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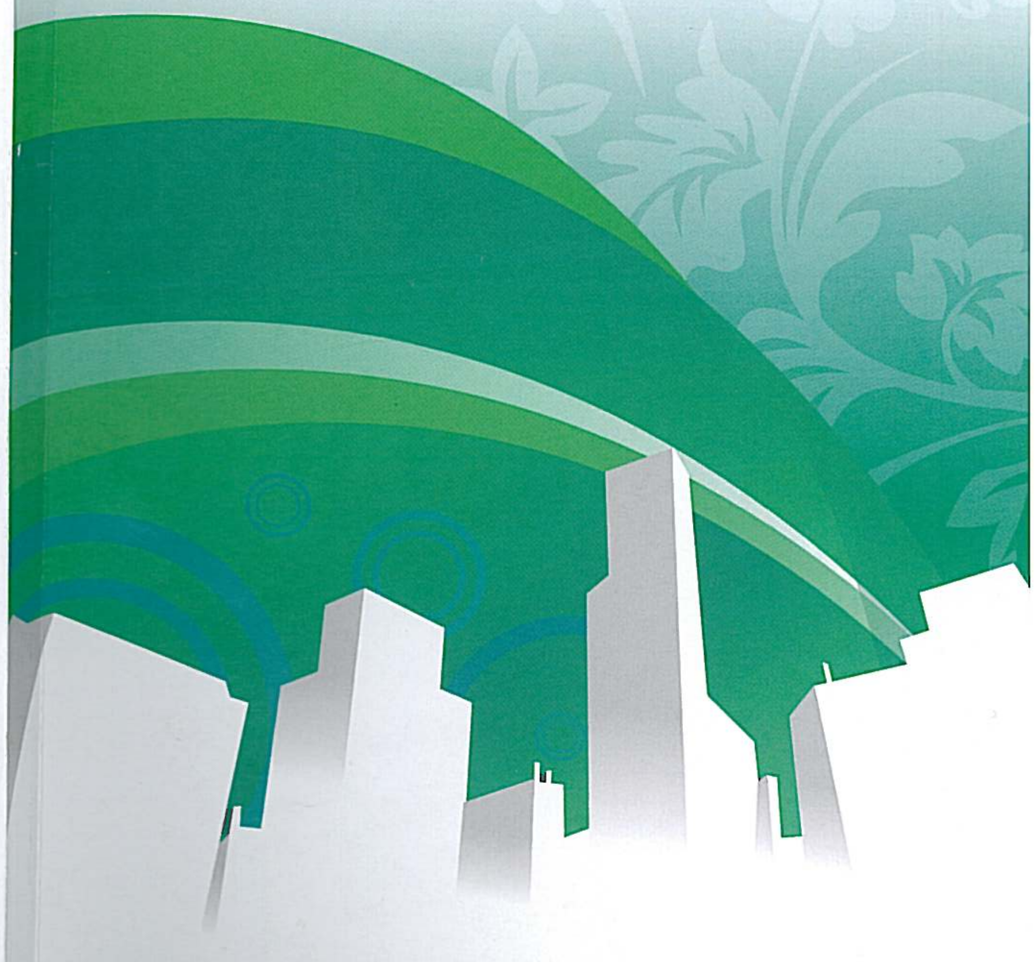
# The Green Building Handbook South Africa

## The Essential Guide

Volume 3



ISBN 978 0 620 45240 3.

www.greenbuilding.co.za

Peer Reviewed

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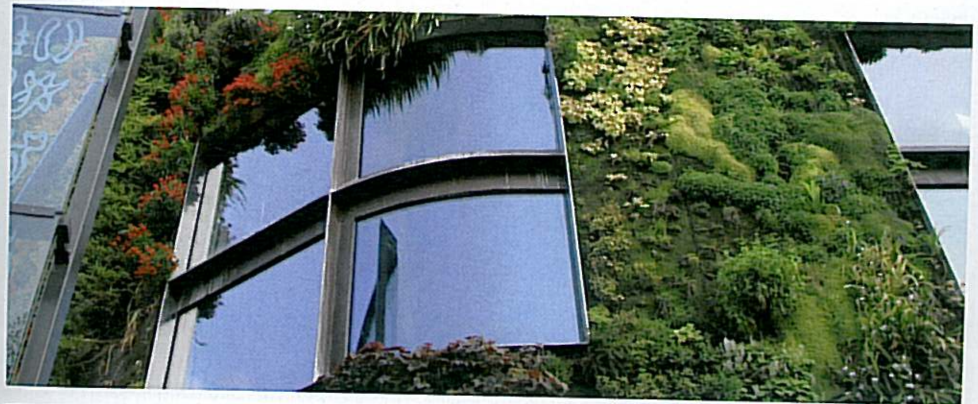

