Specifying and designing public sector low carbon buildings
- the productivity design approach

Delivering the future, today

Setting the scene
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1. Introduction

This document describes many of the issues organisations are facing with their new or refurbished buildings today. It highlights particular problems and illustrates some success stories. It also provides the context for a series of guides and tools that have been created by the Carbon Trust to help guide the procurement process.

It is designed to be read in conjunction with the other guides within the Carbon Trust Delivering the future, today pack. The Delivering the future, today pack contains the following documents and tools:

Documents

Executive summary
A summary of the suite of documents and tools.

Setting the scene
This document demonstrates the benefits that can be achieved and the problems that can be avoided by following a robust process in the procurement of low carbon new build and refurbished buildings.

The project owner’s guide
This brief guide is designed to be read by the senior project owner. It introduces the requirement to change the way we procure new build and refurbished buildings and summarises the Carbon Trust five-step process to achieving that aim.

The project manager’s guide
This more detailed guide should be read by project managers and members of the design team. It lays out a detailed process that, if followed should ensure that a sustainable low carbon building, be it a new build or refurbishment, representing best value with minimum whole-life costs should be delivered.

Tools

Client value preparation tool
Skills, knowledge and experience tool
Low carbon tracker.

To download the tools go to www.carbontrust.co.uk/Scotland

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2. Background

There is mounting significant evidence indicating that most buildings commissioned today provide poor working conditions, are unnecessarily expensive and complex to run and fail to account for the projected effects of climate change in their design. This is the case in both the public and private sectors.

The Audit Scotland report, "Improving the School Estate", (1) investigated how effective the new and refurbished schools are and how well the Scottish Government and the councils were managing the improvements. Although it identified a general level of satisfaction with the design quality, it noted that when assessed against best practice the schools could be better designed. In particular, two areas were identified where improvements could be made:

- Environmental conditions such as the balance between day lighting, ventilation and temperature are often unsatisfactory and;
- Environmental sustainability can be inadequate. It became apparent that these features were only considered where their inclusion did not significantly increase the overall capital costs.

Furthermore, extensive evidence indicates these failures re-occur across all building types. Such problems are not restricted to Scotland. A National Audit Office report on the UK Government estate noted that of the projects that they examined, 80% failed the required sustainability standards (2).

The survey investigated building functionality, build quality and the users’ overall experience. It highlighted a number of issues including unacceptable environmental conditions, heavy reliance on artificial lighting and lack of user environmental controls.

Extract from the CABE report:

"The buildings were visited during some of the hottest months of the year. Problems with environmental conditions were frequently encountered, with temperatures too high and air movement insufficient. Buildings were frequently not allowed to cool at night during hot weather."

"This resulted in the widespread use of electrical fans to relieve heating and ventilation problems for users."

"These environmental conditions have undesirable implications for the delivery of care within premises designed in this way. They damage staff efficiency and morale and add to the discomfort of patients who are already ill, infirm or distressed."

Angus Council's Seaview Primary School won the Carbon Trust Scotland's Low Carbon Building Award for a New Building in 2010.

They used an in-house team to manage the development process consisting of architects, interior designers, mechanical and electrical engineers, quantity surveyors as well as staff from the Council’s energy and maintenance teams. Natural ventilation by automated high level windows is controlled by the BEMS based on inside and outside temperatures and CO₂ levels. Where mechanical ventilation is required, heat recovery is used to temper the incoming air. The school optimises its use of daylight using clerestory windows and skylights combined with artificial lighting controls based on occupancy detection and daylight dimming.

Seaview Primary School had no overall cost premium over a comparable building with higher emissions. The energy consumption is 49.8% lower than a typical new build primary school resulting in a cost saving of 67.7%. The lower energy consumption at the school will provide cost savings year-on-year through the life of the building.
This specification gap needs to be addressed by a number of means. These include ensuring operational targets for a building are adopted, energy efficient measures are properly costed and the procurement team has the skills required to deliver the building. This chapter examines each of these elements in more detail.

There are examples of good buildings where these elements have been taken into account resulting in their occupants liking the working environment and the building having significantly lower energy costs. The Seaview primary case study on page three is a good example of this. The new Invergordon primary schools have also adopted many of these principles.

