DECISION SUPPORT TOOLS FOR BUILDING CODE ENERGY EFFICIENCY COMPLIANCE

Michael Donn, Jacky Lee, Nigel Isaacs
CBPR, Victoria University, Wellington, NEW ZEALAND (cbpr@vuw.ac.nz)

Paul Bannister
Energy Research Otago Limited, Dunedin New Zealand

ABSTRACT

This paper describes research related to the New Zealand Building Code. It reports a survey of international approaches to building energy performance regulation. It also examines the use of simulation and other design tools by New Zealand building consultants. The proposed code approach is only to research the appropriate *Acceptable Solutions* for small buildings Large buildings are such a small percentage of total construction that they will be subject to specific design using simulation programs. The research established that at present: only engincering consultants use computers; a very small percentage use simulation; ali want procedures that are simple; almost ali are interested in energy efficiency.

INTRODUCTION

The Building Industry Authority (BIA) and Energy Efficiency and Conservation Authority (EECA) are cooperating in a project to review the existing provisions for energy efficiency in Clause H1 of the New Zealand Building Code (NZBC). This paper describes a project which forms part of that Work Programme. The paper is in three parts: an international survey of Computer Programs used in energy efficiency parts of building codes; a survey of the use of energy efficiency design tools by building professionals in New Zealand; and a description of the need for and availability of design tools to support the revised Clause H1.

REVIEW OTHER'S SUPPORT TOOLS

Literature reviews have revealed very little published information on the background to the adoption of energy codes. A detailed history of the New Zealand situation has been prepared (Isaacs 1993, Trethowen 1977), but no similar documents have been found for other countries. Part of the review was designed to elicit the reasons for the choice of building categories used in any country. No formal publications were found which provided the detailed background needed to understand these categories. The analysis is based on interviews, correspondence and published documents.

Table I summarises the energy efficiency provisions of the building codes reviewed. It can be seen that there is very little consensus.

The new German and Dutch approaches to calculation methods for means of compliance will use a simplified energy balance system. It is recognised in each country that this examination of both heat gain and loss (as already incorporated into the ALF calculation in the New Zealand building code -Bassett et al 1993) is overdue. It would appear that there is limited allowance yet in these proposed calculation methods for heat storage in building mass.

None of the codes reviewed as listed in **Table I** take account of embodied energy in materials or include carbon equivalence calculations. In fact, most countries avoid all externality accounting at present. Canada has allowed Life Cycle Costing calculations to discount the value of generated energy against saved energy. Only Manitoba has used this option so far, setting generation of energy 10% more expensive than conserved energy. It seems that getting a code compliance tool such as ALF in place has sufficient problems, without adding tools for estimating environmental impact.

All the countries reviewed appear to have a regular review and revision process. However, none appear to have the specific period for this review or the overall target of such a process written into law. The Netherlands and Germany, for example, are investigating the amount of embodied energy in building materials that are used for energy efficiency, with a view to incorporating some of this information into the "next" revision, while their current revisions are to come into law in 1994-95. Danish and Swedish code reviews undertaken during 1993, were implemented in 1994. Canada is on a five year cycle of reviews, with the new National Energy Code for Buildings to come into force in 1995.

The ASHRAE OTTV (Overall Thermal Transfer Value) model represents the type of approach taken at some time in all surveyed countries. Some like Germany have moved on to more complex formulae. The OTTV model is an area weighted energy conduction index for the whole building. In the old German approach it was the "k" value. As the k value it is the simplest form of calculation method: effectively it is the area averaged U-value or *conductance* of all the exterior elements of the building. In Germany, unlike in the New Zealand standard, glass is included in the calculation as a heat loss element.

Hong Kong and the Philippines have introduced new (1993) energy codes for specific building types where they judge that the energy use is greatest. In these climates, the greatest energy use is for cooling, which is assumed to occur in office buildings and prestige hotels. As the effect of the thermal storage in massive elements of the building is expected to affect the cooling load, the calculation uses "effective" rather than actual conductances which allow for the thermal storage effects.

The economic analyses that these countries use to justify each of these codes vary. It would be hard to find a more strict approach than that of the German central Government. They have apparently deemed that if a building element produces a net return in energy over its lifetime then investment in that measure should be mandatory. However, they have determined that the lifetimes they are dealing with are quite short for some building components: e.g 15-20 years for double glazing

By contrast, the Netherlands, Canada and Australia consider economic return to the building owner, under what are deemed to be reasonable assumptions about energy cost increases and discount rates. This kind of analysis could lead to the situation, noted by one official, that unless the government ensured energy prices rose each year by the amount assumed, then the economic justification for the energy code would not hold.