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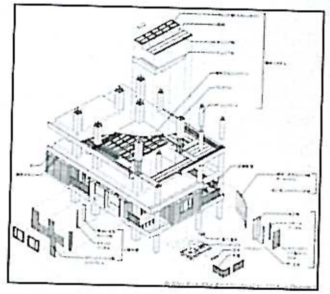



# CAPABILITIES & ACCURACY OF ENERGY MODELLING SOFTWARE

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## INTRODUCTION

Software validation remains an important aspect in terms of producing accurate results with building energy simulations and to this end standards have been developed to ensure that such software is reliable, namely BESTEST and later ASHRAE 140. These are largely comparative standards, ie the results from a software package are compared to the results of others for specific test cases. The main purpose of such a standard is to identify significant differences in results for test cases. The test cases were developed in such a manner that anomalies that do arise are likely due to an error within a specific function within the energy mode. This then allows for easy trouble-shooting. Such methodologies have been highly effective in identifying errors within software which can then be corrected, Indeed, BESTEST identified errors within every software package that was initially included within its development (Judkoff et al, 1995).

Validation methodologies are continually being developed, based on comparative analysis as well as empirical data from buildings and operation that can be accrued from specifically built test cells. Analytical results are also compared, where the energy consumption of simplified building constructs can be calculated. Considering the complexity of building energy simulation software, it is possible that errors still exist. However, considering relative uniformity in results within comparative standards, the errors that still exist are unlikely to be particularly significant. This is potentially so considering the other sources of error within building energy simulation – the discussion of which is the purpose of this chapter.

It is critical that any user of a specific software package is aware of the validation routes that the particular software has been through. Additionally, building regulations internationally and potentially soon locally, as well as green building rating tools, require energy software modelling. Usually they have strict requirements as to which software can be used to fulfil such requirements in terms of validation.

Energy modelling can be used in a number of different ways to fulfil different needs (as are discussed below) including certification within building regulations or green building rating tools. Energy modelling can also be used in order to try and predict what the energy consumption of future building will be. This can aid in selecting design changes to reduce energy consumption. Finally calibrated energy models can be developed using the actual energy consumption results from a real building. Such a process can yield highly accurate models and can be used to determine the most cost effective energy conservation retrofit measures.

## Certification

A number of building codes and green building rating tools, locally and internationally, require compliance via the route of energy modelling. For each particular regulation a modelling protocol is provided according to which the building will need to be modelled. Such a protocol will state requirements as to the operating hours, weather file used; and possibly also internal loads. It will produce energy results that give an indication as to how the particular building will perform under specified circumstances, and provide a fair basis according to which the energy efficiency of buildings can be compared. It should be recognised that it is highly likely that any particular building will not be operated as such a protocol dictates. The results from such a protocol should not be considered as a prediction. However, such a methodology allows dissimilar buildings to be modelled according to identical circumstances (operating hours, occupancy, etc,) allowing a fair assessment as to which building is more energy efficient when operated under expected circumstances.

A building's energy efficiency is not defined by how much energy a building uses in the course of a year per unit area but rather it should be defined in terms of the services it provides per unit of energy consumed - such as man-hours of work per unit energy for an office building.

Leadership for Energy Efficiency Design (LEED) is a green building standard that is used in the USA and internationally. LEED has had considerable market uptake and has been used within the USA market for a number of years and consequently there is substantial data on the performance of LEED buildings.

