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The Effect of Digital Design Tools on Green Architecture

A thesis submitted in partial fulfillment of the requirements of
The Master of Science Degree in Architecture

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Special thanks to my parents for their unselfishly support as my best friends. Last, but not least, thanks to my husband for his patience and understanding. His confidence and faith in me have been a constant source of my strength.

God gives success
The researcher

Dedication

I would like to dedicate this thesis to my daughter “Rodina” who was born during the completion of this research.

بسم الله الرحمن الرحيم

"وَقُل رَّبِّ زِدْنِي عِلْمًا"

سورة طه، اية 114

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AH	Absolute Humidity
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Method
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CEN	European Committee for Standardization
CFCs	Chlorofluorocarbons
CFD	Computational Fluid Dynamic
CIBSE	Chartered Institution of Building Services Engineers
DBT	Dry Bulb Temperature
EEM	Energy Efficiency Measure
EIA	Environmental Impact Assessment
FCS	Forestry Stewardship Council
HVAC	Heating, Ventilating, and Air Conditioning.
ISO	International Standards Organization
LEED™	Leadership in Energy and Environmental Design
LPG	Liquefied Petroleum Gas
NREL	National Renewable Energy Laboratory
PPD	Predicted Percentage of Dissatisfied people
PV	Photo Voltaic
USGBC	United States Green Building Council
VOCs	Volatile Organic Compounds

Introduction

A green approach to the built environment involves a holistic approach to the design of buildings. All the resources that go into a building (materials, fuels or the contribution of the users) need to be considered if a green architecture is to be achieved. Sustainable design attempts to have an understanding of the environmental impact of the design by evaluating the site, the embodied energy, the toxicity of the materials, the energy efficiency of design, materials, and construction techniques. At the same time, digital technology, as a global concept and approach, gained a lot of momentum in the last three decades; in general, it also has an equivalent influence on the practice of architecture and urban design all over the globe. Application of green architecture adopted new trends and ideas coupled with the higher cost of new technologies. Green architecture can only exist when effective energy efficiency becomes integral to the design process.

Research Problem

Relating to the ecological crisis as well as the changing social and economic conditions of globalization, the aspects of greening especially sustainability are getting more and more important in the architectural discussion. About 50% of the world's resource consumption is related to the building sector[1]. And inspite of the appearance of digital technology and digital tools in the Architectural practice especially the green Architecture,

<u>Most architects are not aware that by using these digital tools their green projects can be reached with more accurate concrete results.</u>

Research Goal

The research main goal is:

<u>Investigating the use of the digital tools in achieving the green architecture design strategies.</u>

To fulfill the research’s goal, the following objectives must be achieved:

1. Defining Green Architecture as an approach to Architectural design.
2. Discussing different strategies for achieving sustainable design.
3. Exploring design guidelines which help the architects to obtain a sustainable design.

[1] Architecture 2030 URL: http://www.architecture2030.org/building_sector/index.html (accessed July 2004).

4. Discussing the digital technology and its effect on improving the green design practice.
5. Discussing the relationship between intelligent and green architecture.(intelligent vs. green)
6. Exploring the energy performance simulation programs.
7. Analyzing a simulation study on a building in Egypt using one of the energy performance simulation programs at three different climatic zones.

Research Methodology

To reach the previous mentioned objectives; the following methodologies will be adopted;
The theoretical method, the comparative - analytical method, and the deductive method.

The Theoretical Approach:
Reviewing literature, books, and magazines….etc.

- This methodology will be applied to objectives 1, 2, and 3. The result will be in chapter1
- This methodology will be applied to objective 4, 5. The result will be in chapter 2

The Comparative - Analytical Approach :(Inductive approach)
Analyzing and processing collected data.

- This methodology will be applied to objective 6. The result will be in chapter 3

The Deductive Approach:
On applying a case study.

- This methodology will be applied to objective 7. The result will be in chapter 4

Research Scope and Limitations.

- The research will focus on the Design process producing Green Sustainable Architecture.
- This research introduces the different characteristics of Energy Performance Simulation Programs which support the early phase of the architectural design process regardless of all the other processes follow this phase.

- The research case study will only focus on the thermal performance of the study building by changing one variable (materials and thickness of the wall) and applying it in three locations in Egypt.

Research Contents

The research comprises four chapters presenting the following:

Chapter one: Green Architecture and Sustainable Design.

This chapter highlights the Green Architecture as an approach, by discussing its history and main principles creating this discipline. Then it discusses the Sustainable Design which acts as a holistic approach that integrates the benefits of the green architecture. It also addresses the Sustainable Design definitions, methodology, and its guides in order to achieve the Green principle.

Chapter two: Digital Technology and Green Design Practice.

This chapter discusses the Digital Technology and its effect on the Architectural practice, through introducing the Digital Technology sub disciplines in the Architectural and the response of the Green Architecture toward this Technology. (Digitally Controlled Buildings, Digital Tools). Then it discusses the green design practice which was influenced to a great extent by the green digital tools.

Chapter three: Capabilities of Building Energy Performance Simulation Program

This chapter highlights the capabilities of the Energy Performance Simulation Programs, and their sub simulation tools (Thermal Performance Simulation Tool, lighting Analysis Simulation Tool, and Shadow Analysis Simulation Tool). Then, the chapter will explore, analyze, and compare some of the most commonly used programs. Followed by analyzing for some project used the Energy Performance Simulation Programs in their early stage of design.

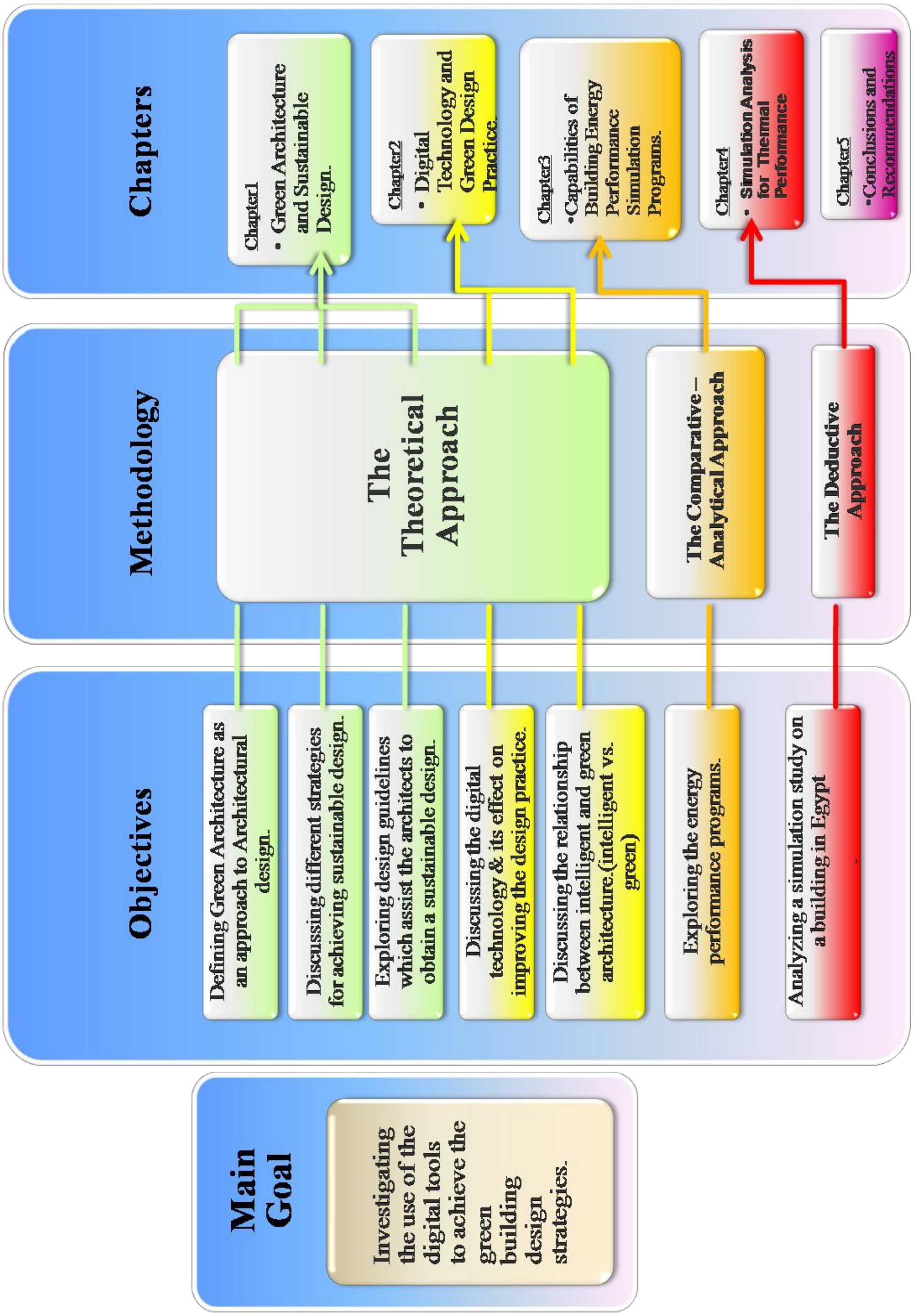
Chapter four: **Simulation Analysis for Thermal Performance** .

This chapter studies a case building using an energy performance analysis tool -ECOTECT- and analyzes the building thermal performance in three different climatic zones in Egypt (Cairo, Alexandria and Aswan), by changing one variable which is the wall material and thickness in each location.

