

An Analysis of Energy Efficient Building Principles

Craig Anthony Blackstone

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Research Report Summary

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1 Introduction

1.1 Until 1970 energy was abundant and inexpensive. During this period building technology soared. Architects and developers embraced the artificial with regards to thermal comfort and lighting and thus, gradually moved away from the traditional, more energy efficient building.

Slessor (2000) states that “Since the Industrial Revolution, but more particularly in the present century, the twin phenomena of more widely diffused wealth and cheaper energy have resulted in a greater prevalence of energy usage.”

Slessor (2000) continues; “Until the oil crisis of the 1970’s shocked the developed world out of its apathy, it had seemed unnecessary and irrelevant to make connections between design and energy use, as the cost of making and maintaining buildings was relatively low.”

Interestingly, during the 1992 Earth Summit in Rio de Janeiro, the building industry was highlighted as ‘the major contributor’ to resource depletion due to massive amounts of water and energy required in common building technology and building climate control.

According to Holm (1996), “buildings constitute at least 20 percent of South Africa’s national energy consumption”

It can thus be deduced that buildings “currently constitute the single largest energy-consuming human creation, with the simple consequence that the sustainability of the built environment has a major impact on the global ecosystem” (Slessor, 2000).

The CIB Report Publication 237, Agenda 21 on sustainable construction concurs; “Although the figure differs from country to country, buildings use about 30% of total energy directly...if indirect use is included the proportion is closer to 50% “

The current crisis regarding global warming, resource depletion, energy availability and rising costs, now dictates an immediate reduction in energy consumption for providing thermal comfort and lighting.

Holm (1996) suggests that “It seems to be part of our mental make-up that we keep on believing that there must be a single elixir (Medicine) that will be the answer to all problems.” As a result, after more than 30 years of experimentation and research, few ‘successful’ examples of energy efficient buildings exist. The danger is that designers and practitioners in the building industry will continue to look to these few examples of energy efficient building and apply the principles blindly with little consideration to context, resulting in inefficient buildings.

1.1.1 Research Hypothesis

With regard to practitioners of energy efficient design, Holm (1996) suggests that “It seems to be part of our mental make-up that we keep on believing that there must be a single elixir (Medicine) that will be the answer to all problems.” This report hopes to discover if such a remedy does or ever can exist.

1.1.2 Research proposition

P1 Practitioners believe that by following a once successful example of energy efficient design, their buildings will also be energy efficient.

P2 The BOTEC building is said to be the solution for energy efficient design in Botswana (the elixir).

1.2 Research Objectives

The author's objective is to establish whether such an elixir does or can exist. In order to realise the objective, the author has attempted to highlight the 'basic principles' of energy efficiency with regard to the built environment and to assist the reader in understanding the practical application of these traditional principles in building design. This is done in order to equip the reader with a fundamental understanding of energy efficient principles, so that these may be applied to the BOTEC case study.

The BOTEC building was selected as the case study for this research report as it is well known as a 'successful' energy efficient building. In fact, the BOTEC building was built as an example and living exhibit for building practitioners to study with regard to alternate design.

Dr Marland (2001), previously Principal Architect, (BOTEC), Gaborone, Botswana is quoted as saying, "From the outset, it was decided that the new headquarters (BOTEC) would be, technologically speaking, a landmark building for the Southern Africa region and would demonstrate a range of technologies beyond the current conventional passive solar design... Apart from being an energy efficient building, it will also serve as a practical demonstration for researchers, developers, designers, etcetera, of appropriate technologies for achieving thermal comfort in buildings in Botswana's hot-dry climate."

With such a description, one may easily assume that the BOTEC headquarters was designed to be somewhat of an elixir with regard to alternate design practice.

Through a case study, the intention, therefore, is to investigate whether the BOTEC building is performing to expectations and if indeed, the principles used at the BOTEC building do result in and can be used as the "elixir that will be the answer to all problems" with regards to energy efficient design.

1.3 Scope of Study

The author acknowledges that the subject of energy efficiency is vast and may include; life cycle costing of buildings and materials, embodied energy of buildings and materials, energy audits, labour, vertical transport, horizontal transport, recycling and much more.