Great Glen House, the headquarters of Scottish Natural Heritage in Inverness, has some excellent design features that contribute to its sustainable reputation. Its exposed concrete ceilings allows the thermal mass of the building to dampen the effects of temperature variations. On a hot summer day in 2006 outside temperatures reached 26°C and the temperature inside did not rise above 22°C. Acoustic treatment is integrated in the lighting trays in the offices and behind the wood panelling in the atrium.

Figure 1. Great Glen House with exposed concrete ceilings for a thermal heavyweight performance, avoiding the need for chilling.

3. Internal environment

The quality of the internal environment of a building is based on a combination of factors. If these are properly considered during the design process then the resulting building will present a productive workplace. While legislation provides both compulsory measures and incentives to guide the design process for a “fit for purpose” building, it cannot ensure that problems are avoided. This creates a shortfall between the expected internal environment as distinct from what is typically specified.
3.1. Productive workplace

One of the issues identified in the Audit Scotland report was the unsatisfactory environmental performance of the new build and refurbished school buildings. This problem can have a significant detrimental effect on the productivity of the individuals in a building. The problem may be exacerbated if a single complaint about temperature or a cold draft triggers dissatisfaction to unrelated issues.

Issues with temperature, daylight, ventilation and acoustics may result in productivity losses. Dealing with them is often expensive and results in decreased energy efficiency. For example, solving an acoustics problem by fitting acoustic panels to the ceiling or walls could mask the thermal mass of the building. Where the design of a building addresses such matters from inception, then such problems do not arise; however avoiding all of the potential issues may be costly. With the need to minimise carbon emissions and reduce energy costs some organisations are choosing to change employees’ expectations of what an acceptable working environment is.

3.1.1. Temperature

The temperature that individuals find acceptable will vary according to a number of factors:

- The outside temperature; on warm days individuals are likely to accept a higher internal temperature than on cold days
- The company clothing policy
- How active they are
- What temperature they are used to at home and in the car.

To achieve acceptable temperatures is not solely a case of adjusting a thermostat. For example permitting staff to wear shorts during summer can solve an overheating problem.

A number of temperature-related problems can occur:

- Trapped warm air at ceiling level; the ceiling will radiate the heat back down causing occupants to sense a sizeable vertical temperature differential. People generally prefer a temperature difference of no more than 3°C from floor to ceiling.
- Wholly or partially naturally ventilated buildings may be uncomfortable if ventilation air is not tempered.
- Large glazed areas can radiate cold and spill cold air. People’s perception of temperature is based on a combination of the air temperature and the radiant heat from walls and windows. A large window can result in an area feeling colder despite a reasonable air temperature. Cold spill is caused by air coming into contact with the inside of a cold window and falling owing to convection, which then draws more warm air to the window, creating a draught.
- Many buildings have a “Monday morning” problem caused by improperly controlled heating/cooling systems or the installation of an incorrectly sized heating plant, resulting in an unacceptable temperature for the building on a Monday morning.
- One of the problems most frequently encountered is overheating, through excess solar gains, internal gains or poorly controlled heating. The latter is more an issue in spring and summer but can occur at any time of the year if a building is not correctly designed or controlled.

There are a number of studies investigating the relationship between temperature and performance. Generally it is acknowledged that performance drops by 2% for every 1°C above 25°C although this is dependent on the clothing being worn. (14)
3.1.2. Daylight

Achieving high levels of daylight results in a reduced requirement for artificial lighting and has been proven to result in improved performance of its occupants.

These improvements in performance are thought to result in:

- Improved visibility due to more consistent illumination levels, better distribution of light and better colour rendition
- Avoidance of seasonal affective disorder and suppression of melatonin production
- Improved mood, alertness and behaviour.

Badly designed daylight schemes can have a detrimental effect on performance. Typical problems include:

- Glare, causing occupants to look away
- Lack of brightness uniformity
- Inadequate integration with artificial lighting.

Wide-ranging research into the effects of day-lighting on productivity in schools, offices and shops has been carried out in California. (16) (17)

It found that in schools, students with the most day-lighting in their classrooms progressed 20% faster on maths tests and 26% faster on reading tests in one year than those with the least.

It also found that some office workers’ performance deteriorated by up to 21% when they were subjected to glare.

