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AN INTRODUCTION TO BUILDING ENERGY PERFORMANCE SOFTWARE

Mark B Luther

SUMMARY OF

ACTIONS TOWARDS SUSTAINABLE OUTCOMES

Environmental Issues/Principal Impacts
- The powerful influence of implementing building environmental performance software at various project stages to ecological sustainable design (ESD).
- The reduction of operational energy compared to base-case design standards.
- Reduced CO₂ emissions to the environment.
- Reduced primary energy demand resulting in greater impact of on-site renewable energy systems.
- Effective, responsive and efficient material selection for buildings.
- A reduction in capital investment (mechanical equipment) together with life-cycle costs.

Basic Strategies
In many design situations, boundaries and constraints limit the application of cutting EDGE actions. In these circumstances, designers should at least consider the following:
- Demonstrating through simulation the benefits of energy efficient design alternatives.
- Transferring capital investment savings into energy efficient and renewable building systems.
- Providing evidence to the client and/or builder how various concepts in environmental design, materials, alternative mechanical system selection etc. could perform.
- Demonstrating alternative control strategies in an environmental building concept and their cost benefit.
- Increased user comfort and control capability together with material and building envelope selection.
- Reduce (non-useable) mechanical equipment building area into more occupant space.
- Potential life-cycle cost reduction due to smaller equipment.

Cutting EDGe Strategies
- Simulation of innovative hybrid (conventional with passive) building environmental systems (i.e. night venting, thermostat set-points, and mechanical equipment selection, integration and operation)
- Increased day lighting into commercial buildings.
- Potential mechanical system cost reduction due to a shift from expensive conventional systems.
- Healthier and more user-friendly buildings.
- Predicting the performance of alternative mechanical systems together with passive conditioning strategies.

Synergies and References
- APACHE – IES, www.ies6d.com
- ECOTECT – by Andrew Marsh: www.squ1.com
- ENERGY-10, Doug Balcomb, National Renewable Energy Laboratory, Golden CO
AN INTRODUCTION TO BUILDING ENERGY PERFORMANCE SOFTWARE

Mark B Luther

1. INTRODUCTION

The purpose of this note is to introduce and highlight the capabilities of energy performance software to the novice user. Although the note does not explain in detail the fundamental deliverables of building energy performance software (BEPs) it provides advice regarding the specific stages at which software could be applied in the design development process. Refer to Figure 1.

A primary aim of BEPs is to calculate the energy load required to maintain comfort conditions. Variations in building design and materials can then be introduced to reduce this energy requirement. Although the fundamental deliverables within energy software are still provided, the emphasis is shifting, with some now providing advice and setting design targets. In fact, a shift from energy to overall environmental assessment is taking place in software packages. Such developments could in fact be inclusive of a life-cycle approach where capital (embodied) energy of a building is considered alongside its operational energy. It is ludicrous to only consider the operative energy of a building, yet most energy software solely deals with this output.

Energy programs still range from the simple to complex. Recently there have been some very sophisticated programs developed to be user-friendly, quick to learn and obtain results, as well as being graphically informative. In general, programs are geared to providing an energy performance evaluation with respect to a particular building typology and its location. The most basic information relates to peak loads for equipment sizing and overall annual energy consumption. However, expectation and increasing demand for detailed information such as: CO₂ emissions, passive system climate analysis, free-running interior temperatures, thermal comfort assessment, a ranking of energy efficient strategies and life-cycle cost analysis, to name but a few.

As mentioned, this Note attempts to discuss several BEPS software programs generally available in Australia and emphasizes categorising the programs according to their application at the various stages of a project. It is intended that this approach will invite the reader to select the appropriate software programs for the desired output at the proper time in the project. It is strongly suggested that an experienced consultant provides an outline of various software applications in accordance with the various project stages. Furthermore, the deliverables of the software should be discussed and identified among the entire project team at project commencement.

