ENVIRONMENTAL PERFORMANCE MODELLING - USE IN PRACTICE

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Why do some designers use energy modelling to assess the performance of their building? What are the advantages and disadvantages? How can an appropriate computer program be selected? What are the implications on fees and methods of working? What are the effects on a building and its performance? Should modelling be more widespread among engineers, and how could this be achieved? The study reported here identified a sample of practitioners who use modelling and, by means of interviews and case studies, sought to answer these and other questions about the use and impact of environmental performance modelling in practice.

INTRODUCTION

In October 1990 the CIBSE issued a policy statement to its members listing the actions they should take to reduce global warming. These included considering the relative merits of alternative energy sources, advising on the best solution for energy efficient structures and systems, and promoting the use of air conditioning only where necessary. The RIBA issued similar advice to its members, including the specific recommendations to use BS 8207, to design buildings that take orientation and other climatic influences into account, and to specify low-energy fabric, plant and controls. BS 8207 *British Standard Code of Practice for Energy Efficiency in Buildings* itself calls for designers to adopt calculation methods for estimating energy requirements that take into account the complex interactions between the climate, the fabric, the plant and the occupants, and to compare design options in terms of the cost effectiveness of energy efficiency measures.

In addition to institutional policies, engineers face changing legislation, technical innovations, and rising occupant expectations about both internal comfort and broader environmental issues. All of these forces appear to demand greater understanding of building performance. The types of iterative analyses that are necessary if designers are to respond actively to these forces require the use of methods that lie beyond the scope of manual calculation.

Techniques for modelling the energy and environmental performance of buildings have already had much effort devoted to their development. However, comparatively little is known about how such tools are used in building design practice and the effect they are having on buildings. This paper reports the findings of a study undertaken by Eclipse Research Consultants on behalf of the Building Research Establishment to establish the extent of take up of modelling, the benefits of modelling as perceived by those who undertake it, and to define how the research community can respond to the needs of practice for improved design tools and associated procedures.

The study was conducted in three parts. First, a literature search was undertaken on the subject of the use of modelling in practice. Second, known users of computer-based design tools were identified, primarily through the membership of the Building Environmental Performance Analysis Club (BEPAC). 19 selected users were then interviewed by telephone about their use of modelling. Finally five case studies were selected where sophisticated modelling had been undertaken, and the case study designers interviewed face to face.

BEPAC was chosen as the initial route to locating practitioners who use modelling because it acts as a focal point for those using and developing environmental performance programs. The Club was established in 1988 and is administered from the BRE on behalf of an elected committee. Its membership comprises interested practitioners, developers of performance analysis software, and those from the academic and scientific research community. It acts as a forum for technical experts in a given modelling field to exchange information and promotes technology transfer - the take-up of modelling - from research to practice.

THE LITERATURE SEARCH

Surveys of take-up of energy software

Evidence of the extent of take up of energy software generally can be gained from the CICA *Building Environmental and Energy Survey.* Take-up by architects only can also be gauged from the most recent RIBA *Survey of Computer Usage.*

The CICA's *Building Environmental And Energy Design Survey* (1991) was prepared for the BRE and the Energy Technology Support Unit (ETSU). One of its objectives was to obtain an indication of the levels of environment and energy calculation in the building design professions. Its survey of sales by program vendors showed that, for example:

- BREDEM-based domestic sector programs have sold around 300 copies over a 7-year period
- over 1000 copies of Hevastar have been sold since 1978
- Cymap have sold 600 copies of Energy
- Abacus Simulation Ltd have sold 65 copies of ESP-7 since 1988.

Most of the sales were to building services engineers and energy/environmental consultants, as well as, in the case of non-domestic programs, to multi-professional firms. Building services engineers in the public and private sectors were found to be making extensive use of calculation methods, both manual and computer based, largely in support of the design of building services.

However, while engineers are already adopting these design tools, the CICA *Survey* reveals low take up by architects. Their use of them was found to be mostly on domestic sector buildings, largely for compliance with Building Regulations and condensation risk analysis. Iterative working by architects was reported to be rare. Sales to architects reported in the CICA study are consistent with the findings of the RIBA *Survey of Computer Usage* (1989). This showed that 4.7% (143 architects practices out of 3,026 who returned the survey forms) claimed to use some kind of energy calculation software. Among these, the most frequently cited proprietary program was Hevacomp with 14 practices citing it. TAS and ESP were each cited once. About 20 practices named proprietary spreadsheet software (9 Supercalc, 6 Excel, 4 Smart), while a further 20 claimed to have their own program. These results suggest minimal usage by architects of modelling, and imply that the influence of computer based calculation on building form, siting, orientation and window design is extremely low.