3.1.3. Ventilation

Inadequate ventilation rates can result in a reduction of cognitive function, increased odours and raised levels of volatile organic compounds (VOCs).

Exeter University has conducted extensive research into the impact of ventilation on cognitive function. Research in a primary school showed a 5% loss of cognitive function when CO$_2$ levels had a mean of 2,900 ppm compared to normal levels of 1,000 ppm. (15)

High ventilation rates or drafts can also cause problems. Any airflow greater than 0.3 ms$^{-1}$ can cause discomfort (4).

Natural ventilation is often the preferred low carbon means of ventilating a building however this can often result in lower ventilation rates than those desired. Natural ventilation schemes can be successful provided a detailed analysis of the proposed design takes place. Using natural ventilation for narrow buildings is more likely to be successful.

Many designs now use mechanical ventilation with heat recovery to decrease this risk. Where this is used, installing large ducts, short runs and clever control can be a lower energy option.
3.1.4. Acoustics

The fourth element influencing productivity is acoustics. Problems with the acoustic behaviour of a building can cause hearing problems, disturb concentration and be problematic for speakers.

**Acoustic measures**

- **Background noise**: Measured in decibels (dB). 30dB gives a quiet room, 60dB makes conversation difficult to hear at 1m apart.
- **Reverberation time RT60**: The time for a sound to decay by 60dB. A room with short (e.g. 0.4 secs) RT sounds dead. A long RT gives noisy rooms.
- **Speech transmission index (STI)**: A measure of the intelligibility of speech in a room. An index of 0.65 is adequate, 0.75 is better.
- **Acoustic isolation**: The prevention of noise transmission, measured in dB. Plastered 140mm concrete blocks can provide 50dBA of acoustic isolation.

Where acoustic measures are required to create an acceptable environment, treatment such as acoustic tiles can be fitted. These tiles are normally very good thermal insulators and will mask the thermal mass of a building significantly affecting the thermal behaviour. Early modelling of building acoustics in the design process should ensure that the correct treatments are used and their properties are taken into account during the thermal design of the building.

Failure to account for acoustics at an early design stage frequently results in costly remedial measures with potential undesirable implications relating to the thermal mass of the structure. An example of a measure to improve acoustics is the use of a curved ceiling design in an auditorium.

3.1.5. Impact on low carbon design

For a productive workplace, the building elements and systems are likely to include good daylight levels, high insulation values and low summer solar gains as stated above. These can all contribute to a low carbon building if designed right.

Good daylight levels only reduce energy demand if the lights can be switched off when light levels are appropriate. High insulation levels mean lower heat demand in winter, but could also mean a significant cooling load in summer if not appropriately designed.

Ventilation rates determine a significant part of the heating and cooling requirements in winter, so increased levels that are continuous will result in higher heat losses. To make it low carbon, the ventilation should be controlled using, for example, CO₂ level control. High daylight levels will often lead to more sunlight that will cause blinds to be lowered, thereby increasing artificial lighting loads. Daylight from north and easterly directions, and coming from high clerestorey lights is a better all round solution.

Figure 5. Excessive light levels in a corridor. Half the lights would still exceed minimum standards.

Ventilation should be controlled using, for example, CO₂ level control. High daylight levels will often lead to more sunlight that will cause blinds to be lowered, thereby increasing artificial lighting loads. Daylight from north and easterly directions, and coming from high clerestorey lights is a better all round solution.

Figure 6. The high clerestorey lights provide the majority of daylight. The low windows face north so there is no glare, and good uniformity of light. The clerestorey lights also open to let hot air escape when needed.
3.2. Legislation and incentive schemes

There is now an increasing body of legislation, regulations, incentive schemes and policy that influence the specification, design and procurement of buildings. These continually changing policy instruments are set at European, UK, Scottish and local level. Some of these are shown below together with the aspect of the building that they affect.

Part 4 of the Climate Change (Scotland) Act 2009 puts further duties on public bodies. It requires a public body to, in exercising its functions, “act in the way best calculated to contribute to the delivery of emissions reduction targets (known as ‘mitigation’), in the way best calculated to help deliver any statutory climate change adaptation programme, and in a way that it considers is most sustainable.” This duty is clarified in the publication “Public Bodies Climate Change Duties: Putting Them Into Practice” (5).