Except for the proposed Dutch code, none of the countries require that a building designer perform a complex building thermal performance simulation. All allow an alternative route for the designer. Typically, this is a prescription of the R-value and maximum size of windows, the R-value of roof and walls, and the lighting installed load, even for the most complex and large building project. The New Zealand proposal is to write *Acceptable Solutions* for small buildings, but to require detailed design of each large building.

Only the USA and Canada, give the option of a complex thermal simulation code to prove compliance as is anticipated will be the option adopted in New Zealand. All codes use these types of programs as part of the research and development phase. However, it should be noted that both Hong Kong and the Philippines require the OTTV to be calculated (not a complex calculation) for all buildings which are of sufficient size to come under the regulations. They do not have an alternative provided by a prescriptive specification of building construction.

APPLICABILITY OF OTHER CODES

There is clearly no "right" answer to the applicability of "overseas" codes to New Zealand. For those interested in reduced development cost and prepared to accept the assumptions made to meet other country's political, technical and social constraints the adoption of, say, the ASHRAE approach may well be the most "economical". Others may well see advantage arising from an energy code tailored to New Zealand's particular mix of fuels, buildings and climates. One need only look to the Canadian code development effort (National Energy Code For Buildings 1995), to see how comprehensive the adaptation process can be for one country geographically and economically closer to the USA than New Zealand.

The following paragraphs examine the four principal factors likely to affect the decision to adopt a foreign building energy performance code in New Zealand: climate; range of building constructions; regulatory framework; and relationship to trading partners.

Climate

It has become almost cliché when "translating" passive solar design from the USA to New Zealand, to note that the latitude and sun/rain distribution in New Zealand is very similar to that of the West Coast of the USA. Los Angeles and Auckland, San Francisco and Wellington, Seattle and Christchurch are related to each other in this model. However these locations are different in the range of temperatures, the amount of heating and cooling required, and available solar radiation throughout the year. Finally, if daylighting is to be allowed for, the particularly clear skies in New Zealand would appear to be worth at least a 10% increase in daylight availability over the USA.

This question has proven to be impossible to answer definitively. However, a few principles can be laid down:

Acceptable Solutions: An approved "solution" needs to be developed for a very specific mix of climate, building construction type and economics. It seems unlikely that approved solutions in overseas codes will be sufficiently independent of climate that they will be able to be simply adopted for use in New Zealand.

Means of Compliance: In most countries, a general compliance tool like a computer simulation of the thermal behaviour of a building is not yet offered. Rather, the Netherlands, Germany, Switzerland, Sweden, all have developed an energy balance calculation procedure which is very like the ALF method (Bassett et al 1993). These procedures rely completely on climate-based studies conducted in their countries of origin and hence are unlikely to be applicable in New Zealand.

General calculation procedures incorporated into overseas codes or available commercially, such as DOE2.1E (Winkelmann, 1993), SUNCODE (Palmiter, 1981) and BUNYIP (Wooldridge, 1983), do have potential in New Zealand. Local weather data files are available for each of these particular programs, and could be developed for other programs.

