DESIGNER ORIENTATED PERFORMANCE EVALUATION OF BUILDINGS

Veronica I. Soebarto and T. J. Williamson
School of Architecture, Landscape Architecture and Urban Design
The University of Adelaide
Adelaide, South Australia 5005

ABSTRACT

The objective of the work presented in this paper is to develop a building performance assessment tool that will assist the design process rather than be aimed at giving endorsement to a completed design. The paper discusses the concepts behind the on-going development of this new assessment tool. To effectively place it into the designer's hand, this tool is self-contained – the simulation programs are directly linked to the assessment modules. Its features also include: (1) an interface for entering the input, (2) a module for automatically generating the reference building, (3) changeable databases, (4) validated calculation engine, (5) a user-accessible assessment-criteria module, and (5) presentations of the assessment results.

INTRODUCTION

Using a computer simulation to estimate the energy-efficiency of a building during the design process is a well-known procedure and many programs exist for this purpose. When using these packages, the performance of a proposed building is usually investigated by exploring design changes that provide incremental improvement measured against criteria such as reduced energy consumption and/or improved thermal comfort. This procedure, however, gives no direct information to the designer on the performance of the building compared to other similar buildings, or on the degree to which the "limits" of potential improvement have been approached.

In several countries "rating" schemes[1] have been introduced that do provide this additional information for assessing energy-efficiency compared to an archetype building. These schemes have a variety of objectives forming either part of the requirements for building/planning code compliance or part of a scheme to market energy-efficient / environmentally responsible buildings. Despite claims to the contrary, most of these assessment programs are not design-orientated. They are constructed to give endorsement to a completed design rather than to assist the designer during the design process. While "environmental assessment" of proposed new and modified buildings is potentially one of the biggest future uses of computer simulation, the conceptual work on appropriate methodologies is still in its infancy.

The project described in this paper is aimed at exploring methodologies and producing a prototype designer orientated assessment tool. To begin, some existing schemes are examined from the point of view of the designer.

BACKGROUND

"We live in an era that places high demands on the quality and performance of products. The public are now accustomed to being able to obtain factual reports on the performance of toasters, cars and electronic equipment, and they are also becoming used to seeing product labels that symbolize the achievement of certain levels of performance. Can buildings be far behind?" (Larsson and Cole 1998).

Home Energy Rating

Home energy rating schemes (HERS) are widely accepted and operate in many countries. HERS or HERS-type schemes exist in a variety of forms and the means of assigning a rating can vary from compliance with prescriptive guidelines, a standard (sometimes manual) calculation, a correlation technique, and simple or full simulation. In many cases, the "software" driven aspect of the scheme conceals the underlying simplifications inherent in the rating methodology. The discussion here relates mainly to simulation-based certification type HERS.

---

[1] Rating schemes are generally of two sorts, "certification", which is taken to mean evaluating a building for good performance at the design stage, or "labeling", assessing the in-use performance of a building compared with other similar buildings. This paper deals mainly with pre-occupancy or design stage assessments of performance.

"HERS measure and rate the relative energy efficiency of any house, regardless of its age, location, construction type, or fuel use. The rating evaluates the performance of the thermal envelope, glazing strategies, siting, HVAC system and other criteria .... HERS calculations include estimates of annual energy performance and costs, and can provide insight into cost-effective, energy-efficiency improvements." (HERS Council 1999)

In many jurisdictions around the world (eg US, UK, Australia), the political commitment to improving household energy-efficiency requires a certain level of energy rating in order to obtain planning or building approval. In other situations, the rating provides a deem-to-comply condition for building certification. In situations where participation in the HERS is voluntary or linked to incentive schemes such as energy-efficient or energy-improvement mortgages, market forces will gradually lead to an improvement in the energy-efficiency of the housing stock. In developed countries that have undertaken an international commitment under the Kyoto Protocol to limit greenhouse gas emissions, HERS (and energy-rating in general) are seen as an important tool in achieving their goal.[2]