However, due to time constraints, the scope of this analysis has been confined to the principles of energy efficient design which affect heat gain and heat loss in a building. If these principles are understood and implemented correctly, energy wastage will be drastically reduced. Therefore, the principles dealt with include; building orientation, building envelope design, insulation, lighting and HVAC.

2 Overview and conclusion of the literature review

The literature reviewed depicted quite clearly that in looking at the global economy today, one has to be increasingly aware of energy as a scarce resource; the need for architects to design for a sustainable future becomes a self-evident imperative.

The literature reviewed also highlighted the following elements as the most important with respect to energy efficient design; the building envelope, lighting systems, and heating, ventilation, and air-conditioning (HVAC) systems.

Most researchers were in agreement regard to the extent and complexity of skills, measures and elements used to obtain energy efficiency. “The measures employed in ecological building are complex and derive from several specialised disciplines – from urban planning, architecture, construction, and façade design to active technical building

services and their applications. Planted surfaces, indoor and outdoor, fresh air, soil, water, and rainwater all contribute to an integrated design, as does the management of building services and utilities that use the abundant resource of the environment” (Daniels, 1997). Holm (1996), however, suggests that many of the aforementioned applications and elements are used carelessly and therefore often have the adverse effect of rendering a building unsustainable or inefficient.

A literature analysis of Energy efficient building principles was undertaken which included a historical overview of energy efficient building principles as well as contemporary design principles with regard to energy efficiency. The analysis highlights the principles used in the past and analysed how these were adapted through the years.

The objective of the literature analysis is to highlight and extract basic principles of energy efficient design and formulate a literature model which could be used as an analytical tool in the BOTECH case study.

In addition, the literature analysis highlighted major common oversights and misconceptions with regard to basic energy efficient principles.

3 Research Methodology

3.1 Case Study Methodology

3.1.1 Research Design

The *exploratory* case study as used in the BOTECH analysis makes use of fieldwork and data collection. Pilot studies were employed to determine the final protocols that were used.

Survey questions were dropped or added based on the outcome of the pilot study. The pilot studies involved interviews with selected architects and building practitioners for the purpose of creating a suitable questionnaire for the users of the BOTEC building.

The following image taken from Tellis (1997) depicts how the study questions were subdivided into the propositions, which were in turn linked to the Data compiled. The units of analysis were linked back to study propositions through the data, resulting in findings and the interpretation thereof.

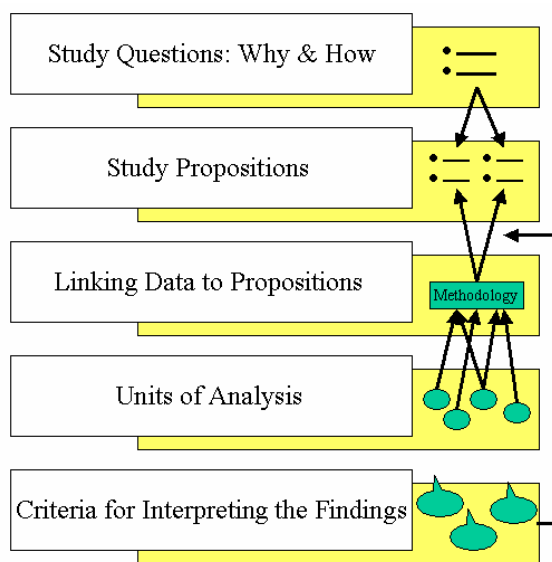


Figure 3. Case Study Design Components

Tellis (1997)

4 Data Analysis and Findings

4.1 Sample description

The recipients of the questionnaire were all staff members working in the BOTEC building. Each recipient was selected by management of the BOTEC building according to age, gender, and hierarchy ensuring that a diverse sample of staff opinions was achieved.

4.2 Units of analysis

A questionnaire was circulated which was designed to probe into the likes and dislikes of the user with respect to the following;

1. Heating (thermal comfort)
2. Cooling (thermal comfort)
3. Lighting
4. Noise
5. Ventilation
6. Window use

The questionnaire therefore was categorised in order to promote active thought when answering the questions. These categories were;

1. Employee particulars (type of job, age, experience)
2. General performance of building
3. Temperature (comfort)
4. Lighting
5. Noise
6. Ventilation
7. Windows

The author also conducted site visits and analysed the building first hand. This technique falls under the 'direct observation' method. This technique was useful for providing additional information about the energy efficient systems at BOTEC and thus formed a critical component of the BOTEC case study analysis.