Table I Energy Efficiency in Building Codes - Country Summary

COUNTRY	SPLIT		EXEMPT BUILDINGS	ELEMENTS COVERED
AUSTRALIA	Residential	Commercial	Unknown as yet	Residential: - regional, wall R values Commercial: - under development; probable window size and R values limits; may include simulation program means of compliance;
CANADA	Residential Low Rise: ≤ 3 stories ≤ 600 m^2	All Other Buildings	-farm buildings other than dwellings -seasonal buildings	-building envelope -heating equipment -ventilation equipment -air conditioning equipment -water heating equip. -lighting -electrical power except process loads (trade off against U-values) -ventilation -heating systems -heating control systems
DENMARK	Small buildings, houses -Single -Detached -Semidetached -Terraced -Chain -Cluster	All Other Buildings	-thoroughly ventilated spaces -heated by internal gains (waste heat) -heated only for short periods (All still must be insulated but to level suitable for their use)	- envelope U-Values walls, ceilings, floors, windows -% window area
JAMAICA	Low Rise Residential	All Other Buildings (except low rise residential ≤3 storeys above grade)	-manufacturing -commercial processing -industrial processing -buildings with energy ≤ 10.8 $W.m^{-2}$ -buildings ≤ 93 m^2	Envelope U-Values -window: Shade coefficient external shading % wall area -lighting -ventilation -air conditioning -service water heating -energy management
GERMANY	ONE CODE Area to Volume ratio used in setting various performance indices for the energy balance calculation. For temperatures >15 °C		Small dwellings with up to 2 storeys may use the old average building conductance system of code compliance. ALSO: buildings where: - temperatures <15 °C	- element U-values - solar gain - internal gains - ventilation heat gain/ loss - mechanical/ natural venting - heat recovery
NETHERLANDS	Residential -existing -to be built	Non-residential - existing -to be built	Caravans: different regulations, not absence of them. If a process in a building requires cooling, the energy use for this is discounted.	- Element U-values - solar gain - internal gains - ventilation heat gain / loss - mechanical ventilation - air-conditioning - heat recovery
HONG KONG	Hotels	Commercial buildings	- Any space not air-conditioned	ASHRAE OTTV (Overall Thermal Transfer Value: average U value across all building surfaces
PHILIPPINES	ONE CODE : OTTV only where total cooling load > 175 kW;		Residential units; premises with high process heat gain; - peak design energy use < 10 W/m^2	ASHRAE OTTV; plus specific lighting levels for different building uses.
SWEDEN	ONE CODE dwellings - others (different required U-values)		-Used for short periods -No heating required (greater part of year) -Process heat provides enough heat	-Envelope avg U-values -Min & Max floor temp -Air tightness -Ventilation -Heat recovery -Window area
USA - ASHRAE	Residential	Non-residential	Depends on implementing authority	
USA - CALIFORNIA	One code (16 climate zones) Different requirements by use type: some common / separate chapters low rise residential - other		-historic buildings -seasonally occupied farm buildings -residential heated by wood fire & non-depletable -hot water -lighting	U-Values of :- walls, floor, ceilings, windows. Window areas & shade coefficients Efficiency of:- space heat & cool, water heating equip.

Wind: Sitting as it does across the 40's latitudes, and being a relatively narrow set of islands, New Zealand is windier than most of the countries which might be an inspiration for the development of our energy code. Further study is required before the relative importance of this feature of New Zealand is understood.

Fuel Mix: The mix of fuels in New Zealand is very different to most other countries, and this mix will affect economic calculations. In addition, definitions of energy efficiency may vary from country to country depending on the availability of renewable sources of energy.

BUILDING CONSTRUCTION

There are clear similarities between the timber frame construction in New Zealand and some building practices in the USA, Canada and Australia. There are sufficient similarities that there is at least a *prima facie* case for examining these countries' energy performance codes closely in regard to house building design.

There are also clear similarities between the "international Corporate architecture" of the Central Business Districts of most major towns in New Zealand and the buildings in almost any country's CBD. There seems every reason to believe that approved solutions and generalised thermal simulation calculation programs for such (large) buildings will be able to be applied in New Zealand. The differences in structure due to differing earthquake provisions are unlikely to make significant differences to the energy performance of these buildings.

REGULATORY FRAMEWORK

Of the countries examined, only the Netherlands had an energy code in place as part of a comprehensive performance based building code in a style similar to the code in New Zealand. Although the other countries investigated operate a building energy code, it is often developed and maintained in a separate manner from the rest of the building code.

The Regulatory Framework is seen to be of little consequence in the designation of a building energy performance requirement in a regulation or law. Starting from first principles, an energy performance target developed for the USA is as likely to be applicable in New Zealand as one devised in the Netherlands. What should govern the adoption of one target over another is consideration of economic and building construction similarities, not the manner in which the requirements are administered.

SURVEY OF SUPPORT TOOL USE

The survey of the use of energy performance design decision support tools by professionals involved in the building industry was designed to cover the range of present and possible future users of Clause H1, and their present and possible future use of support tools. Questions covered both design and building practice, along with attitudes to and experience of the Energy Efficiency Clause H1 of the NZBC. The sample was selected with approximately equal numbers of designers (architects, engineers, draughtspeople) and builders primarily working in "small" and "large" buildings. A small number of support organisations were also surveyed. (Donn et. al. 1995)

ENERGY EFFICIENCY AND DESIGN

Participants were asked to comment on the frequency with which energy efficiency considerations affect design decisions. Only 6 of the 67 said that passive solar considerations **never** affect their designs. 49% said that passive solar design **always** affects the design of their homes. This is high, by comparison with other energy conservation activities that could be influenced by an altered H1 clause in NZBC; e.g. only 21% said that they choose efficient hot water cylinders and heating appliances every time.