2.0 PROGRAM CONTENT AND TYPOLOGY

Table 1 lists several programs common in Australia according to their prime category of simulation output. Many of today’s programs are capable of providing results which should allow them to provide and qualify for energy rating, energy (peak) load and energy consumption. However, it still remains the objective of some software programs to achieve a specific output category as discussed below.

<table>
<thead>
<tr>
<th>Building Environmental Performance Software (BEPs)</th>
<th>Energy Rating</th>
<th>Energy Load</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>BERS</td>
<td>CAMEL</td>
<td>BERS</td>
<td></td>
</tr>
<tr>
<td>NathERS</td>
<td>CHVAC</td>
<td>ESP-II</td>
<td></td>
</tr>
<tr>
<td>FirstRate ABGR</td>
<td>CARRIER</td>
<td>TRANSYS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RESLOAD</td>
<td>TAS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECOTECT</td>
<td>IES-VE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BDA</td>
<td>ENERGY Plus</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENERGY-10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENERGY Express</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Various energy programs typically used in Australia

Figure 1. The building project phases according to IEA Task 23 (Lohnert et al, 2002)
2.1 Star rating and energy rating

Quite often the expectations from a user (or client), on a particular energy software simulation, are very different from those actually delivered by the program. Clients want to have evidence of a building's performance almost right from the start of a project. They want to know how much better their environmental building will perform over a 'base-case' or standard. In a sense, 'star-ratings' offer this analysis.

Star rating schemes operate by allocating a point score for each of the design elements used in a building envelope. The First Rate and Building Energy Rating Scheme (BERS) programs provide star-rating information whereas NatHERS does not. However, NatHERS is the foundation to First Rate and BERS programs. The Australian Building Greenhouse Rating (ABGR) provides for a star rating tool for commercial office buildings. A calculation tool is provided on its website at www.abgr.com.au.

Recently, building environmental rating systems which go beyond the building envelope, by investigating and ranking the entire ecological footprint of a building have been released. Green Star, the Green Building Council of Australia office rating tool is an example of such a rating scheme. Refer to BDP Environment Design Guide note GEN 57 for a description of individual rating schemes.

In energy rating software it is the annual energy consumption (kWh/m²/year) that gets assessed. Ranges of consumption are allocated stars. In other words, the less energy consumed the higher the star rating. At present star ratings generally go to 5-stars at the highest, although there is an exceptional 6-star possibility. A zero net energy building would represent 10-stars. These systems are constantly being revised and updated.

The idea behind energy and environmental star rating programs is that they are relatively simple to use. It is recommended that the new software user begin with these programs. However, although the information is generally limited to stars, programs such as First Rate are beginning to provide interactive program assistance and advice on how improvements in a design can be made. 'Optimisation' buttons are becoming the artificial intelligence of the programs. These provide the user with advice on improving their building and highlight the 'weakest links'. With other programs a trial and error process of changes (e.g. double glazing, insulation levels) can assist in design changes to improve the output of the building.

2.2 Peak loads – mechanical (HVAC) systems programs

In terms of program complexity, the calculation of a building energy load is the next progressive step. Building energy peak loads imply the sizing of mechanical equipment for conditioning air to an interior set-point temperature. The total energy consumed (over an hour) will consider the efficiency of the mechanical system and this load.

A building load is calculated under a peak climatic condition occurring at a particular hour for the design climate. The load needs to meet the designated comfort design temperatures for the building i.e. those which are individually exceeded on 10 days per year. For critical processes (extreme cases) the design temperatures are individually exceeded on 0.25 per cent of the plant operating hours (AIA, 1998).

Figure 2 illustrates a graphic result from an energy load program. Shown is the total energy (40,560 W) required to accommodate the peak load condition for the cooling system (heat gain) in watts. The usefulness of this program output (a pie chart) is in recognising the contributions to this peak load. A user can quickly conclude that the window systems and electric lighting loads are huge contributors to this load, suggesting a review of these components in the design.

