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Energy Performance of Schools

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Introduction

Both the market and legislation are asking the professions involved in building design to commit to energy performance predictions. The pressure has ranged from direct financial pressure – you'll be fined if you exceed predictions – to pressure on reputation, with the development of Display Energy Certificates.

Reduction of waste, particularly energy, in buildings was a founding principle of our practice nearly 50 years ago, so it's natural for us to want to understand the discrepancy between design intent and building performance in order that we can do something about it.

We have worked in collaboration with the Bartlett Faculty of the Built Environment, University College London, on a study of the energy performance of schools from October 2008 to September 2010. The paper 'Bridging the gap between predicted and actual energy performance in schools' will be presented at the World Renewable Energy Congress in Abu Dhabi September 2010, and top line findings have been presented to the CIBSE Schools Design Group.

This paper is a summary of the findings. It illuminates the key factors that contribute to the discrepancy between predicted and actual energy use in schools. The way the building is used is the dominant factor. Higher than predicted energy use is the unintended consequence of choices made by people managing and using schools.

We have used the detailed insights from the study to develop a risk management tool specifically targeted to mitigate the risks that lead to high energy use. The risk mitigation measures do involve building design and specification but, most importantly, they involve engagement with the whole school community so that they understand their buildings and their choices about how they use them.

Background

Building energy calculations are usually generated by a computer model. This can only ever be an approximation of reality. We simplify the geometry, and the algorithms that describe the building energy flows are also a simplification. We have to make pragmatic choices to make models manageable, both in complexity and time. These approximations place a limit on the accuracy of the output of the model, in this case the energy use predictions.

But we believe that a far more significant reason for the predictions differing from reality is the assumptions the model is built on. These assumed *input factors* include U-values, operating hours, lighting levels, occupancy levels, temperature set points and so on. The designer determines some of these, others depend on how the building is constructed, commissioned and operated. The assumed values of these *input factors* used in the model will be based on the designer's experience, published guidance and the client brief.

Research summary

In collaboration with the Bartlett at University College London, we have investigated the sensitivity of energy use calculations to variations in the assumed *input factors*. As part of this research, we needed to know how widely the input factors vary in practice, so we visited 15 schools around the UK (built or refurbished since 2002) to get a feel for the variability.

From the school visits, we learnt that buildings were in use for between 180 and 364 days a year (average 260); the heating is on for between 30 and 79 hours a week (average 60) and the heating set point is between 15 and 25 °C (average 21°C). The schools' carbon emissions varied between 27 and 73 $kgCO_2/m^2/yr$, with an average of 51.

These examples illustrate how widely these factors can vary in practice. It may be possible to predict accurately some factors, such as the number of days a year that the school will be open, although this may well change over time, but others, such as the heating set point, are harder to anticipate as they are subject to occupant control.

Having established the variability of the operational input factors and made estimates of the other input factors, we used a computer model of one of our schools to determine the sensitivity of building energy use to changes in the input factors. This involved identifying a *base case* scenario, using the values assumed at design Stage D, and repeating the simulation with each input factor changed to the likely maximum or minimum value in turn. For each input factor, this generates a range in energy use. For example, by varying the heating set point between 16 and 24°C, the building carbon emissions go from 16% below the *base case* to 29% above. This technique is known as *Differential Sensitivity Analysis*.

We ranked the input factors in order of significance according to the size of the energy change. The 10 most significant input factors are shown on chart 1.