The CICA *Survey* found agreement between the opinions of program vendors, designers and purchasers that the main inhibiting factors to the take up of programs were the time and cost involved in first learning and then using them. There was also broad agreement that although factors such as independent endorsement and better marketing of programs might encourage take-up, the computer industry could do little itself and what was really needed was a general change in the climate of opinion about the importance attached to energy and the environment.

Consultancy schemes based on the use of modelling

Computer programs underpin several new initiatives whose aims are the promotion of energy efficient building design. In the offices sector the Building Research Establishment Environmental Assessment Method (BREEAM) uses the program Esicheck, while in the domestic sector BRE's BREDEM program is the core of both the National Home Energy Rating and MVM Starpoint schemes.

Energy efficient design advice has been promoted via the Scottish Energy Design Advisory Service (EDAS). Operated jointly by the Royal Incorporation of Architects in Scotland and the ABACUS unit at the University of Strathclyde, it was established in 1987. A free initial consultation was offered together with, where appropriate, more detailed advice which was frequently based on computer modelling, at 50% of its full cost.

Following a successful review of the Scottish EDAS, a national Energy Design Advice Scheme is currently being implemented. It is being managed by the Building Research Energy Conservation Support Unit (BRECSU) acting on behalf of ETSU. It will establish Regional Centres to manage the Scheme locally and to offer initial free advice. Where appropriate, the Regional Centres will act as clearing houses, recommending their clients to associated consultants who will be responsible for providing detailed technical advice over a more extended period. Computer methods are to have no special place in the Scheme although, on the evidence of the pilots in Scotland and elsewhere, modelling will be prominent among the techniques on which the detailed extended advice will be based.

Existing published case studies of the use of modelling in practice

EDAS has been a source of about a dozen case studies of the use of modelling in practice. These have been published in the *EDAS Brochure*, in *Scottish Energy News*, and in the ESP newsletter, *The ESPRESS*. Emslie presented some cases at the 1989 CIBSE National Conference (Emslie, 1989). Other published case studies are shown in the following table:

REFERENCE	PROGRAM USED	BUILDING TYPE AND TOPICS INVESTIGATED THROUGH MODELLING
Sharman (1982)	THERM	Checking consultant's recommendations about cooling plant capacity for a 1950s lightweight office building suffering from overheating, including assessments of blinds and solar control film. Equipment sizing and running costs of alternative heating systems.
Bennett, Barnes and Gibson (1985)	THERM	A study of the thermal characteristics and potential for energy conservation at four representative London office buildings - assessment of the effects of good housekeeping and fabric measures. Aim was to provide rules of thumb for designers to apply to similar buildings.
King and Packer (1985 and 1986)	TAS	Use of the model in the design of Clacton St John's Primary School in Essex. Fabric choice, construction type, selection of heating and ventilation system including controls.
Yaneske (1987)	ESP	Old Persons Home. Simulations to assess the effect on thermal comfort of variations in percentage glazing and thermal response, overheating risk, the effect of an overhang, and interstitial condensation.
Rigg and Hall (1988)	ESP-2 (US version?)	52 storey tower in Melbourne, Australia - selection of air handling systems, optimisation of the energy centre design, development of control strategies.
McLean (undated)	ESP	Shopping centre complex, Marlands, Southampton. What-if scenarios for summer and winter thermal performance of the public spaces, using various fabric measures and control strategies, airflow profiles.
Ridout (1989)	not stated	Royal Bank of Scotland 30,000 sqm administration centre. Energy simulation program used to design the building, then linked to the BEMS.
Stuart (1991)	ESP	Two Future Technology Centres in Germany. Parametric runs used to assess effect of increasing thermal resistance and capacity of fabric. Also effect of Transparent Insulation Material for roof or walling.
Eppel & Lomas (1991)	ESP	School of Engineering and Manufacture, de Montfort University, Leicester. Ascertaining feasibility of natural ventilation in lecture theatres and design optimisation.
Anon (1991) and Cohen, Ruyssevelt & Abu-Ebid (1992)	SERI-RES	Meadowbrook Montessori Farm School, Berkshire. Parametric runs used to define position and size of roof glazing and windows, and depth of roof overhang with intention to reduce summer overheating and achieve good daylight distribution in classrooms.
Ruyssevelt (1992)	Not stated	Student residences at University of East Anglia. Assessment of benefits of high levels of insulation, and passive versus mechanical ventilation.