In general, HERS are seen as seeking similar objectives to the more widely known Energy Labeling, or Minimum Energy Performance Standards (MEPS). These standards are applied to household appliances, such as air-conditioners, water heaters, dishwashers, and refrigerators. The argument goes something like, *"If you can give a rating to a clothes dryers surely you can rate a house in a similar manner. In this way a homeowner or the occupant who chooses a house with a high rating is likely to gain the benefit of reduced energy bills and/or energy consumption."* In the same way appliances are subjected to a standard test for energy labeling purposes, dwellings are subjected to a standard simulation test for rating. Assumptions are usually made for the following:

- typical weather for that climate zone (based on climate records)
- standard occupant behavior (based on assumed thermostat set-points, hot water usage, personal appliance usage, etc.)

2 Some examples of HERS software include U.S. - Building Energy-Efficiency Rating System (BEERS), California Home Energy Efficiency Rating System (CHEERS), Home Energy Ratings of Ohio (HERO), EZ Rater, RemRate: Canada - HOT2000 & AUDIT2000: Australia - NatHERS (The approach adopted here of rating the building envelope ie. excluding the effect of the energy consuming heating and/or cooling plant, in fact, should not be termed an "energy rating" scheme): UK – NHER, StarRate

The pitfall from a designers point of view in using a "universal" energy rating tool is that, for a project where the occupancy patterns, heating/cooling systems, and other factors are different from the standard assumptions, the resulting design is likely to be far from optimum when judged by the normal criteria. This tends to be the case in the more temperate climates. Stein (1997) in examining the accuracy of HERS found that *"The case studies also demonstrated that it is more difficult to accurately predict energy use in mild climates than in more severe climates."*

In Sydney, as an example, there is significant variance in household characteristics. We know that houses may or may not be heated and/or cooled. Any single scheme that makes "standard" assumptions will, for a number of actual cases, cause design decisions that more than likely will lead to an increase in energy consumption compared with what could otherwise be achieved. This case was also shown in a monitoring study of two Habitat for Humanity houses in Houston, Texas (Haberl et al 1998). The supposed-to-be energy efficient house apparently used more energy than predicted. When modeled with assumed 'standard' thermostat settings, the energy-efficient building would use much less electricity than the standard house. In reality, the energy-efficient house used more electricity due to the way the occupants set the thermostat (ie lower in the summer and higher in the winter compared to the settings in the standard-efficient house).

For a HERS mechanism to be sufficient for compliance testing it is only necessary that the scoring system be relatively correct. *"The actual numerical scores are not important as long as the houses are ranked in the correct order."* (Stein, 1997). To be useful as a design tool used in life-cycle assessment and life-cycle cost analysis, however, the results must also show some approximate absolute relationship to energy usage and energy cost. Such a tool would allow an investigation of different household characteristics and the sensitivity of design options. For example, in a hot humid climate, it must be possible to test different choices of thermostat settings and ventilation rates, depending on whether the building is air-conditioned or free-running.

Commercial Buildings Energy Rating

Like HERS, energy rating of commercial buildings operates in several countries. ASHRAE Standard 90.1, which incorporates the Building Energy Cost Budget Method (ASHRAE 1989), is used as the basis for Commercial Energy Codes in several states in the US. The method involves the use of an energy simulation program to estimate the performance of the proposed building compared to a prototype or reference building[3]. The reference building approach is to be used when a prototype building description is not relevant for the proposed design. The method is intended "only for the purpose of demonstrating design compliance" (clause 13.1).

Input parameters for the prototype or reference buildings are suggested by the Standard, based on the type of the proposed building. The suggested input parameters include the quantity/density and schedules of the occupancy, light, HVAC, and water, HVAC system types, and the thermostat settings. It is also suggested that the prescriptive values for code compliance be used for the reference building's envelope's thermal properties. The performance of the proposed building is compared to that of the prototype or reference building in terms of the *annual energy cost*.

