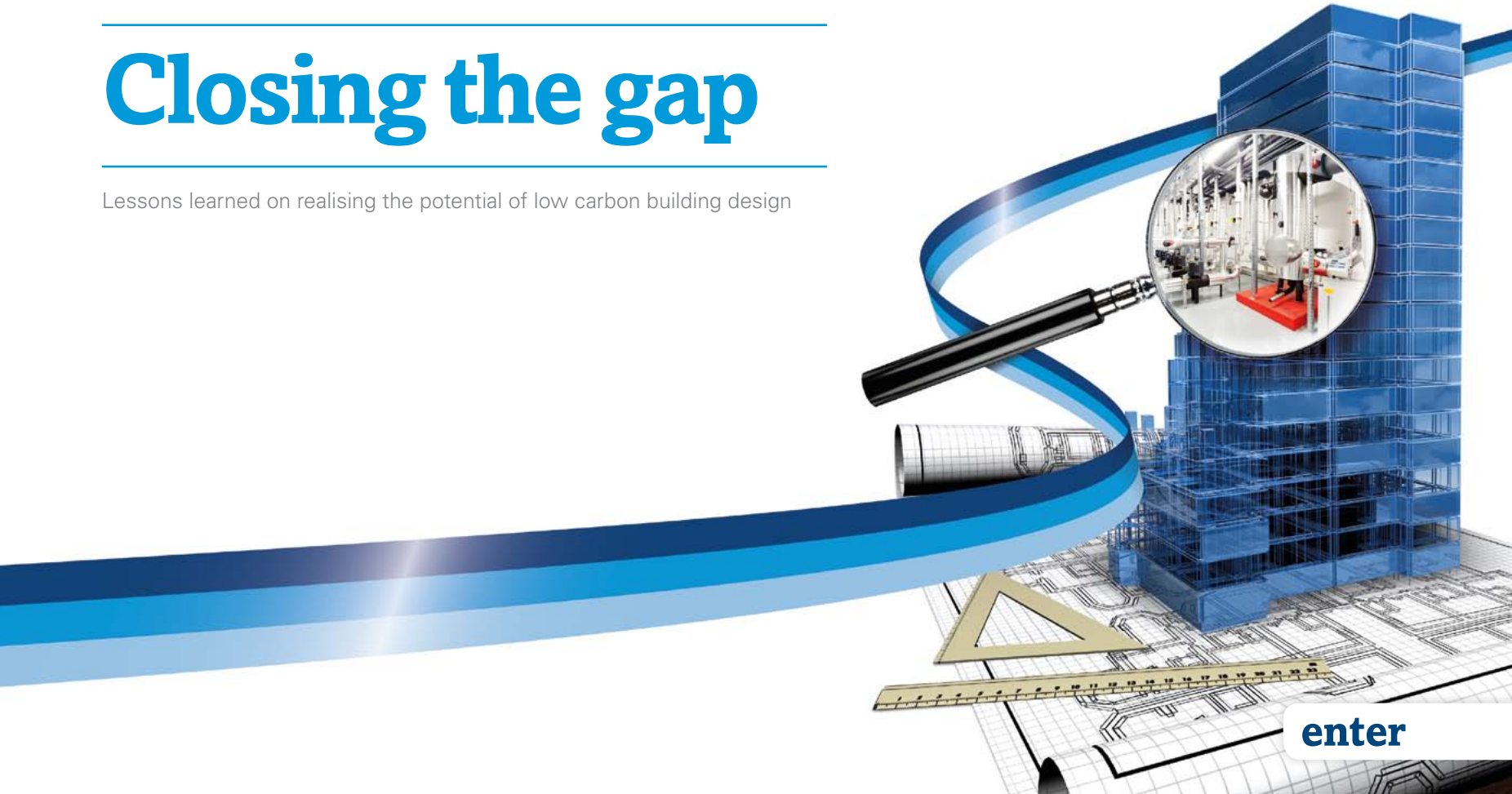
CARBON TRUST
Making business sense of climate change

Closing the gap

Lessons learned on realising the potential of low carbon building design



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> “For our case study projects, the operational energy use was up to five times higher than estimates during design. There is an opportunity to close this gap and save money and carbon”

Sharing our experience: About this booklet

Closing the gap is part of the 'Sharing our experience' series. These booklets provide advice and tips to help you plan, build and manage cost-effective low carbon buildings that really work to save you money and carbon.