Conclusions and Recommendations.

This research has reached several general conclusions through using the theoretical study or the practical one while depicting its various parts. The research also contains some recommendations for the Architectural Designer and the Educational Organizations.

Research Structure



Chapter1
Green Architecture and Sustainable Design.

1-1 Introduction.
1-2 Green Architecture Background.
1-3 Green Architecture as an Approach.
1-4 Defining Sustainable Design.
1-5 Methods and Strategies for Achieving Sustainable Design.
1-6 Guides for Sustainable Design.
1-7 Applied Example on Green Building.
1-8 Conclusion.

1.1 Introduction

Although green architecture, as a global concept and approach, gained a lot of momentum in the last three decades, in general, it still does not have an equivalent influence on the practice of architecture and urban design all over the globe. Producing green buildings involves resolving many conflicting issues and requirements. Each design decision has environmental implications. Measures for green buildings can be divided into four areas:

- Reducing energy in use.
- Minimizing external pollution and environmental damage.
- Reducing embodied energy and resource depletion.
- Minimizing internal pollution and damage to health.

Green architecture attempts to find solutions that provide quantitative, qualitative, physical, and psychological benefits to building users. There are many possibilities for achieving this seemingly difficult goal. The sustainable design provides a broad awareness of the environment issues associated with economy in architecture. The success of the sustainable design is only possible when green buildings possess a value added that captures the interest and confidence of professionals, clients, and investors alike. This chapter deals with the green architecture approach which looks to design in harmony with and in response to the environment, economy, and society. Producing sustainable design which is the key of this different element co- operates with each other to “live lightly on the earth” so that there will be quality and resources remaining for generations to come. The strategies within each principle of sustainable design focus on more specific topics. These strategies are intended to promote an understanding of how a building interacts with the internal, local, and global environments. Also the chapter will explore the guides for sustainable design, which have been a very successful stimulus for the creation of numerous green buildings.

1.2 Green Architecture Background.

Green Architecture as a way of thinking and as a discipline for architectural design was developed from its appearance till present that can be described as waves influenced its development.

1.2.1 First Green Wave

Three decades ago, several geopolitical conflicts triggered a concern over possible interruption of the global energy system. A number of economic and ecological crises in the 1960s and 1970s led to a reexamination of energy use in buildings and a rediscovery of passive strategies. However, significant public concern only grew with the oil embargo of 1973. When the cost of heating and cooling increased exponentially, the researchers focused on reducing energy consumption in buildings.[1] The first wave was heavily concerned with energy conservation, mainly because of the recent energy market interruptions. In general, a few prominent international architects pioneered the then-newly engineered passive and energy-efficient techniques and building systems. Mainstream architecture continued business-as-usual[2]. Pilot projects designed by prominent international architects did not echo into the architectural arena. In fact, energy prices had fallen and stayed below the 1970s level ever since, subsequently, cost effectiveness was not an issue. The fossil fuel based global energy system and economy enjoyed a relative stability. That is how the first green wave faded away[3].

1.2.2 Second Green Wave

By the 1990s, architects interested in environmentally sensitive architecture supported a theoretical concept that was called “sustainable development” or more commonly, “sustainability.” Forecast studies showed that mankind is facing an unprecedented challenge in which the Earth’s ecosystems cannot anymore sustain the current ever-expanding economic activity and material consumption. Current rates of resource harvesting and waste generation deplete nature faster than it can regenerate. The Earth became ecologically overloaded. An irresistible economy seems to be on a collision course with an immovable ecosphere[4]. Parallel to sustainability, there was a rising interest in “ecological design.” Ecological design is defined as “any form of design that minimizes environmentally destructive impacts by integrating itself with living processes.” In other words, it is simply the adaptation and integration with nature’s processes[5].

At the threshold of the 21st Century, the concern about the global environment took another dimension. The second green wave is not only

[1] Lloyd Jones, David, "Architecture and the Environment: Bioclimatic Building Design". The Overlook Press, New York (1998) p.38-40.

[2] Khalid Mansy, “Market-Based Sustainability, A model to stimulate an ever-lasting green wave,” published paper, Cairo University first conference, (2004).p1

[3] Ibid, p2.

[4] Mathis Wackernagel and William Rees, “Our Ecological Footprint, Reducing Human Impact on the Earth,” The New Catalyst Bioregional Series, Canada, (1996).p31

[5] Sim Van Der Ryn and Stuart Cowan, “Ecological Design”, Island Press, Washington, D.C, (1996).p18

concerned with energy conservation, but also with conservation of all life-supporting natural resources. This time, architects are concerned about three different natural resources, i.e., energy, water, and materials. Then, architects have to consider integrating their buildings into three natural cycles. Architects have to search for innovative solutions to reduce, reuse, and recycle these three resources, when applicable. Sustainable architecture is then much more challenging than just energy conservation in buildings.

Numerous recent publications focus on sustainability as a new trend that is qualified to shape the future practice in Green architecture and urbanism. Conferences are being held annually to discuss the future global and local role of sustainability. However, application of sustainable ideas is again lagging behind. The risk usually associated with adopting new trends and ideas coupled with the anticipated higher cost of new technologies is hindering, so far, the wide spread of sustainable practice and investment in green architecture indeed, should be considered in architecture and urban design.

1.3 Green Architecture as an Approach.

A "green" building places a high priority on health, environmental and resource conservation performance over its life-cycle. These new priorities expand and complement the classical building design concerns: economy, utility, durability, and delight. Green design emphasizes a number of new environmental, resource and occupant health concerns. The emphasis is on the integration of the design into a whole, for the purpose of minimizing their impacts on the occupants (Indoor Environmental Quality) and on the globe. This includes such issues as building site, materials selection, energy efficiency, water conservation, construction waste management, indoor air quality, and others. Many architects have already involved their designs into the process of considering the green architecture approaches. Among those who identified principles of green architecture[1].

1.3.1 Principles of Green Architecture

The following principles of green architecture could serve as guide lines for architectural practices.

[1] Vale, R. and Brenda (1991) “Principles of green architecture”. In Wheeler, S. and Beatley, T. (2004) “The Sustainable Urban Development”. Routledge Press New York.p189

- **Principle 1: Conserving energy**

"A building should be constructed so as to minimize the need for fossil fuels to run it."[1]

Due to the growing of life standards in the recent decade and the provision of new materials and technologies, this principle of minimizing the use of energy seems to be ignored or lost. People used to live in communities to provide more shaded area and cooler air between buildings. On the contrary, people today are more adapted to the individualism way of life supported by a policy of cheap energy which encouraged people to use –for instance- automobiles. Such way of life affected the performance of the traditional community and -as a consequence- affected the ambition for minimizing the use of energy.

Recently, many architectural attempts are more adapted to conserving energy as a main goal in its performance rather than its dependence on the fossil fuels. Thus those experiments should be widely recognized as creative experiments for achieving more green architecture.

- **Principle 2: Working with climate**

"*Buildings should be designed to work with climate and natural energy sources"* [2]

The idea behind this principle is to reduce the dependence on fossil fuels for both warming and cooling a building. The conventional attempt to reduce such dependence on the fossil fuels in design building is by using insulation in the building structure. On the other hand, new approaches suggest that by making use of building form and the nature of building elements can provide comfort conditions inside the building. In the past, people used the natural resources such as wood to generate energy, thus the growing shortage of this resource made them switch to the use of solar energy to generate heat. Buildings were more orientated to the winter sun and therefore buildings were more sensitive for solar design.[3] Another challenging matter was making buildings more adapted to warm climates. To provide comfort cooler atmosphere inside the building, the modern solution affords air conditioning systems which surely consume a lot of energy and increasingly contribute in the current pollution issues.

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[1] Vale, R. and Brenda (1991)" Principles of green architecture". In Wheeler, S. and Beatley, T. (2004) "The Sustainable Urban Development". Routledge Press New York.p189

[2] Ibid.

[3] Ibid.

- **Principle 3: Minimizing new resources**

"*A building should be designed so as to minimize the use of new resources and, at the end of its useful life, to form the resources for other architecture"*[1]

Obviously, the current built environment requires vast resources in order to meet the demands on new buildings due to the population and the economic growth in today's world. This world has not the sufficient resources that can meet the other generations' needs to build new environment by adapting demolition and rebuilding to meet those needs. Therefore, the need for re-using in a form of recycling materials and spaces is much more significant and on the other hand, rehabilitation and upgrading for minimal the environment impact is also important. Unfortunately, those who have an easy access to resources are unlikely adapted to the approach of re-using existing structures which have been designed for one purpose and that can suit a different need than its designed purpose. But what if the existing building's components have been re-used in a different state but another problem emerges here which is the conservation of historical buildings. Many argue that it can still be useful if those buildings can be conserved in a changed state. Green approach suggests solutions that depend on resources and suggest that if the resources need to be modified/changed/replaced in a building are less in quantity than those used for demolition and rebuilding then the replacement is the solution and this solution also denies the historical importance of a building

However, the total benefits of reusing an existing building that has a historical importance can ignore the internal concerns and the renovation of existing building can also minimize resources instead of demolition and rebuilding.[2]

- **Principle 4: Respect for users**

"*A green architecture recognizes the importance of all the people involved with it"* [3]

Since different resources are included in the process of making a building, green architecture highlights the importance of human beings involvement in the building process. The respect of users can be illustrated in two forms; for the professional builder, it's important to realize the effect of materials and processes that form the building on users, workers and on the construction site. Thus such materials and processes should have less

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[1] Vale, R. and Brenda (1991) "Principles of green architecture." In Wheeler, S. and Beatley, T. (2004) "The Sustainable Urban Development". Routledge Press New York.p189.