Although this methodology is more comprehensive than most energy rating schemes for residential buildings it also, however, poses some limitations for the designer. First, since the criteria used is annual energy cost, nothing is known of other possible aims, eg low CO_2 emission, life-cycle costs, etc. Another limitation is that it does not take into account the building location in suggesting the thermostat settings and HVAC systems.

Environmental Assessment

While the schemes described above deal with energy (or energy costs) as a single rating criterion, several schemes also exist which attempt to combine other environmental factors into a single rating score. The BREEAM scheme introduced in the UK in 1990 (Prior, 1993) is a voluntary environmental assessment scheme intended to encourage building owners and operators to adopt "green" practices. The scheme provides a tool and authoritative assessment procedures for quantitative evaluation of the environmental impacts of a building. The evaluation relates to a number of broad issues including, operational energy use and CO_2 emission, sick building syndrome, pollutants released during fire, embodied energy, radon emissions and the life-cycle use of the building. Credit points are accumulated against the various performance requirements. These are summed to a total score to define Fair, Good, Very Good and Excellent overall performance, with additional requirements of having attained minimum scores in the three performance categories: Global/Resources, Local, and Indoor. The LEED™ "Leadership in Energy and Environmental Design" (U.S. Green Building Council, 1998) scheme operated by the Green Building Council in the US works in a similar way. Applicant buildings must satisfy a number of performance prerequisites and obtain a number of performance credit points to qualify for Bronze, Silver, Gold or Platinum certification.

A recent international initiative to investigate comprehensive building environmental assessment was a project titled Green Building Challenge'98 lead by Canada. The overall goal of GBC'98 was to "*develop, test, and demonstrate an improved method of measuring building performance*". The project reconciled the work of many around the world and a so-called "second-generation" framework for assessing energy and environmental performance was developed during the process. The method is embedded in a computer tool GBTool (Larsson and Cole 1998). The work is now being extended for GBC2000.

The Eco-Quantum packages developed in Netherlands are also intended to enable a designer "*to quickly identify environmental consequences of material choices and water and energy consumption of their designs*". (Kortman et al 1998) The approach used in this program estimates the environmental performance of the building on the basis of a life-cycle assessment (LCA) technique where specified environmental effect scores are converted into four environmental indicators: raw material depletion, emissions, energy consumption and waste, which all represent the environmental consequences of design decisions. Each environmental effect is weighted based on an environmental assessment methodology.

APPRAISAL OF EXISTING RATING SCHEMES

For several reasons none of the rating schemes described above could be considered as an adequate design tool. The issues are:

- Where a single criterion only is considered, conflicts with other design issues may be hidden. For example, low site energy consumption (the basis of most HERS), does not necessarily correspond to the life-cycle energy use (including embodied energy) or CO_2 emissions.
- All real-world design decisions (even "green" designs) operate within an economic framework that must be considered in conjunction with the "objective" criteria. The GBC'98 process appears to have appreciated this important point but excluded cost for "practical" reasons.

[3] A *prototype building* – a building of the same occupancy type as the proposed building but with specified form, orientation, use profiles etc. A *reference building* – a building with the same form, area, orientation, and HVAC as the proposed design but with other characteristics specified.

"…..the inclusion of cost or otherwise must be linked to the primary objectives of the assessment process. If it is an objective assessment of a buildings ecological impact, then costs are not relevant; if it is an assessment of relative improvements within existing economic and regulatory constraints then it should." (Cole and Larsson, 1998).

Where energy cost is adopted as a single rating criterion, (eg. ASHRAE 90.1) only part of the total cost is included.

- Schemes that do not weight environmental factors assume erroneously, in effect, that all factors are of equal importance. Similarly, schemes that use fixed weightings (even if "objectively" derived) misconstrue the real-world design process in not allowing values and priorities to be tested.