The insights are based on real data from 28 case studies from the Department of Energy and Climate Change's Low Carbon Buildings Programme and our work on refurbishments. The projects cover many sectors including retail, education, offices and mixed use residential buildings.

Further information

To find out how we can help with your low carbon building project, contact us on 0800 085 2005 or visit www.carbontrust.co.uk/buildings

Understanding the performance gap

A low carbon building needs to deliver on its design expectations. The gap between predictions and real performance can be very large. Only the right approach will close the gap and save you money when running your building.

What is a low carbon building?

A low carbon building is one that uses significantly less energy and emits less carbon than current industry benchmarks while providing a comfortable and productive space.

Evidence from our research suggests that a low carbon building is not necessarily one which costs more to build, but it should certainly be more cost effective to operate.

But evidence from our case studies also shows that, when comparisons to relevant industry benchmarks were made, 75% of case study designs did not perform as well as expected.

Meeting expectations

This booklet helps you recognise and address the issues that create the gap between design and performance across the entire process of creating a low carbon building.

Measuring up

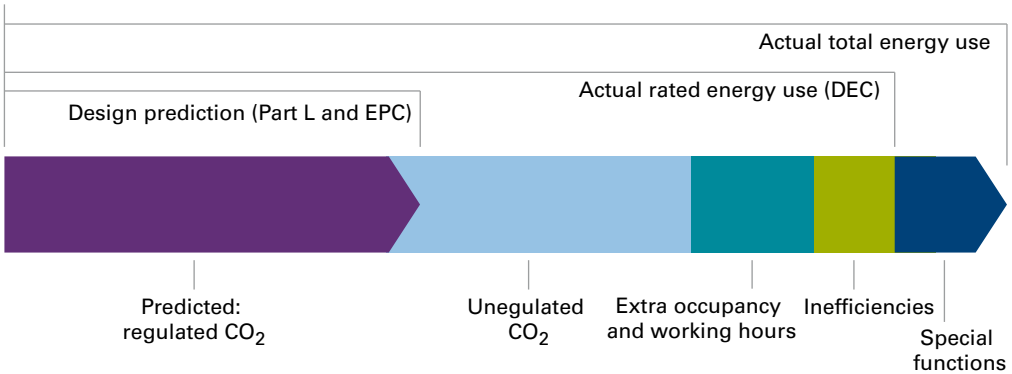
There are a few common metrics to understand if you are to assess whether you have a low carbon building.

Part L of the Building Regulations requires that you calculate a building's CO_2 emission rate (BER) expressed in $kgCO_2/m^2/year$. It is calculated from the energy used for heating, ventilation, cooling and lighting systems, based on standardised occupancy, and the carbon intensity of the energy used. A software tool, such as Simplified Building Energy Model (SBEM) or Dynamic Simulation Model (DSM) or Standard Assessment Procedure (SAP) for dwellings is used to calculate the BER.

This BER is also used to calculate the A to G rating on the Energy Performance Certificate (EPC). An EPC is required when a building is constructed, sold or let. But as *Figure 1* demonstrates, the BER and EPC ratings do not pick up all energy use in a real building.

A Display Energy Certificate (DEC) has an A to G rating representing the in-use carbon performance of your building. A DEC is calculated after measuring 12 months of metered energy use and takes into account all energy uses in the building, allowing for only minor exclusions. So currently, it cannot be compared to an EPC rating.

Figure 1 Design predictions for regulatory compliance don't account for all energy used in a building (adapted from Carbon Buzz)



- Regulated energy use includes modelled heating, hot water, cooling, ventilation and lighting
- Unregulated energy use includes plugload, server rooms, security, external lighting, lifts, etc
- Extra occupancy and equipment and extra operating hours (e.g. evening/weekend working)
- Inefficiencies from poor control, bad commissioning, bad maintenance, etc
- Special functions (separable energy uses) include trading floors, servers rooms, cafeteria, etc

How big is the gap?

Predicting the energy performance of a new or refurbished building is complex and often not accurate.

On one case study project the modelling for Part L and the EPC underestimated actual energy use in the first year by five times. Even when, on other projects, more detailed modelling and benchmarking was done, the gap averaged 16%.

You should be very cautious about assuming that the output of modelling aimed at demonstrating compliance with regulations will indicate actual performance. *Figure 2* illustrates the significant gap which occurred for some of the case study projects.

Cost impacts

In the worst case recorded, the gap between design and performance added over £10/m^2 in unexpected annual operating energy costs.

