sky was clear.

As part of the energy audit process, we had meetings with the building services manager and the facilities services supervisor.

During our visit on-site, we undertook visual inspections of the premises including open plan and cellular offices, meeting rooms, circulation and stairs, plant rooms, lifts, toilets and the roof.

There are a number of reasons to commission this report and to implement the energy saving opportunities that are recommended, as detailed below:

Legal

Legislation such as the Climate Change Levy, Energy Performance Certificates, air conditioning inspections and carbon reduction schemes are clear indications that the energy performance of buildings is on the political agenda and further incentives to improve energy performance can be expected.

In July 2014, the Energy Savings Opportunity Scheme (ESOS) Regulations 2014 were introduced in the UK. This legislation requires large undertakings to carry out mandatory energy audits and identify energy saving opportunities. As a large undertaking with over 250 employees as of 31st December 2014, the client was in scope of the ESOS Regulations 2014 and therefore is required to carry out energy audits.

Financial

It is widely accepted that the future price of fuel is likely to increase significantly in the long term, any savings to utility expenditure is therefore likely to provide benefits in the future.

Environmental

The release of carbon dioxide and other greenhouse gases is believed to be causing global warming and climate change. The UK has committed to the Copenhagen accord to reduce greenhouse emissions to 50% below 1990 levels by 2025 and 80% below by 2050. It is widely understood that commercial buildings contribute to the UK's total emissions by approximately 50% and therefore significant improvements in energy efficiency is required for current commercial building stock in order to meet or exceed these targets.

Social

The effects of global warming and climate change are now high in the public's awareness. Many companies have corporate social responsibility statements that provide information regarding the company's impact on the environment, which may inform a clients' future decisions, improve energy performance and a company's image to prospective clients.

The building is air conditioned via Fan Coil Units (FCUs), circa 200no per floor, with 7no AHUs serving the offices, the atria and the catering facilities. Cooling is supplied by 3no york chillers with R407c refrigerant gas located at roof level. The chilled water (CHW) distribution was observed to be very well insulated with lagging jackets installed for all valves. The chillers' operational hours are usually 07:00 to 19:00 and 06:00 to 22:00 during the summer. A number of small split systems are located on the roof and a Mitsubishi air conditioner is installed in the meter room on the ground floor. Mechanical ventilation is usually switched on at 06:00 and off at 22:00. Natural gas is used by 3no Andrews wall-hung water heaters installed on the roof, running during weekdays from 07:00 to 22:00, and in the winter (December to March) by direct gas-fired burners installed in the main supply AHUs, located in the basement. The main AHU fans, rated at 75kW each, and the 3no Gamak CHW pumps, rated at 30kW each, are all fitted with Danfoss VSD inverters, which are manually adjusted. Hot water for the toilets is provided by electric Oso Direct 20 RD unvented water heaters.

The building services are circa 10 years old and were observed to be well-maintained and operated by the facilities team via the existing Metasys Building Management System (BMS), which was installed before the main central plant. The BMS is now aged but the building services manager and facilities services supervisor have overcome the limitations of the current software by putting excellent 'human management' procedures in place. In fact, the chillers' operation is manually adjusted by the technicians on a weekly basis based on a seven-day forecast. The central plant is usually switched off on weekends, unless the facilities team is informed that the building is going to be occupied. Cooling is required throughout the whole year, even in winter, and whenever possible free cooling is exploited on-site by leaving only one CHW pump and chiller circuit on. These operations are set manually by technicians who look after the central plant and equipment. The overall procedure would clearly benefit from a new BMS software, which could remotely activate the free cooling mode. The WC extract fans run from 07:00 to 22:00. The set temperature for areas served by the main supply AHUs is usually 18°C and occupants in the cellular offices and meeting rooms can alter temperatures up to 24°C maximum using local controls. There are 10no lifts on-site, six of which are of hydraulic design, and an irrigation water package pump set for the roof garden.