- All rating schemes assume heating and/or cooling and prescribed thermostat set points. None are suitable for assessing naturally ventilated buildings.

- The time, effort and expense required to input the data is generally excessive. *"The full assessment of the building (using the GBTool) could take even (a) few weeks with thousands of fields to be filled out and with use of other supplementary programs for energy or mechanical systems."* (Anon, 1998)

- No schemes, except for prescriptive ratings, have been implemented in a practical single rating tool/program. Energy performance ratings are done by running a simulation program, at least twice (once to simulate reference building and another run to simulate the proposed building). Multiple criteria assessments require input data from several simulation or similar programs.

DEVELOPMENT OF A NEW ASSESSMENT TOOL

With the limitations of existing schemes in mind, our aim has been to develop an assessment tool addressing the requirements of designers. An important consideration is that the methodology should give design information while comprehending that environmental performance is not the only design objective (and in general not the most important). Based on the assessment of existing rating schemes and tools as outlined above, we summarize that an environmental rating tool should:

- be self contained, both in inputting data, performing simulation, and providing the assessments,

- be easy to operate and to enter data, supported with built-in but changeable databases,

- automatically generate the reference building according to certain rules,

- have transparent assumptions, including the operating assumptions and assessment criteria,

- be based on a validated calculation engine, and

- provide multiple and/or single criteria assessments based on a robust and relevant technique.

The following sections describe how these objectives have been addressed.

Self contained

An existing user-interface of a simulation program has been modified to perform environmental ratings. The program is ENER-WIN, a Windows®-based program, originally developed to perform hourly thermal and energy simulation of buildings (Soebarto and Degelman 1995). The program's interface allows the user to easily enter information about the building including: the building location, building geometry, envelope data (thermal properties, embodied energy) external ground condition, internal use patterns and load densities (for occupancy, lighting, small equipment and domestic hot water), and heating and cooling systems (ventilation rate and schedules, thermostat settings and heating/cooling equipment types, system efficiency and set points). It also allows the user to specify naturally ventilated operations and the use of daylighting. The program has currently been modified to allow the user to also enter a subjective environmental degradation factor based on raw material uses, longevity, recyclability, and environmental impacts.

Two types of weather data are accepted: (1) recorded weather data in either TMY2, WYEC2 and Custom formats, and (2) the monthly summaries which are contained in the built-in weather database (Degelman and Soebarto 1995). The program's weather generator will develop synthetic hourly weather data from these summaries (Degelman 1991).

The user can also enter the economic parameters of the project. These include the building and mechanical system's economic lifetime, the cost rate of each fuel type used (gas, electricity, water, etc) including the demand charges, and the discount as well as inflation rates. Also entered are the unit prices of the building components, such as the envelope elements (wall, roof, window, skylight), lighting (and daylighting) system, and HVAC system installation and maintenance costs.

The assessment can be performed as soon as all inputs for the proposed building have been entered into the program. A prototype or reference building will automatically be generated just before the simulations are performed (see *Automatically generated reference building* section). The program will perform two simulations, one for the proposed building and another for the prototype/reference building. Results of the simulations are then passed to the Assessment Module for reporting results. The project multiple-criteria summary (as described below) will be displayed together with assessment results for individual cases. Suggestions of where the building may perform poorly compared to the reference building will be pointed out. The user can then make alterations and the new design will be assessed, adding to the "project" database. The same process can be repeated for any number of design alternatives until the designer is satisfied with the range investigated.

Supported database

The program is supported with several databases; however, the entire program is written with an open architecture, meaning that all variables including input from databases may be changed by the users.

Two types of databases are provided within the tool. The first one is the existing database of ENER-WIN, which is accessible by the designer to describe the proposed building. This includes wall/roof/door/ window/skylight material types or assemblies and their thermal properties, use profiles and schedules, thermostat settings, lighting types, HVAC equipment types and efficiencies, and economic parameters. Parts of the database are based on ASHRAE 90.1 (ASHRAE 1989). When the user select a building type, the program automatically retrieves default values from these databases. These values can later be changed in the model to better describe the proposed building. The databases can also be changed to better match local "common practice".