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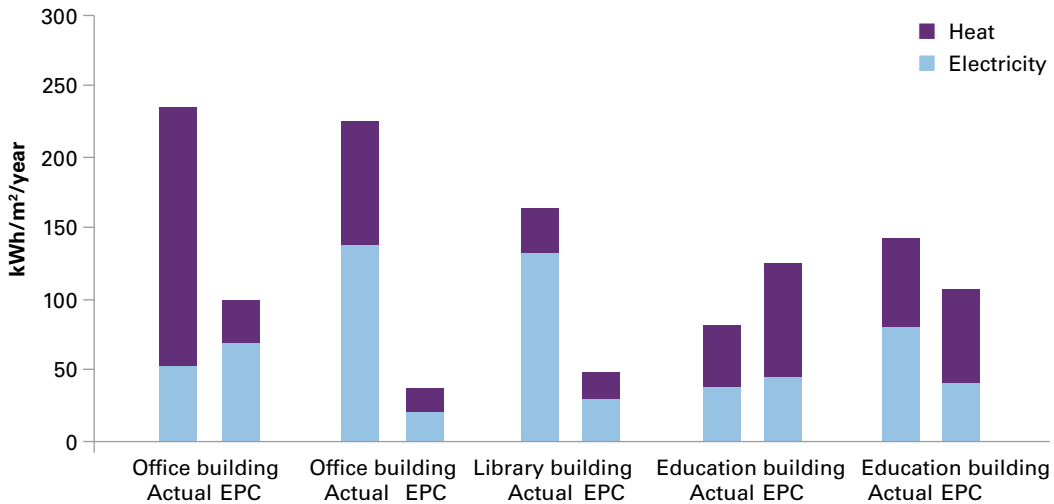
Why do good intentions not translate into low carbon buildings?

Our research shows that despite genuine intentions to develop a low carbon building, these often fail to translate into reality. This is due to issues that can occur at all stages of a project, from inception to completion, including:

- the aim to make the building low carbon in-use is not clearly conveyed to the design team
- predictions during design were inadequate
- designers do not robustly test the design at regular stages through the process
- building controls and systems are overly complex
- design intent is not delivered on-site during construction
- commissioning is inadequate or not completed satisfactorily
- there are insufficient means of measuring and managing the building systems' performance once operational
- the designers/constructors are not involved after the building has been completed.

Figure 2 A comparison between actual regulated energy consumption and the output of modelling, used to generate the EPC rating for five case study buildings



- The building is not operated properly by the facilities team or occupiers

However, if you are clear about your low carbon objectives at the start of the project and understand what these objectives mean in terms of budget, time and resources throughout the project, you will significantly increase your chances of success.

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Managing projects

We found that the way you manage your building project can have as much, or more, influence on low carbon outcomes than the technology you install.

Making your ambitions clear

You will need to make sure that the design team are clear from the outset that a key ambition for the project is to deliver a building that is low carbon in-use.

This means they should begin to consider total energy consumption rather than the more typical approach of purely focusing on complying with Part L of the Building Regulations.

Assigning responsibility

You should make sure that someone can provide impartial low carbon advice directly to you as the client. The specific appointment of a low carbon specialist would satisfy this need, but it may be that the building services consultant could offer this advice as long as they are not novated to the contractor during the detailed design stage.

Evidence from the case studies shows that it is important to have an individual or organisation with a long-term involvement in making sure the building is low carbon in operation and to make someone responsible for this throughout the process. Someone should also be responsible for seeing that the low carbon design intent is accurately transferred between parties such as designers and contractor.

Case study

Ceredigion County Council

Ceredigion County Council's design manager for their new office project now works in the new building and is part of the same team of individuals who operate the building. He also had prior experience with biomass heating on smaller low carbon projects for the Council. His experience and long term buy-in has proved to be a key success factor in ensuring the building is low carbon.

Lessons learned

- Set low carbon in-use as a goal.
- Consider appointing a specialist with responsibility for driving the low carbon goal throughout the project if you don't have one in-house.
- Make sure that the design intent is maintained in the transfer to the contractor and from the contractor to the sub-contractors.
- Make sure contracts specify that the contractor and/or designers are engaged after handover to fine-tune the building and ensure low carbon operation.
- Allow for time and resource for the additional activities that will drive a low carbon outcome throughout the project.