The energy efficient principles extracted from the literature analysis were compiled tabulated and used as an analysis tool in the BOTEC case study.

The case study analysis therefore consisted of data which was gathered from various sources so that conclusions could be drawn from a holistic perspective.

4.3 Sources of evidence

Sources of evidence used were,

- Documents
- Interviews
- Direct observation , and to some degree,
- Participant-observation

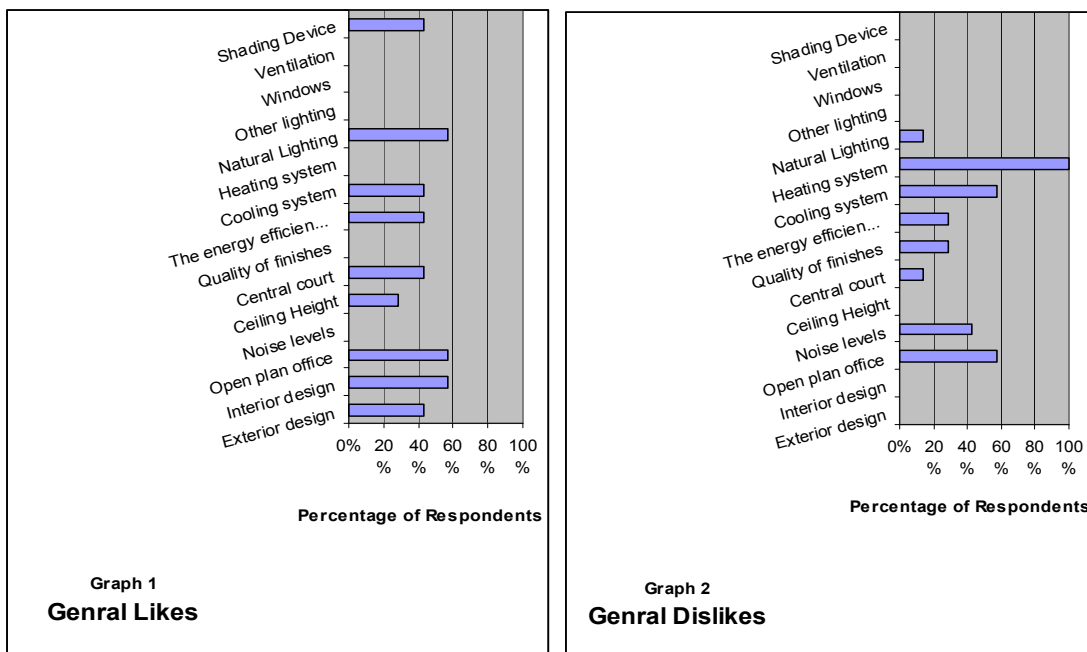
According to Tellis (1997), interviews are one of the most important sources of case study information. There are several forms of interviews that are possible: Open-ended, Focused, and Structured or survey. All three were used for the BOTECH case study. In an open-ended interview, respondents were asked to comment about certain events and feelings. They were encouraged to provide insight into these.

The focused interview was used where the respondent was interviewed for a short period of time. Here questions were set and prompted brief answers from the recipient. This technique was used in conjunction with the structured interview technique and made up the most part of the questionnaire. The questions were detailed and developed in advance, much as they are in a survey.

The data was then placed in categories, tabled and graphed using means, variances and cross tabulations to examine the relationships between variables, and other such techniques to facilitate analysis.

4.5 Results

4.5.1 General likes and Dislikes



The first two questions deal with the general performance of the building, as well as likes and dislikes the users may have of the BOTEC building.