Lighting is provided by a mixture of T5 and T8 fluorescent tubes, compact fluorescent lamps and tungsten halogen dichroic lamps. The BMS controls key plant and equipment throughout the building but does not control lighting, which was continuously on during the survey, not only in various open plan areas with no occupancy but also in vacant cellular offices and print rooms. It was observed that some meeting rooms have dimming control (especially on the 1st floor) and some PIR controls have been installed in a few areas, such as the toilets and part of 4th floor offices.

The 2no main electrical intake meters are installed in the security office on the ground floor. The total authorised supply capacity (ASC) is 2,500 kVA but there is no power factor (PF) correction. In fact, PF was recorded as low as 0.939 during the survey. Some plant and office areas (such as chillers, lifts and 1st and 4th floor offices) are sub-metered and the facilities team take monthly readings of all sub-meters installed on-site. There is 1no gas supply meter for the whole site but half hourly data is not available for this fuel. The electricity and natural gas consumption figures used in the report are based on actual energy bills.

Conversion factors in line with the CRC energy efficiency scheme, published on the calculation of carbon dioxide emissions from fuel usage by the Department of Energy & Climate Change (DECC) on 15th June 2015, have been used. We have used the published conversion factors for the year 2014/15 (Phase 2 of CRC): 0.53 kg of CO_2 for each kWh of grid supplied electricity and 0.18 kg of CO_2 for natural gas.
To understand recent energy usage, utility data for one year's consumption has been analysed. The site consumes 6,031 MWh of energy per annum (based on August to July bills) costing a total of £ £659,489 (96% due to electricity costs).

The average unit costs for electricity and natural gas used in calculating annual costs and any savings are 10.93 p/kWh for electricity and 4.21 p/kWh for natural gas (excluding VAT).

The actual energy consumption of the site has been compared to CIBSE Guide F 'Energy Efficiency in Buildings'. For the purpose of analysis, we have compared the site with the energy consumption of a 'prestige air conditioned office' (Type 4), assuming a gross internal area (GIA) of 230,000 ft^2.

Overall, findings show that the building is performing very well with regards to natural gas (84% below the proposed benchmark) and poorly with regards to electricity (29% above the relevant benchmark). The very low gas consumption is mainly due to central heating not being provided by conventional gas-fired boilers but by direct gas burners serving the main supply AHUs, which are only in operation four months per year.

With regards to the very good performance in gas consumption, it should be noted that hot water for the toilets is mainly provided by electric point-of-use systems and that excellent levels of insulation were observed in the pipework distribution and the building envelope, which features high performing double glazing. As explained previously in this report, lack of lighting controls and electric heating are causing the site to score poorly against the proposed electricity benchmarks.

A breakdown of electricity and gas consumption during the year has also been provided. It is based on the survey's findings and CIBSE Guide F typical values for prestige air conditioned offices:

- Fans, pumps and controls: 26%
- Lighting 23%
- Cooling: 16%
- Electric heating and hot water systems (HWS): 17%
- Desk equipment: 12%
- Catering: 6%

It should be noted that targeting significant energy-use areas can lead to greater reductions in energy consumption. It is emphasised that these are approximate estimates and that load measurement would be required to produce accurate figures.

The main energy reduction measures are shown below, ranked by estimated simple payback. We recommend implementing projects in order of their payback period, starting with the project that has the lowest.

It should be noted that before any of these measures are taken to full design and implementation, a detailed design specification should be produced and any payback criteria recalculated by the designers and installers. The savings associated with some of these opportunities overlap each other; if all were implemented, the total delivered savings would be less than the total figure indicated above. All are presented in full in this report to provide the complete picture.

1. Replace the existing BMS

The building services are currently very well operated by the facilities team via the existing Metasys BMS, which was installed before the main central plant and is over 15 years old. The technicians have overcome the limitations of current software by manually fine-tuning the central plant operation on a regular basis. The overall procedures would clearly benefit from a new BMS software which could allow full control of central plant and equipment, including lighting fittings, fans and pumps' VSD inverters which are not currently monitored remotely. It is recommended to upgrade, or possibly replace, the existing BMS as a new system which would be expected to give a reduction in energy usage of up to 10%. The savings quoted above are based on a 2% saving for each utility, which should be readily achievable.