A picture emerges of professionals who think they understand the issues, and are responding to a general public that is actively demanding sun in their homes, and who want solar passive energy. Linked with these ideas was a strong belief that passive solar design worked. It should be noted that the survey did not test the level of competence of the respondents to produce good passive solar design.

TYPICAL SIZE OF BUILDINGS

For the purposes of this research, a natural split has been determined between "small" and "large" buildings in New Zealand. It is likely that the energy efficiency requirements of the code will split by size rather than into activity related sections. Research has determined that 88.8% of buildings are "small": less than 3 storeys in height and under 300 m^2 in area.

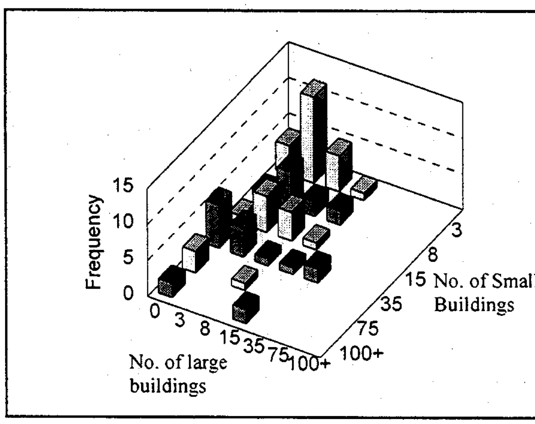

Figure 1 Number of buildings over 300 m^2 and under 300 m^2 by each firm surveyed

Only 0.3% of the buildings (representing 6.8% of the total built area in New Zealand) are "large": over 3 storeys and greater than 300 m^2 in area. The remainder, buildings over 300 m^2 but under 3 stories, make up 10.9% of buildings (34.5% of floor area). It can be seen from **Figure 1** that, although many (50%) of the respondents work with a mixture of large and small buildings, a significant number work predominantly (48%) or exclusively (22%) with small buildings. While this separation of work is not as pronounced as anticipated it is still relatively large.

It has been recommended that the building code be presented in a unified manner across size categories to provide consistency for the majority who work with large and small buildings. However, it will be important also to make some special provision for those who deal only with small buildings.

DESIGN TOOLS

Fifty nine of the respondents said that they used design tools such as those recommended in the current H1: ALF (Bassett et al 1993), NZS2418P and NZS4220, or other aids such as books, manufacturers information, computer programs, or attendance at a seminar. There was no real correlation between their assessment of ease of use of a design tool and the amount of training received.

A clearer pattern was found when the methods used were compared, with ease of use, and training. Most people who used only NZS4218P and/or manufacturers information found them easy to use but had also had no training! As a result, it was recommended that Acceptable Solutions intended for use by the majority of the industry be sufficiently simple that even those who are disinclined to read background material can develop a way of working that produces buildings that are in compliance.

Among the architects, designers, builders and developers there is a very high percentage (81%) use of the structural verification (calculation) method allowed for in Clause B1. The use of the energy efficiency verification method (ALF) is significantly lower. Few (14%) of these respondents had used it at least once in the last year. It was concluded that the high use of the structural code verification option demonstrates that the extra cost of specific design and certification is not a deterrent in situations where the design team can see a benefit.

NZS4220 (1982), the commercial building energy efficiency advisory standard, had been used by 7 out of the 12 engineers for code compliance in the last year. However, only 2 of the 12 said that they used it for more general energy efficiency information. As the code of practice is only advisory, and reference to it as a means of compliance is only vague in the current energy efficiency clause, it had been expected that few if any practitioners would be using it.

Of all code compliance methods ALF(Bassett et al 1993) is used the least; only 6 (9%) of the 67 people from the construction industry have used it in the past year. (3 of these were architects) . It was concluded that the current lack of interest in verification methods is likely to change if the thermal performance levels become more stringent. New Zealand industry's acceptance of verification methods for structural compliance would tend to support this conclusion as would the California experience (Goldstein 1988): "*Currently [in California] it is estimated that 80% of houses use the computer methods, and only 5% use the prescriptive packages.*"

TYPES OF DESIGN TOOLS

With the exception of the engineers, most professional groups show preference for checklist type design support tools. Manual calculations were least favoured, with computer calculations coming second. The engineers favoured computer calculation over the checklist. The designers were equally divided in preference for checklists and computer tools.