Graph 1 shows that the most liked features of the BOTEC building in order of their preference are; the interior design (57,14%) the open plan offices (57,14%) and the use of natural lighting (57,14%). The exterior design (42,86%), central court (42,86%), energy efficient cooling system (42,86%), and shading devices (42,86%) following with the ceiling height (28,57%)

4.5.2 Most Disliked Features

Graph 2 demonstrates the most disliked features in order of rank which are; energy efficient heating system (100%), open plan offices (57,14%), energy efficient cooling systems (57,14), noise levels (42,86%), quality of finishes (14,29%), and central court (14,29%). An

interesting comment was made by one recipient who stated that the energy efficient systems in place at the BOTECH building are “very theoretical and do not work practically”.

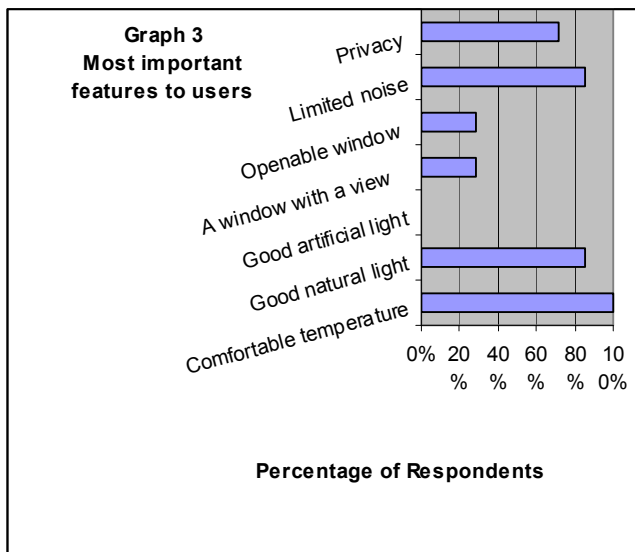
Other comments also refer to the poor performance of the energy efficient heating system, the fact that open plan offices facilitate a noisy environment and that the open, central court should be minimised as to control the inflow of dust and birds. A comment was made by a recipient in the architectural department who suggested a ‘reverse mechanical system’ for winter heating.

What was alarming and prompted further investigation was that 100% of the recipients seemed to be completely dissatisfied with the energy efficient heating system in the BOTECH building.

Interestingly, the features that the users deemed most important, were also the features that, according to the users, performed the worst.

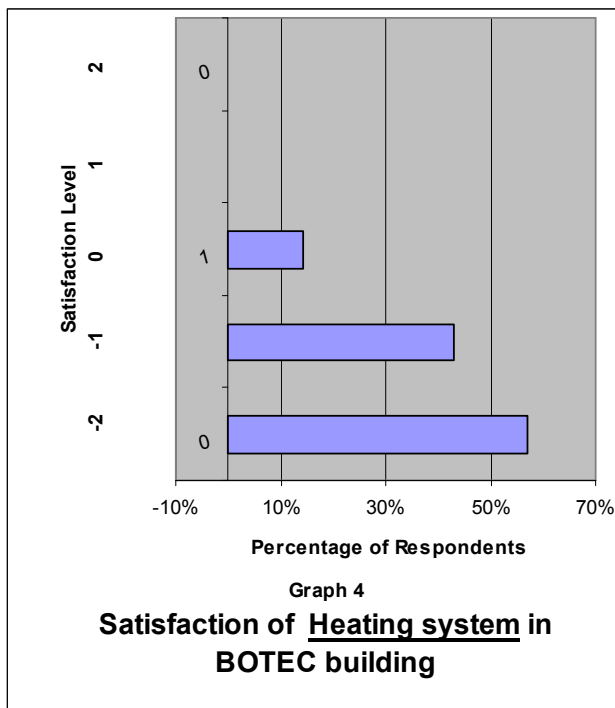
4.5.3 Most Important Features

In order of preference, according to the users of the BOTECH building, the most important features that should be present in any building is, a comfortable temperature (100%), good natural light (86%), limited noise (86%), privacy (71%), openable windows (29%), and a window with a view (29%). These figures are represented in the following graph 3.



In comparison to graph 3, the satisfaction levels of the users of the BOTEK building are represented by the following graphs. The graphs depict 'satisfaction ratings' from -2 to 2; 2 being completely dissatisfied and -2 being completely satisfied.