[2] Ibid.

[3] Ibid p190.

polluting and dangerous effect. Therefore, the use of insulating materials that contain Chlorofluorocarbons (CFCs) and methods of timber treatments that contains chemical components has poisoning effect on both workers and working -site environment and such processes should be eliminated from any green building practices.[1]

Another form of respecting users is recognizing the importance of human participation in the design and construction process. This value should be further developed in a way that could increase the level of satisfaction with the construction of a building. In parallel to that, people should freely engage into the process of design and creating a building.

- **Principle 5: Respect for site**

"*A building will "touch-this-earth-lightly"* [2]

This phrase illustrates another green principle which highlights the awareness with the interaction between a building and its site. A building will touch this earth lightly means that in a case of removing a building from its site, that building could leave it in a condition as it was before placed there. And it also carries concerns of the materials with which a building was created from. Therefore, any building consumes heavily energy, creates pollution and eliminates users, does not touch this earth lightly.

Temporary designs, structures for exhibitions, performances and other cultural events are considered good illustration of this principle because at the end of the event, these structures could leave the site without any alteration and it could easily be else where.

- **Principle 6: Holism**

"*All the green principles need to be embodied in a holistic approach to the built environment"*[3]

All green principles that have been previously demonstrated can not be easily embodied in a single building, rather it can be involved into an interaction of systems-systems of playing, living, and working- among buildings that represented into built forms. On the other hand, green architecture includes not only buildings and its designs but also sustainable form of urban environment.

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[1] Vale, R. and Brenda (1991)" Principles of green architecture. " In Wheeler, S. and Beatley, T. (2004) The Sustainable Urban Development". Routledge Press New York.p190

[2] Ibid p191.

[3] Ibid p192.

As other architects and developers who have engaged into proposing these principles, all of them have almost the same themes: which are encouraging designers to conserve energy and non-renewable energy, consider the local characteristics of a place and to consider the building users. United States Green Building Council (USGBC) was formed largely to synthesize and spread the definition of "green."

The USGBC's definition states that green design is a holistic approach that considers impacts on human health and their wellbeing and the natural environment at every stage of a building's lifecycle. [1]

"Producing green buildings involves resolving many conflicting issues and requirements that are aimed at creating natural environments[2]." Many different people have offered many different definitions for green building and green development. Some focus on environmental goals alone, while others focus on environment and community health. Other definitions center on balancing community, financial, and environmental concerns in what is often called a triple bottom line or "triple E" framework, which stands for equity, economy, and ecology[3]. The practice of green building aims to harness synergy between the economic, social, and ecological systems. It operates under natural laws that negate the concept of waste, demand sustainable resource use, place-specific solutions and reliance on current solar income. Hence, it does not use more than it gives back, and sits lightly on the landscape that inspired it, for it is either highly durable or reversible. It offers its occupants sustenance, partnership, comfort, and stability, and connects them to the larger ecosystem while protecting or restoring their health and dignity. [4]

1.3.2 Benefits of Green Buildings

The benefits of green buildings are so tangible, comprehensive, and logical, that many of its promoters argue that no other type of building should be allowed at all. The practice of green buildings is in line with the paradigm of sustainable development. In addition to being environmentally sensitive, it is socially responsible[5]

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[1] US Green Building Council. URL: http://www.usgbc.org. (accessed June 2006).
[2] Pearson, D. "The Natural House Book" Gaia Books, London 1991. P37
[3] William B. Bradshaw II "Buying Green" M.Sc. Thesis submitted at the Massachusetts Institute of Technology February 2006.p9
[4] GAIAM. "Shelter and Passive Solar Design." URL:http://www.gaiam.com/retail/gai_content/learn/gai_learnArticle.asp?article%5Fid=1240&category%5Fid=158 (accessed May, 2005.)
[5] "Green Buildings and First-Costs – a Controversy that Will Not Die." (2004, November) URL:http://findarticles.com/p/articles/mi_hb3601/is_200411. (accessed June 2006).

The benefits of green building can be arranged into three categories[1]: Environmental, Economical and Social Benefits.

- **Environmental benefits**

Environmental benefits can be summarized in the following points:[2]

- Protection of the quality and supply of freshwater resources
- Protection of oceans, all kinds of seas and coastal areas
- Integrated approach to the planning and management of land resources
- Managing fragile ecosystems: combating desertification and drought
- Managing fragile ecosystems: sustainable mountain development
- Promoting sustainable agriculture and rural development
- Combating deforestation
- Conservation of biological diversity
- Environmentally sound management of biotechnology
- Protection of the atmosphere
- Environmentally sound management of solid wastes and sewage-related issues
- Environmentally sound management of toxic chemicals
- Environmentally sound management of hazardous wastes
- Safe and environmentally sound management of radioactive wastes

- **Economical benefits**

As the green building is becoming more popular, the financial benefits for developers and homeowners are becoming clearer. The majority of savings from green building are in maintenance and utility costs. It includes improving the bottom line of building's lifecycle costs, decreasing operation costs, and increasing asset value. In addition, green building decreases insurance rates and legal liabilities while easing market differentiation, offering competitive advantage, and nurturing local economies. [3] Where economical benefits can be summarized in points as follow:[4]

- Changing consumption patterns
- Financial resources and mechanisms
- Transfer of environmentally sound technology, cooperation and capacity-building.

[1] US Green Building Council. URL: http://www.usgbc.org. (accessed June 2006).
[2] Agenda 21, URL: http://habitat.igc.org/agenda21/(accessed July 2007)
[3] US Green Building Council. URL: http://www.usgbc.org. (accessed June 2006).
[4] Agenda 21, URL: http://habitat.igc.org/agenda21/(accessed July 2007)

- **Social benefits**.

Green design is linked with increased worker productivity and using green materials increases health benefits.
Where social benefits can be summarized in the following points:[1]

  - Combating poverty
  - Demographic dynamics.
  - Promoting education, public awareness and training
  - Protecting and promoting human health
  - Promoting sustainable human settlement development

The three major benefits of green architecture are integrated together to produce green architecture. This integration is known as sustainable design. In which it consists methods that embodies those benefits. Fig 1-1

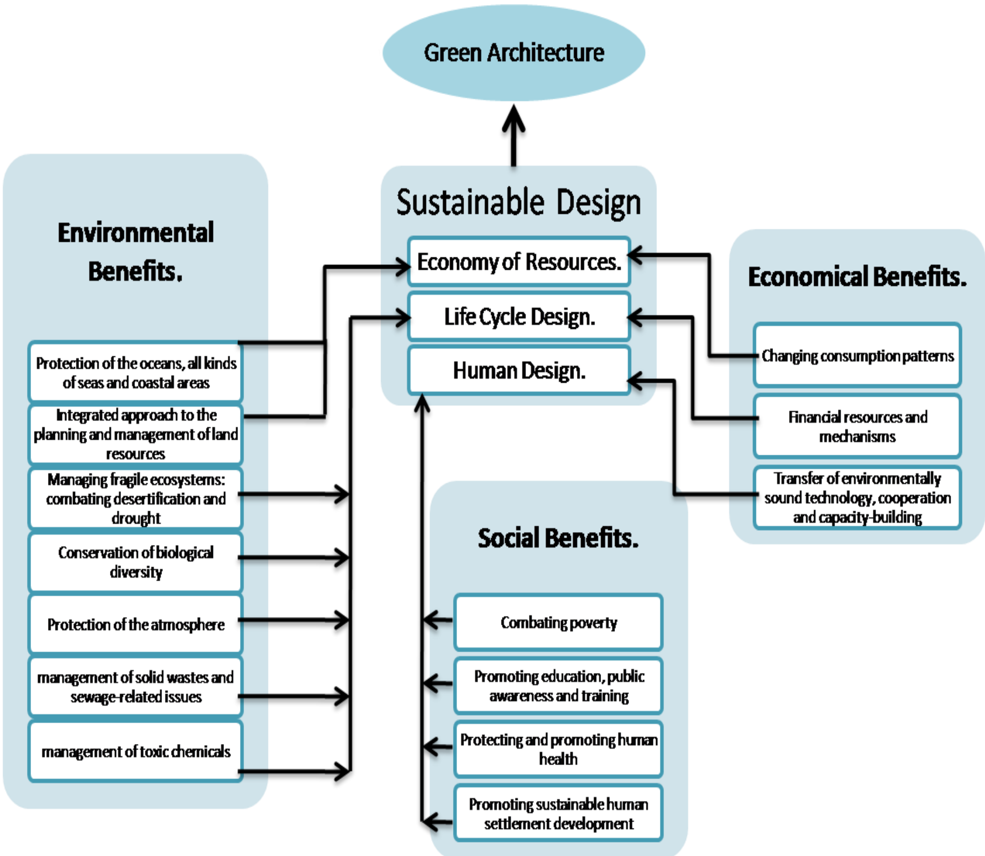

Figure 1-1 The integration of the three benefits producing green architecture.