Transferring design intent

The aspiration for a low carbon building can be lost in the transition between the various stages of the project. This can be a particular problem, where the two stages involve different people or organisations, such as the handover between designers and the construction team.

Regardless of your procurement approach, having a robust design to take to market is very important. Some forms of procurement, such as design and build, require a greater degree of interpretation by the contractor than others. This in itself is not a problem but the design intent must be fully understood by the contractor, their designers and sub-contractors so that the necessary interpretation does not result in a "watering down" of the design intent.

Making the in-use energy consumption target a contractual obligation may be difficult, as this will present an additional risk for contractors. It may only be possible where they have a longer term interest in the building and in demonstrating it is low carbon in-use.

"Low carbon buildings will become routine, but they aren't yet, so there's a need for an expert as part of the design team"

Derek Quilter, Bath & North East Somerset Council

Extending contractor involvement

One way to make sure that the contractor is involved in the long term is by making it a contractual requirement that they and the design team remain engaged with the building for some time after occupation. The 'Soft Landings' initiative promotes just such an approach.

At Edge Hill University, continuing involvement by the contractor in on-going projects on the campus meant they were around to assist in resolving minor operational issues with the Faculty of Health building and tuning systems.

Figure 3 *The relative cost and impact of a variety of measures which a client might take to deliver their low carbon buildings aspirations*

Additional key activities

There are many things you can do during the procurement process that may cost a little more up-front, but pay dividends later. To help you prioritise, we have set out some in *Figure 3*. Remember that every building is different and this may not reflect your situation exactly, as some activities may have more value in the context of one project than another. The key is to take advice from your team when looking at where value can be derived without compromising performance. *Figure 4* describes the activities in more detail.

Figure 4 ***Measures which a client might take to deliver their low carbon buildings aspirations***

Activity	Description
Feasibility study for low carbon technologies	This exercise looks at a full range of renewable and low carbon technologies and determines which are likely to be the most appropriate for the building in terms of cost, energy and carbon saving.
Predicting performance	Initially using benchmarks and later bottom-up modelling, this helps to focus the design team on your low carbon in-use aspirations and gives you something to measure performance against once the building is operational.
Full dynamic modelling	Full dynamic modelling of energy use in the building is particularly useful at the design stage for comparing a variety of options to determine which is relatively better or worse for your building.
Carbon reviews	Every time you review the cost plan, you should review the energy performance and key features of the design to ensure that the aspirations are still intact.
Low carbon consultant	A low carbon consultant, appointed at the very start of a project and retained throughout, can ensure the focus on your low carbon in-use aspirations is maintained.
Metering strategy	An effective metering and monitoring strategy describes what you are metering and allows you to understand the breakdown of energy use in your building and take action to improve outcomes.
Independent commissioning engineer	An independent commissioning engineer will ensure that all of the various parties not only set their own equipment to work properly but that complex, integrated systems work with each other effectively.
Soft Landings	This BSRIA framework allows a graduated handover of a building, designed to help you in the transition from handover to occupation and to extend designer and contractor involvement beyond the handover period.
Seasonal commissioning	Commissioning building systems , such as heating and lighting, at a number of key points during the year (rather than as a one-off event at handover) will help ensure they perform at their best.
Post Occupancy Evaluation (POE)	Extremely useful, both as a method of formally reviewing the energy and carbon performance of the building, and to gauge whether employees and occupants are satisfied with the building.
Training of Facilities Management team	Essential for the efficient operation of the building, this process should not be compromised by time constraints and should be allowed to continue beyond initial occupation if necessary.

Design for performance

The design process should have low carbon 'performance in-use' as one of its key drivers. Without this focus, your building will be a matter of chance rather than design.

Occupant feedback and client input

During the concept design process, you'll be heavily involved in conveying the vision of your new building to the team. For the design team to work toward the right low carbon outcome, you will need to share key pieces of information through briefings, consultations and your formal Employers Requirements, including:

- the level of occupation in the building
- the hours of use of the building
- the level of expertise of the operation and maintenance staff
- the size of any specialist areas and their servicing requirements
- the level of flexibility you want once the building is operational
- any planned changes to your working practices
- any specific energy/carbon performance targets
- key outcomes for the building or wider project.

Providing feedback from existing buildings you own or occupy and any contemporary buildings with good performance you would like the team to investigate is also useful. This may help to challenge assumptions and conflicts in the brief.