![Figure 2. An example of the output from an energy load program (CHVAC – Elite Co)](image)

2.3 Energy consumption programs

Energy consumption programs report annual total energy consumption, hourly consumption, and air temperature results for commercial and residential buildings. These packages are often classified as energy performance or thermal performance programs. They are typical of the programs described in greater detail in BDP Environment Design Guide note DES 17, Building Energy Performance Simulation. These programs rely on hourly climate data that is generally representative of a 'typical' year. Energy consumption is not to be confused with peak energy load. Also, it is important to appreciate that programs using hourly climatic data may not obtain a peak load. As a result, energy consumption program results do not necessarily provide the worst case scenario for a given climate condition. Energy consumption programs yield thermal performance information and emulate a realistic hourly behaviour. Results from some energy consumption programs allow an assessment of user schedules, natural ventilation, zonning operation and thermal comfort.

Figure 3 illustrates the annual energy consumption (kWh/m²/year) performance simulated for a reference
building (base-case) against that of a high-performance low energy building of similar design. This graphical output is very useful in the development of the building design. Such output is not only useful but becoming typical when a particular building is evaluated against a base-case. Energy rating programs essentially rely on this information to place them into a 'star' category. The illustrated example is from the US based program ENERGY-10 and provides such results prior to any formal design commitment, using a shoebox design in the preliminary (pre-design) stage. This is an ideal example of where energy software can be applied at the inception of a design project.

2.4 Integrated environmental software

This is the next step in energy performance software. It is expected that a user will have all the analysis tools at hand within one software package. Although this note is intended to introduce energy performance software it is useful to know of such progressive and forthcoming developments. Such programs go beyond energy consumption. Among the BEPS listed in Table 1, many now have the features to provide:

- a climate analysis
- day and electric lighting integration with simultaneous energy analysis
- base-case or reference building energy performance standards
- libraries of various mechanical equipment and system type options
- implementation of several typical energy efficient strategies
- thermal comfort indices and adherence to various standards
- humidity and condensation analysis
- life-cycle cost analysis over baseline alternatives
- total CO₂, SO₂ and NOₓ, pollutant emissions
- ventilation or computational fluid dynamics (CFD)
- various HVAC and passive control strategy operations.

However it is important for the novice to understand that the three main features of energy performance software remain as presented in Table 1: energy rating, energy (peak) loads and energy consumption. Simulation programs such as ECOTECT, IES-VE or TAS, have a program agenda to become a one-stop-shop for building performance analysis. These programs are linked to a 2-D or 3-D geometric model of the design. Building envelope compositions, glazing, shading devices and interior surface materials are selected with the intention of simulating an overall energy, daylighting, acoustic, ventilation etc. analysis. Several of Australia’s leading engineering firms have acquired one or more of these program packages and are using them for advanced consulting of environmental concepts. These programs are quite exceptional for assisting in the alternative design concept stages of a project.

IES-VE or TAS can apply a single model, allowing the user to undertake all aspects of thermal analysis from heat loss and heat gain, thermal simulation to HVAC as well as control strategy simulation. In addition the model can be used for solar analysis, day lighting, glare, electric lighting design and layout, internal and external CFD, value engineering, Cost Plan, Life Cycle Analysis, pipe and duct sizing and layout, and occupant evacuation.

However the use of such integrated environmental modelling software may also stretch the skills of many services engineers, requiring not only a good knowledge of traditional HVAC systems but also of ‘passive’ techniques and particularly the design and integration of natural ventilation systems and use of the building fabric together with the HVAC systems. Perhaps even more importantly, the use of such programs requires that the practitioner has considerable real building operation experience to help correctly validate or commission the
modelling results within the actual building. Thus, it is believed that the successful deployment and use of integrated environmental modelling software may be contingent upon appropriate training and above all interdisciplinary working practices.