Taking CAD use as an indicator of high level computer use, 83% of the engineers use CAD and thus could be expected to be able to utilise complex computer based design support tools with most ease. However, the overall industry use of CAD is only 42.5%. At the other end of the scale, 89% of all practices surveyed did some kind of computing.

It has been recommended that Acceptable Solutions (AS) which are intended for use by the majority of the industry adopt a checklist approach and Verification Methods (VM) should be computer based calculations rather than manual analysis methods. It is accepted that if the VM's are complex and require high computing power, then they will be accessible to only 40% of the industry. VM's of this type are the only ones currently available for use in the revised Clause.

Only 7 people used tools specifically for calculating air conditioning requirements. There was little commonality in the tools used. The ACADS[1] and CIBSE[2] tools were each used by two people; the other 3 people used in house programs, the Australian standard and the "Amazon" program. There is no obvious choice for an approved design tool. It may be necessary for many different tools to be approved for use by designers to demonstrate compliance with the energy efficiency requirements of Clause H1. It is proposed that the IEA BESTEST (Judkoff, 1995) methodology will be used for determining whether a computer design tool produces building designs which can comply. At the outset, it is likely that the two computer codes used by the code developers (SUNCODE, DOE2.1E) will be approved for use as Verification Methods.

---

[1] Association for Computer Aided Design, Sydney, Australia

[2] Chartered Institution of Building Services Engineers, U.K.

Respondents were asked at which stage of design they would like decision support tools to be applicable. Preference was very clearly towards tools that could be used early in the design process. Preference was also clearly expressed for tools that could inform the energy design process rather than just produce code compliance reports. Only the building inspectors expressed a differing view.

LIGHTING

The survey results suggest that there is very little involvement by any of the people we talked to in the design of energy efficient lighting. There is clearly a great need for the daylighting and lighting design requirements in Clause H1 to be well supported by information and education programmes.

SUPPORT TOOLS

Support tools are extremely useful to designers as an aid in the design of buildings and the associated mechanical services. Normally, their use as energy efficiency tools is secondary to their use in ensuring that equipment performs the function for which it is intended. As a result, few such tools are explicitly designed for the optimisation of energy efficiency.

For the purpose of the study, support tools were split into three basic categories:

Input tools. These comprise data that characterise the performance of an individual item, e.g. R-values for insulation, or fan curves.

Rules of Thumb. An example may be the estimation of the spacing and sizing of luminaires to achieve a standard level of lighting. Also included in this category would be the number of hours on average that such luminaries might be operating. Many designers have "house rules" based on experience that are used in design and calculations.

Design Tools. This category of tools includes calculation methods that are used to design aspects of building construction and fitout. Examples are building performance simulation programs such as DOE-2(Winkelmann, 1993), and the ALF Manual (Bassett et al 1993).

These categories are hierarchical, as design tools generally require both rules of thumb and input tools to prepare their input data. Each of these categories is discussed in detail below.

INPUT TOOLS

Nearly all the survey respondents noted that they used manufacturers data as a support tool in the design process. This is a fairly broad ranging category, as it could be interpreted to mean everything from a fan curve to a relatively complex simulation tool such as DOE-2.

Most HVAC and lighting equipment used in New Zealand is built and tested overseas. There are no air conditioning suppliers, for instance, who undertake routine testing of equipment within New Zealand, even for local variants of international products. As a result building designers are dependent on overseas standards and procedures for rating the performance of equipment.

Given the high level of designer dependence on manufacturer's information, it is of little surprise to find that overseas codes often list applicable Standards to ensure that equipment information is correct. The California Energy Code 1992, for example, lists 43 standards and a number of other documents as instruments necessary for Code compliance.

In New Zealand, there are twenty standards that might be referenced in a building code energy efficiency clause. Six relate to HVAC systems; five to insulation material performance specification and measurement; three relate to DHW systems; two to lighting and one to glazing. However, not all of these may actually contain information of direct relevance to energy efficiency.