4.5.4 Heating System

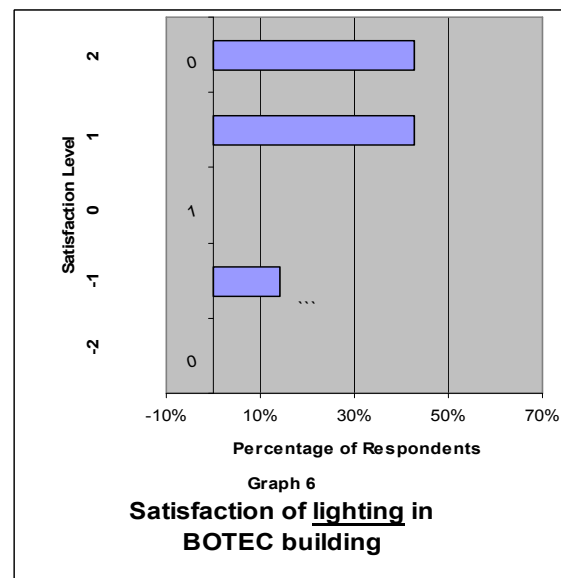
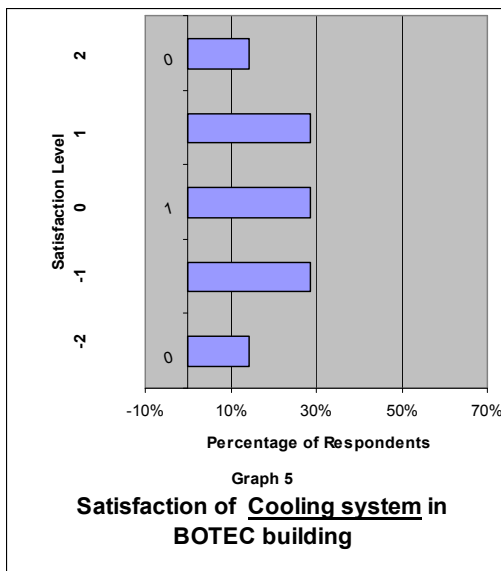


Graph 4 demonstrates the high level of dissatisfaction with the performance of the energy efficient heating system at the BOTEC building. This is in line with graph 2 which depicts the heating system as a feature which is unanimously disliked. The performance of the heating system was therefore found to be poor.

4.5.5 Cooling System

The respondents were generally indifferent about the energy efficient cooling system of the building. It must be said, however, that exterior temperatures climb to well beyond 40° Celsius in this area of Botswana. Therefore, the mere fact that the recipients aren't concerned about the performance of the cooling system in the BOTEC building, suggests that the system is functioning well and to the design expectations. This is demonstrated in graph 5 below.

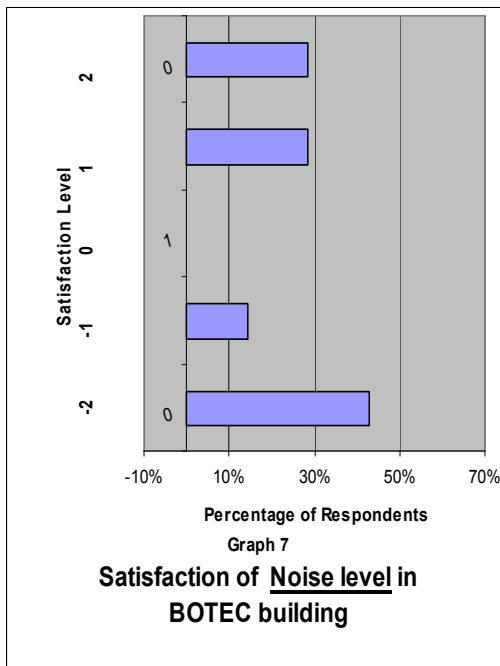
It must also be noted that according to the recipients, no allowance has been made to control the temperature of their environment individually, i.e. the systems cannot be individually shut of or turned on.



4.5.6 Lighting

With regards to lighting, 85% of recipients were satisfied with the level of lighting in the building with 100% of the recipients preferring a combination of natural and artificial lighting.