The second type of database contains parameters for the prototype/reference building. The data in this database can be changed (or have restricted access, depending on software use) to suit the "local target" or "local practice". These include the insulation values and glazing characteristics, lighting and small equipment power densities, use profiles and schedules, thermostat settings, heating/cooling equipment types and efficiencies, and the assessment criteria.

Automatically-generated reference building

The reference building is automatically created before simulations are executed, based on several rules derived mainly from ASHRAE 90.1. Some of the rules include:

- the reference building will have the same occupancy type as the proposed building,
- the form, orientation, number of floors and the area of each floor shall be the same as the proposed building, alternatively
- a reference building may be designated as a rectangular shape with the aspect ratio and the orientation specified,
- natural ventilation or daylighting shall be assumed to occur if the proposed building uses natural ventilation and daylighting,
- internal loads (occupancy, lighting, equipment, ventilation, hot water), use profiles and schedules, as well as HVAC system types, efficiency and operating schedules are from the database of the corresponding building type,
- thermostat settings and heating/cooling equipment set points are based on the building location/weather data, and
- envelope thermal properties (eg U-Values, absorptivity) are determined based on the building location and type.

Choosing an appropriate reference building acknowledges the contextual and social dimension of the individual problem in time and place. The aim of environmental assessment may be seen as providing design advice for a "better" solution relative to the reference building.

Figures 1 shows the flow of input and assessment processes. Figure 2 shows the assessment criteria dialogue screen.