3.0 INPUTS TO BUILDING ENERGY PERFORMANCE SOFTWARE

The types of inputs to BEPS vary only slightly between the three categories: energy rating, energy load or energy consumption with a few exceptions being primarily between residential and commercial simulation programs. A general listing of program inputs to BEPS is provided in Table 2. This table is constructed with reference to the programs previously given in Table 1. An extensive study and review of all existing programs would be required if more detailed information is desired. The intention of this note is to provide an overview of what BEPS can provide the software user. It is not intended to be a critique of available products, nor a recommendation of any particular product.

### 3.1 Climate

Energy rating and energy consumption programs rely on hourly averaged climatic data that is location specific. Such data is often for a 'typical' year and should not be altered. Since rating programs rely on comparisons of performance in a given location they use default thermostat settings. Energy load programs apply monthly average peak temperatures which have a default setting of ambient dry-bulb (DB), wet-bulb (WB) temperature along with solar radiation. Interior temperature and humidity have default settings as well. Quite often, the user can alter the climatic input data for energy load programs.

The climatic output as shown in Figure 4, as used by the program ECOTECT with information according to Szokolay (1982), provides the user with a graphic illustration of the climate being considered. Figure 4 illustrates, (starting on the right vertical figure) for a given month; the hours of daylight, average solar radiation and monthly maximums, averages and minimums for temperature. Wind data and its direction are provided in the wind rose diagrams. Degree hours for heating and cooling are also presented (bottom right). These are the hours above or below a baseline temperature (generally 20°C) that may be encountered for a specific month.

It is essential to consider climate and location, at the early stages of any project.

### 3.2 Site

Most programs except some residential energy load type allow for a building orientation typically within a 45 degree resolution. However some programs can specify exact orientation in relation to north and provide a high accuracy in this regard e.g. NATHERS.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Factors to be considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
<td>Hourly files according to location ambient dry-bulb (DB) and wet-bulb (WB) temperatures, humidity ratio, solar radiation, wind, wind direction (Szokolay, 1982). For Peak Loads: mean monthly values of DB &amp; WB temperature and maximum solar radiation values are sufficient.</td>
</tr>
<tr>
<td>Site</td>
<td>Orientation: N, NE, W, NW, E, SE, S, SW etc</td>
</tr>
<tr>
<td></td>
<td>Obstructions: adjacent buildings, trees, etc.</td>
</tr>
<tr>
<td></td>
<td>Topography and elevation of the building on site</td>
</tr>
<tr>
<td>Spatial Geometry</td>
<td>Area and volume of individual zones (spaces)</td>
</tr>
<tr>
<td>Walls</td>
<td>Area and material:</td>
</tr>
<tr>
<td></td>
<td>Default construction composition including insulation</td>
</tr>
<tr>
<td></td>
<td>Material selection menus with heat transfer coefficients (U-value)</td>
</tr>
<tr>
<td>Floor</td>
<td>Area and material:</td>
</tr>
<tr>
<td></td>
<td>Default construction composition including insulation</td>
</tr>
<tr>
<td></td>
<td>Material selection menus with heat transfer coefficients (U-value)</td>
</tr>
<tr>
<td></td>
<td>On ground or above ground specification</td>
</tr>
<tr>
<td></td>
<td>Perimeter floor slab exposed</td>
</tr>
<tr>
<td>Roof and ceiling</td>
<td>Area and material:</td>
</tr>
<tr>
<td></td>
<td>Default construction composition including insulation</td>
</tr>
<tr>
<td></td>
<td>Material selection menus with heat transfer coefficients (U-value)</td>
</tr>
<tr>
<td></td>
<td>Roof spaces ventilated or non-ventilated</td>
</tr>
<tr>
<td>Equipment and light</td>
<td>Default and user assigned electrical load - watts</td>
</tr>
<tr>
<td></td>
<td>Default and user assigned lighting load - watts</td>
</tr>
<tr>
<td></td>
<td>User schedule and diversity factor</td>
</tr>
<tr>
<td>Occupancy and</td>
<td>Number of people per m²</td>
</tr>
<tr>
<td>ventilation</td>
<td>Ventilation: Ls/ m² or Ls/person</td>
</tr>
<tr>
<td></td>
<td>User schedule and diversity factor</td>
</tr>
<tr>
<td>Window glazing</td>
<td>Glazing selection: double, single, low-E etc</td>
</tr>
<tr>
<td></td>
<td>Orientation</td>
</tr>
<tr>
<td></td>
<td>Area</td>
</tr>
<tr>
<td></td>
<td>Shading details: internal, external and overhangs</td>
</tr>
<tr>
<td></td>
<td>Material U-value and shading coefficient (SC) and or solar heat gain coefficient (SHGC).</td>
</tr>
<tr>
<td>Schedules</td>
<td>Daytime or night time specification: for lighting, occupancy, HVAC operational strategies, fans etc.</td>
</tr>
<tr>
<td>Fuel source</td>
<td>Fossil-fuels (i.e. coal-fired electricity or gas) vs renewable sources (i.e. solar, wind, hydro etc)</td>
</tr>
</tbody>
</table>