Case study

Changing parameters

One of the case study buildings was treated as a school when looking at energy in design but they are now actively encouraging community use of the building in the evenings and at the weekend. This lack of clarity about the level of occupancy at the earliest stages of design means that the benchmarks they have to test whether the building is operating as expected will be incorrect and benefits of some energy efficiency measures underestimated.

The influence of occupiers

Whilst designers can influence many aspects of the building that determine low carbon outcomes, there are still important areas that only the occupiers can influence. *Figure 5* shows the different aspects that designers and occupiers can influence. For example, energy-intensive ICT equipment will have a significant effect on the internal heat gains in the building (requiring more cooling) as well as increasing the electricity use.

Hampshire County Council switched to 'thin-client' computers to reduce the heat gain in the space, which enabled the use of a low energy natural ventilation strategy.

Figure 5 ***Impact of building designers and occupiers on energy***

Building occupiers can influence	Designers can influence
• Behaviour of the occupants in the new building. • Hours of use of the building and the plant/equipment. • Facilities management, including re-commissioning, maintenance, and so on. • Significant change of use. • Amount and use of PCs, printers, chargers, vending machines, compressors, tools and so on	• Controls that have good feedback on whether they are working. • Mix of automation and manual control so not reliant entirely on occupants to control building. • Intuitive design that doesn't need lots of explanation. • Installed capacity of plant/equipment. • Choice of appropriate technology for likely operators. • Complexity of design. • Metering strategy. • Commissioning and handover. • Robust and flexible design that can accommodate changes of occupant/uses

Predicting performance

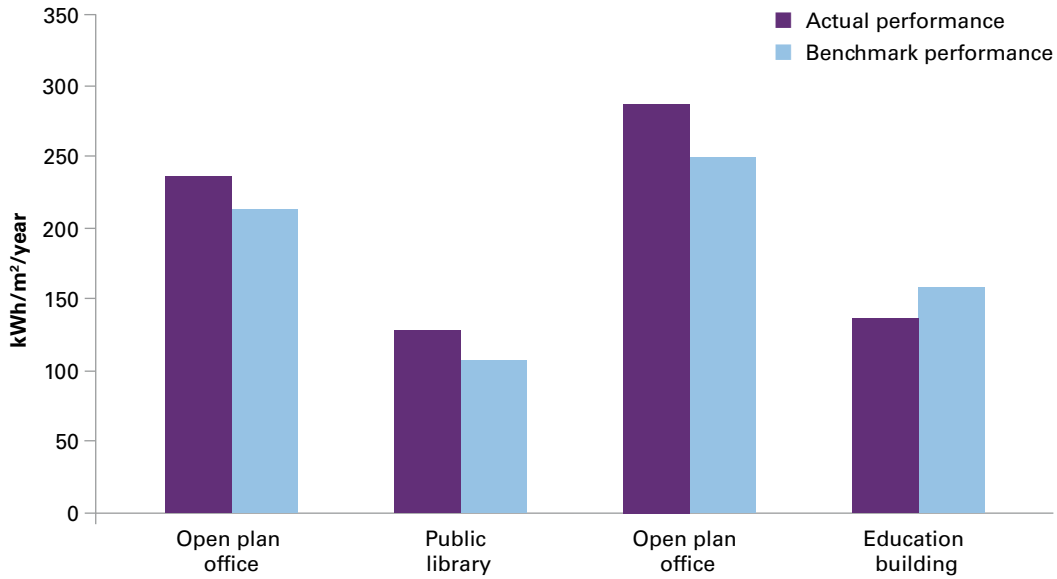
To determine whether the building you are procuring will be low carbon, you need to predict its likely performance at various stages through the design and construction process and then ensure you can monitor its performance in operation to allow you to fine-tune and reduce energy consumption.

Don't underestimate the complexity of developing accurate predictions. You should highlight this as a key task at the earliest stage of design. Also be aware that predictions of energy use are inherently limited as factors like weather conditions vary from year to year.

Using benchmarks

The best way to begin to understand potential performance is to use benchmarks for the type of building you are developing. When we looked at the buildings we studied that had used benchmark-based predictions, we found they were accurate to within about 15%.

Figure 6 Chart showing a comparison between energy benchmarks for four case study buildings and actual energy use form the monitoring data for each site



Using modelling

Following on from the early work carried out at concept stage, the designers should develop and use energy models which will assist them in the design process.

Each type of model has its strengths and the various types will be suitable for different tasks throughout the life of the project, as shown in *Figure 7*.