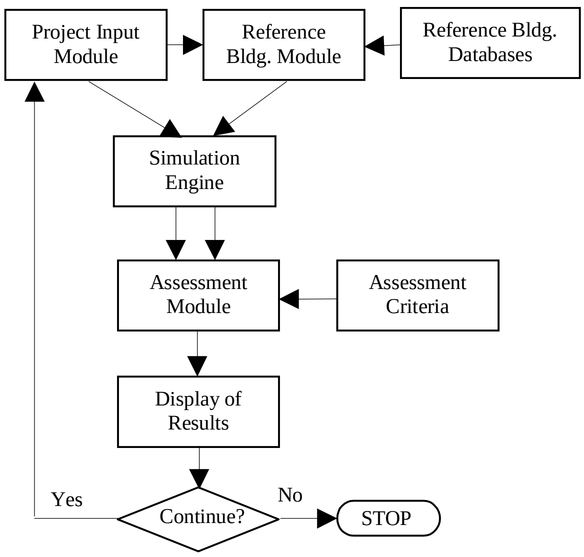

Figure 1. Flow of input and assessment

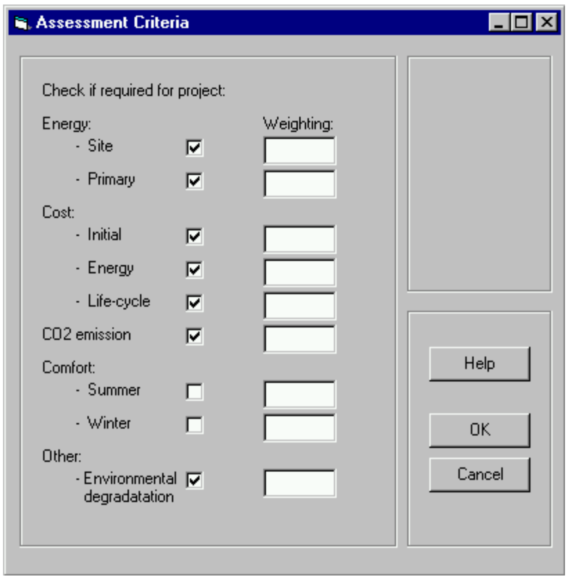

Figure 2. Assessment Criteria dialogue screen

Validated calculation engine

The simulation engine of the ENER-WIN program has been tested against other programs such as DOE2 as well as measured data from operating buildings. An example is the tests that included comparisons of heating and cooling degree days, dry bulb and wet bulb temperatures, global and horizontal insolation, total heating and cooling loads, electricity, gas and total energy uses, in a 100-sqm house (Degelman 1997). In a study by Soebarto, two large and small office buildings were monitored and the simulated hourly energy uses (electricity, gas, water) were compared to measured data, showing an agreement of more than 90% (Soebarto 1996).

A further validation of the simulation program in this assessment tool is required, particularly to validate the free-running (naturally ventilated) building simulation. The first author is currently conducting a monitoring of a free-running residential building for the purpose of validating this program.

Single and multiple criteria assessments

In making an environmental assessment of a proposed building there are several objectives which designers could be expected to address, either explicitly or implicitly. These are likely to include:

- energy use:
  - delivered energy: operational primary (non-renewable) energy
  - life-cycle energy use, including embodied energy
- greenhouse gas production particularly CO_2
- indoor air quality, particularly the thermal environment
- operating plant load
- costs:
  - initial or capital costs
  - operating costs, fuel, power, maintenance, etc
  - life-cycle costs, sum of the initial plus discounted future costs
- other environmental degradation, eg. using nuclear fuel, atmospheric pollution, employing timber from non-sustainable forests, etc.

Where many objectives are to be addressed explicitly as quantified variables in a design (or qualitative variables where ordinal scales or nominal classifications can be applied) multiple-criteria decision techniques provide a method of comparing proposed solutions. Williamson (1997) has described the application of these techniques where the benefit and cost values of a proposed building are expressed as standardized values against a "reference" building. In this way, they represent a relative benefit and cost compared with the reference building. Using this technique, a Pareto or noninferior set of solutions can be identified as shown in Figure 3[4]. Since there is no *a priori* method for choosing among the solutions that comprise the Pareto set various solutions, for example, the highest benefit solution, the lowest cost, the greatest net benefit, the solution with the greatest benefit-cost ratio, etc. may be identified. Within this methodology *rating* schemes that excluded cost factors essentially can be described as defining "benefit" values (R1,R2,R3,R4,.etc.) on the solution space to delimit the rating levels.

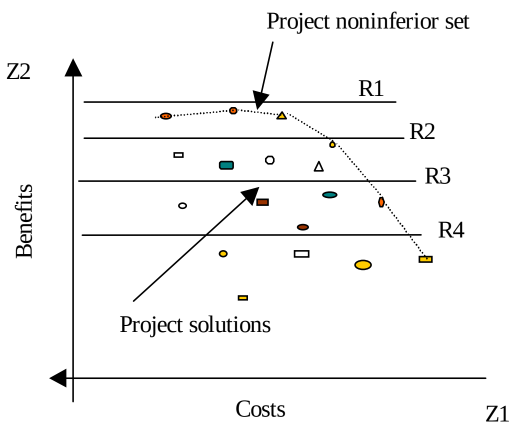

Figure 3. Project Solution Performances for Two Criteria Z1 and Z2

PRESENTATION OF ASSESSMENTS

After the simulations of both the proposed and reference building have been executed, the results will be presented to the user in both graphical and text forms. The first three of the following graphical outputs are the existing features in ENER-WIN while the last three are still under development:

[4] For more details on significance and derivation of the Pareto set (named after Vilfredo Pareto) see Radford and Gero, 1988.

1. Energy use and loads: peak, monthly and annual loads (heating and cooling), monthly and annual energy use breakdown, annual site and primary/source energy
2. Indoor thermal comfort: highest and lowest operative and radiant temperature, relative humidity, and discomfort degree hours
3. Life cycle costs: initial, operating, and maintenance costs
4. Life cycle of embodied energy of the construction, based on the building geometry, material data, embodied energy tables, and the building life time
5. Life cycle CO2 gas production
6. Other environmental degradation, eg. using nuclear fuel, atmospheric pollution, employing timber from non-sustainable forests, etc.