- Estimated cost savings: £13,711 per year
- Estimated CO_2 savings: 66.6 tonnes per year
- Estimated energy savings: 132,991 kWh per year
- Estimated budget: £50,000
- Simple payback period: 3.6 years

2. Install VSD control on all pumps and fans

In any pump or fan application that has a varying load, it is recommended to fit VSD controls to improve management and reduce energy consumption. Due to the cubic relationship between energy and motor speed, a small reduction in motor speed will result in a significant energy reduction. Manufacturers claim 30-60% savings in energy when these controls are installed and linked to the BMS. In most motors, for pumping or fan applications, the systems are designed for maximum internal load and the highest ambient temperature. VSD controls will cause variation in motor output, depending on the load of the systems. The control of these units can be linked to return temperature, operating pressure set points or a simple reduction in the speed of the motor and fix. An indicative £40,000 budget has been provided, but most VSD manufacturers can provide a detailed service with savings and costs. If the AHU supply and extract volumes were to be reduced, the system would need to be rebalanced and this would require the calculation of pressure drops down each of the main riser to the distribution point at each floor. This will require the appointment of a mechanical services consulting engineer. The engineer will calculate required air volumes and then the commissioning engineer will balance the system.

- Estimated cost savings: £10,299 per year
- Estimated CO_2 savings: 50.2 tonnes per year
- Estimated energy savings: 94,187 kWh per year
- Estimated budget: £40,000
- Simple payback period: 3.9 years

3. Install PF correction capacitors

There is sometimes a small reactive power charge of circa £11.20 per month on average on the electricity invoices, excluding VAT. The reactive charges are much higher in summer, reaching up to £66.51 per month. This indicates a poor PF and could be countered through the installation of fixed capacitors at the main incoming distribution boards.

- Estimated cost savings: £134 per year
- Estimated CO_2 savings: 0 tonnes per year
- Estimated energy savings: 0 kWh per year
- Estimated budget: £600
- Simple payback period: 4.5 years

4. Carry out a night time energy audit using infra-red thermography

Half-hourly (HH) data for the two smart meters installed on site has showed a very high night baseload of circa 200kW per metre. The building baseload doesn't change much at weekends, nor during the 2014 Christmas holidays or early May bank holidays. In fact, we have also taken into account the consumption on Monday 4th May 2015, when a constant 280kW load was registered from 07:00 until 22:00, which would merit further investigation. We recommended that the client engages with an ISO 9712 certified thermographic professional to undertake a night-time energy survey to investigate what the building baseload is made of. An infra-red thermographic survey would also help to more precisely identify energy losses, presence of moisture and water penetration, which affect performance and durability of building materials. The associated energy savings could be considerable but for the purposes of this report a new 100kW night baseload has been considered.

- Estimated cost savings: £328 per year
- Estimated CO_2 savings: 1.6 tonnes per year
- Estimated energy savings: 3,000 kWh per year
- Estimated budget: £1,500