The figure 6.1 is a compilation of predicted energy use intensity (EUI) of LEED buildings for which actual measured values are compared (Turner et al, 2008). It can be seen from the figure below that the energy use predictions can be highly inaccurate and at times predictions are out by more than 100%. To comply with the LEED energy efficiency requirements, the buildings have to be modelled in accordance with Appendix G of ANSI/ASHRAE/IESNA Standard 90.1-2007. While some buildings within LEED did manage to predict their own energy requirements almost precisely, it is the opinion of this author that it is more likely that many errors existed which are largely cancelling each other out. Interestingly, it is worth noting that the average EUI of the total buildings matches well with the average actual use.





## Energy Consumption Prediction

In the event that energy modelling is being utilised to predict the energy consumption of a new building, the energy modeller can use all the information available to best predict the building's actual energy consumption and not be restricted by a modelling protocol. For example, most modelling protocols will dictate occupancy hours. However, if it is known before hand what the occupancy hours are likely to be then those should be used.

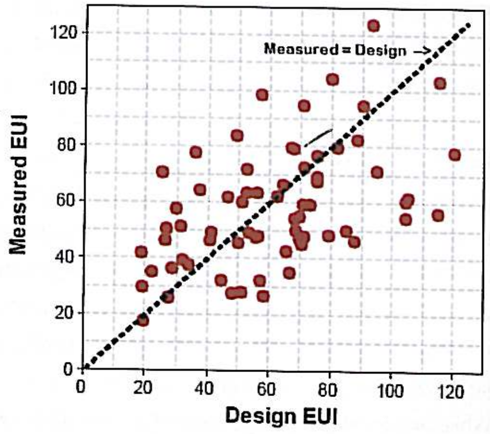


Figure 6.1 Measured EUI versus Design EUI (Turner et al, 2008).

Additionally, such energy modelling should form an intrinsic part of the design process, providing regular feedback as to the potential performance of the building as the design is being finalised and in so doing, the energy modeller should make recommendations to the design team as to options to reduce energy consumption. Regardless, accurate energy modelling in such a scenario is still very difficult. Nevertheless, sensible recommendations to reduce energy consumption can be made and as such will be based on comparative performance with or without a specific building feature.

Once an energy model for a building has been created it can be calibrated to the actual energy consumption of the building. Such a procedure, however, clearly requires the building in question to exist and to be fully operational. Once the model and actual consumption are available, the input data for the energy model can be modified to best reproduce observed results. Input data that may be modified can include operational hours, lighting use, HVAC operation and other internal heat gains. Once an energy model can accurately reproduce actual observed results it can be used to accurately predict the effect on energy consumption of any retrofit options. Such information would be very useful in determining the most cost effective retrofit options.

Due to the 'fudging' nature of calibration, there is a risk that errors are introduced that will cancel each other out and reproduce the observed values. However, such a model would not accurately predict energy savings from any particular retrofit option. In order to reduce this risk, several calibration standards have been developed, including ASHRAE Guideline 14-2002, International Performance Measurement and Verification Protocol and the Federal Energy Management Program, to aid in the development of trustworthy calibrated energy models.

Yiqun Pan found that several steps of calibration where required in order for the model energy consumption calculation to match that of a specific actual building. Sub-metering of energy loads becomes a necessary requirement for such calibration to be possible (Pan et al, 2007).

## WEATHER FILES

Heating and cooling loads are a significant portion of any commercial buildings energy loads and these loads are sensitive to outside weather conditions. As outside weather conditions change, so does the output of the HVAC system to maintain a comfortable thermal indoor environment. A weather file consists of meteorological data that is a reflection of the climate at the specific site and which is essential for accurately determining HVAC energy loads.

While any location has a climate that describes average weather, significant variances can and do occur between individual years. While a specific year's weather at a location can be used to run an energy model, it would be better to use a Typical Meteorological Year (TMY) Weather File that the most average weather that occurs at the location, sometimes based on many years of historic weather data. Each month of data within a TMY weather file is actually the weather that occurred in a specific year, selected as being the most average, such that the February weather data in a TMY could be the weather that occurred in 1992. At the interface between months, the data is smoothed so that there is a realistic transition in the weather. The purpose of a TMY is to provide the most average weather which can be expected at a particular location which can then be used for energy modelling.