The multi-criteria "project" environmental assessments, taking into account criteria weightings, are also displayed.

Figure 4 shows two examples of the assessments.

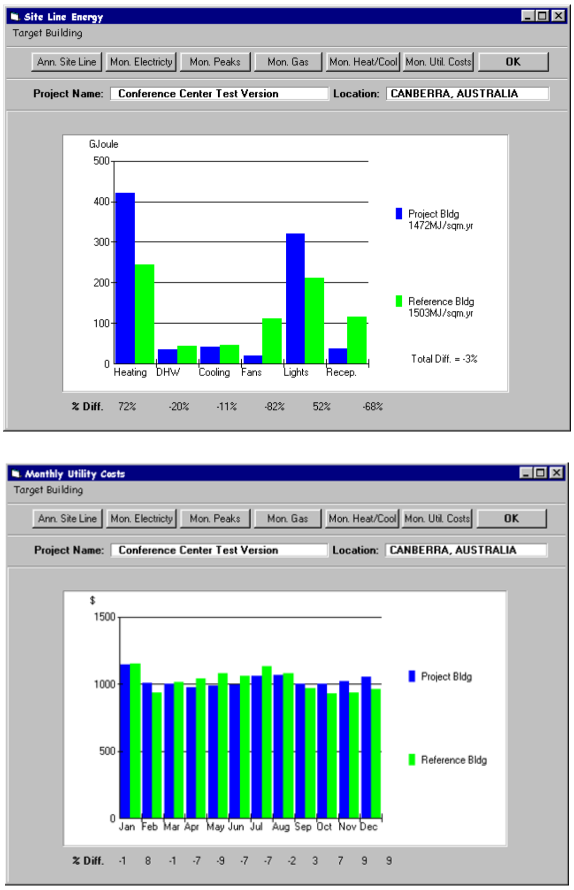

Figure 4. Assessments of Annual Energy Use Breakdown and Monthly Utility Costs

CONCLUSIONS

Elsewhere Coldicutt and Williamson (1995) have argued that,

> *"…design problems do not come fully pre-defined, but rather need to be explored, applicability [of 'tool-like' devices, computer programs, etc] can best be determined by an iterative approach in which initial understandings of the problem and means of addressing it are refined."*

Inherent in this view is the need for comprehensiveness of design tools so that applicability is maximized. Constraints and lack of flexibility may lead to *either:*

- the misapplication of the "science", where the ends are construed to match the instrumental application (eg. energy cost is taken to equate with CO_2 emissions), or means are adopted to coincide with the instrument (eg. buildings are assumed to be air-conditioned because evaluation of free-running buildings is beyond the scope of the evaluation technique), *or*
- the interrelationships of design ends (local versus global) are overlooked or ignored (eg. using electricity generated by nuclear energy to reduce CO_2 emissions).

As shown in this paper, existing "rating" schemes, while ostensibly providing some insight into the issue of the comparability of design solutions, are in general inadequate as assessment tools to be used in the design process. Existing assessment packages would appear to be either too limited (ie only assess one criteria such as energy use), or too difficult to use due to the number of input required for multiple-criteria assessments. In many cases, the parameters of the reference buildings are neither transparent to nor accessible by the user, resulting in an unrepresentative reference building.

In the general case, context-specific and problem-specific issues will determine which assessment criteria and their weighting are to be included (and excluded). An appropriate assessment tool must provide the possibility for a designer to consider the sensitivities of these factors in single and multiple analysis together with the sensitivity of the weighting. To be effective and useful, this tool must be applicable during the design process. The software developments described in this paper combined with the existing ENER-WIN package are aimed at addressing this objective.