Consequently, both client and design teams must ensure that they remain current with legislative developments in order to fulfil their legal obligations.
3.3. The Specification gap

Avoiding the design flaws that undermine employee productivity as outlined on page 8, demands a new approach to building design and specification. Typically, few targets are given to building designers. Organisations procuring buildings, whether new build or leasehold, tend to specify one or two headline targets and then rely on compliance with building regulations to deliver an acceptable level of energy performance.

As figure 7 shows, the Building Standards provide a minimum standard for some of the necessary factors that influence energy performance. However there are still a considerable number of elements that are unregulated or at the discretion of the building users and operators. For the building specifier it is important to be familiar with what Building Standards include and exclude, so that a comprehensive specification can be provided to the designers that will minimise energy in use and give Best Value, whilst providing a productive environment.

The minimum standards set by the Building Standards are set to increase over the next few years aiming to reduce carbon emissions. The new section 7 enables organisations to set higher measurable targets for the design of buildings to achieve silver or gold sustainability label, however this is still based on the design of the building and does not govern how the buildings can be operated in practice.

Further advice on the specification gap is in the Carbon Trust publication Closing the Gap - CTG047.

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**Figure 7.** Some of the regulated and unregulated aspects of building energy use. The green boxes represent the items influenced by building regulations and the red boxes are within the specification of the client organisation.

For example, the Building Standards specify an initial minimum level of luminaire lumens per circuit watt and the control systems that are acceptable in different scenarios. However, there are a number of other factors that need to be specified to ensure that the building minimises its operational lighting load:

- Minimum daylight levels and uniformity
- Blinds to be located where they do not obstruct the windows when open
- How much artificial light will be displaced by daylight
- Brightness levels of walls and ceilings
- The maximum acceptable level of lumens in a room from artificial light
- Acceptable level of degradation of a luminaire over its life
- Acceptable range of colour rendering and colour temperature.
Lamp and luminaire measures

The performance of lamps can be described by the following measures:

- **Efficacy** (Lumens/m²) is the ratio of the light output of the lamp to the power it requires.
- **Colour temperature** (K) is a measure of the warmth or coolness of the lamp. A warm white fluorescent lamp will typically have a colour temperature of 3000K and will appear slightly yellow in colour. Daylight lamps are around 5500K.

Luminaires also have a set of measures that describe their performance:

- **Light output ratio** is the ratio of the luminous flux output of a luminaire to the luminous flux output of its lamp.
- **Maintenance factor** is the ratio of the illuminance provided by an installation at a stated period, compared to the installation when new.

Incorporating as many of these measures as possible should ensure that the lighting design is carried out in sufficient detail that it is suitable for purpose and low energy in operation.

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### 3.3.1. Common design targets

As stated above a range of targets are often specified early in the design process. These targets vary but typical targets used are:

- EPC rating (Energy Performance Certificate)
- BREEAM
- Percentage improvement on elements of the building standards.

These targets assist in the process of designing a low carbon building but they will not ensure that the building operates well. The EPC is based on the intended design of the building and does not evaluate how the building can operate in practice. The EPC is not designed to identify any problems introduced during construction such as gaps in insulation or unintended thermal bridging.

Similarly, BREEAM has driven some good design behaviour but historically has been based on the design and not the operation of a building. While BREEAM addresses a wide range of sustainability measures, it can only concentrate on a small number of energy targets. An Outstanding BREEAM rating will not necessarily result in a building that has a pleasant internal environment and is low carbon.

Finally, Figure 7 illustrates that setting building targets in a percentage improvement on building regulation will only influence some of the parameters dictating the eventual energy use.

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### 3.3.2. Existing operational targets

In England and Wales public buildings used by the community are required to have Display Energy Certificates (DECs) produced annually. These certificates show an operational rating for that building based on its actual energy use adjusted for weather and benchmarked against similar buildings. This can be of great assistance in evaluating potential operating costs when acquiring or leasing a building.

The Carbon Trust report “Building the Future Today” (6) recommends that the requirement for DECs should be applied to all non-domestic buildings by 2015. At present Scotland has no operational energy targets, yet some organisations in Scotland voluntarily conduct their own operational ratings to allow them to better manage their existing building stock.