[1] Agenda 21, URL: http://habitat.igc.org/agenda21/(accessed July 2007)

1.4 Defining Sustainable Design.

Over the last thirty years, human's relationship to the natural world has come under uncomfortable scrutiny as a result of the anticipation and experience of a growing range of environmental crisis. The interaction of the man-made environment with the natural world has become a profound cause for concern. During a building's existence, it affects the local and global environments via a series of interconnected human activities and natural processes. Sustainable design appeared to less this environmental crisis.

"Sustainable design is the development which meets the needs of the present without compromising the ability of future generation to meet their own needs." [1]

The word development in this definition implicates two important aspects of the concept: firstly it is Omni disciplinary, it cannot be limited to a number of disciplines or areas, but it is applicable to the whole world and everyone and everything on it, now and in the future. Secondly, there is no set aim, but the continuation of development is the aim of the development. The definition is also based on two concepts:

- The concept of needs, comprising of the conditions for maintaining an acceptable life standard for all people. The needs consist firstly of basic needs such as food, clothing, housing and employment. Secondly, every individual, in every part of the world should have the opportunity to try and raise his or her life standard above this absolute minimum.
- The concept of limits of the capacity of the environment is to fulfill the needs of the present and the future, determined by the state of technology and social organization. The limits consist of natural limitations like finite resources, but also of declining productivity caused by overexploitation of resources, declining quality of water and shrinking of biodiversity.

For the future, it will be best if the needs are fulfilled while limits didn't increase, but preferably decreased. This would lead to the quite simple conclusion that all political, technical, and social developments can easily be evaluated in the light of sustainable development by these two arguments.

[1] World Commission on Environment and Development, "Our Common Future," Oxford University Press, New York, 1987. p. 4

Any development should help fulfill needs and should not increase limitations.

Sustainable is also defined as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles.” [1] Sustainable designed buildings aim to lessen their impact on our environment through energy and resource efficiency. It includes the following principles[2]:

- Minimize resource consumption
- Maximize resource reuse
- Use renewable or recyclable resources
- Protect the natural environment
- Create a healthy, non-toxic environment
- Pursue quality in creating the built environment

Sustainable design can be summarized as those designs that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings, and the broader regional and global setting. Although sustainable design communicates slightly different meanings, nevertheless it is a paradigm change. It serves as a rallying point for creating greater concern about the built environment and its long term viability, and a critical concept and direction for the design professions.

1.5 Methods and strategies for achieving Sustainable Design.

Sustainable design begins with an intimate understanding of place. If the architect is sensitive to the nuances of place, he can inhabit without destroying it. Understanding place helps determine design practices such as solar orientation of a building on the site, preservation of the natural environment, and access to public transportation. Connecting with people, whether the design site is a building in the inner city or in a more natural setting, connecting with nature brings the designed environment back to life. Effective design helps inform its place within nature.

[1] Alaa El-Dien Adel El-Alfy2004. “Sustainable Architecture,” published paper in the first conference for sustainable architectural and urban development submitted to department of architecture Cairo University, Cairo, Egypt, 2004. P1

[2] Kibert, C. J. “Establishing Principles and a Model for Sustainable Construction,” Sustainable Construction - Proceedings of the First International Conference of (CIB TG) 16, November 1994, p. 7.

Sustainable design must take into consideration the wide range of cultures, races, religions, and habits of the people who are going to be using and inhabiting the built environment. This requires sensitivity and empathy on the needs of the people and the community. "Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations."[1] Conceptual framework of sustainable design will be set. The levels of the framework (Methods and Strategies) correspond to the objectives of environmental architectural education: creating environmental awareness, explaining the building ecosystem, and teaching how to design sustainable buildings.Fig1-2

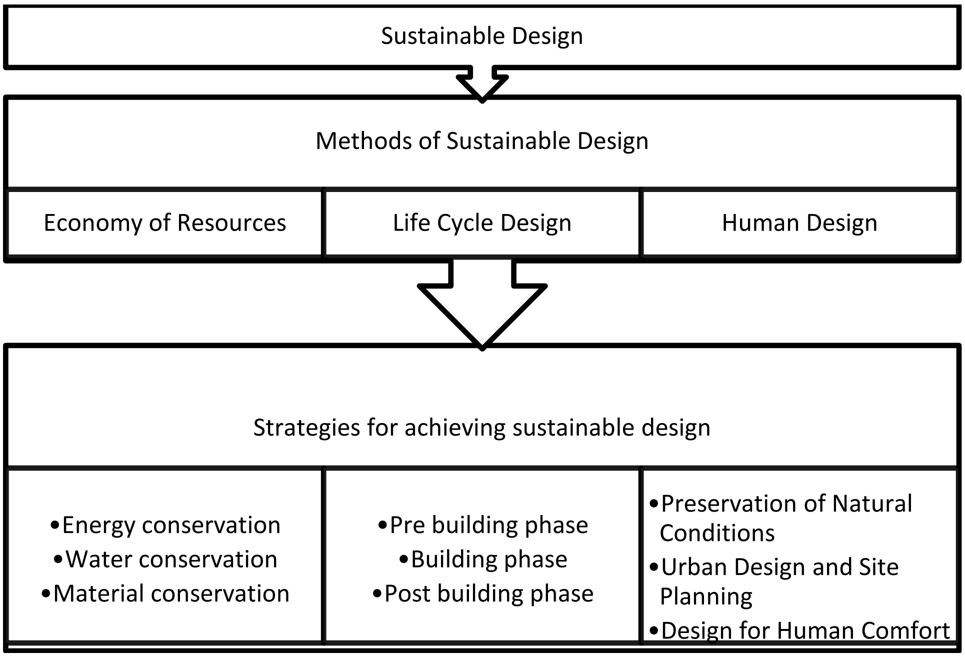

Figure 1-2 Conceptual framework for Sustainable Design in Green Architecture.

The three methods of sustainable design are:[2] Economy of resources, Life cycle design and Human design. Each of these methods embodies a unique set of strategies. Studying these strategies leads to more thorough understanding of architecture's interaction with the greater environmental,

1 WCED "Our Common Future." In Wheeler, S. and Beatley, T. (2004) "The Sustainable Urban Development." New York p.57.

2 Jong-Jin Kim "Introduction to Sustainable Design," Published by National Pollution Prevention Center for Higher Education, December 1998.p9

economical, and social awareness. This allows further disaggregating and analyzing specific methods architects can apply to reduce the overall impacts of the buildings design.

1.5.1 Method 1: Economy of Resources

By economizing resources, the architect reduces the use of nonrenewable resources in the construction and operation of buildings. There is a continuous flow of resources, natural and manufactured, in and out of a building. This flow begins with the production of building materials and continues throughout the building's life span to create an environment for sustaining human well-being and activities. After a building's useful life, it should turn into components for other buildings. When examining a building, consider two streams of resource flow. Fig1-3. Upstream, resources flow into the building as input to the building ecosystem. Downstream, resources flow out of the building as output from the building ecosystem. On the long run, any resources entered into a building ecosystem will eventually come out from it. This is the law of resource flow conservation.

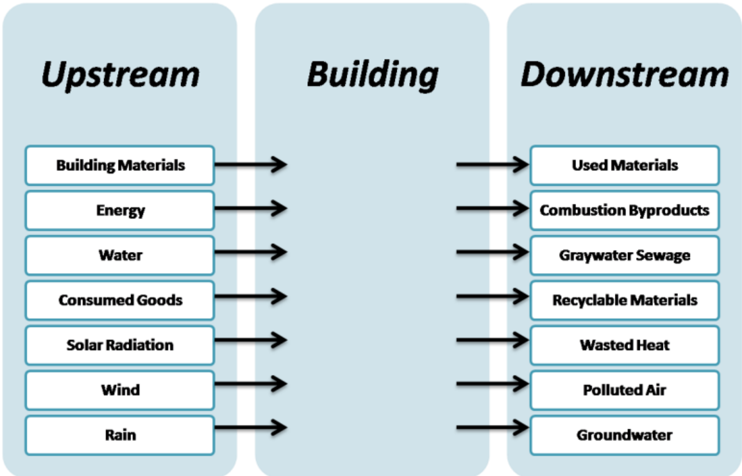

Figure 1-3 The input and output streams of resource flow.
(Source: Jong-Jin Kim "Introduction to Sustainable Design," Published by National Pollution Prevention Center for Higher Education, December 1998.p9)

The three strategies for the economy of resources method are energy conservation, water conservation, and material conservation. Each focuses on a particular resource necessary for building construction and operation.

And also can yield specific design strategies that will improve the sustainability of architecture .Fig1-4. These strategies can be classified into two types:

1) Input-reduction strategies:

Reduce the flow of nonrenewable resources input to buildings. A building's resource demands are directly related to its efficiency in utilizing resources.

2) Output-management strategies:

Reduce environmental pollution by requiring a low level of waste and proper economical management for waste.