- Simple payback period: 4.6 years

5. Review lighting levels and install automatic lighting controls

The highly glazed façades and the three atria ensure that there is good natural daylight entering the building from the outside. However it was observed that in most areas, the lights are left on continuously, even during sunny days. There are a number of improvements that can be made to better control lighting systems and reduce energy consumption and costs. A variety of lighting controls that can be installed in commercial sites are available to ensure that lights are operated only when they are needed. In areas near the external windows and the glazed atria we recommended fitting photocell controls with daylight sensors to automatically switch off lights when light levels are sufficient. These controls monitor the level of good natural light entering the building and automatically switch on/off the local artificial lighting. In intermittently occupied communal areas (plant rooms, toilets, storage areas, circulation areas not open to the public), occupancy/motion sensors (presence detectors/PIR sensors) provide an effective way to manage lighting systems during unoccupied periods. These sensors detect the absence of motion and switch off unwanted lighting. Any reduction in light usage on site will save energy. The installation of automatic sensor controls eliminates the 'human factor' and guarantees that savings will be achieved. It is imperative to ensure that background lighting levels are maintained and that general circulation areas and emergency escape routes are not affected, health and safety of staff must not be compromised. Savings are based on lights being switched off for 20% of the time and an indicative £200 budget per installed PIR/daylight sensor. We recommend that the client engages with staff and carries out a specific lighting audit to identify areas of low occupancy where PIR sensors could be fitted, and areas where good natural daylight is entering the building where daylight sensing photocell electric sensors should be installed. If in doubt, carry out a trial run in selected areas and then obtain quotes for the work.

- Estimated cost savings: £3,072 per year
- Estimated CO_2 savings: 15 tonnes per year
- Estimated energy savings: 28,091 kWh per year
- Estimated budget: £20,000
- Simple payback period: 6.5 years

The following opportunities should also be considered. These measures in some cases represent longer-term approaches that may not be appropriate now but could be considered during the next energy audit in three to five years:

We recommended that an ACI Energy Assessor is instructed to carry out an air conditioning inspection (ACI), which still hasn't been undertaken on site. In order for the air conditioning plant to run efficiently, the correct technical functioning of the building services must be assessed on a regular basis. In particular, for all systems with an effective rated output (combined cooling capacity) of more than 12 kW, an ACI should be carried out every five years in compliance with CIBSE TM44, and the ACI certificate and report should be lodged in the Non-Domestic Energy Performance Register for England and Wales operated by Landmark.

Adhering to the principal and procedures of ISO 50001 energy management system (EnMS) standard would promote the concept of continual improvement and help identify and prioritise actions to reduce energy waste, increase efficiency and plan/control future energy use. A certified ISO 50001 EnMS that covers all energy use counts as an ESOS assessment, and the company would only need to notify the Environment Agency for compliance, without appointing an ESOS lead assessor. This could reduce the financial cost of ESOS compliance in the long-term. We recommended that a gap analysis is carried out to confirm the level of effort required to attain ISO 50001 certification.

Case study 2 – Residential premises

This is an example of bad practice where the landlord in the first instance replaced the existing gas-fired boilers at the end of their life expectancy with like-for-like biomass alternatives and only at a later stage commissioned an energy survey to evaluate the benefits of exploiting external insulation to lower the energy costs at the site.

The building was a care home located in north east England built in the later 1980s. The site primarily comprised a floor area of approximately 1,800 m^2, with 33 bedrooms and other standard care home service areas. The external envelope was made of conventional cavity walls and the purpose of the proposal was to provide an energy audit, inspecting the site's energy related services to produce a report on saving opportunities.

The site audit took place in November and involved a visual inspection of the occupied rooms, cellular offices, common areas including reception, conservatory, circulation and stairs, toilets, food preparation and dining areas, plant rooms, the lift and the summer house located in the garden. The inspection examined each room type as well as plant systems, light fittings and controls.

The building was occupied to over 90% under normal operation, staffing levels and mode. At the time of the audit the weather was partly cloudy and the outside temperature was approximately 9°C.

The on-site audit involved a non-intrusive inspection and off-site desktop analysis of the availble energy records. The reported energy consumption could not be cross-referenced to the actual invoices, because energy bills for 12 consecutive months had not been made available.

The inspection included a detailed discussion between the energy auditor and the care director. No O&M manuals were available in the plant rooms and the maintenance technician responsible for the building services was not present during the energy survey. However, a telephone call was arranged between the energy auditor and the maintenance technician to get confirmation about how the main plant is currently operated and maintained.