The method of testing equipment can be critical to the accuracy of the performance information obtained. Davis (1992) conducted measurements on florescent light fittings and compared them with manufacturers ratings based on ANSI measurement standards. It was found that the manufacturer's ratings for such fittings were typically 4%-7% higher than the in situ measurements. As lighting is normally the largest internal load in office buildings, this over-estimate would contribute significantly to over-capacity in cooling plant design. Unfortunately, the error in power measurement is dependent on fitting and situation, and Frey et al. (1993) recommend repetition of the measurement on a site-by-site basis for DSM evaluation purposes. However, an estimate based on standard in-diffuser operating conditions would be an improvement on no estimate at all.

Similar studies were performed for computer equipment by Hejab and Parlsoe (1992) and Wilkins & McGaffin (1994) These studies identify that nameplate ratings are often up to three times higher than average power consumption. Again, these are a significant part of the overall cooling load and consequently the use of nameplate ratings would lead to significant oversizing.

The importance of computer loads is increasing, as offices become more sophisticated and as computers become a standard part of an office worker's equipment. This has led the USA to the Energy Star scheme, a voluntary energy efficiency standard that prescribes partial power-down of the computer after a user-specified time period. Computers complying with Energy Star standards are now becoming widespread internationally, and their heat generation may be lower by as much as 60% than standard units (Smith et al. 1994). Clearly, therefore, improved information on actual PC power consumption has to be made available in a form that is useful to HVAC designers. Without it, estimation of the energy performance of a building for compliance with the building code may be prone to error. Certainly the code or its supporting documents will have to specify very clearly what values are to be assumed in any use of a Verification (calculation) Method to demonstrate compliance with the code's energy performance coefficient.

RULES OF THUMB

Operators in all professional fields have rules of thumb by which they size and design systems. In general, these are local or in-house and difficult to verify. Levermore (1986) described the typical design process as being one plus one equals three, where the extra one is for safety. Levermore continues by demonstrating that a 10% oversizing of radiators operating on a compensated loop leads to a 7% increase in energy use at low load. This is an example of the generally accepted wisdom that over-sizing is a source of energy inefficiency.

However, many aspects of HVAC design encourage over design purely as a means of ensuring that plant performs its allotted task. As a consequence, rules of thumb that originate from this sector are prone to incorporate an element of over design. Similarly, in lighting design, it is common for the electrical consultant to design by in-house methods which are seen as tried and true. The resultant lighting patterns, however, can show little regard for energy efficiency. E-Source (1992) notes that there are a number of institutional factors that promote over-design, and that this is reflected in the rules of thumb used in industry.

DESIGN TOOLS

There are a number of tools available in New Zealand for the design of building systems. The discussion in this section will be limited primarily to HVAC design.

Use of computer based design tools raises a range of issues for discussion:

Static/Dynamic Calculation. Some simple tools currently in use do not allow for the dynamic behaviour of building materials and systems when subjected to the dynamics of people and weather. (Mathews et al. 1994)

Input data. The output from a computer simulation is only as accurate as its input data. The natural tendency is to program to allow for "worst-case" scenarios, which again cause equipment sizing to be over-estimated. Bowman and Lomas (1986) summarise the situation succinctly:

"the [lack of] availability of accurate and sufficiently complete input data, especially on occupant behaviour, limits the ability of even detailed models to accurately predict energy usage"

Lack of plant representation. Some tools do not attempt to represent HVAC equipment at all. This leaves many of the crucial design decisions open to the "rules of thumb" discussed above.

Accuracy of Plant Representation. Some models include plant representations that allow the user to investigate different operating systems and scenarios to maximise performance by whatever criteria are considered relevant. However, E-source (1992) has questioned the ability of such tools to represent equipment types adequately.

Accuracy of energy use calculations. As a consequence of the above problems, the energy use calculation is of potentially uncertain accuracy.

Scope of Model. Correlation based models such as ALF have definite limits on the range of buildings they are designed to accurately represent (Bannister et al, 1994). Models used outside their prescribed range of function will inevitably produce results of poor accuracy.

Little literature has been found on the validity of intermediate-level computer tools such as the ASHRAE, CARRIER and CIBSE methods, although it is understood that none of these tools has the facility to model interactions between different spaces. The following discussion applies to all tools, but more particularly to high level simulation models such as DOE2.1E, SUNCODE/ SERI-RES and ESP.