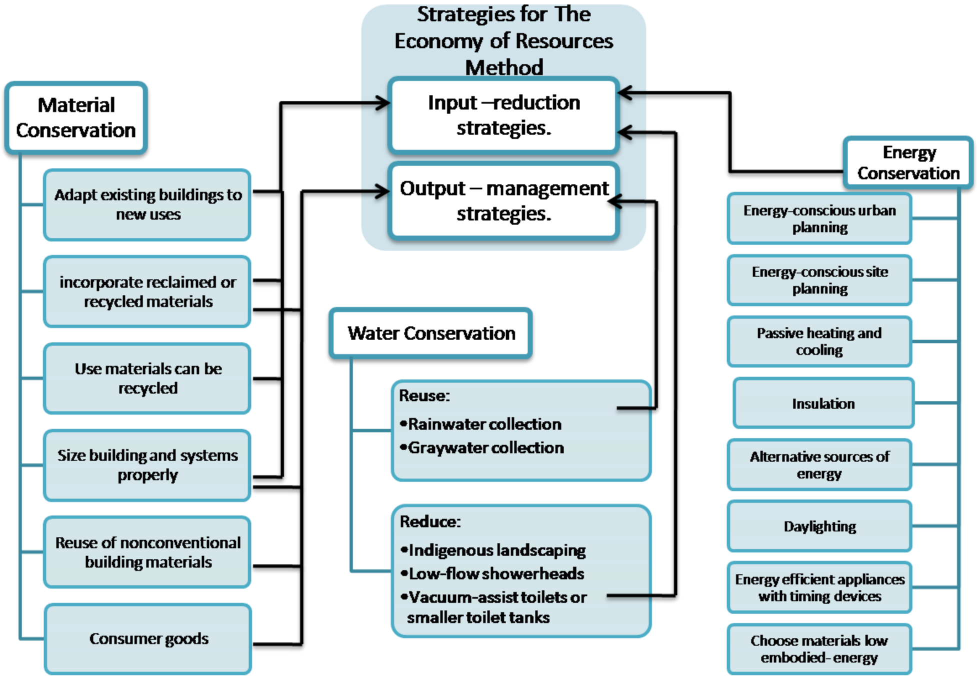

Figure 1-4 The strategies types

1.5.1.1 Energy Conservation

Energy conservation is an input-reduction strategy. The main goal is to reduce consumption of fossil fuels. Buildings consume energy not only in their operation, for heating, lighting, and cooling, but also in their construction.[1] The materials used in architecture must be harvested, processed, and transported to the building site. Construction itself often

[1] T. Gorst, "Buildings Around Us." Taylor & Francis,1995 P 132.

requires large amounts of energy for processes ranging from moving earth to welding.

- **Energy-Conscious Urban Planning**

Cities and neighborhoods that are energy-conscious are not planned around the private cars, but around public transportation and pedestrian walkways. These cities have zoning laws favorable to mixed-use developments, allowing people to live near their workplaces. Urban sprawl is avoided by encouraging redevelopment of existing sites and the adaptive reuse of old buildings. Climatic conditions determine orientation and clustering. For example, a very cold or very hot and dry climate might require buildings sharing walls to reduce exposed surface area; a hot, humid climate would require widely spaced structures to maximize natural ventilation.[1]

- **Energy-Conscious Site Planning**

Such planning allows the designer to maximize the use of natural resources on the site. In temperate climates, open southern exposure will encourage passive solar heating; deciduous trees provide shade in summer and solar heat gain in winter. Evergreens planted on the north of a building will protect it from winter winds, improving its energy efficiency. Buildings can be located relative to water onsite to provide natural cooling in summer.[2]

- **Passive Heating and Cooling**

Solar radiation incident on building surfaces is the most significant energy input to buildings. It provides heat, light, and ultraviolet radiation necessary for photosynthesis. Historically, architects have devised building forms that provide shading in summer and retain heat in winter. This basic requirement is often overlooked in modern building design. Passive solar architecture offers design schemes to control the flow of solar radiation using building structure, so that it may be utilized at a more desirable time of the day. Shading in summer, by plants or overhangs, prevents summer heat gain and the accompanying costs of air-conditioning. The wind, or the flow of air, provides two major benefits: cooling and hygienic effects. Prevailing winds have long been a major factor in urban design. For instance, proposals for Roman city layouts were primarily based on the direction of prevailing winds.[3]

[1] Jong-Jin Kim "Introduction to Sustainable Design," Published by National Pollution Prevention Center for Higher Education, December 1998.p16

[2] Ibid.p18.

3 Ibid.p18.

- **Insulation**

High-performance doors, windows and wall insulation prevent both heat gain and loss. Reducing such heat transfer reduces the building's heating and cooling loads and thus its energy consumption.[1] Reduced heating and cooling loads require smaller Heating, Ventilating, and Air Conditioning (HVAC) equipment, and the initial investment need for the equipment will be smaller. Aside from these tangible benefits, high-performance windows and wall insulation create more comfortable thermal environments. Due to the insulating properties of the materials, the surface temperatures of windows and walls will be higher in the winter and lower in the summer. The installation of smaller HVAC equipment reduces mechanical noise and increases sonic quality of the indoor space.

- **Alternate Sources of Energy**

Solar, wind, water, and geothermal energy systems are all commercially available to reduce or eliminate the need for external energy sources. Electrical and heating requirements can be met by these systems, or combination of systems, in all climates.

- **Daylighting**

Building and window design that utilizes natural light will lead to conserving electrical lighting energy, saving peak electric loads, and reducing cooling energy consumptions. At the same time, daylighting increases the luminous quality of indoor environments, enhancing the psychological wellbeing and productivity of indoor occupants. These qualitative benefits of daylighting can be far more significant than its energy-savings potential.[2]

- **Energy-Efficient Equipment & Appliances**

After construction costs, a building's greatest expense is the cost of operation. Operation costs can even exceed construction costs over a building's lifetime.[3] Careful selection of high efficiency heating, cooling, and ventilation systems becomes critical. The initial price of this equipment may be higher than that of less efficient equipment, but this will be offset by future savings. Appliances, from refrigerators to computers, not only

1 Frederick S. Merritt, Jonathan T. Ricketts. "Building Design and Construction Handbook", McGraw-Hill Professional 2000. p11-112.

2Michael J. Crosbie ,"The Passive Solar Design and Construction Handbook," John Wiley and Sons,1998 p8.

3 Dell'Isola, Alphonse J., and Stephen J. Kirk." Life Cycle Costing for Design Professionals." New York: McGraw-Hill, 1981.p64

consume energy, they also give off heat as a result of the inefficient use of electricity. More efficient appliances reduce the costs of electricity and air-conditioning.

- **Materials with Low Embodied Energy**

Building materials vary with respect to how much energy is needed to produce them. The embodied energy of a material attempts to measure the energy that goes into the entire life cycle of building material. For instance, aluminum has a very high embodied energy because of the large amount of electricity that must be used to manufacture it from mined bauxite ore; recycled aluminum requires far less energy to prefabricate.[1] By choosing materials with low embodied energy, the overall environmental impact of a building is reduced. Using local materials over imported materials of the same type will save transportation energy[2]

1.5.1.2 Water Conservation

A building requires a large quantity of water for the purposes of drinking, cooking, washing and cleaning, flushing toilets, irrigating plants, etc... All of this amount of water requires treatments and delivery, which consume energy and money. The water that exits the building as sewage must also be treated.[3]

Strategies for water conservation may reduce input, output, or both. This is because, conventionally, the water that is supplied to a building and the water that leaves the building as sewage are all treated by municipal water treatment plants. Therefore, a reduction in use also produces a reduction in waste.

- **Reusing Water Onsite**

Water consumed in buildings can be classified as two types: gray water and sewage. Gray water is produced by activities such as hand washing. While it is not of drinking-water quality, it does not need to be treated as nearly as intensively as sewage. In fact, it can be recycled within a building, perhaps to irrigate ornamental plants or flush toilets. Well-planned plumbing systems facilitate such reuse. In most parts of the world, rainwater falling on buildings has not been considered a useful resource. Buildings are typically

[1] Jong-Jin Kim “Introduction to Sustainable Design,” Published by National Pollution Prevention Center for Higher Education, December 1998.p18

[2]Clarke Snell “The Good House Book: A Common-sense Guide to Alternative Homebuilding”, Lark Books2004, p42

[3] Jong-Jin Kim “Introduction to Sustainable Design,” Published by National Pollution Prevention Center for Higher Education, December 1998.p18

designed to keep the rain from the occupants, and the idea of utilizing rain water falling on building surfaces has not been widely explored. Building envelopes, particularly roofs, can become rainwater collecting devices, in combination with cisterns to hold collected water. This water can be used for irrigation or toilet-flushing.[1]

- **Reducing Consumption**

Water supply systems and fixtures can be selected to reduce consumption and waste. Low-flow faucets and small toilet tanks are now required by code in many areas of the country. Vacuum-assisted and bio-composting toilets further reduce water consumption. Bio-composting toilets, available on both residential and commercial scales, treat sewage on site, eliminating the need for energy-intensive municipal treatment. Indigenous landscaping — using plants native to the local ecosystem — will also reduce water consumption. These plants will be adapted to the local rainfall levels, eliminating the need for additional watering. Where watering is needed, the sprinkler heads should be carefully placed and adjusted to avoid watering the sidewalk and street.[2]

1.5.1.3 Material Conservation

A range of building materials are brought onto building sites. The influx of building materials occurs primarily during the construction stage. The waste generated by the construction and installation process is significant. After construction, a low-level flow of materials continues in for maintenance, replacement, and renovation activities. Consumer goods flow into the building to support human activities. All of these materials are eventually output, either to be recycled or dumped in a landfill.[3]

The production and consumption of building materials has diverse implications on the local and global environments; Extraction, processing, manufacturing, and transporting building materials. All cause ecological damage to some extent. There are input and output reduction strategies for materials conservation. As with water, some of these strategies overlap.

[1] Jong-Jin Kim "Introduction to Sustainable Design," Published by National Pollution Prevention Center for Higher Education, December 1998.p21

[2] Ibid.p20.

[3] Ibid.