What to expect from your design team

Unless you ask for it, designers are unlikely to predict operational energy use. Typically, energy modelling will be undertaken during design only to demonstrate compliance with Building Regulations.

Our experience on refurbishment projects shows that by requiring the team to go through the process of developing predictive models, there will be a clearer focus on in-use performance, which is rarely the case if this exercise is not undertaken.

If you want a low-carbon building, make sure your design team produce this prediction and update it throughout the design by writing the requirement explicitly into their scope. Detailed modelling may incur a small additional cost.

This work will generally fall to the building services engineer, but you should make sure other members of the team provide their full support to this process.

Staff responsible for energy and carbon once the building is operational should understand how the predictions have been derived (even if they don't understand the details of the modelling itself). This will allow them to examine the various energy uses of the building in-use discretely and see where consumption differs from predictions in order to understand why, and what to do to improve performance.

Case study
Metering strategy

Despite being one of the smaller case study projects, one building was provided with 12 meters, only four of which provide useful data. This was due to a lack of a clear metering strategy, inadequate training of maintenance and facilities staff, and poor commissioning.

CarbonBuzz

You can use resources such as CarbonBuzz to compare predictions from other actual buildings and benchmarks. CarbonBuzz is a collaborative project between CIBSE and RIBA.

www.carbonbuzz.org

Figure 7 Types of energy modelling

	Type of modelling	When to use	When to avoid
Static calculations	• Generally used to size major items of plant and equipment • Used to determine peak load associated with the system being examined • May be all that is offered by designers	• When sizing plant for non-cooling systems	• To predict energy consumption in-use
Compliance modelling	• Mandatory requirement for compliance with Building Regulations • Produces Design and As Built Energy Performance Certificate (EPC)	• When demonstrating compliance with Building Regulations • To assist in ensuring quality of construction meets design requirements	• If trying to predict in-use performance of whole building or specific systems
Bottom-up modelling	• Uses installed capacities and usage to calculate energy consumption • Generally the most accurate at predicting energy consumption	• When attempting to create a detailed breakdown of end-use energy consumption • To predict in-use energy consumption	• For sizing of plant • For comparing the relative merits of various design options
Dynamic thermal modelling	• Advanced method of simulating internal conditions of the building over time, based on 3D model of building including fabric, equipment, internal heat loads, solar gain etc	• For comparing the relative merits of design options (optioneering) • For the sizing of cooling plant	• When trying to predict energy consumption in-use • When modelling buildings with unpredictable occupancy levels

Reducing design complexity

When designing a low carbon building, there's a temptation to install as many low carbon technologies as possible.

In our research, all projects which over-complicated the building by installing multiple low carbon technologies as well as conventional systems failed to meet their performance goals in their first year of operation. This is especially true where more than one technology is part of the same system, such as heating.

Wherever possible, simplicity should be the aim of the design whilst still delivering the performance you require. However, whatever the level of complexity, it is essential that the control systems and monitoring tools are carefully considered and designed to assist in the efficient operation of the building rather than simply fulfilling the requirements of a compliance process.

Control strategy is key

The control strategy regulating the operation and interaction of the various systems in the building should be designed as a whole, rather than the controls for each system being considered individually.

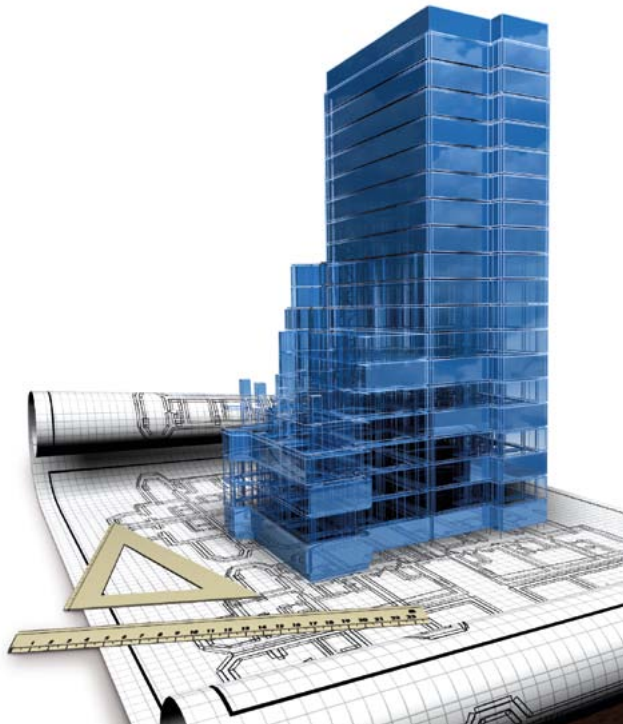
In one case study, a back-up gas boiler is providing most of the heating for a building instead of the lower carbon sground source heat pumps, because the control system was not set up to prioritise between the heat sources.