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Whitecross School in Herefordshire is a good example of what can be achieved when low carbon is addressed in a systematic way early in the project life. It was built under a PFI arrangement by Stepnell.

It uses half the energy of similar schools and has an internal environment in the classrooms with good levels of daylight, high thermal comfort and well controlled ventilation.

Since it opened there have been hot summer days where the majority of local schools have had to close due to excessive temperatures and Whitecross has remained open and pleasant to work in.

The only complaint is that it has a slightly utilitarian feel in some areas but this is outweighed by the benefits of the high-quality internal environment and its influence on the learning environment.
3.4. Operational targets (continued)

The introduction of operational design targets can assist design and construction teams to deliver a building that operates in an energy efficient manner.

An issue that is sometimes highlighted by design teams is lack of guidance on detailed environmental design requirements provided by clients. Design teams are normally provided with the user requirements for room layouts, furniture and physical adjacencies but environmental conditions or building service requirements tend to be minimal with no distinction of room types. To help designers ensure that a building is fit for purpose, further guidance is required describing the internal environment required for the building. This will normally take the form of an overarching technical brief and detailed room data sheets with supporting schedules.

On the other hand, operational targets should not be a straitjacket for designers. A blanket approach that does not allow flexibility or discussion between a prospective design team and the users has often led to a building that becomes unnecessarily expensive and more complex to operate.

3.4.1 What they can achieve

Operational targets have been seen to improve the process of designing a building.

New South Glasgow Hospital
Use of operational targets in this project has changed the way the project team discuss options. Both cost and the carbon impact are now considered when design changes are proposed.

3.4.2 What they are

Operational targets are measures of building and equipment performance that are easily defined without ambiguity, are measurable and should be enforceable. One of the challenges with targets is to ensure that responsibility for delivering the target is clearly defined. They should also not be so onerous that they are unreasonably expensive to implement. They typically cover aspects including building fabric losses, internal thermal gains, energy for services, overall carbon emissions and internal environmental conditions.

Figure 9. Although daylight levels are good, they are not displacing the artificial lighting demand.

3.4.3 How they are used

Initially the types of high-level targets that are to be used should be set at project inception.

The values for these high-level targets are then set out in an overarching technical brief (OTB) or combined into the project brief. This is described further in the project manager’s guide. It should specify each target in a reasonable level of detail and describe how it is to be applied. For example, a target air tightness of 3 m³/hour.m² façade at 50 Pascals is easily measured by air pressure testing and will ensure unplanned ventilation is minimised.

Compulsory air pressure testing is being phased in over 2011. Section 6 of the Building Standards Technical Handbook outlines the requirements.

There are some buildings in Scotland that have been built to the PassivHaus standard with air leakage rates of less than 0.6 m³/hour.m² façade at 50 Pascals.

How these targets are applied will depend on the contracting structure. The Scottish Futures Trust (SFT) published an invitation to tender in February 2010 for a design team for the Lasswade & Eastwood High Schools Joint Project. The intended project structure was a design and build contract using competitive dialogue. The project brief contained a number of high-level energy targets. Introduction of these targets at the earliest possible stage of the project should ensure that the tenders received properly address the sustainability aspects of the building.
Some extracts from the SFT project brief:

“The overall aim is to achieve a building that meets EPC B+ before the addition of ‘renewables.’”

“Energy in all spaces larger than 20m², occupied for more than two hours/day shall be not more than 2.4W/m²/100 lux. Unless specified, the maximum light level from indoor artificial lighting shall not exceed the required lighting level by more than the sum of 40 lux + 30% of the required lighting level at any point in any space larger than 15 m².”

“Boiler standing losses shall not exceed 20% of the heat input on an annual basis.”

More detailed targets for individual rooms should be included in the room data sheets (RDS) and their supporting environmental schedules. These describe a wide range of parameters for each room such as minimum and maximum lighting levels and room temperature parameters.

The room data sheets detail specific requirements for each room. These may include temperature requirements, minimum and maximum lighting levels and acoustic limits. This is discussed further in the project manager’s guide.

The building commissioning process and defects period needs to accommodate the greater use of targets. Commissioning needs to be considered in detail at the beginning of the design process to ensure that the necessary aspects for the buildings can be monitored either through continuous or spot monitoring.