These case studies have a valuable role to play in helping engineers to assess the relevance of computer-based performance assessment to their practice. But it is notable that they are relatively few in number and have mostly been written either by program vendors or those closely associated with them, rather than by independent reviewers. Few describe in depth the technical issues addressed and the modelling assumptions used. Neither do they cover issues such as the choice of program, the learning curve for using it, or how the output was fed into decision making. For these sorts of reasons, the extent to which these case histories have effectively promoted modelling to practitioners is questionable. The most explicit coverage of non-technical issues is to be found in King and Packer (1986), whose description included:

- the role of an expert user
- data collection and entry requirements
- the need to formulate questions to ask of modelling
- the cost/benefit of asking particular questions of modelling
- the effect of model limitations on asking particular questions
- designers' concerns over comparisons between the predictions and results from manual methods, and their feelings of vulnerability when they were unable to corroborate the predictions.

TELEPHONE INTERVIEWS

Using the membership list of the Building Environmental Performance Analysis Club and other users known to Eclipse, contact was made with a selection of users of energy programs. Telephone interviews were conducted, using an open ended structured questionnaire, with 19 people. These were drawn variously from organisations such as consulting engineers, energy consultants, local authorities, fuel utilities, architects, academics who undertake consultancy and a bureau service. Of course, the interviewees were not chosen as a randomly selected representative sample but rather the opposite - as a set of users who are at the leading edge of the use of these new design tools.

Why was modelling used?

Where the choice to use modelling was made by the interviewee, the main reasons given were:

- the desire to reduce the perceived risks of poor performance, such as overheating
- the complexity of the building or use of innovative features or plant.

There was broad agreement that a non-domestic sector project has to be of a sufficient size to warrant modelling. The consulting engineers who were interviewed implied that only a small fraction of their projects were subjected to modelling. But three architectural firms, all known to be interested in energy conscious design, said that nearly all their projects were modelled.

The criteria used to select a program

There was broad agreement about the criteria employed to select a program - the five key ones were:

- productivity - a high ratio between the value of the information generated and the effort in entering data
- ease of use, including clear inputs and outputs
- model accreditation
- low cost
- good documentation, including descriptions of the algorithms.

What was modelling used for?

In the domestic sector programs were used for whole building energy consumption and labelling, and for condensation risk analysis. In the non-domestic sector steady state calculation methods were commonly used at the whole building level for plant sizing. Dynamic simulation was undertaken on part only of the building, such as a room or space (atrium, auditorium, south facing office) to investigate detailed aspects of performance such as air movement or peak summertime temperatures. Again detailed investigation about a particular part of the services, such as CHP viability, may be modelled using a program specific to that application. In the non-domestic sector, it was generally reported that concern over energy consumption *per se* did not typically drive the use of dynamic simulation (although one or two respondents disagreed).

What were the perceived benefits of using modelling?

For the individual designer, several benefits of modelling were consistently identified. The key ones were:

- greater confidence in how the building would perform, and greater understanding of building performance.
- speed
- the potential for iterative working.

One engineer suggested that having access to the best design tools could also be used as a marketing edge by design practices, who could link it to a claim that they also had the best design thinking. However another interviewee was sceptical of such claims and suggested that some firms acquired sophisticated modelling primarily as a marketing tool rather than for day to day use.

There was a consensus that the main advantages of modelling to design teams lay in improved communication between design team members, arising from better presentation, and leading to greater credibility. There was strong agreement that modelling had minimal effect on the organisation of design teams and the sequence of decisions, and it was reported that modelling had no effects on other consultants' fees.

Service to clients and the impact on fees

In terms of the service provided to clients, there was consensus that they benefited from accurate information about how their buildings would perform. Modelling was also described as capable of providing evidence to clients about the effects in practice of using an innovative but untried building form or construction arrangement, and convincing them that they were not the subject of an experiment with unforeseeable results. One respondent said that developer clients may themselves be able to use the information in their marketing of the building.

The impact on fees varied. For steady state modelling, the fees charged to clients were reported as unchanged, although for dynamic simulation the engineering practices canvassed were not willing to absorb the costs within their normal fees, and attention was drawn to the high level of skill and experience required to use modelling effectively. There was little agreement among the interviewees about whether the use of modelling extended or reduced design time.