Consequently, if the weather that the building actually experiences in its first year of operation is

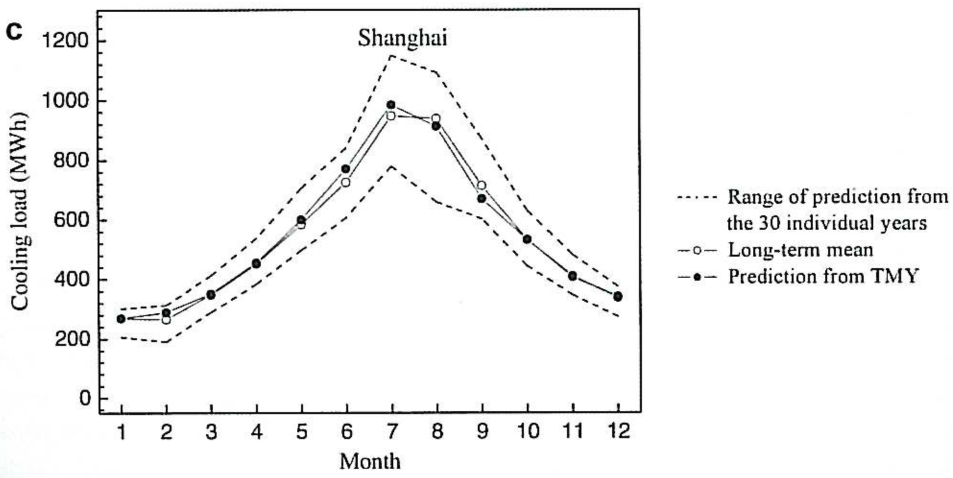


Figure 6.2: Comparison of predicted monthly cooling load profiles for Shanghai. (Yang et al, 2008).





significantly different to that of the TMY then that would be the cause of a deviation between the predicted and actual energy consumption. Considering that predicting future weather for a whole year is an impossibility, this is an escapable source of error in energy consumption prediction.

Figure 6.2 is from a study that investigated the influences of using different weather files on the energy consumption of the same building construct. As can be seen, the TMY reproduces results that are very similar to the long term mean. However, there is a large variance in the cooling load for the months of July and August when using the weather data from individual years.

For calibration purposes, after the building has been in operation for over a year, the actual weather is then known, and can be used in the energy model so that the actual energy consumption can be compared with the energy consumption predicted by the energy model with actual weather.

### Location

Weather files are generated from data that are gathered from a specific station. The US Department of Energy has made two South African weather files publicly available on their website which were produced by ASHRAE, namely Cape Town 688160 (IWEC) and Johannesburg 683680 (IWEC). These two specific weather files are based on weather measurements beginning in 1982 and on 17 years of subsequent measurements. The specific locations of both these weather files are the international airports at these cities.

Weather can be markedly different at two relatively close locations depending on local topography. It is therefore the responsibility of the energy modeller to make sure that the use of any particular weather file is reasonable; that the locations are sufficiently close; and that micro climates do not significantly influence the weather at either the measuring location or the building site.

### Urban Heat Island

The Urban Heat Island (UHI) effect is a well known phenomenon where the temperatures within urban areas are higher than the surrounding rural areas with a number of factors contributing to this effect. These include the thermal mass of urban environments, differing solar absorption and emissivity properties. Tall buildings provide greater surface area for solar absorption and influence wind patterns. Additionally, heat is generated within urban environments from automobiles, electrical equipment and air-conditioning systems. The UHI is not purely a linear increase in average temperatures but its influence also experiences diurnal and seasonal variations.

Considering that measurements for the TMY weather files for both Cape Town and Johannesburg began in 1982 around their respective airports, they will not capture the full urban heat island effect from highly developed urban areas within the respective cities. Additionally, significant development of the areas around the airports has taken place since 1982 and consequently such construction should have a warming effect on the measurements taken by these weather stations with a greater warming influence in later years.

Using these weather files to model buildings located within the highly developed urban areas of either Cape Town or Johannesburg could introduce additional uncertainty as the weather files would not capture the intensity of the urban heat island effect. Additionally, inaccurate results could also be achieved if the Cape Town weather file is utilised throughout Cape Town where strong micro climates are known to exist.