It also requires a longer commissioning period to allow the building to be tested over a greater range of weather periods and operational conditions and to allow the required monitoring to take place.

The Soft Landings Framework developed by an industry taskforce led by BSRIA (7) recommends a number of measures to improve the building handover process. These include extending the duties of the delivery team during and in the weeks immediately after the handover, for the first year of occupation and for the second and third years. With this approach, issues identified during the first year of occupation are dealt with in the defects period and those identified after this time are used to educate further projects. Optimally the defects period should be extended beyond one year to allow all issues to be identified and rectified.

Another possible structure is to use a design, build and operate structure where the contractor remains responsible for the operating costs of the building until the Operational Targets are met.

3.5. The characteristics of a successful client

With the increasing complexity of our buildings, the skills and processes required to procure a sustainable building are continually changing and increasing.

3.5.1. Understanding of the users

The intended users of the building must contribute to the successful delivery of the project. The users include the eventual occupants of the building, visitors to the building and those who will be responsible for its operation and maintenance. The greater the understanding of the users’ needs and priorities, the more likely that the building will be capable of meeting their needs. One important aspect that can be omitted is their willingness to adapt to different working environments such as more flexibility in clothing policy allowing for warmer room temperatures in summer and cooler temperatures in winter and their willingness to accept cooler temperatures in corridors and thoroughfares.

Part of obtaining an understanding of their needs usually includes providing some training on climate change, sustainability and adaptive comfort.
3.5.2. Understanding of procurement team

The client procurement team needs to be able to:

- Understand the user requirements and to provide the design team as detailed a specification as possible for the building that they want to procure
- Ensure that the building they are given meets the initial criteria that they set.

The greater the level of specification at the beginning of the project, the more likely that they are to end up with a building that provides a productive workplace and is cost effective to run.

3.5.3. Skills

In order to achieve a higher level of specification, the procurement team needs to have a wide range of skills available to them. Frequently knowledge gaps exist within procurement teams in the following areas:

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<tr>
<th>Aspect</th>
<th>Skills and knowledge</th>
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<tr>
<td>Architectural</td>
<td>Passive design</td>
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<td></td>
<td>Thermal mass</td>
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<td>Air tightness</td>
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<td></td>
<td>Day-lighting and brightness to reduce artificial lighting</td>
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<td>Design for low summertime overheat</td>
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<td></td>
<td>Facade modelling</td>
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<td>Space planning and massing</td>
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<td>Allowing for appropriate internal heat gains</td>
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<td>Ceiling shapes that give good acoustics</td>
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<td>M&amp;E</td>
<td>Interaction with architects to improve the fabric design</td>
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<td>Interpretation of daylight modelling</td>
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<td>Thermal &amp; ventilation modelling</td>
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<td>Seasonal operational efficiency of heating and cooling plant</td>
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<td></td>
<td>How building services are controlled with their integral controller and BMS to minimise energy use</td>
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<td></td>
<td>User appropriate BMS systems</td>
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<tr>
<td>Finance</td>
<td>Whole-life costing</td>
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<td>Single action – multiple benefit</td>
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Where these skills are not present in the client team it can result in dependence on external advisers who are responsible for delivery of the building and who therefore may not have their interests fully aligned with the clients.

If a knowledge and skills gap analysis is carried out at the start of the process of procuring a building, any training needs or external advisers’ requirements can be identified. Where external advisers are used to fill these knowledge gaps, it is beneficial to ensure that they are independent of the building delivery team.

Similar knowledge and skill gaps occur within design teams as is evidenced by the variations in quality of Scotland’s newer building stock. A knowledge and skills gap analysis can be used during the selection process to ensure that the design team is competent to deliver the required building.

3.5.4. Tools

The procurement team can also benefit from having a range of tools to assist them. This is particularly true of refurbishments where they can be used to gather information and model the state of the existing building to enable the most beneficial improvements to be identified. They can also assist during the construction and commissioning period to ensure that the insulation and air tightness is at the required standard.
Thermal imaging

A thermographic survey of an existing building can identify a wide range of issues such as gaps in building fabric insulation, inadequate u-values, thermal bridging and problems with water ingress. On completion of a new build or a refurbishment, a thermographic survey can ensure that the integrity of the insulation is at the required standard and that there is no unintended thermal bridging.