The building was mainly naturally ventilated with central heating provided continuously by LTHW radiators fitted with individual thermostatic radiator valve (TRV) control and served by two ETA PEK90 biomass boilers, which had been installed a few months prior to the energy survey. A gas fired Ideal Concord CXA boiler was still used as a back-up generator and an electrically heated VES Andover AHU provided fresh air to the dining room. The AHU was an original installation: it delivered 1.2 m^3/s of tempered air, its supply fan was rated at 2.2 kW and the electric heating batteries at 10 kW. Pumps were not inverter driven and would benefit from VSD control. The most recent heating plant was installed by contractors who also monitor and operate the building services remotely and are responsible for setting up operative temperatures and time schedules too.

Electric heaters were fitted in the highly glazed solar house located in the lawned gardens. DHW to the toilets and the kitchen was provided by secondary LTHW circuits and the distribution pipework throughout the building was found to be lacking in adequate insulation. All toilets and the kitchen were fitted with extractor fans. Washing machines and kitchen appliances were usually in operation from 06:00 to 18:00.

Artificial lighting was mainly provided by compact fluorescent lamps and by T8 fluorescent tubes, rated at 56W each in the food preparation area. Three 40W halogen lamps were fitted in the manager's office. The external lighting was time-controlled but no daylight sensors had been fitted yet.

The energy survey and on-site discussion with the care manager identified the following key points:

- An energy manager with specific responsibilities for addressing carbon and energy reduction projects has never been appointed at the site
- No KPI/benchmarking analysis against industry standards has ever been undertaken on site
- Energy bills are not kept on site, but managed centrally via energy brokers and not brought to the attention of the care manager, who only makes sure that the temperatures of the different building areas are comfortable
- The energy end-uses are not sub-metered. There is simply one main electricity meter for electricity and one supply meter for natural gas.

Based on figures provided by the Bureau analyst employed by the energy brokers responsible for electricity and natural gas on-site, the combined annual consumption was 620,297 kWh, of which 26% was electricity and 74% was natural gas. The annual energy expenditure was £31,580.33, of which 54% was due to electricity charges and 46% to natural gas. Based on the figures provided, the average unit costs used in calculating energy savings were 10.56 p/kWh for electricity and 3.15 p/kWh for natural gas.

During the energy survey it was observed that the two pellet boilers and their associated plant were installed in March. It was reported that the cost for purchasing wood pellets was £13,296.95 for the six-month period (April-September). Based on a typical 4.4 p/kWh cost for wood pellets, the associated energy consumption for these six months would be 332,424 kWh, which is circa 50% of the annual energy usage on site. It was recommended that the client monitored wood pellet consumption associated with biomass boilers and re-assess the breakdown of fuels used on-site once a full year's worth of data was available.

Electricity bills have been provided at a later stage for 11 months (January – November) and the total consumption and associated costs were 152,793.38 kWh and £16,096.67 (VAT excluded), respectively. Assuming an average value based on the previous 11 month's figures for December, the annual electricity consumption for the site would be 166,684 kWh, which is in line with the figure provided by the energy broker (162,531 kWh) and also used in the report to estimate the payback periods associated with proposed recommendations.

Benchmarking is a valuable tool to compare and evaluate relative energy consumption and the potential for energy reduction. For this report, thermal and electrical site energy was evaluated against CIBSE TM46 (Table 1, general accommodation).

A new heat meter was installed in the plant room where the biomass boilers are located and the reading during the site survey was 358,036 kWh. Assuming that this was installed together with the biomass boilers in March, it should have been recording usage for circa 8 months. For the purposes of this analysis, an annual wood pellet consumption of 358,036 / 8 x 12 = 537,054 kWh has been assumed.

A benchmark study highlighted that the fossil fuel consumption was in line with the proposed benchmarks. However, we recommended that the site performance is reassessed once estimated data is replaced by actual usage.

The site was not performing well with regard to electricity and, considering the higher cost of this fuel compared to natural gas and wood pellet, we recommended that supply was prioritised rather than focusing on fossil fuels.

Infra-red thermal imaging has also been included in the report to identify thermal losses and inefficiencies occurring at the site.