Ideally numerous reliable weather files should be available for each of our major cities accounting for any major micro climates and urban heat island effects, much like the USA where numerous weather files are available for its major cities. Indeed, 16 different weather files are available for California alone and account for its differing climates across the state not including its city specific weather files.

As the situation stands, energy modellers will have to make do with what weather data is available, recognising that it might not best represent the weather that a building may experience and that it may have an influence on the final results of the model.

**Climate Change**

The planet is known to be warming, affecting climates across the globe and consequently also the weather. Considering that weather files are based on a long period of historic data over which the influence of climate change would be increasing and that they are essentially average weather of this period, these weather files could be slightly under predicting expected temperatures for future years.

## CONSTRUCTED BUILDINGS AND THEIR OPERATION VERSUS DESIGNED

The physical building is not always constructed as it was designed or intended for a number of reasons and such variances can affect their energy performance. A study performed by the National Renewable Energy Laboratory (NREL) investigated six high performance buildings as case studies from design to completion (Torcellini et al, 2006). Many construction variances were discovered, including missing insulation, window and door frame thermal breaks incorrectly installed, as well as electrical circuitry incorrectly installed. Such errors were discovered only because these buildings were being studied as part of a case study and it is very likely that such errors would normally go undiscovered.

Additionally, buildings are not always operated as assumed by the design teams. In the same case study it was found that there was often a lack of control software or control logic to allow the different





low energy technologies to work well together. Design teams were too optimistic as to the behaviour of the occupants and their acceptance of new systems; and plug loads were often higher than design predictions. The higher than expected occurrence of idle computers contributed to the plug loads.

It was also found that operational failures in many energy saving technologies go unnoticed as a result of there being backups. For example, if a daylight sensor fails, sufficient lighting will still be provided by the lighting system. However, the lights can no longer be dimmed in the presence of sufficient natural light and as such those energy savings are not realised.

Five out of the six buildings had installed PV systems and they experienced a range of operational performance degradations, including snow; inverter faults; shading; and parasitic losses. While snow would be an unlikely occurrence on a South African PV installation, the other issues are unlikely to be noticed unless such faults are actively monitored.

Torcellini et al, in particular highlight the need for constant monitoring of buildings to make sure that energy efficient building systems and technologies are performing as designed and that the building is being operated as it should, especially if new and unfamiliar systems or technologies are being implemented.

## BUILDING OPERATION UNCERTAINTIES

A study performed by Neto and Fiorelli investigated the accuracy of a building model and which aspects thereof produced the greatest uncertainty within the predicted results. They concluded that the major source of uncertainty within the model predictions are related to the proper evaluation of lighting, equipment and occupancy schedules when compared to the uncertainties produced by weather parameters. Often when a building is being designed and potentially modelled, there is a lack of knowledge as to who the potential tenants may be or how they will operate the building. Indeed, even when such influences are known, accurate predictions as to the behaviour of the occupants cannot be made and remains a large source of uncertainty within predictive energy models.

A prime function of calibrated energy models is to determine such schedules through sub-metering the energy use of specific systems, such as lighting and computers. However, a level of intrinsic randomness in human behaviour remains and cannot be explicitly modelled, eg, a company celebrates an achievement and leaves the office early on a Friday afternoon.

Furthermore, even the same technological interventions can have very different effects on energy consumption depending largely on the specific humans that are occupying a space. Figure 6.3 comes from a study wherein occupancy sensors were placed in 21 different occupied offices on the third floor of the Phillip Burton Federal Building in San Francisco (Jennings et al, 2000). As is demonstrated within the figure, the energy savings accrued from controlling the lights with occupancy sensors vary largely on the individuals occupying the offices, with some installations saving no energy as the occupants either worked without the artificial lighting on or that they did not leave their office at all during the day; while other installations are saved up to 85% of energy that would otherwise be spent lighting spaces that were not occupied. This study highlights the randomness that is very difficult for energy modellers to capture in a prediction of energy performance of a building that is still being designed.