Impact on building design

There was a strong consensus that the use of modelling led to improved building design, in terms of cost and performance. This was reported as being due to the potential of modelling to allow iterative working in which technical options, such as building shape and form, and complex spaces, could be evaluated for their expected performance. Three quarters of the interviewees reported that modelling led to a reduction in annual energy consumption and energy costs, with estimated savings varying from 10-50%. However, these estimates appeared to be based on intuition, and no hard evidence was offered to support them. The remaining quarter were more circumspect, although no-one said modelling increased fuel consumption.

In the domestic sector, initial capital costs were reported as being increased by the use of modelling. The increases represent investments in energy efficiency measures which in turn lead to reduced life-cycle costs. In the non-domestic sector there was less consistency in the replies. Modelling could lead to dramatic savings through the elimination of unnecessary plant, and minimising the plant installed. Another source of identified savings was through the reduction in cumulative design margins compared with manual calculations. But modelling could alternatively lead to an increase in initial capital costs.

Did users wish to use modelling more than at present?

Two thirds of the current users said they would like to use modelling more than they do at present, and identified the reasons for this and the features they would like to see included in programs. The most radical reply was from an engineer who said he would like to see modelling replace manual calculations, and that the Building Regulations and CIBSE fee structure should be modified to bring this about.

The barriers to modelling

There was broad agreement about the barriers that exist to the use of modelling in design practices. These related to four main areas:

- issues to do with the broad area of the skill to use them and the time and cost of acquiring that skill
- lack of training and documentation
- lack of independent information about the strengths, weaknesses and areas of application of current programs
- a lack of variety among non-domestic sector programs.

In design teams the barriers were identified as relating to three areas:

- designers working in isolation
- energy having a low priority
- a scepticism about the value of modelling.

Lack of awareness and interest about energy among clients was identified as a barrier, as was the absence of a lead from CIBSE in promoting modelling, and lack of government support for energy efficient design.

Overcoming the barriers

The means which the interviewees recommended to overcome the barriers and encourage the take-up of modelling range from government initiatives, through actions by the professional institutions and independent organisations, to the development of better programs, and to changes to education, training and practice.

CASE STUDIES

All the case studies undertaken were for non-domestic buildings, and all but one (a two-classroom school) were large. Although the selection criteria were mainly based on the choice of building rather than the designer, the process of selection led to designers who proved to have long standing interests in energy efficiency and/or the development of calculation procedures in their own organisations or academic institutions.

In all the five cases, the use of modelling, at least in part, was associated with investigating building performance rather than energy consumption *per se*, and in particular, concerns over summertime overheating associated with gains from some combination of internal equipment, occupants and sunshine. Typically, the case study designers had used modelling to increase the efficiency with which energy was used in the building, and (at least within the framework provided by prior strategic decisions such as, in one case, to install air conditioning) to provide the minimum plant necessary. At the same time, in only one of the five had the designers used modelling to quantify total annual energy consumption, while in one other an energy target was established. Many of the decisions taken were believed to provide benefits in terms of less plant and reduced energy consumption. But these beliefs were mostly based on intuition and not judgments arising from formal cost benefit analysis. In the case of one of the buildings (not one where modelling was used to calculate energy savings) consumption was monitored and the building was subsequently publicised under the Energy Efficiency Office's Best Practice programme as a Good Practice case study.

Another general similarity was that more than one program was used to assess the building. In some cases, this was so that the results from one program could be fed into the running of the next. For example, results from a daylight program may be fed into a thermal simulation program. In other cases more than one program was used because different parts of the building, or different issues of performance, were analysed for different purposes using different tools. It was also found that steady state methods were used in parallel with the dynamic ones, either by those responsible for the dynamic modelling as a check on the predictions, or separately by other engineers. In one case physical models were also used.

The use of modelling was associated with the search for answers to very specific questions, such as the optimum size of windows for balancing lighting and thermal aspects of a building, or the feasibility of naturally ventilating an auditorium or an office. In one case modelling was associated solely with the design of the fabric (e.g. disposition of windows and atrium design), in another mostly with plant and services (CHP and chillers, although blinds and opening roof lights were also assessed in this case). In the other three cases, the use of modelling was associated with both fabric and services.