Table 2. General data input to energy rating, load and consumption programs
3.3 Schedules (function/use of building)

Occupancy concerns the ventilation needs of people and occupant heat gains to the building. For energy rating and residential programs the additional conditioning of ventilation air tends to be fixed and assigned a default value generally of 1.0 air change per hour (ACH). However, the ventilation code requirements for specific spaces are more accurately defined in the Australian Standard (AS, 1668). Energy load and energy consumption programs often allow this value to be adjusted according to occupant diversity factors and occupant user schedules.

3.4 Zoning

Both residential and commercial programs allow for user defined zoning. In the case of residential, the zoning is relatively simple: zoning is divided into day and night areas. For commercial buildings the zoning, due to the occupant restrictions, is quite different and should account for perimeter (orientation specific), interior and/or specialised central (e.g. computer equipment) zones. Zoning is area and volume as well as orientation based and generally considers the control of the HVAC system for a defined thermostat location.

For circular or curvilinear plan areas, a user must 'generalise' the area input into a rectilinear format with an associated orientation. Complex floor plan shapes might be divided into several rectilinear areas descriptive of the entire area. Experts state that such abstractions from the real space would have little impact on achieving an accurate overall simulation, (Wiltrath, 1996; Delante, 1995).

3.5 Envelope

The building envelope is the most important input to energy simulation programs, as most programs are considered to be 'envelope based'. This implies that the selected U-value, and for most simulations, thermal capacity and density of the materials are accounted for. The notion that blinds, shading or other control devices can be applied to the building envelope should be and is often considered. It is important to realise however, that the building envelope is not the only influencing factor on energy consumption, yet, it is the most simple to quantify. People, appliances, variable thermostat settings, occupant adaptation and endless schedules all can have a very realistic, yet complicated influence on energy consumption.
3.5.1 Walls
Most programs allow for wall heat transfer factors (U-value) to be selected or constructed. The more sophisticated energy consumption programs allow for construction composition to be assigned. In such programs the thickness of materials and their location (internal to external) is of importance. Energy rating programs are simpler in that they supply "typical" (default) wall constructions which are menu selected. These programs take into account the thermal characteristics of the wall.

3.5.2 Floors
Again the energy rating programs provide a menu selection of typical (default U-value) construction types. Energy load programs for commercial buildings request inputs on the perimeter of the ground floor slab. Residential programs request 'on ground or above ground' information. Floors with or without insulation are also considered.

3.5.3 Roof and ceilings
Residential and commercial programs permit specification of ceiling type e.g. suspended or not, and whether there is insulation present or not. Selected default construction types are generally provided.

3.5.4 Windows and openings (fenestrations)
Basic energy rating programs limit the input information on windows allowing primarily a selection between single or double glazing to be made. In more sophisticated energy load and energy consumption programs the selection of glazing types including U-value and Shading Coefficient (SC) entries are permitted. Programs with a library selection may or may not provide inputs as to glazing type. Resulting input data from expert glazing software packages such as: WINDOW 5, FRAMEPlus 5.1 will permit a window and its glazing type to be independently evaluated. The results from such programs will provide visible (light) transmittance, solar heat gain coefficients (SHGC) and SC values.