ACKNOWLEDGEMENTS

A Faculty Development Grant provided by the School of Architecture, Landscape Architecture and Urban Design, The University of Adelaide supported the work reported in this paper. We also wish to acknowledge the collaboration of the authors of the ENER-WIN program.

REFERENCES

Anon. "Green Building Assessment Tool - GBTool 1.3 - a second-generation tool for building performance labelling", *Green Building Challenge '98 Conference Retrospective*, 1998. (http://www.greenbuilding.ca/gbc98cnf/speakers/gbtool.htm)

ASHRAE. *ASHRAE Standard 90.1. Energy efficient design of new buildings except low-rise residential buildings.* American Society of Heating Refrigerating and Air-conditioning Engineers, Inc. Atlanta, GA., 1989.

Coldicutt, S. and T.J. Williamson. "The limits of instrumentalism", *Proceedings of Australian and New Zealand Architectural Science Association (ANZAScA) Conference,* University of Canberra, Canberra, pp. 23-29, 1995.

Cole, R. J., and N.K. Larsson. "Preliminary Analysis of the GBC Assessment Process", *Green Building Challenge '98 Conference Retrospective*, 1998. (http://www.greenbuilding.ca/gbc98cnf/speakers/cole.htm)

Degelman, L.O. and V.I. Soebarto. "Software description of ENER-WIN: A visual interface model for hourly energy simulation in buildings", *Proceedings of Building Simulation '95 Fourth International Conference*, International Building Performance Simulation Association, Madison, WI., Aug.14-16, pp. 692-696, 1995.

Degelman, L. O. "A statistically-based hourly weather data generator for driving energy simulation and equipment design software for buildings", *Proc. of the 2nd World Congress on Technology for Improving the Energy Use, Comfort, and Economics of Buildings Worldwide*, International Building Performance Simulation Association, Nice, Sophia-Antipolis, France, Aug., pp. 592-599, 1991.

Haberl, J., T. Bou-Saada, A. Reddy, and V. Soebarto. "An evaluation of residential energy conservation options using side-by-side measurements of two Habitat for Humanity houses in Houston, Texas", *Proceedings of the 1998 ACEEE Conference,* American Council for An Energy Efficient Economy, Pacific Grove, CA, Aug. 23-28, 1998.

Kortman, J., H. van Ewijk, J. Mak, D. Anink, and M. Knapen. "Eco-Quantum the LCA-based Computer Tool for the Quantitative Determination of the Environmental Impact of Buildings", *Proceedings of Buildings and Environment in Asia Conference,* Singapore, 1998.

Larsson, N. K., and R.J. Cole. "A Second-Generation Environmental Performance Assessment System for Buildings", *Keynote address, Green Building Challenge'98 Conference*, 1998. (http://www.greenbuilding.ca/gbc98cnf/speakers/larsson.htm)

Prior, J. (Ed.) *Building Research Establishment Environmental Assessment Method - BREEAM,* Version 1/93, BRE, 1993.

Radford, A.D. and J.S. Gero. *Design by Optimization in Architecture.* Van Nostrand Reinhold, New York, 1988.

Soebarto, V.I. and L.O. Degelman. "An interactive energy design and simulation tool for building designers", *Proceedings of Building Simulation '95 Fourth International Conference*, International Building Performance Simulation Association, Madison, WI., Aug.14-16, pp. 431-436, 1995.

Stein, J. R. "Accuracy of Home Energy Rating Schemes", *Report No 40394,* Lawrence Berkeley National Laboratory, Berkeley, CA, 1997.

U.S. Green Building Council. *LEED™ (Leadership in Energy and Environmental Design) - Green Building Rating System*, Draft, 1998.

Williamson, T. J. "Concept(s) of the Energy-Efficient House in the Temperate Regions of Australia: A Critical Review", *Ph.D. Dissertation*, Department of Architecture, The University of Adelaide, Adelaide, 1997.