Why did the interviewees use modelling? In one case the client expected that some sort of sophisticated modelling would be used. But, in the other cases, the design teams themselves wished to use modelling in order:

- to increase their understanding of how the building would perform
- to raise their confidence in making design decisions, and
- to justify those decisions to their clients.

One designer was able to discuss the results of modelling with a knowledgeable client, while another reported that a formal presentation was made to the client by the various members of the modelling team.

There was a consensus that modelling was appropriate to the issues with which they were dealing. Using strikingly similar vocabulary, all five designers confirmed that there were no alternative methods to investigate the issues they had identified. This suggested that they were seeking answers to questions which other designers do not even ask.

The impact of modelling in the case studies was reported as being substantial. Energy consumption and annual energy costs were both described as being reduced in all five cases. However, as with the telephone interview findings, the energy savings arising from the modelling were generally not quantified, although consumption was predicted in one case. As for capital costs, they were reported as being at worst unchanged by modelling, but at best there could be substantial reductions, particularly through minimising plant, or omitting items like sun-blinds which modelling showed to be unnecessary.

The impact of modelling on design teams and fees also bore out the findings of the telephone interviews. It is interesting to note that one architect - who had co-ordinated the use of both physical and computer modelling by modelling specialists - reported that the services engineers did all the calculations they would normally do anyway. In this sense, modelling appears to be additional to, not a substitute for, regular engineering calculations of plant loads, duct sizes, and so on.

Some were more satisfied than others that the programs they selected had provided them with the information they were seeking. Those in practice who have been closely associated with the academic modelling community over many years appeared more satisfied with the programs they used - perhaps because they employ different expectations in judging such design tools from those used by mainstream engineering or architectural practitioners.

In one case study quality assurance issues were investigated. Here quality management procedures divided programs into *controlled* and *uncontrolled*. Controlled programs were defined as those from a commercial source, which were regularly updated and were supplied complete with manuals and had technical support. Programs lacking these attributes were defined as uncontrolled. The use of an uncontrolled dynamic program in the case study building had necessitated a detailed account being prepared by the energy advisor for the quality manager. This set out the validation procedures to which the particular program had been subjected (in a government funded research programme) in order to justify its use in practice.

CONCLUSIONS

Perhaps not surprisingly, given the basis on which they were selected, there was a clearly identifiable enthusiasm for modelling among the the interviewees and the case study participants for this study. These designers say that modelling increased their understanding of building performance and raised their confidence in advice-giving and decision-making. Two thirds would like to use modelling more than they do at present although, with one or two exceptions, they do not considered it appropriate for each and every project. They do believe it leads to improved building design in terms of cost and performance, with annual energy costs reported as being, at worst, unaffected, and at best reduced by between 10 and 50%.

Modelling has primarily been promoted (through EDAS and elsewhere) as a means to aid energy efficiency. Program users <u>in the domestic sector</u> expressed a clear commitment to energy efficiency and their use of modelling was for whole building energy analysis. Their commitment to energy efficiency led them to seek a detailed understanding of energy flows in buildings. Through this improved understanding they said they were able to reduce energy consumption by the incorporation of cost-effective energy efficiency measures, and the tools available enabled them to assess and quantify savings. In the domestic sector this was achieved largely through paying attention to winter heating requirements.

In the non-domestic sector the predominant use of modelling appeared to be to investigate the internal environment of the building. While users claimed their buildings were energy efficient, most of these claims were based on intuition; there was little evidence that designers are yet using modelling to quantify annual energy consumption or running costs, nor to undertake the cost/benefit analyses of energy efficiency measures identified in BS 8207 and the CIBSE policy statement. Nor, it appears, do clients generally expect such cost/benefit studies to be undertaken, nor estimates to be provided of annual running costs.

In four of the five case studies (the four where the dynamic simulation models TAS, SERI-RES or ESP were used) the designers chose to pursue energy efficiency through the design of a building which was climate-interactive rather than climate-rejecting. Modelling was used not to ascertain the energy savings over and above a conventional design, but instead to check that the internal conditions would be satisfactory.

This is because the climate-interactive approach to building design demands more thorough understanding of the dynamic interactions between inside and outside - between solar gains, orientation, natural daylight, thermal mass, and internal heat gains from occupants and equipment. They are also more open to occupant effects (Evans, 1992). Accordingly, climate-interactive buildings require modelling, not as a means of identifying possible energy savings, but to minimise risk associated with the achievement of internal comfort conditions.