Dynamic thermal simulation

There are a number of software packages available that allow dynamic thermal simulation of buildings. The building geometry is modelled and the orientation, building fabric, services and occupancy are entered. The software uses detailed local weather data to determine the building’s likely performance for a set interval, usually at least every hour if not shorter, during a typical year. They can also check for overheating under different global warming scenarios. In most cases, the software can be used to generate Energy Performance Certificates and building regulation compliance reports.

Pressure testing

Pressure testing involves sealing any ducts or vents and pressurising the building using a fan. The rate of air leakage can then be tested. This can be combined with a smoke test to determine where the air leakage is occurring.


Some software packages can also carry out Computation Flow Dynamic (CFD) analysis of a room or a building. Where a building plans to use a natural ventilation strategy CFD analysis can confirm that the strategy is likely to work.

Wind tunnel testing

Another method of testing the effectiveness of a natural ventilation strategy is to use a wind tunnel to test the flow of air through a model of the building.

Daylight and artificial lighting simulation

There are a wide variety of packages available that can simulate daylight and artificial lighting strategies including some that are available for free. They model the impact of the sun path on the building allowing solar contribution to lighting requirements to be assessed. These can be used to determine the levels and uniformity of daylight in each room. They can also be used to predict lux levels from artificial lighting and to test artificial lighting layouts and controls. Some dynamic thermal simulation software packages have day-lighting and artificial lighting modules available so the thermal gains from the lighting and the daylight can be correctly incorporated into the simulation.
4. Cost and time implications

To deliver a building that is low carbon and has an appropriate internal environment requires a rebalancing of capital spending to allow more time for design. There may also be a minor overall increase to capital costs, however, this should be outweighed by the resulting reduction in the revenue budget.

To achieve a low carbon building and productive workplace significant amounts of effort are required at RIBA stages A to E to ensure that the initial options considered are properly evaluated and the design encompasses all of the required low energy features. This will require additional expenditure both for design and to ensure that sufficient time is allowed for the architect and M&E engineer to discuss energy saving opportunities and to carry out the necessary modelling.

The impact on revenue expenditure of implementing a low carbon strategy should more than justify any additional expenditure. This is explored in more detail in the whole-life costing section below.

4.1. Capital cost implications

There is a range of estimates that have been published on the capital cost impact of achieving a low carbon building.

A report (8) was commissioned by the Building Standards Division of the Directorate of the Built Environment of the Scottish Government to investigate the cost of improving the energy efficiency of non-domestic buildings against 2007 building regulations. The report investigated the costs of energy efficiency improvements to four different buildings: a primary school, a secondary school, a city centre office and a retail warehouse. It is estimated that CO₂ reductions of 23.5 – 32.1% could be achieved for a 1.8 – 2.8% increase in capital cost and CO₂ reductions of 27.7 – 43.8% were achievable for a 2.9 – 5.7% increase in capital cost.

There is evidence from the schools building programme that significant operating cost savings have been achieved with minimal capital cost implications:

- The Angus Council Seaview Primary School project discussed in Section 2 achieved a 49.8% saving for no capital cost premium.
- Whitecross school in Herefordshire has an energy consumption of 50% of typical new build secondary schools for a 0.7% cost increase.
- Inverclyde Council has recently built four schools that encompassed many of the principals discussed in this document. They incurred a 4% increase in capital and expect to achieve a 30% reduction in operational energy usage.

Most of these projects have in common that decisions on the design and value engineering were made in favour of productivity and low carbon at the expense of other aspects.

It should be noted that some of the additional costs of a low carbon building come from the increased design and professional fees required at the beginning of the project. These fees allow the design team to spend more time finessing the building orientation and design in the first stages of the project. The architect and the M&E engineer will need to carry out more iterations of the dynamic thermal simulation and the lighting models, experimenting with different options to optimise the design. Depending on the project, additional fees may also be required to give the design team access to a particular expertise such as an acoustics expert.

Figure 15. All Saints Primary school, Inverclyde dining room with good daylighting, insulation and air tightness.
4.2. The true cost of low carbon measures

During the research for this guide, it became apparent that there was a wide variety of opinions as to how the low carbon elements of a building should be valued.