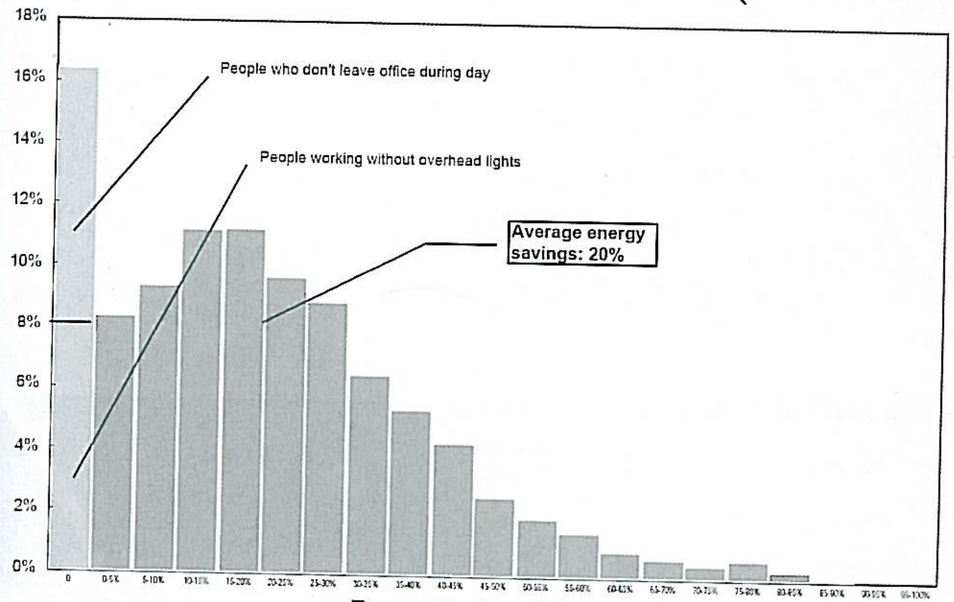


Figure 6.3: The energy savings from occupant sensors in 21 offices on the 3rd floor for occupied days between June 1 and December 31, 1998 (Jennings et al, 2000).

## ENERGY MODELLING TO GENERATE PERFORMANCE TARGETS

Energy modelling can be used to produce a performance target under conditions of ideal human behaviour and building systems operations, generating a theoretical maximum for energy efficiency which the building can achieve. This target could then serve as a goal for which the building operators should strive to achieve, and their shortfall would be an indication of inefficiencies within the building systems or its occupants. The idea is to use simulation predictions as performance targets with which to compare monitored system outputs for performance validation and energy analysis (Salsbury and Diamond, 2000). The utilisation of a calibrated energy model should highlight where such inefficiencies exist and aid in achieving optimal performance.

## CONCLUSION

Energy modelling is a tool and its usefulness should be judged in terms of its application. While being difficult for an energy model to accurately predict what the actual energy performance of a building that has not yet been built will be, if the purpose of the modelling is to inform the design process and to allow for informed decisions to be made with regard to reducing energy consumption, is the model then accurate enough to serve that purpose? Notwithstanding these difficulties energy modelling has been successfully used to aid in the design of high performance buildings globally and has been shown to be very useful in this application.

Additionally, energy modelling is also found in many building regulations internationally as a means of raising the energy performance of the building stock of the respective countries. As discussed, such methodologies utilise dictated protocols as to how a buildings should be operated for such modelling to be effective. Consequently, this introduces inherent inaccuracies and outcomes of such modelling should not be viewed as a prediction of energy performance of any specific building. However, it provides for a very fair baseline for the comparison of the energy performance of buildings within the building stock if they were theoretically operated in an equal fashion. This allows for fair determinations as to which buildings are more energy efficient and if they are above a minimum requirement.

Energy models of existing buildings can be calibrated to actual use and these can be quite accurate. However, intrinsic randomness in human behaviour and building operation will always remain. Such calibrated models can be useful in trouble-shooting inefficiencies within building operations as well as for the determination of the efficacy of any number of retrofit options to a specific building.

Inaccuracies do exist within all types of modelling, be it energy or otherwise. However, the pertinent question is as to whether the model is good enough for its intended purpose.

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