In comparison with the easily perceptible internal comfort conditions in buildings, energy consumption is far less frequently made the subject of detailed assessment. Sub-metering and disaggregation into even the most gross divisions between, say, heating, lighting, ventilating, catering and computing is rare. Design "errors" such as oversized plant operating at part-load with a low efficiency often remain undetected in practice. There is also a general lack of expectation among clients to be provided by designers with energy use predictions. Inevitably, the result is that designers pay most attention to internal comfort conditions. This conclusion applied even to those case study designers (with one exception) who expressed a detailed interest in achieving energy efficiency through utilising ambient energy.

The case study designers reported that there was no alternative to computer modelling to answer the questions they were seeking to answer. It seems they were seeking answers to questions (about climate-interactivity) which other designers do not ask. It appears that only a small minority of designers take a climate-interactive approach to building design, and it is largely within this community that modelling is conducted. Such a conclusion would explain, at least in part, why the take up of dynamic simulation programs is so low. Unless and until the majority of designers begin to ask detailed questions about building performance, models which are geared to addressing these issues are unlikely to become widely used.

However to stimulate the use of modelling through the promotion of climate-interactive design begs a question about the robustness of designs which attempt to utilise ambient energy. A possible resolution is that modelling should be promoted as a means to achieve internal environmental quality within buildings, with energy efficiency as a secondary benefit. In view of the recent publication of BS 7750:1992, *Specification for Environmental Management Systems*, a stronger link could be made between the internal environment of buildings and the external environment - to promote environmental quality at both micro and macro levels. Environmental performance modelling will have a clear role to play in demonstrating compliance with the requirements of this recent Standard - if clients and building designers decide they need to conform to it.

Another force which could encourage modelling is the effect of market demand. If clients regularly expected to be provided with detailed information about predicted energy consumption and performance of their building, this would act as a major stimulus to the take-up of modelling. If such predictions were, for instance, built into the BREEAM assessment the required market-pull could be stimulated.

To prepare for this development attention in R&D into thermal modelling needs now to be directed much more towards ensuring that predictions match reality and can be compared directly with measured consumptions. The research required to reach this stage will have to address the many uncertainties that are faced when modelling a building - for example, uncertainties about building fabric, about the operation in practice of building services and controls, about the behaviour of occupants, and about the climate. Program users will need advice about the limitations of modelling, the interpretation of predictions, and the importance of sensitivity analyses for checking the robustness of designs under varying weather and occupancy conditions.

Once programs can be used confidently for predicting total energy consumption, and once building designers begin to provide this information to clients, then it may become the norm for building design services to include predictions of fuel use and building performance. This will raise clients' expectations and, perhaps, encourage them to pay to have their building's energy performance assessed. In this scenario dynamic modelling may come to be seen as an essential part of the design team's tool kit.

RECOMMENDATIONS

According to those interviewed for the study, thermal modelling offers a number of benefits in terms of building performance and energy efficiency. They claim there is no alternative when addressing certain issues of building performance, and they believe modelling has a unique role to play in energy efficient building design. However the participants in the study also identified a number of barriers to the take up of modelling in practice, and made suggestions about how they could be overcome.

Arising from the identification of the barriers and possible means to overcome them, the following general recommendations for actions were included in the study:

- action by government to explore the policy options available to promote a greater awareness of the benefits of adopting a modelling approach to building energy assessment
- action by the professional institutions, to endorse pro-actively modelling in their energy policies for members, and to incorporate remuneration for it into their fee scales
- action to revise BS 8207 to be more explicit in its recommendations about the value of thermal modelling and to replace its linear version of the design process with an iterative one, together with the completion of sector based Standards following on from BS 8211: Part 1.
- action by independent organisations in areas such as validation and checking, development of quality assurance procedures, guidance on how to use modelling for various applications, advice on program selection, regular review of program availability, case study material illustrating the use and value of modelling
- actions by model developers to create better, simpler, cheaper, easier to use and quicker models, especially in their input requirements, suitable for use on small and medium projects; and links to CAD; more sophisticated models; and enhanced programs with improved graphics and better interfaces
- action on education and training, to bring about better design training on environmental and energy issues and the potential of modelling, and better training in the use of programs
- actions by the professions to ensure environmental engineers are appointed at the early stages of the design process, not after the approval of the sketch scheme by the client when fundamental decisions affecting energy performance will already have hardened.

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