The controls system should be designed to be easily operated and maintained by those who will look after and use the building. It is counter-productive to make them any more sophisticated than necessary.

Low carbon control

The hot water system of one public building is supplied with heat from four different sources: ground source heat pumps, solar thermal arrays, gas fired boiler and an electrical immersion element. Ensuring that the control system meets the demand for heat whilst minimising carbon emissions is extremely complicated and has not been achieved in practice. It is unlikely that it will now be resolved as poor monitoring means it is not clear which technology is supplying the heat at any one time.

> “Wherever possible, simplicity should be the aim of the design whilst still delivering the performance you require”



Lessons learned

- Provide feedback on your existing buildings, learn from good results and don't repeat mistakes.
- Use energy benchmarks at the earliest stages of design.
- Predict and discuss energy performance in-use, create breakdowns and carbon budgets throughout the design process and complete the building log book.
- Monitor progress through regular communication with the team and track issues relating to energy and carbon performance
- Challenge the use of complex solutions, understand how they will be controlled, operated and maintained.
- Ensure a metering strategy is produced to allow you understand the operation of the building.

Using renewables successfully

Covering your building with renewable energy systems is no guarantee of it being low carbon. Projects we examined, with multiple renewables, as well as conventional systems generally failed to meet performance goals.

Whilst technologies performed well individually, where many technologies were used in a single project, control often becomes overly complex and therefore the systems perform poorly or at least not as well as they might do individually.

Evidence from the case studies also suggests that where predictions of LZC performance are taken from software intended for other uses (in the main, that used for Part L compliance modelling), predictions vary significantly from actual performance. Whilst it's possible that this may have been as much due to interpretation and approach as the software or technique itself, it seems clear that the assumptions which are often built in to the software package being used do have a significant impact.

Designing in energy management

A clear metering strategy should be in place from early in the design process to allow you to monitor the various systems and sub-systems of the building during occupation.

In many of the buildings studied, metering was installed to satisfy BREEAM or Building Regulations without considering the need to understand the operation of the building. The intention of the metering system should always be to provide accurate, useful information to allow building performance to be monitored for feedback and recognise when systems are not operating as intended.

Lessons learned

- Ensure your design team is clear about how you intend to use and operate the building and include feedback from people who will use and run the building.

Ensuring best performance

Achieving low carbon performance in-use is an ongoing process which you need to work at. Here are some of the key actions for getting the most from your building.

Getting to know your building

To get the best from your building, the handover process must include adequate training so that the building managers and occupants understand enough about how it works to operate it effectively and efficiently.

Training

It is essential that the design intent of the various systems is conveyed to the facilities management team. They need to fully understand how systems are supposed to perform in terms of energy as well as their operation and maintenance. This allows early identification of anything unusual, particularly if the design includes unfamiliar systems such as renewables.

Training should also include occupants. Whilst less extensive than training for the FM team, it should communicate the aspiration for the building to be low carbon and enable users to interact with the building effectively.

Training will cover many aspects of operating the building, but in terms of carbon, it should cover at least:

- identification of the building services that are the principal systems using energy and producing carbon emissions
- BMS and controls, including any user controls
- metering and monitoring strategy (including whether meters are operating correctly)
- identifying and correcting faults
- maintenance arrangements.

"A low carbon building is not achieved at Practical Completion. Practical Completion is a point you pass through, not the end of the process"

Rod Bunn, BSRIA

Case study

Ceridigion County Council – continuous improvement

- The main entrance to the building, consisting of two sets of sliding doors, allowed cold drafts to enter the atrium. As this space is open to the general office floor plates, the drafts proved uncomfortable for those working nearby. Within the bedding-in period, a solution was devised and installed to fit a revolving door in place of the inner set of sliding doors. Understanding that issues such as these will arise during the bedding-in period means you can react in a considered manner and work with your contractor in a constructive way to resolve them.
- One practice adopted on a regular basis was checking the moisture content of the wood fuel being delivered for use in the biomass boiler system. This revealed that the moisture content was regularly outside the specified limits, affecting the efficiency of the boiler's operation. Without the regular checks, this wouldn't have been discovered.
- The client has had the biomass boiler re-commissioned in order to optimise its performance and ascertain its efficiency. Results indicate that the boiler is operating at efficiencies of nearly 90% at part load and over 90% at low load, which is within the manufacturer's stated performance range and has reassured the client about the boiler performance.