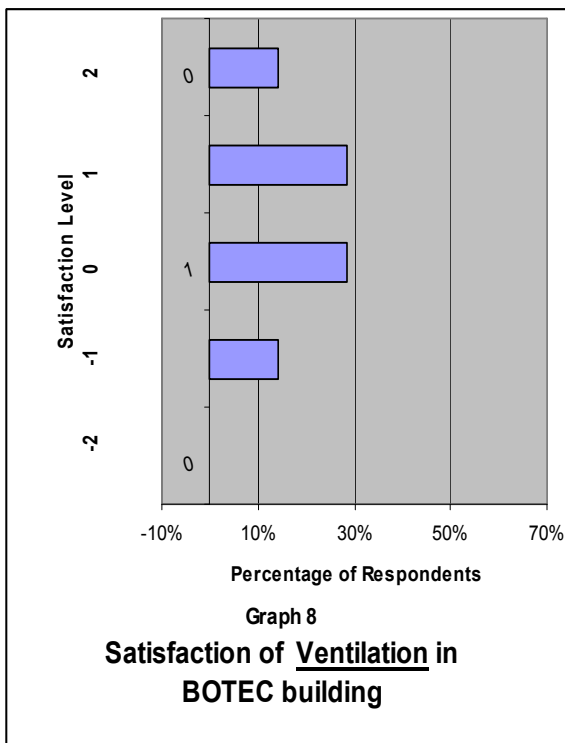
4.5.7 Noise



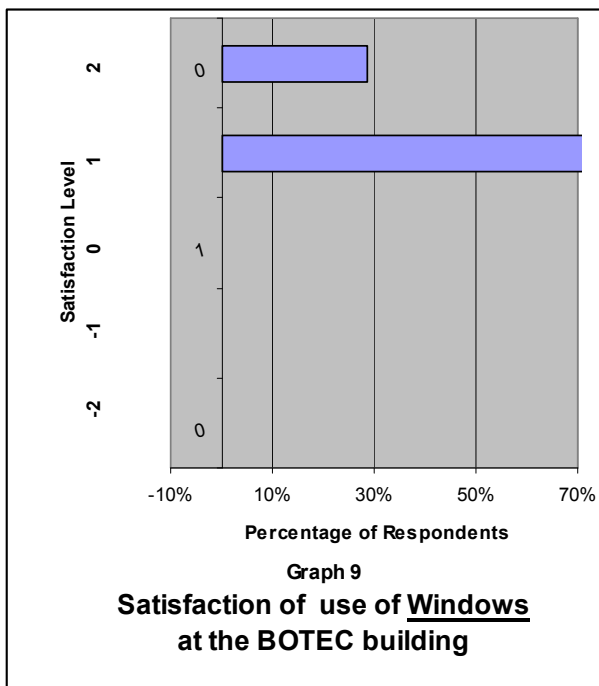
The level of satisfaction for the reduction of noise is mixed. Generally the staff members working in an open plan environment complained that their environment was too noisy. The staff members in cellular offices were less affected by noise made by other staff members, telephones etc.

4.5.8 Ventilation

By large the recipients seem to be satisfied with ventilation in the building, with over 70% of the recipients being relatively satisfied. Again taking into consideration the extreme heat of the Botswana climate, one can ascertain by the level of satisfaction, that the users are generally comfortable with the rate of ventilation allowed for in the design of the BOTEC building.



4.5.9 Windows



The vast amount of windows, shaded and insulated, is well received by the recipients with 100% of the recipients being satisfied and 28,57% being absolutely satisfied as depicted in graph 9 above.

47% of the recipients regard the most important feature of a window as letting sunshine in to warm the room, 44% think it is to let fresh air in, and 25% of the recipients think the most important feature of a window is to keep you in contact with the outside, letting you know how the weather is or to allow for a view to break the work monotony. Only 19% thought that a window is useful to make a room feel more spacious.

4.5.10 Findings

The BOTECH building seems to be performing well and to design expectations with the one surprising exception; the energy efficient heating system. According to the answers to the questionnaire, an alarming 63% of the recipients said that the building becomes so cold, it makes them feel uncomfortable 'every day' in winter, with the remaining 37% stating that the building often becomes so cold that it makes them feel uncomfortable. (100% of recipients feel uncomfortable).

Clearly there is a serious problem with the heating component of the BOTECH building. Such a 'failure' must be investigated to determine where the design is flawed.