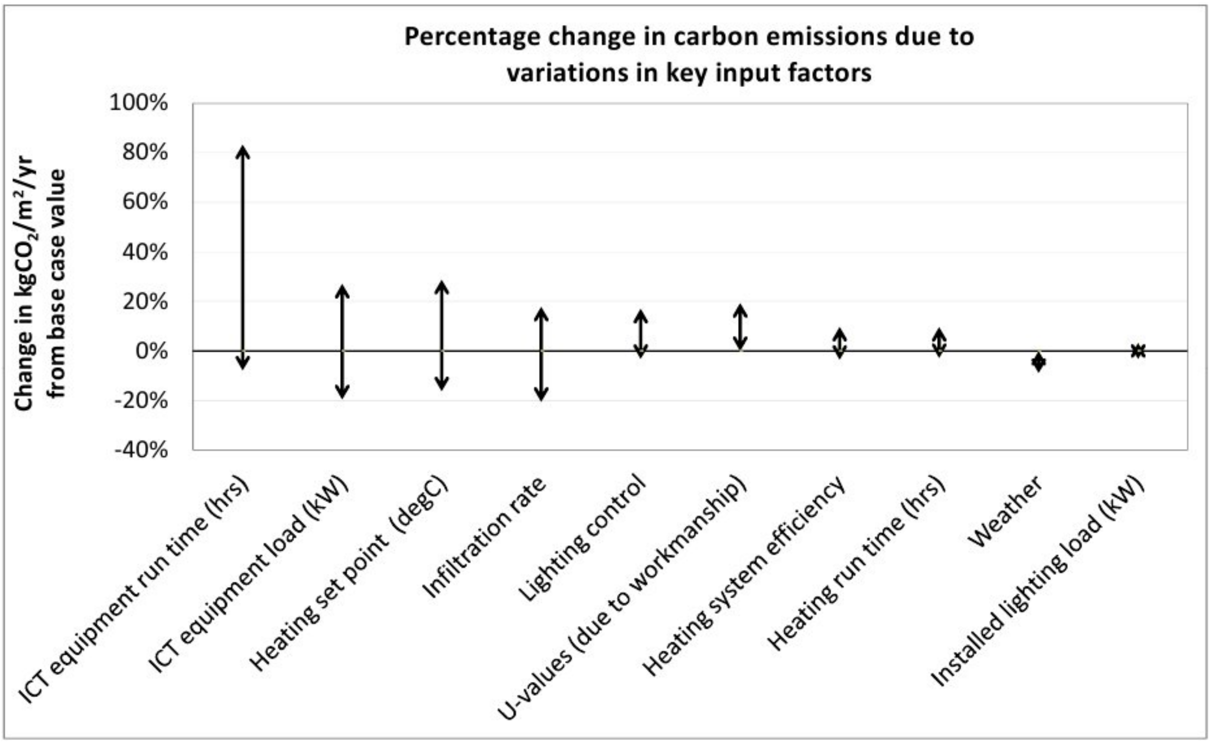

Chart 1

What we found was that the way the building is used is the dominant factor in the difference between actual and predicted energy use.

The influence of ICT equipment on building energy use

Our study found that ICT use is most significant factor in the energy performance discrepancy.

Typically, in offices we found PCs, printers and photocopiers, while classrooms had a number of PCs, a data projector and an interactive whiteboard, and in some cases plasma screens and laptops. In our analysis, the *base case* scenario assumes that electrical equipment is on for 7.5 hours a day. In many of the schools we visited, equipment was left on all the time. This can increase the carbon emissions of the building by a massive 83% and could cost the school an additional £6700 a year to run (assuming 8.5p/kWh for electricity and a 2400m^2 school).

As people become more aware of the significance of ICT on building energy use, it is hoped that the leave-it-on-all-the-time attitude will disappear. Power management software is available which can shut down equipment at a specified time so that it is not left on overnight. Over time, equipment is likely to get more sophisticated such that it can power itself down when not in use.

In addition to the variation in operating hours, the actual power consumption of ICT equipment is difficult to predict. There is considerable variation between products, and they use different amounts of power depending on whether they are being used or are idle. The age of the equipment is also a significant factor. Although there is a trend towards more efficient equipment, the quantity of devices considered necessary or desirable in a classroom is increasing. For example, an energy intensive data projector may be used to display a recipe on the wall of a cookery classroom for the duration of a lesson, instead of each pupil working from a paper copy.

Our *base case* scenario assumes each classroom has a PC with flat screen, a laser printer and either an interactive whiteboard or data projector. This comes to about 300W per classroom. Many classrooms will have both an interactive whiteboard and data projector, adding a further 200-300W. If every child has a laptop, this could add between 400W and 1300W.

It is easy for the ICT load to creep up. If a school is serious about achieving an energy efficient building, then energy must be a factor in its ICT planning and procurement policy.

Energy Risk Management Tool

To make the results of this research into a form that is more accessible to design teams, we have developed an Energy Risk Management register to help identify areas where actual energy use could be significantly greater than predicted. This treats each of the *input factors* as an element of risk to be managed, and describes ways to minimise the possible variations with a list of mitigation measures.

The risk factors may either be ranked in order of significance (as below) or may be grouped under headings such as Building Fabric, Mechanical Systems, Management, etc.