Image supplied by Ceridigion County Council

Use the building logbook

The handover should include the provision of a building logbook. This is a simple, easily-accessible summary of a building's services, controls strategy, predicted energy performance and the means to monitor it. It should be separate to the Operation and Maintenance manual. CIBSE TM31 includes a useful proforma for developing a logbook.

Very few projects we studied had completed logbooks, which meant some facilities staff were unaware of key design elements.

The logbook is also where you record the data from your metering and monitoring activities that allows you to compare performance with design predictions.

Bedding in

It is normal, during the first year or so of occupation, to have to fine-tune your building. This may include altering set-points in the BMS, changing stop-start schedules for plant, setting up your monitoring systems or making simple changes to improve the comfort of occupants. All the buildings we studied required a bedding-in period in to resolve faults and improve energy performance.

Ongoing improvement

Wherever possible, an individual or organisation should be given responsibility for both energy and carbon and tasked with continuously monitoring and fine-tuning performance.

Identifying and correcting faults

The metering system should allow you to understand trends in energy use, for instance over the seasons of the year so that when you see something unusual you can investigate. It should also be designed so that you can understand the performance of individual pieces of equipment, such as boilers, heat pumps, PVs and so on. This will enable you to quickly identify and resolve issues and ensure that your building stays low carbon in-use.

Your window onto exactly what is happening at an individual system level as well as for the building as a whole is likely to be your Building Management System (BMS) and you should make sure you know how to use it to find information about specific systems.

Maintenance arrangements

It is essential that the correct maintenance regime is adhered to if you want to get the most from your building.

The maintenance arrangements will include work which will be carried out by third parties as well as work you will need to do in-house. During the training and handover period you should ensure that you fully explore and understand what needs to be done, by whom and how regularly.

Seasonal commissioning

It is of course necessary for the commissioning of systems to take place at some specific point in the year meaning that the external conditions under which the commissioning takes place will be whatever the weather of the season dictates.

An extremely valuable activity is to re-commission weather-sensitive systems in the opposite season of the year and perhaps even during every season of the year. At Bideford College in Devon, the main commissioning happened in the summer, and the heating system was not as extensively commissioned as possible because of the lack of demand for heating at that time. Instead the system was re-commissioned in the winter and checked in the spring and autumn to ensure optimum operation throughout the year.

Occupants and equipment

Despite attempts by the project team to account for the likely unregulated energy loads, such as IT equipment, it is often the case that the reality of occupation differs from the assumptions made, leading to a performance gap. Evidence from the case studies shows that there is often significant potential to reduce the energy use associated with this equipment.

Lessons learned

- Only accept training that covers every system in the building.
- Communicate the aspiration for the building to be low carbon to all occupants and the key features for them.
- Check you have a complete building logbook with in-use energy predictions for you to compare against operation.
- Recognise that there will be a bedding-in period of at least a year for your new building.
- An individual, FM contractor or similar needs to have responsibility for energy.
- Implement energy monitoring and targeting to fine tune performance including comparison to design predictions, and benchmarks.
- Don't forget to manage the addition of extra equipment by occupants.

Further information

Carbon Trust

The rest of the 'Sharing our experience' booklets provide more tips and advice on areas highlighted in this booklet. These include:

- Making buildings work – Lessons learned from commissioning low carbon buildings
- Green gauges – Lessons learned from installing and using metering and monitoring systems in low carbon buildings
- Taking control – Lessons learned from installing control systems in low carbon buildings
- Down to earth – Lessons learned from putting ground source heat pumps into action in low carbon buildings
- Taking the heat – Lessons learned from using biomass heating in low carbon buildings
- A place in the sun – Lessons learned from designing low carbon buildings with photovoltaic electricity generation
- A natural choice – Lessons learned from low carbon buildings with natural ventilation
- Low carbon refurbishment of buildings – Management guide

Visit www.carbontrust.co.uk/buildings to download them

Carbon Trust

www.carbonbuzz.org/

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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CARBON TRUST
Making business sense of climate change