VALIDATION EXPERIMENTS ON COMPUTER DESIGN TOOLS

The major concern with the proposal to require designers to use thermal simulation design tools to demonstrate that their (large) buildings comply with the code is the accuracy or reliability of those tools. A significant amount of work has been performed on the accuracy of the more complex design tools. However, Wiltshire and Wright (1988) summarise the situation well:

"In attempting to resolve the question of accuracy, a number of inter-model comparison exercises have been carried out, which have all observed fairly substantial differences between the predictions of different models. For example in the Building Research Establishment study, the variation between the annual space heating consumptions, predicted by three detailed simulation models, was 30%. Furthermore, the models were not always in agreement in evaluating the effects of relatively minor changes."

One major international study in this area is the Commission of the European Communities' (EC) PASSYS project, which adopts a four-point validation methodology (Clarke, 1993):

- Examination of methodology and computer code
- Comparison with analytical solutions for well

defined, simple cases.

o Inter-model testing with more familiar codes

o Empirical validation through comparison of predicted values with measured data for a test building or cell.

The last of these is generally considered to be the most important and is certainly the most expensive part of the validation process. A number of publications are available that describe various aspects of empirical validation both within the PASSYS project (e.g. Strachan 1993, Wouters et al. 1993) and elsewhere (Martin and Watson 1993, Winkelmann et al 1993).

Bowman and Lomas (1986) note that attempts to validate code empirically can often be frustrated by any one of many source of external error, with the effect that at that stage none of the empirical validation studies on the programs ESP, SERI-RES, DEROB and BLAST had produced conclusive evidence of internal errors in the models.

Empirical validation appears to have matured somewhat since that date, as shown by Winkelmann et al. (1993), where test cell measurements are used to demonstrate the improved accuracy of DOE2.1E over DOE2.1D.

Overall it is concluded that advanced tools such as SERI-RES/SUNCODE and DOE2.1E should be expected to be capable of generally accurate simulation given appropriate input data. However, this input data is critical. Irving (1988) summarises the problem as follows:

"Any comparison of model versus experimental results is therefore a 'validation' not only of the model, but also of the model-user interface which is usually hard to define, and certainly varies between models. . . it has become apparent that the specification of the building and its mode of use is one of the most important causes of variations in the results obtained"

SIMULATION & CODE COMPLIANCE

There are clearly difficulties in obtaining accurate output from computer simulation tools in the more general situation. But the use of such tools for Code Compliance is far simpler in that many of the input data conditions can be standardised. For instance, the thermal characteristics of the building structure can be specified using a standard, while standard internal load types can be defined based on building type and use. This is the approach used in California and planned for the revision of Clause H1. Users of a Verification Method will be required to model their building design twice: once with the minimum permitted wall insulation, window size and other standard settings (lighting load, glazing U-value and shading coefficient); and once with the settings they want. If their program demonstrates no decline in performance, then their building will be deemed to comply.

CONCLUSIONS

It is proposed that the new energy efficiency clause in the New Zealand Building Code will be consistent across all building types. However, the designers of large buildings will have to demonstrate the compliance of their building with the performance requirements by computer simulation. Designers of small buildings will have a range of options, from copying the construction specified in the Acceptable Solutions, to use of a simple heat balance calculation (Bassett et al, 1993) and even with thermal simulation.

REFERENCES

Bannister, P., Lee, J., Isaacs, N., (1994) "**Sustainable Energy and the Building Code**", Report to BIA/EECA Building Code Energy Efficiency Standards Contract 6.

Bassett M.R. Bishop R.C. & van der Werff I.S. (1993) "**ALF Manual:1990 - Annual Loss Factor Design Manual, an aid to thermal design of buildings.**" Wellington : BRANZ (reprinted with amendments, 1993).

Bowman, N., and Lomas, K., (1986) "**Does Dynamic Simulation Work?**" Building Services The CIBSE Journal, March 1986, pp30-31.

California Energy Commission (1992) " **Energy Efficiency Standards for Residential and Nonresidential Buildings**" July 1992

Canadian Commission on Building and Fire Codes (1993); "**National Energy Code for Buildings 1995**": Draft 4 for Committee Review only. National Research Council - quoted in Isaacs N 1993. "**Energy Efficiency in Building Codes -Canada, Denmark & Sweden -Travel Report Oct/Nov 1993**" Report to EECA. Wellington : CBPR.