Based on the findings of the energy survey and the analysis of the energy bills provided, we recommended that the client focused on a few key recommendations - some of which are summarised below - before taking into consideration capital investments with longer payback periods (ten years minimum), such as external insulation or solar PV.

Electricity sub-metering, PIR sensors and LED retrofitting have been identified as the most suitable recommendations for the site but, above all, before implementing any measures, it couldn't be stressed enough that the site needed a high-level energy strategy to comply with.

Based on the energy data provided, circa 75% of the electricity used is consumed during the day and circa 25% at night. It was recommended that a night-time survey was undertaken using infra-red cameras to identify which equipment and appliances are left switched on and to understand how the building baseload could be lowered.

According to the requirements of Modification P272/HH settlement for profile class 5-8 meters (a mandatory industry-wide change that will be implemented by all suppliers), from 1st April 2017 electricity consumption must be settled using automated HH interval data. The current supply meter does not allow HH data collection and we recommended that the client moves to HH bills as soon as possible to allow more precise analysis of actual electricity consumption during different periods of the day and at night.

The new energy bills confirm that natural gas consumption has been progressively decreasing since March when two new biomass boilers were installed on-site. From May onwards there has not been any significant natural gas consumption and the odd figures recorded for the second half of the year (especially September with 27,896 kWh) were only based on incorrectly estimated readings, which explain the negative figures for natural gas usage in June and October.

It might also be worth renegotiating the current contract terms with the natural gas supplier, as it was observed that the monthly standing charges were circa £300 on average with no natural gas consumed on site.

Among the various energy saving measures identified for the site, the following are worth mentioning:

1. Insulate existing valves and flanges

It was observed that the insulation on large sections of hot water pipes, valves and flanges is either damaged or missing. Uninsulated steel pipework will typically lose 10 times that of pipes insulated with 50mm of standard insulation and the heat loss from one un-insulated valve is the same as a 1m length of pipe. It is recommended to fit lagging jackets to all valves and flanges. For the purpose of calculating the associated payback periods, it was assumed that general maintenance staff could install them.

- Estimated cost savings: £102 per year
- Estimated CO_2 savings: 0.6 tonnes per year
- Estimated energy savings: 3,246 kWh per year
- Estimated budget: £250
- Simple payback period: 2.4 years

2. Replace halogen lamps and T8 fluorescent lighting with LED

We recommended that all artificial lighting is replaced with energy efficiency alternatives, such as LED. LED lighting is the latest lighting technology on the market and can be replaced in most applications (fluorescent tubes, metal halide and tungsten halogen lamps). Another benefit of LED lighting is the life expectancy: 50,000 hours operating shelf life compared to 10,000 or even less, in the case of halogen lamps, resulting in reduced maintenance costs. Savings are based on the lights being switched on 12 hours per day and replaced by their LED alternatives (10W LED for the three 40W halogen bulbs in the manager's office and 22W LED for the 26n 5-foot 58W fluorescent tubes in the kitchen). Compact fluorescent lamps could be replaced with LED lighting, but the estimated payback periods would be longer and we would recommend a rolling programme for a phased lamp replacement once all the other lights have been replaced. The next step should be to contact an electrical contractor to carry out a detailed feasibility study and subsequent design for any alterations. Quotes should be obtained for any proposed work and if in doubt, a trial run carried out in selected areas. Works should be scheduled to minimise operational disruption and a 'guarantee of performance' should be included, showing a period of energy monitoring before and after the installation to quantify savings.