3.6 Equipment and occupants
Equipment and occupant loads can often be assigned and scheduled via a diversity factor, which allows different percentages of a load to occur at various hours. In energy rating programs these loads tend to be fixed and assigned default values so relative comparison among building orientation and material selections will be strictly observed. People provide a latent (heat by moisture) and sensible (direct convective/radiative) heat gain to a space.

3.6.1 Lighting
Lighting loads are heat gains to a building. This load is generally expressed as a power density factor (W/m²) of electric lighting for a specific space. Programs which integrate day lighting calculate the daylight source from the solar components provided in the weather data. Window opening orientation, size, as well as visible transmittance allow for a daylight calculation. Most programs do not include an integrated daylight dimming control routine. ENERGY-10 provides for an integrated (simultaneous) assessment of HVAC conditioning while electric lighting is dimmed and daylight is introduced into a space.

3.6.2 HVAC
The Heating Ventilating and Air-Conditioning (HVAC) equipment may add heat gains or a load into a space through fans and ducts without insulation. The placement, location and equipment type require consideration with respect to additional loads upon a space.

3.6.3 Other equipment
It is important to consider other sensible and latent heat loads from equipment used in the space. For instance, fridges, hot water systems, copiers, computers, fans, desk lights and coffee machines are all load contributors.

4.0 DELIVERABLES OF SIMULATIONS

4.1 Accuracy
The result and its interpretation by the user can be a potential shortcoming of building energy performance simulation. Users expect that program results will always be reliable and correct, which is not necessarily the case. For instance, often the more difficult to use (energy consumption) programs are non-discriminatory in their acceptance of input data, erroneous or not. Additionally several programs have made efforts to simplify their results so as not to be misinterpreted. It should not be forgotten that these are state-of-the-art programs that only provide a simulation; an abstraction of the real world. As indicated in Table 2, programs rely on a number of parameters, some of which are considered default inputs and remain constant throughout the simulation. Depending on the circumstances an actual performance can vary markedly from its simulated value. For example, the simulation of both unbuilt and existing buildings is greatly influenced by climatic data. The application of averaged weather data, or those selected for a typical year, can vary from actual localised data. As a result, initial simulation attempts of energy consumption for buildings can be in error as much as ±30%.

Having said this, simulations of existing buildings are generally 'tuned' to actual performance via adjustments to program inputs (i.e. on-site climate data, building envelope, user schedules), and simulation accuracy in such cases may improve to within ±10% of actual consumption.

4.1.1 Validation of BEPS
There is an increasing need for us to discover whether our building energy performance targets from simulation have been met. The Green Building Council of Australia has made it part of their agenda to inform of and emphasise methods that get measured on existing and newly completed projects through the Green Star program. Such overall building analysis rating schemes will put new demands on building energy performance simulation packages to demonstrate their validation.
To a limited extent energy simulation tools have been rated among themselves through a method known as the BESTEST (Judkoff and Neymark, 1995). However projects such as Mobile Architecture and Built Environment Laboratory (MABEL), endorsed by the Victorian Government, will eventually provide the relevant data needed to make individual component or total building analysis comparisons with simulated results. Further research studies and energy software developments will also allow the inclusion of appliances and their actual energy consumption as well as a more accurate scheduling of their use.

So why do we rely on simulation tools? One answer is that they provide a tremendous accumulation of knowledge and research about building performance encapsulated into a single resource tool. It is the best we can deal with at the time. If for no other reason, and in spite of a possible lack of accuracy, simulations allow a relative comparison between the use of materials, building orientation, surface areas, user patterns, diversity factors, etc. to be made. BEPS simulation tools allow us to make intelligent decisions while educating us in the process as users.