Clarke, J.A. (1993) "**Assessing Building Performance by Simulation**" Building and Environment Vol 28, No 4 pp 419-427.

Crawley D.B. (1992) "**Development of Procedures for Determining Thermal Envelope Requirements for Code for Energy Efficiency in New Buildings (Except Houses)**" Martin, Tennessee : D.B. Crawley Consulting for Building Performance Laboratory, Institute for Research in Construction, National research Council of Canada.

Davis, R.G, (1992) "**Explaining the difference between DSM Predictions and Actual Savings for Fluorescent Light Systems**" Proc. 1992 ACEEE Summer Study, American Council for an Energy Efficient Economy, Washington D.C. pp1.43-1.44.

Donn, M. Lee, J, Isaacs, N and Bannister P (1995) **"Energy Design Support Tools"** CBPR Wellington

Frey, D.J., Jacobs, P.C., and Johnson, K.F., (1993)**"Commercial Building Performance Evaluation System"**. Int'l Building Performance Association, Proc. Third International Conference, Adelaide, Australia pp145-151.

Goldstein, David B (1988) **"The American Experience with establishing energy Efficiency Standards for New Buildings: Case studies of California and National Energy Standards"**. The third Soviet American Symposium on Energy Conservation Yalta Crimea, U.S.S.R. National Resources Defence Council, San Francisco

Hejab, M., and Parsloe, P. (1992) **"How low can you go?"** Building Services The CIBSE Journal, October

Isaacs N (1993) **"Thermal Efficiency in New Zealand Buildings - A Historical Overview"** Wellington: VUW CBPR 5 pp 37 July 1993 (for BIA)

Judkoff, R. And Neymark, J (1995) **"Building Energy Simulation Test BESTEST and Diagnostic Method"** (IEA Report) NREL, Golden Colorado

Mathews, E.H., Shuttleworth, A.G., Rousseau, P.G., (1994) **"Validation and Further Development of a Novel Thermal Analysis Method"**, Building and Environment, Vol 29, No 2, pp207-215.

NZS4218p(rovisional): 1977; minimum thermal insulation requirements for residential buildings; Standards Association of New Zealand, Wellington

NZS 4220: 1982; Code of practice for energy conservation in non-residential buildings; SANZ, Wellington

Owashi, L.D., Schiffman, D.A., and Sickels, A.D., (1994) **"Lighting hours of operation: building type versus space use characteristics for the commercial sector"** Proc. ACEEE Summer Study, American Council for an Energy Efficient Economy, pp8.157-8.182.

Palmiter L., Wheeling T., (1981, 1985) **"SUNCODE - PC"** Ecotope Inc Seattle WA, USA.

Shaw, K (1993) **"Attitudes Towards Energy Efficiency among Specifiers"**; by MRL Research Group for the Energy Efficiency and Conservation Authority and The Ministry of Commerce

Smith, L.A., Harriss, J.P. and Blatt, M.H., (1994) **"Office Equipment Energy Efficiency: Taking the Next Few Bytes"**, Proc. ACEEE Summer Study on Energy Efficiency in Buildings pp3.241-3.249.

Strachan, P., (1993) **"Model Validation Using the PASSYS Test Cells"** Building and Environment Vol 28, No 2, pp153-165

Trethowen H.A. (1977) **"New Zealand Standard for Home Insulation"**. Wellington : BRANZ

Wilkins, C.K., and McGaffin, N. (1994) **"Measuring Computer Equipment Loads in Office Buildings"** ASHRAE Journal Vol 36, No 8, August

Wiltshire, T.J., and Wright, A.J. (1988) **"Advances in Building Energy Simulation in the U.K. - The Science and Engineering Research Council's Programme"**, Energy and Buildings Vol 10 pp175-183

Winkelmann, F.C., Birdsall, B.E., Buhl, W.F., Ellington, K.L., Erdem, A.E., Hirsch, J.J., and Gates, S. (1993) **"DOE-2 Supplement Version 2.1E"** pp15.

Wooldridge, M.J., Moller, S.K., (1993)**" Users guide for the Computer Program BUNYIP: Building Energy Investigation Package"** CSIRO Division of Energy Technology. Victoria Australia.

Wouters, P., Vandaele, L., Voit. P. and Fisch, N., (1993) **"The Use of Outdoor Test Cells for Thermal and Solar Building Research within the PASSYS Project"** Building and Environment, Vol 28, No 2, pp107-113.