- Estimated cost savings: £497 per year
- Estimated CO_2 savings: 2.4 tonnes per year
- Estimated energy savings: 4,560 kWh per year
- Estimated budget: £1,700
- Simple payback period: 3.4 years

3. Review lighting levels and install automatic lighting controls

Good natural daylight enters the building from the outside. However, in some areas the lights are left on continuously, mainly because of manual controls. There are a number of improvements that can be made to better control lighting systems and reduce energy consumption and costs. A variety of different lighting controls that can be installed on site are available to ensure that lights are operated only when they are needed. In areas near the external windows and for all external lighting, we recommend that photocell controls are fitted with daylight sensors to automatically switch off lights when light levels are sufficient. These controls monitor the level of good natural light and automatically switch the local artificial lighting on/off. In intermittently occupied communal areas (such as plant rooms, storage and circulation areas), occupancy/motion sensors (presence detectors/PIR sensors) would provide an effective way to manage lighting systems during unoccupied periods. These sensors detect the absence of motion and switch off unwanted lighting. Any reduction in light usage on site will save energy. The installation of automatic sensor controls eliminates the ‘human factor’ and guarantees that savings will be achieved. It is imperative that background lighting levels are maintained and that general circulation areas and emergency escape routes are not affected, health and safety of staff must not be compromised. For the purpose of this evaluation an indicative £200 budget per installed PIR/daylight sensor has been assumed as well as a limited energy reduction of 5% of electricity.

- Estimated cost savings: £858 per year
- Estimated CO_2 savings: 4.3 tonnes per year
- Estimated energy savings: 8,127 kWh per year
- Estimated budget: £6,000
- Simple payback period: 7.0 years

Thermal modelling - some considerations on energy performance certificates

Exploiting energy modelling is required to predict the likely carbon emissions of a newly built property and estimate the beneficial effect of building retrofits in existing buildings. Since the transposition at national level of the mentioned EPB Directive, thermal simulation has been used to generate EPCs for both new and existing buildings. From 1st April 2018 it will be unlawful for landlords in the UK to let and renew a lease to an existing tenant if the property has an EPC asset rating of F or G, as stated in the Minimum Energy Efficiency Standard (MEES) Regulations. From 1st April 2023 the regulations will also apply to all privately rented properties where a lease is already in place.

EPCs are based on government approved software, however most of them are currently generated using simplified building energy modelling (SBEM), which is based on monthly average values, steady-state heat transfers and a number of assumptions, which are correct for many, but not all, properties. SBEM is the most popular methodology for calculating a building’s EPC asset rating, but is not sophisticated enough to provide an accurate assessment for certain buildings, for example those with high thermal mass (ie featuring stone façades, brick/blockwork walls, concrete structures) or in close proximity of obstructions such as adjacent buildings or high trees that provide external shading only during certain hours of the day.

Using advanced dynamic simulation modelling (DSM) it is possible to assess the real effect of solar gain on surfaces, surface temperatures and radiant exchanges at sub-hourly time steps (ie intervals of 10 minutes).

Current UK legislation specifically requires DSM for generating the EPC asset rating of buildings with the following features:

- Night ventilation strategies
- Ventilation with enhanced thermal coupling to structure
- Demand-controlled ventilation
- Automatic blind control
- Variable speed pumping
- Light transfer between highly glazed internal spaces such as atria or lightwells

The complexity of these buildings is such that only certified professionals accredited as Level 5 energy assessors are qualified to run DSM calculations. Although DSM is mandatory only for the most complicated buildings, it is still possible to assess the energy efficiency of simpler buildings using DSM rather than SBEM. The analysis usually takes longer due to more inputs being entered into the model (such as the actual thermal templates and the site's weather data including the sun path) but the outcomes are more accurate. As a result of minimising the default settings, which usually represent worst case scenarios, the EPC asset ratings obtained using DSM are usually lower (better) compared to SBEM, and this could make a huge difference when assessing the energy performance of a property portfolio.

ISO 50001 certified energy management systems

When most of the low cost energy saving measures have been implemented and there is no budget for investing in capital expenditure projects, the most efficient way to lower the energy bills in an existing building is to embrace the principles of good energy management practices. The best recognition for the efforts put towards energy efficiency is to get certified by the International Organization for Standardization (ISO), whose 50001 standard sets the requirements for a correct energy management system.

Businesses cannot control energy prices, government policies or the global economy, but they can improve the way they manage energy and the risks associated with these uncontrollable external factors. Implementing an EnMS enables organisations to use energy more efficiently, helping to cut costs, conserve resources and tackle climate change through carbon emission reductions.