- **Adapting Existing Buildings to New Uses**

One of the most straightforward and effective methods for material conservation is to make use of the resources that already exist in the form of buildings. Most buildings outlive the purpose for which they were designed. Many, if not all, of these buildings can be converted to new uses at a lower cost than brand-new construction.[1]

- **Integrating Reclaimed or Recycled Materials**

Buildings that have to be demolished should become the resources for new buildings. Many building materials, such as wood, steel, and glass, are easily recycled into new materials. Some, like brick or windows, can be used whole in the new structure. Furnishing, particularly office partition systems, are also easily moved from one location to another.

- **Using Materials That Can Be Recycled**

During the process of designing the building and selecting the building materials, architects search for ways to use materials that can themselves be recycled. This preserves the energy embodied in their manufacture.

- **Sizing Buildings and Systems Properly**

A building that is oversized for its designed purpose, or has oversized systems, will excessively consume materials. When a building is too large or small for the number of people it must contain, its heating, cooling, and ventilation systems, typically sized by square footage, will be inadequate or inefficient. This method relates directly to the programming and design phases of the architectural process. The client's present and future space needs must be carefully studied to ensure that the resulting building and systems are sized correctly. Architects are encouraged to design around standardized building material sizes as much as possible. In the U. S., this standard is based on a 4'x8' sheet of plywood. Excess trimming of materials to fit non-modular spaces generates more waste.

- **Reusing Non-Conventional Products as Building Materials**

Building materials from unconventional sources, such as recycled tires, pop bottles, and agricultural waste, are readily available. These products reduce the need for new landfills and have a lower embodied energy that the conventional materials they are designed to replace.

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[1] Jong-Jin Kim "Introduction to Sustainable Design," Published by National Pollution Prevention Center for Higher Education, December 1998.p20

- **Consumer Goods**

All consumer goods eventually lose their original usefulness. The "useful life" quantifies the time of conversion from the useful stage to the loss of original usefulness stage. For instance, a daily newspaper is useful only for one day, a phone book is useful for one year, and a dictionary might be useful for 10 years. The shorter the useful life of consumer goods, the greater the volume of useless goods will result. Consequently, more architectural considerations will be required for the recycling of short-life consumer goods. The conventional term for consumer goods that have lost their original usefulness is waste. But waste is or can be a resource for another use. Therefore, in lieu of waste, it is better to use the term "recyclable materials." One way buildings can encourage recycling is to incorporate facilities such as on-site sorting bins.

1.5.2 Method 2: Life Cycle Design

The second method of sustainable architecture is life cycle design. This method recognizes environmental consequences of the entire life cycle of architectural resources, from procurement to return to nature. Life cycle design is based on the notion that a material transmigrates from one form of useful life to another, with no end to its usefulness. For the purpose of conceptual clarity, the life cycle of a building can be categorized into three phases: pre-building, building, and post-building. Fig.1-5.

These phases are connected, and the boundaries between them are not obvious. The phases can be developed into life cycle design strategies that focus on minimizing the environmental impact of a building. Analyzing the building processes in each of these three phases provides a better understanding of how a building's design, construction, operation, and disposal affect the larger ecosystem. Design strategies that will improve the sustainability of architecture focus mainly on reducing input. [1]Consuming fewer materials lessens the environmental impact of the associated manufacturing processes. This then reduces the eventual output of the building ecosystem.

[1] Dell'Isola, Alphonse J., and Stephen J. Kirk. "Life Cycle Costing for Design Professionals." New York: McGraw-Hill, 1981.p1

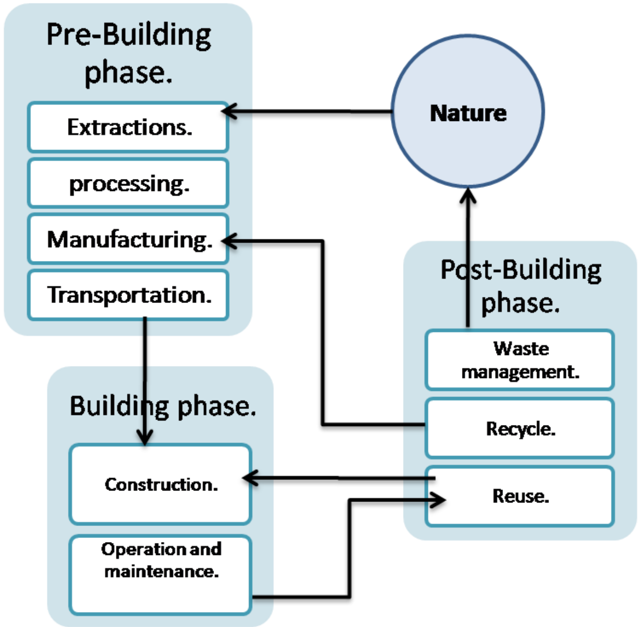

Figure 1-5 The sustainable building life cycle.

1.5.2.1 Pre-Building Phase

This phase includes site selection, building design, and building material processes, but not including installation. Under the sustainable-design strategy, it examines the environmental consequences of the structure's design, orientation, impact on the landscape, and materials used.

During the Pre-Building Phase, the design of a building and materials selected for it are examined for their environmental impact. The selection of materials is particularly important at this stage, the impact of materials processing can be global and have long-term consequences.[1]

- **Materials Made From Renewable Resources**

Renewable resources are those that can be grown or harvested at a rate that exceeds the rate of human consumption. Using these materials is, by definition, sustainable. Materials made from nonrenewable materials (petroleum, metals, etc.) are, ultimately, not sustainable, even if current supplies are adequate. Using renewable materials wherever possible reduces the need for nonrenewable materials.[2]

[1] Dell'Isola, Alphonse J., and Stephen J. Kirk. "Life Cycle Costing for Design Professionals". New York: McGraw-Hill, 1981.p53

[2] Ibid.

- **Materials Harvested or Extracted Without Causing Ecological Damage**

Of the renewable materials available, not all can be obtained without significant environmental effects. Therefore, the architect must be aware of how various raw materials are harvested and understand the local and global ramifications.

- **Recycled Materials**

Using recycle materials reduces waste and saves scarce landfill space. Recycled materials also preserve the embodied energy of their original form, which would otherwise be wasted. This also reduces the consumption of materials made from virgin natural resources. Many building materials, particularly steel, are easily recycled, eliminating the need for more mining and milling operations.

- **Materials with Long Life and Low Maintenance**

Durable materials last longer and require less maintenance with harsh cleansers. This reduces the consumption of raw materials needed to make replacements and the amount of landfill space taken by discarded products. It also means occupants receive less exposure to irritating chemicals used in the installation and maintenance of materials.

1.5.2.2 Building and operation Phase

This phase refers to the stage of a building's life cycle when a building is physically being constructed and operated. In the sustainable-design strategy, the construction and operation processes were examined for ways to reduce the environmental impact of resource consumption; it also considered long-term health effects of the building environment on its occupants. The methods associated with the Building Phase strategy are concerned with the environmental impact of actual construction and operation processes.

- **Minimize Site Impact**

Careful planning can minimize invasion of heavy equipment and the accompanying ecosystem damage to the site. Excavations should not alter the flow of groundwater through the site. Finished structures should respect site topology and existing drainage. Trees and vegetation should only be removed when absolutely necessary for access. For sensitive sites, materials that can be hand-carried to the site reduce the need for excessive road-building and heavy trucks.

- **Employing Nontoxic Materials**

The use of nontoxic materials is vital to the health of the building's occupants, who typically spend more than three quarters of their time indoors. Adhesives used to make many common building materials can outgas — release volatile organic compounds into the air — for years after the original construction. Maintenance with nontoxic cleansers is also important, as the cleaners are often airborne and stay within a building's ventilation system for an extended period of time.

1.5.2.3 Post-Building Phase

This phase begins when the useful life of a building has ended. In this stage, building materials become resources for other buildings or waste to be returned to nature. The sustainable design strategy focuses on reducing construction waste (which currently comprises 60% of the solid waste in landfills) by recycling and reusing buildings and building materials.[1]

During this phase, the architect examines the environmental consequences of structures that have outlived their usefulness.

At this point, there are three possibilities in a building's future: reuse, recycling of components, and disposal. Reuse and recycling allow a building to become a resource for new buildings or consumer goods, disposal requires incineration or landfill dumping, contributing to an already overburdened waste stream.

- **Reusing the Building**

The embodied energy of a building is considerable. It includes not only the sum of energy embodied in the materials, but also the energy that went into the building's construction. If the building can be adapted to new uses, this energy will be conserved. Where complete reuse of a building is not possible, individual components can be selected for reuse — windows, doors, bricks, and interior fixtures are all excellent candidates.

- **Recycling Materials**

Recycling materials from a building can often be difficult due to the difficulty in separating different substances from one another. Some materials, like glass and aluminum, must be scavenged from the building by hand. Steel can easily be separated from rubble by magnets. Concrete can be crushed and used as aggregate in new pours.

1 Frederick S. Merritt, Jonathan T. Ricketts "Building Design and Construction Handbook", McGraw-Hill Professional 2000. p17-69.