4.2 Parametric studies

Parametric studies are those which allow various parameters such as the size, number, and type of glazing in a window to be altered. What the user needs is a performance comparison of their building with that of a reference or ‘base-case’. Figure 5 provides an output example of such a program. Parametric studies also consider the comparison of different materials for the same design. An example of this would be to evaluate an insulated lightweight envelope against a heavy massive building.

4.3 Multi-criteria comparative outputs of building environment performance software

An extensive study of the available programs would conclude that no two programs are alike. This does not exclude their relevance in the least. Each of the program types has a purpose as well as a limitation to the results it can provide. An example of several program capabilities extending beyond energy performance is presented in Table 3. The table aims to identify the level of program integration between energy simulation and other environmental criteria such as day lighting, thermal comfort, ventilation etc. Note: not all programs listed in Table 1 are shown here, as Table 3 is intended to be an example of the integration among energy program software.

<table>
<thead>
<tr>
<th>Integrated program</th>
<th>Energy load</th>
<th>Energy consumption</th>
<th>Free-running temp</th>
<th>Comfort analysis</th>
<th>CFD/ventilation</th>
<th>Life-cycle costing</th>
<th>Shading analysis</th>
<th>Day lighting</th>
<th>Electric lighting</th>
<th>Acoustic</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECOTECT</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>ENERGY-10</td>
<td>O</td>
<td>O</td>
<td>NA</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>IES-VE</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>TAS</td>
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<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

Level of integration: O - Low, ● - Medium, ● - High

Table 3. Additional capabilities of integrated software packages

5.0 APPLICATIONS

5.1 Pre-design stage

The need to simulate energy efficient design strategies at the early stages of a project is becoming very important. Budgets are set at the programming stages based on a square metre per building reference typology basis. A building reference typology relates to the energy consumption, for example, of grocery stores, offices, warehouses, community centres etc. Few programs are structured (although they claim to be) for a quick and relatively accurate analysis of energy efficient and passive solar strategies at a pre-design stage in a project.

As mentioned earlier, climate analysis needs to occur at the pre-design stage. A form of climate analysis is the appropriateness of various building conditioning strategies in reference to a local climate. An example of this is provided by the program ECOTECT where environmental system conditioning strategies are applied to a local climate (Figure 6). The result is the optimum performance of indoor comfort that could be achieved when implementing the proposed strategies for the climate considered. Shown in Figure 6 is Wodonga, Victoria with a design implementing the three strategies: passive solar heating, exposed internal mass and direct evaporative cooling.

![Figure 5. An example of informative graphical analysis, the ranking of applied strategies (ENERGY-10)](image-url)

Savings %
(BaseCase = 167 MWh)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Savings (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC controls</td>
<td>15.67</td>
</tr>
<tr>
<td>Insulation</td>
<td>15.78</td>
</tr>
<tr>
<td>Daylighting</td>
<td>14.91</td>
</tr>
<tr>
<td>Glazing</td>
<td>12.67</td>
</tr>
<tr>
<td>High efficiency HVAC</td>
<td>11.04</td>
</tr>
<tr>
<td>Energy efficient lights</td>
<td>9.57</td>
</tr>
<tr>
<td>Duct leakage</td>
<td>8.05</td>
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<td>Air leakage control</td>
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<tr>
<td>Thermal mass</td>
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<tr>
<td>Passive solar heating</td>
<td>2.65</td>
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<tr>
<td>Economizer cycle</td>
<td>2.08</td>
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<tr>
<td>Shading</td>
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</table>

Annual energy savings (MWh)
ENERGY-10 is another example of a program which provides a pre-design building analysis. Developed by the National Renewable Energy Laboratory, USA, ENERGY-10 is a shoebox design allowing a selection of 14 different energy efficient strategies to be implemented. The program also provides very useful graphical output of the heating, cooling, lighting and other plug-loads as well as a ranking chart of the various systems and strategies. One of ENERGY-10's greatest strengths is its comparison to a base-case building typology (grocery stores, office buildings, warehouses, residential, schools, etc). Comparisons for a particular building performance are made with reference to a base-case. ENERGY-10 is one of the few programs allowing a simultaneous analysis of day-lighting and energy performance at this project stage. The downfall of this program is that it requires a work-around for the southern hemisphere and will not work directly with Australian hourly weather files.