ISO 50001 is an international standard for energy management systems, which was issued for the first time in June 2011 to help organisations save money as well as helping to conserve resources and tackle climate change. For those already familiar with other well-known standards such as ISO 9001 or ISO 14001, it is still based on the same continual improvement model, also known as plan-do-check-act (PDCA). According to this framework, the following steps need to be undertaken:

- Plan: conduct the energy review and establish the baseline, energy performance indicators, objectives, targets and action plans necessary to deliver results to improve energy performance in accordance with the organisation's energy policy
- Do: implement the energy management action plans
- Check: monitor and measure processes and the key characteristics of operations that determine energy performance against the energy policy and objectives, and report the results
- Act: take actions to continually improve energy performance and the EnMS

Implementation of ISO 50001 is intended to lead to reductions in greenhouse gas emissions and other related environmental impacts and energy cost through systematic management of energy. This standard is easily applicable to all types and sizes of organisation, irrespective of geographical, cultural or social conditions. Successful implementation depends on commitment from all levels and functions of the organisation, and especially from top management.

The simple yet revolutionary idea is that organisations are encouraged to set the boundaries of the investigation to meet exactly the business' specific needs. If a manufacturing company realises that it would not be cost effective to certify the newest and most energy efficient facilities, there is no need to take into account the whole building portfolio. ISO 50001 is not 'yet another carbon tax', it is a flexible tool that provides a real opportunity to change an organisation's attitude to manage energy and improve its carbon footprint.

Ideally, before embracing ISO 50001, it would be wise to liaise with a competent energy strategist who could assist in identifying the most suitable route to achieve realistic energy goals in a phased and programmed manner. This would maximise the value that you can get out of the energy audits and would ensure that duplicated efforts made at senior management level and by the local EHS managers will be minimised. Today, firms need to be very reactive when new social, economic and political matters affect their medium and long term corporate business plan. With ISO 50001, even if the wrong strategy had been chosen at the early stages of the certification procedure, the risk of jeopardising the whole process is removed because the PDCA method is designed to continually re-assess the company's energy targets and re-calibrate the existing course of actions accordingly. ISO 50001 is not an ESOS energy audit report, which runs the serious risk of being forgotten in a dusty file room until 5th December 2019, when the next ESOS compliance date will remind you to submit a new list of energy saving opportunities for your board directors to sign off. It's a proper protocol of actions that once agreed at top management level becomes a habit embedded into the standard business practice. This is what makes it effective and guarantees that energy savings are actually met.

On top of that, if an organisation has operations spread across several EU Member States, ISO 50001 makes perfect sense as a valid alternative to mandatory energy audits required by Article 8 of the EED 2012/27/EU and I would recommended thinking beyond Europe. One of the greatest challenges for me as ESOS lead assessor has been international clients who all of a sudden had to comply with different legislations that transposed Article 8 of the Energy Efficiency Directive 2012/27/EU at national level. The fact that each EU Member State has interpreted the requirements of Article 8 differently has made this challenging. In some countries small to medium enterprises were exempt from undertaking mandatory energy audits, in others they were captured by the legislation if linked to large enterprises based abroad. Some countries accepted energy auditors listed in the approved register of accredited professionals of a different EU Member State, others still have not published the requirements to join their own national register, and so on. The administrative burden of coordinating a programme of compliant energy audits has been difficult for most pan-European companies but ISO 50001 is universally accepted in each and every EU member state as an alternative route to compliance.

Some organisations based in the UK are still asking us why they can't just wait for the next ESOS compliant audit in 2019. Our answer is that they can, but we would recommend a more active outlook, such as having an ambitious corporate social responsibility, to show their vision to their staff and shareholders, to adopt a system that demonstrates to their investors how transparently and efficiently their organisation is run, how they drive culture and behaviour changes, how to enhance existing services and create opportunities for new business, boost competitiveness and profitably for their company.