- **Reusing Existing Buildings and Infrastructure**

It has become common for new suburbs to move farther and farther from the core city as people search for "space" and "nature." Of course, the development of new suburbs from virgin woods or fertile agricultural fields destroys the very qualities these suburbanites are seeking. Moreover, in addition to the materials for new houses, new development requires massive investments in material for roads, sewers, and the businesses that inevitability follows. Meanwhile, vacant land and abandoned structures in the city, with its existing infrastructure, go unused, materials wasted.[1]

The life cycle design concept calls for consideration of the environmental and economical consequences of buildings in all three phases of the life cycle. Each phase of building life cycle is associated with two groups of environmental elements: site and building. Table 1-1. The principle domain of architectural design is in the building phase, but sustainable building can be achieved by finding ways to minimize environmental impacts, and the economical consuming as well during all three phases of building life cycle.[2]

Table 1-1: Ecological elements of Site and Building associated with the building life-cycle phases.
(Source: Jong-Jin Kim "Introduction to Sustainable Design," Published by National Pollution Prevention Center for Higher Education, December 1998.p13)

	SITE: Elements of site ecology that exist within or in the vicinity of a building site, including sun- light, wind, precipitation, water table, soil, flora, fauna, etc. ...	BUILDING: Natural or manufactured resources, such as building materials, water, or energy ...
pre-building phase	... Before construction.	... Before they arrive at the site.
building phase	... from the time construction begins through the duration of The building's useful life.	... from the time they arrive at the site for installation or Operation though the duration of the building's useful life.
Post-building phase.	... After the building's useful life.	... After the building's useful life.

[1] Vale, Brenda, and Robert Vale. Green Architecture: "Design for an Energy-Conscious Future". London: Thames and Hudson, 1991.

[2] Jong-Jin Kim "Introduction to Sustainable Design," Published by National Pollution Prevention Center for Higher Education, December 1998.p13

1.5.3 Method 3: Human Design

Human design is the third, and perhaps the most important, Method of sustainable design. While economy of resources and life cycle design deal with efficiency and conservation, human design is concerned with the livability of all constituents of the global system. This Method arises from the humanitarian and altruistic goal of respecting the life and dignity of fellow living organisms. Further examination reveals that this Method is deeply rooted in the need to preserve the chain elements of the environment that allow human survival. This Method embodies three parts: preservation of natural conditions, urban design and site planning, and design for human comfort. These parts, in turn, yield specific design strategies that will improve the social sustainability of architecture. Fig.1-6

1.5.3.1 Preservation of Natural Conditions

- **Topographical Contours**

The existing contours of a site should be respected. Radical terra forming is not only expensive but devastating to the site's microclimate. Alteration of contours will affect how water drains and how wind moves through a site.

- **Water Table**

Selecting the sites and building designs that do not require excavation below the local water table by Placing a large obstruction (the building) into the water table will disturb natural hydraulic process. If the water table is exposed during construction, it will also become more susceptible to contamination from polluted surface runoff.[1]

- **Existing Flora and Fauna**

Local wildlife and vegetation should be recognized as part of the building site. When they are treated as resources to be conserved rather than as obstacle to be overcomed, native plants and animals will make the finished building a more enjoyable space for human habitation.[2]

- **Urban Design and Site Planning**

The methods associated with the Urban Design and Site Planning strategy apply sustainability at a scale larger than the individual building.

- **Integrating Design with Public Transportation**

Sustainable architecture on an urban scale must be designed to promote public transportation. Thousands of individual vehicles moving in and out of

[1] John Lyle,"Design for Human Ecosystems: Landscape, Land Use, and Natural Resources", Island Press .1999P4.

[2] Ibid

an area with the daily commute create smog, congest traffic, and require parking spaces.

- **Mixed Use**

Sustainable development encourages the mixing of residential, commercial, office and retail space. People then have the option of living near where they work and shop. This provides a greater sense of community than conventional suburbs. The potential for 24-hour activity also makes an area safer.

1.5.3.2 Design for Human Comfort

- **Thermal, Visual, and Acoustic Comfort**

People do not perform well in spaces that are too hot or too cold. Proper lighting, appropriate to each task, is essential. Background noise from equipment or people can be distracting and damage occupants' hearing. Acoustic and visual privacy also need to be considered.[1]

- **Visual Connection to Exterior**

The light in the sky changes throughout the day, as the sun and clouds move across the sky. All humans have an internal clock that is synchronized to the cycle of day and night. From a psychological and physiological standpoint, windows, and skylights are essential means of keeping the body clock working properly.[2]

- **Provide Operable Windows**

Operable windows are necessary so that building occupants can have some degree of control over the temperature and ventilation in their workspace.

Provide Fresh clean air through clean air ducts, which are vital to the well-being of building occupants. The benefits of fresh air go beyond the need for oxygen. Continuous recirculation of interior air exposes people to concentrated levels of bacteria and chemicals within the building.[3]

- **Nontoxic, Non-Out gassing Materials**

Long-term exposure to chemicals commonly used in building materials and cleaners can have a detrimental effect on health.[4]

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[1] Detailed guidelines for the design and construction of environmentally sustainable buildings, URL: http://www.admin.cam.ac.uk/offices/environment/guidance/buildings_guidance.pdf (accessed January 2007)

[2] Detailed guidelines for the design and construction of environmentally sustainable buildings, URL: http://www.admin.cam.ac.uk/offices/environment/guidance/buildings_guidance.pdf (accessed January 2007).

[3] St,Benjamin , "Mechanical and Electrical Equipment for Buildings." Wiley Press 2005.p 75

[4] Jong-Jin Kim "Introduction to Sustainable Design," Published by National Pollution Prevention Center for Higher Education, December 1998.p17

- Accommodating Persons with Different Physical Abilities

One aspect of sustainable design is its longevity. Buildings that are durable and adaptable are more sustainable than those that are not. This adaptability includes welcoming people of different ages and physical conditions. The more people that can use a building, the longer the building is useful life.[1]

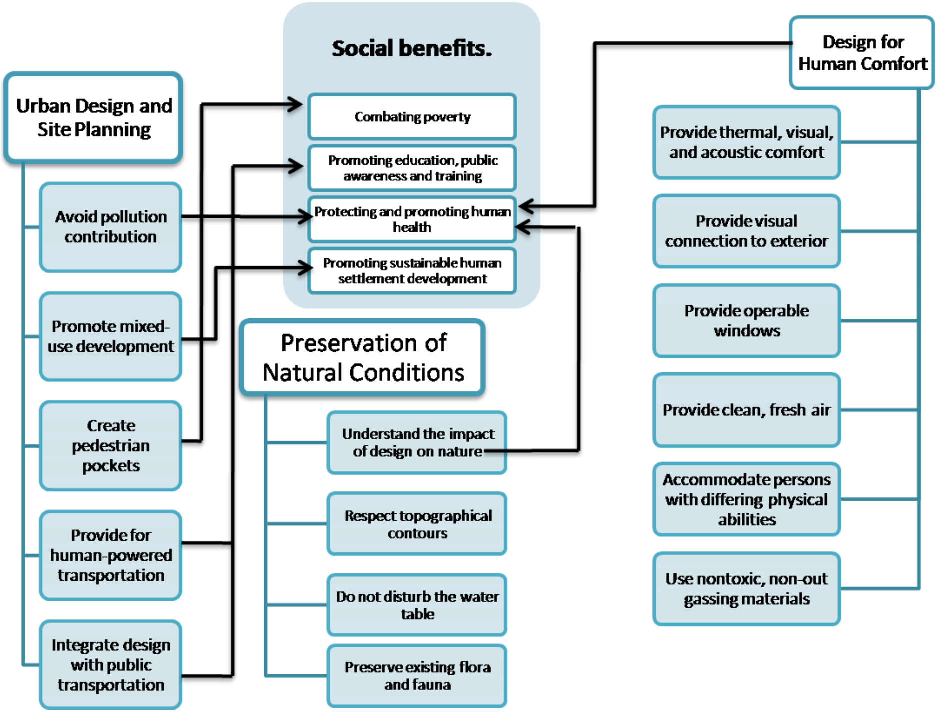

Figure 1-6 The human design strategies.

1.6 Guides for Sustainable Design

These are green building programs to promote the construction and operation of buildings in ways that would reduce their negative impacts on the environment. Guides for sustainable design educate and assist architects, building owners, occupants, educators, students, and the general public concerning sustainable building design.Fig.1-7. The guides are applied to both new and renovated facilities in different building types like medical, institutional and office buildings. It can be used to set sustainable design priorities and goals, develop appropriate sustainable design strategies; and to determine performance measures to guide the sustainable design and decision-making processes. The guide also contains a scoring system that

[1] Vale, Brenda, and Robert Vale. “Sustainable Living: the Role of Whole Life Costs and Values”. by Elsevier Limited 2007.p32

enables the design team and building operators to evaluate building performance. Each guide has performance indicators, which set the benchmarks that must be met in order to obtain credit for sustainability.

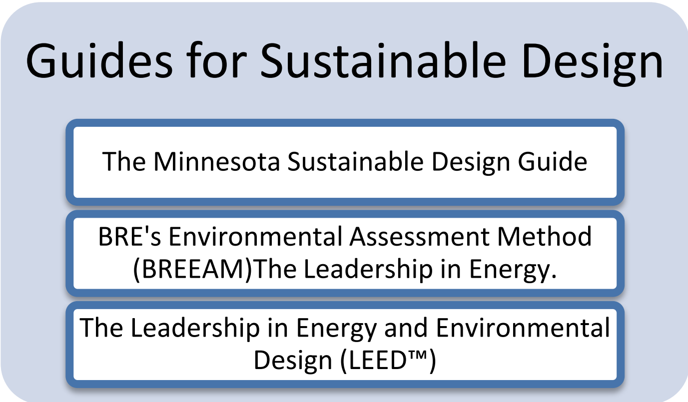

Figure 1-7 Guides for sustainable design.