Available simulation tools which provide pre-design analysis is rare and their use is discussed elsewhere (Luther and Cheung, 2003).

5.2 Concept design and design development stages

The 'architects' version of Energy Express developed by the CSIRO, Australia, is useful at the concept and design development stages. This package has quite a user-friendly 2-D plan interface allowing envelope materials, glazing types, shading and operating options as well as electric lighting to be included. More sophisticated and time consuming programs to be used at the design development and HVAC implementation stage would be the engineer's version of Energy Express, Energy Plus, Apache and TRNSYS.

Energy Plus is the latest ground breaking program combining the best parts of BLAST (Building Loads Analysis and System Thermodynamics) and the DOE-2 programs. It has links to COMIS (a zone air flow program), TRNSYS and other libraries. Energy Plus allows for day and electric lighting analysis to be included with an energy simulation. This program is free; however, the user interface is not friendly. Third party organisations are in the process of improving this feature.

A final energy simulation stage might consider building innovations and their coupling into hybrid systems. Such programs allow control scheduling and limited equipment capacities to be tested. Hybrid environmental systems might involve evaporative cooling coupled together with solar chimneys or a ground buried air duct intake system together with a variable refrigerant volume split conditioning system. Programs moving into this direction are TAS, Apache and Energy Plus, although one of the original founders to passive solar thermal design processes is TRNSYS.

<table>
<thead>
<tr>
<th>Program</th>
<th>Learning curve</th>
<th>Input/output time</th>
<th>CAD interface</th>
<th>Pre-design</th>
<th>Concept design</th>
<th>Design development</th>
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<td>●</td>
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</table>

* add on program required.

Performance: O - Poor, ● - Medium, ● - Good

Table 4. Description of Building Energy Performance Software
TRNSYS has many modules on various building systems (ground buried air ducts, desiccant cooling, photo-voltaic and solar hot water collection, to name a few) which can be linked quite easily through an interface program called IliBat (pronounced 'easy-bat'). The problem with such programs at this stage in a building project is that they require expertise and a huge learning curve. They are generally used by engineers and building scientists.

Table 4 provides an evaluation of several of the programs discussed in this note. In consideration of the novice user an indication of learning curves, input/output time and whether or not the BEP has a CAD interface is provided.

6.0 CONCLUSION

This note is intended to inform the novice user of energy programs about the input requirements and limitations as well as the deliverables of various software packages. It is to be noted that environmental rating systems such as Green Star, NABERS, BASIX, etc., are not covered in this note. As mentioned earlier, refer to BDP Environment Design Guide note GEN 57 for a description of individual rating schemes.

The primary messages of this design guide were to acknowledge the following:
1. The importance of understanding the 'deliverables' from a particular software package and what their limitations might be.
2. The role of software packages which simulate several building energy performance criteria simultaneously, such as, day lighting, electric lighting, natural ventilation and thermal radiative exchange as well as comfort indices.
3. An understanding and expectation of 'relative' (or simulated) performance versus 'absolute' (actual) energy performance.
4. The validation of energy tools and what accuracies are to be expected.
5. The importance of including day lighting, glazing type and shading selection in a commercial energy simulation.
6. A distinction between software capable of early pre-design development through to refined environmental concept analysis.
7. The development of 'base-case' (reference energy performance) criteria for commercial building typologies (warehouses, grocery stores, offices, etc.) in Australia.
8. Finally, (and probably most importantly) the need for a more sophisticated roadmap to applying energy performance software at the various stages of a building project.

REFERENCES


BIOGRAPHY

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