Risk Title	Risk Description	Mitigation Measures
ICT & Electrical equipment	1. Electrical equipment in classrooms and offices (especially computers, monitors, printers and photocopiers) left on when not in use. Building energy use is highly sensitive to the length of time such equipment is on for. 2. The amount (and energy efficiency) of ICT in classrooms is difficult to estimate and is likely to increase with time. Combined with the typically long hours of use, this often contributes to electrical consumption being significantly greater than anticipated.	1. Prioritise energy efficiency in IT brief. 2. Operation and energy efficiency measures to be fully explained to client at briefing, procurement and handover stages. 3. Ensure office equipment is switched off at the end of the working day. May be achieved by good discipline or with specialist software. 4. Set up equipment to go into "sleep" mode when not in use *during the day*. 5. When the school is planning the procurement of ICT equipment, the energy efficiency and amount of additional equipment should be considered as this can add significantly to the running cost of the building.
Heating set point	Raising the heating temperature set point significantly increases energy use. Thermostats are often wrongly assumed to control the *amount* of heat that comes from a given source.	1. Provide training and information on local room control to avoid misuse. 2. Caretaker and other staff to be aware of the impact of their choices.
Overheating during heating season	Rooms can overheat due to inappropriate use of thermostats, windows are then opened to cool the room down. Especially a risk in rooms with slow response heating systems (such as under-floor heating) and/or TRVs as occupants can easily turn these up too far	1. Occupants (especially staff) need to understand correct use of TRVs. 2. Designers to ensure heating zoning will not exacerbate this.
Building envelope	1. Fabric insulation may be compromised by a. incorrect installation b. cold bridges. 2. Infiltration can be a significant cause of heat loss and may be greater in reality than the design assumption.	1. Design to the highest standard of air-tightness reasonably affordable. 2. Ensure robust detailing to minimise cold bridges and air-leakage. 3. Monitor construction to ensure integrity of insulation and that air-tightness standard is achieved. 4. Pressure test building to ensure compliance.
Lighting control	Lighting control design strategy may not be realised in practice for several reasons: 1. Controls equipment may not live up to its claims. 2. Controls may not be set up and commissioned adequately. 3. Users may not understand system or may find it inconvenient. 4. Maintenance of system is difficult or expensive. Additionally the control strategy for security and emergency lighting may not be considered, and may be excluded from energy assessment.	1. Specify equipment with a proven track record and readily available. 2. Check commissioning thoroughly. 3. Consult school at design stage and ensure school is happy with design strategy. 4. Designers to consider control of security and emergency lighting. 5. Provide training and/or information for users.
School opening hours	The hours of use of the building has a significant impact on the energy consumption.	An accurate picture of the building usage is needed to make realistic energy estimates. In addition to the core operating hours, there may be breakfast clubs, after-school activities, community use in evenings and weekends and potential staff and community use during school holidays.

This approach can be supported by using the Soft Landings Framework, see www.softlandings.org.uk, which aims to close the gap between client expectations, design predictions and building performance.

Discussion

We are all familiar with ways to make buildings more energy efficient, from increasing insulation to switching off lights and lowering thermostat settings. What we have learnt from our research is where to focus the effort to deliver not just a low energy design, but also a high performance building, and to understand the range of scenarios found in real schools.

The findings bring to light one of the main difficulties in making energy predictions: occupant behaviour is highly variable and unpredictable, yet factors controlled by occupants are among the most influential in determining energy consumption.

Part of the problem is that energy calculations done for compliance with Building Regulations or Planning are carried out within a specific framework for comparison purposes that does not represent reality. And in many cases, these compliance calculations are later treated as a prediction, although this may not be appropriate.

Generally energy use calculations represent ideal operating conditions that are unlikely to be achieved in practice. For example, it may be assumed that lights will only be on when a room is occupied and that electrical equipment will be switched off at the end of the working day. In practice, this is seldom the case as human behaviour comes into play.

Through this study, we have developed the understanding that making an accurate prediction of the eventual energy use is not realistic, given the number of factors that are outside the control of the designers. Instead, we should aim to give clients a range of likely energy use, and help the design team and building management and occupants to understand how they can influence their school's energy performance.

As part of delivering this aim, we have developed an Aftercare Service in which we will help to optimise the building performance, assisting the building management team to understand and operate their building efficiently, and working with occupants to understand the impact of their choices. This service can dovetail with a Soft Landings programme, to further enhance the likelihood of delivering and achieving a highly energy efficient building.

It is important to state that this study does not imply that the way the building is used is *more* important than the design of the building in determining its energy performance. Our sensitivity analysis compares variations between the completed building and the Stage D design. It therefore does not consider the possible effects of different design choices.

Conclusion

In order to minimise the gap between predicted and actual energy performance of schools, we can now highlight to clients and design teams the factors at greatest risk of turning out differently in the completed building. With the help of our Energy Risk Management tool, we can enable the team to manage and mitigate these risks so to deliver better performing buildings.