Some organisations use a simple payback methodology to assess options whilst others use whole-life costing with a variety of different components included. To properly evaluate the benefits of an energy efficiency measure whole-life costing must be used. It is also a legislative requirement that public bodies use whole-life costing.

The Best Value requirement on public bodies gives clear guidance as to how options should be appraised. This is specified in a variety of documents including the Treasury Green Book (9), the Scottish Procurement Construction Manual (10) and the Scottish Public Finance Manual (11).

4.2.1. What to include

ISO 15686 Part 5 (12) describes a comprehensive method for calculating whole-life costs for a building. The process involves evaluating all costs involved in:
- Acquisition and construction
- Operation and maintenance
- End of life costs and residual value.

The following diagram shows the typical elements that organisations have failed to include within whole-life costing:

Figure 16. Whole-life costing issues.

4.2.2. Forecasting techniques

The QS will need to know forecasts for any items whose prices will not escalate with inflation. This includes energy and carbon prices.

Historic data from the Department of Energy and Climate Change document “Quarterly Energy Prices” table 3.3.2 (13) demonstrates how delivered energy prices have changed over the last ten years. The following graph shows those rises on a real basis (with the effects of inflation removed) based on an index year of 2000.

Figure 17. Energy Price Increases.

Linear regression shows that this is equivalent to a year on year increase of:
- 10% for electricity
- 15% for gas
- 20% for heavy fuel oil.

This clearly demonstrates that assuming fuel prices will increase with inflation is inappropriate and will undervalue energy efficient solutions.

These increases are set to continue due to issues with global energy supply, increasing demand, requirements for investment in generation and distribution infrastructure and increasing legislation affecting energy production.

The project owner’s guide in this series proposes the use of a forecast for energy prices. Either this should be based on an annual escalator or a forecast purchased from an energy price forecasting company.
5. Conclusion

There is considerable scope for improving the quality of the buildings that will be built over the next few years to ensure that they have a good internal environment and are affordable to operate. This will require changes to the procurement process, in house and external team member skills and construction techniques.

This document has highlighted a wide range of problems including:

- High operating costs
- Overheating
- Glare
- Acoustics issues
- Ventilation problems.

A number of exemplar buildings have also been identified where an excellent working environment and low operating costs have resulted from the use of an appropriately skilled team and a well-planned design.

The problems can be avoided by following a few simple steps. The Carbon Trust has created a suite of guidance documents and tools to assist this process. These include a project owner’s guide; a project manager’s guide; tools to help evaluate team members’ and bidding parties’ skills, knowledge and experience; templates for agendas and meeting report and documents to assist in the detailed specification required.
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7. Definitions and acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
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<tbody>
<tr>
<td>CABE</td>
<td>Commission for Architecture and Built Environment</td>
</tr>
<tr>
<td>LIFT</td>
<td>Local Improvement Finance Trust</td>
</tr>
<tr>
<td>BEMS</td>
<td>Building Energy Management Solutions</td>
</tr>
<tr>
<td>LZCT</td>
<td>Low and Zero Carbon Technologies</td>
</tr>
<tr>
<td>BREEAM</td>
<td>Building Research Establishment (BRE) Environmental Assessment Method</td>
</tr>
<tr>
<td>PFI</td>
<td>Private Finance Initiative</td>
</tr>
<tr>
<td>BSRIA</td>
<td>Building Services Research and Information Association</td>
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<tr>
<td>BMS</td>
<td>Building Management System</td>
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<tr>
<td>RIBA</td>
<td>Royal Institute of British Architects</td>
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The Carbon Trust is a not-for-profit company with the mission to accelerate the move to a low carbon economy. We provide specialist support to business and the public sector to help cut carbon emissions, save energy and commercialise low carbon technologies. By stimulating low carbon action we contribute to key UK goals of lower carbon emissions, the development of low carbon businesses, increased energy security and associated jobs.

We help to cut carbon emissions now by:

- providing specialist advice and finance to help organisations cut carbon
- setting standards for carbon reduction.

We reduce potential future carbon emissions by:

- opening markets for low carbon technologies
- leading industry collaborations to commercialise technologies
- investing in early-stage low carbon companies.

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