According to the recipients, portable heaters have to be brought in to assist with the heating of the working spaces during winter. The use of highly energy intensive heaters throughout the winter months is counterproductive in terms of the other energy efficient systems in place in the BOTECH building, not to mention a bad example to people hoping to learn from this particular building.

4.6 Further Investigation

Through Additional interviews with BOTECH's architect Ken Stuche, it was discovered that the heating system at BOTECH was under performing due to a simple oversight in design.

The extraction system was not designed to shut off and as a result, any warm air generated by the building is efficiently vacuumed out.

4.7 Finding

The BOTECH building is the quintessential example of a building that has strictly followed the typical design principles for energy efficiency. It was shown that even if the design team does not use principles of energy efficient building blindly and manages to adapt almost every aspect of these principles to suite a specific building (as is the case at BOTECH), a solitary element that is overlooked will undo any advantage generated by all of the other elements in place.

Therefore, and in concurrence with Holm's (1996) thinking, not all of the design principles are applicable to any situation. It is therefore important not to apply a once successful solution time and time again, but to consider each condition in accordance with its specific context and, where possible, to test the performance of these systems as soon as possible to minimise discomfort and inefficiency.

5.0	Conclusion
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This research was conducted in order to highlight the misconception that there may be a single answer to the challenges of energy efficient design; a "single elixir that will be the answer to all problems" (Holm, 1996).

Although BOTECH appeared to perform well, interviews with the users of the BOTECH building suggest that the building does not perform well in winter at all. Interviews with the architectural consultant who worked on the BOTECH building expose a simple oversight in design which leads to 'this building's underperformance in winter'.

Highlighted in this investigation, is the threat of environmental catastrophe due to resource depletion and the fact that the building industry is a major contributor to environmental resource depletion. With regards to energy efficient design principles, existing literature was analysed together with the suitability of these principles in today's economy.

The results of the analysis show clearly the relevance of energy efficient design in today's economy and that energy efficient design can save money in the long term despite initial increased capital costs. It is also shown that basic principles of energy efficient design do generally apply to many building types however these elements must firstly adapt to context and must also incorporate a complete and controllable system that may be turned on and off at will.

In concurrence with Holm therefore, this report ultimately shows that there are no perfect solutions to energy efficient design and by applying a once successful solution without taking cognisance of specific climatic and geological differences, the building will not function correctly.

The objective of this investigation therefore was to prove that there is not one solution (elixir) or one set of solutions for solving our problems with regard to resource depletion and energy efficient design.

In proving this, a number of questions had to be asked.

1. Is the building industry an important component in combating resource depletion?
2. Can one justify including energy efficient design and alternate systems into our buildings with regards to the perceived increased financial burden, and risk?
3. Does the economy allow for the inclusion of energy efficient design and alternate systems? (Will it save money?)

4. Finally, if one follows basic principles of energy efficient design and alternate systems, is one guaranteed of a successful, comfortable building?

The answers to these questions were;

1. Yes, the building industry is definitely an important component in combating resource depletion as it was shown to be the largest consumer of energy in most countries.
2. With the threat of global warming, resource depletion, one can most definitely justify the use of energy efficient design and alternate systems in our buildings. Not only was it shown that our fuel supplies have a mere 40 years till they are depleted and that energy prices are already on the increase, but in most cases, energy efficient design was shown not to cost more than traditional design. An element such as correct orientation does not cost more to design or to build, but has a massive impact on the thermal performance of a building.
3. With rapidly increasing energy prices, incentives given by government and energy efficient design and alternate systems becoming more prominent in the building industry (Thus decreasing in cost), It was shown that there has never been a better time, financially, to implement energy efficient design and alternate systems.
4. The BOTEC case study, with respect to the questionnaire that was circulated, showed clearly that by following basic principles of energy efficient design and alternate systems, one is by no means guaranteed of a successful, comfortable building. It was shown that every element must adapt to the specific context of the building into which it has been incorporated. As a result of this finding, It can be shown that, in accordance with Holm (1996) there is no, nor can there ever be a single elixir that will be the answer to all problems with regard to energy efficient design. Context is the defining factor.

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