- The Minnesota Sustainable Design Guide[1] is developed to offer a design tool that can be used to overlay environmental issues in the different building stages building cycles, pre-design, design, construction, and operation phases. Strategies that are organized accordingly to six environmental design topics - site, water, energy, indoor environmental quality, materials, and waste. Each topic contains a series of design strategies that address the related sustainable design issues.

- Building Research Establishment's Environmental Assessment Method (BREEAM) which was established to assess indoor environmental performance covers a wide range of buildings, from superstores and supermarkets both new and existing offices. BREEAM's success stems from its unique ability to cover a wide range of environmental issues within one assessment. It allows building owners and occupants to find out about impacts on a variety of environmental factors, including ozone depletion, global warming, and the destruction of rainforests and other resources[2], and a number of other building issues, like air pollution, lighting and hazardous

[1] Minnesota Sustainable Design Guide. URL http://www.sustainabledesignguide.umn.edu/ (accessed January 2005)

[2] Townsend, A.K. “The Smart Office: Turning Your Company on its Head. “ Gila Pr., 1999. BREEAM. URL:http:/products.bre.co.uk/bream, www.battlemccarthy.demon.co.uk/ (accessed January 2005)

materials It is regarded by the UK's construction and property sectors as a measure of best practice in environmental design and management. It presents results in an easy way to those involved in property procurement and management. It is independent and authoritative, based on many years of construction and environmental research carried out at BRE together with input and experience of the construction and property industries, government and building regulators.

To mention a few of BREEAM guiding principles for achieving sustainable buildings are:

- demolish and rebuild only when it is not economical or practicable to reuse, adapt or extend an existing structure;
- reduce the need for transport during demolition, refurbishment and construction and tightly control all processes to reduce noise, dust, vibration, pollution and waste;
- wherever feasible, use the construction techniques which are indigenous to the area, learning from local traditions in materials and design;
- Build to the appropriate quality and to last. Longevity depends much on form, finishes and the method of assembly employed as on the material used.

- The Leadership in Energy and Environmental Design (LEED™) rating system is also one of the most significant developments in the transition towards more sustainable design[1] . It evaluates "greenness" in five categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Innovation Credits and Design/Build Process and Indoor Environmental Quality. For Existing Buildings LEED™ ratings are based on actual operating performance measures of buildings rather than prescriptive regulations. Where this new LEED™ rating system differs is in its provisions for green standards as they relate to operating, maintaining or converting existing buildings into high performance, sustainable facilities in order to achieve certain levels of efficiency (performance measures), established by e.g. ASHRAE[2] or others.

[1] McLennan, J.F. & Rumsey, P. The Green Edge: "Is LEED the Holy Grail of Sustainable Design", Environmental Design and Construction. July-Aug., 2002. URL:http://www.edcmag.com/CDA (accessed January 2005.)

[2] American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Such programs often have been part of comprehensive policies and programs to promote sustainability.[1] Because of the current rapid pace of construction and development, the sooner these obstacles are removed, the greater will be the economical, social, and environmental benefits that can be achieved through green buildings. By leveraging new resources and developing innovative partnerships to provide training, and technical resources. The innovative building and sitting techniques that can realize these goals-typically referred to as "green building"-are gaining currency in the design and construction industry. The spread of these practices is hindered, however, by: lack of information, regulatory disincentives, and financial barriers.

Determining the "greenness" of a building is to evaluate it based on an appropriate green rating system. The categories cover broad areas, such as increased water efficiency or improved indoor environmental quality, in which environmental goals can be specified. To rate a building, it receives one or more points for meeting individual requirements specified in the rating system. The total of all points constitutes the building's rating and, based on the rating, the building can be classified into one of four certification levels (such as the Gold Level), which are defined based on a range of points (or the building can fail to meet the requirements of the minimum certification level). , LEED™ provides credits for building on brown field sites to reconsider the original sitting decision and determine what brown field site options were available and what the costs and impacts of choosing one would have been.[2]

Table 1-2 LEED™ Rating System Point Categories & Possible Points.
(source: LEED™ system, Version 2: Ballot Version, published by the USGBC. in January 2000)

Category	Possible Points
Sustainable Sites.	
Erosion end Sedimentation Control	**0**
Site Selection--not developed on environmentally inappropriate site	**1**
Urban Redevelopment--sited in high density area	**1**
Brownfield Development--developed on Brownfield site	**1**
Alternative Transportation	**4**
Reduced Site Disturbance	**2**

[1] Allen Lee, "green city buildings: applying the LEED^{tm} rating system" XENERGY Inc. Portland, Oregon June 2000 p1-1.
[2] "LEED^{TM} system", Version 2: Ballot Version, published by the USGBC. in January 2000 p2-2.

Category	Possible Points
Storm water Management	2
Landscape and Exterior Design to Reduce Heat Islands	2
Light Pollution Reduction--meet IESNA exterior lighting requirements AND eliminate direct-beam illumination from building	1
Water Efficiency.	
1 Water Efficient Landscaping	2
2 Innovative Wastewater Technologies--reduce potable water for sewage by >50% OR treat all wastewater to tertiary standards	1
3 Water Use Reduction	2
Energy and Atmosphere.	
Fundamental Building Systems Commissioning—implement standard commissioning Minimum Energy Performance--meet ASHRAE 90.1-1999 or local code if more stringent CFC Reduction in HVAC&R Equipment--use no CFC refrigerants in major systems and water coolers, spot coolers, etc.	
1 Optimize Energy Performance (new buildings.)	10
2 Renewable Energy	3
3 Best Practice Commissioning—include 3rd party review of commissioning documents	1
4 Elimination of HCFCs and Halons--eliminate in HVAC&R and fire suppression systems	1
5 Measurement and Verification—install monitoring equipment for lighting, motor loads, VFDs, chillers, cooling load, economizers, air distribution system, boilers, etc.	1
6 Green Power-- 2 yr. contract for at least 30% green power	1
Materials and Resources.	
Storage & Collection of Recyclables--ground-floor recycling center	0
1 Building Reuse	3
2 Construction Waste Management	2
3 Resource Reuse	2
4 Recycled Content	2
5 Local/Regional Material	2
6 Rapidly Renewable Materials (5%)	1
7 Certified Wood (min. of 50% of wood-based materials)	1
Indoor Environmental Quality (IEQ).	
Minimum IAQ Performance—meet ASHRAE 62-1989 Standard Environmental Tobacco Smoke (ETS) Control—prohibit smoking or provide ASTM approved smoking facility	
1 Carbon Dioxide (CO_2) Monitoring--provide system and specify parameters to maintain CO_2 at <530 ppm higher than outdoors	1
2 Increase Ventilation Effectiveness--involve >90% of room/zone in air flow	1

Category	Possible Points
3 Construction IAQ Management Plan	**2**
4 Low-Emitting Materials	**4**
5 Indoor Chemical and Pollutant Source Control—permanent entryway systems to capture dirt etc. and separate outside venting/negative pressures for chemical use areas and drains for disposal of liquid waste where water/chemical mixing occurs	**1**
6 Controllability of Systems	**2**
7 Thermal Comfort	**2**
8 Daylight and Views 2	**2**
Innovation Credits and Design/Build Process.	
1 Innovation Credits	**4**
2 Accredited Professional	**1**
Notes: The points possible for each option are shown in the rightmost column. Major option categories are shown between solid lines. Prerequisites are shaded and are awarded no points. Options are numbered within each major category.	

To rate a building, it is necessary to determine which of several specific requirements it meets within each of the six major categories. In many cases, this is a simple exercise to determine whether the building has a certain type of equipment or whether certain practices were implemented during sitting and construction. In other cases, a more complicated process is required. For example, for the energy efficiency options included under the Energy and Atmosphere category, it is necessary to analyze the energy consumption of the building as-built and compare the estimated usage with what it would have been had the building been built to just meet ASHRAE Standard 90.1-1999. If the consumption is estimated to be less than it would have been under the Standard, then the percent improvement is used to determine the number of points the building would receive for this subcategory. [1] In the case of several options under the Materials and Resources category, it is necessary to determine the cost of components that might qualify for a specific option, such as recycled content, and compare their cost to the overall building materials cost. The percent of total cost that these materials constitute determines how many points the building would earn for this option.

The Innovation and Designed Build Process category allows the building to receive credit for innovative performance in categories not specified in the

[1] Allen Lee, "green city buildings: applying the LEED[tm] rating system" XENERGY Inc. Portland, Oregon June 2000 p2-3.

system or receive credit for having a project team member who has completed the LEED™ Accredited Professional exam successfully. The points that the building receives in each category are then added up to determine the total that would be awarded to the building. The rating system has a total of 64 core points; core points exclude the points possible in the Innovation and Design/Build Process category. The total received by the building gives the building's point score rating and the building can be classified into one of five certification levels depending on the number of points it receives— uncertified (less than 32 points), Certified (32-3 8 points), Silver (39-45 points), Gold (46-51 points), or Platinum (52 points or more).

It is important to note that LEED™ was designed to cover a very wide range of nonresidential building situations and provide opportunities for buildings to be certified without having to override major sitting and construction constraints. For example, although building on a brown field site would earn a point in one category, a building that was not built on a green field site could still earn a point in another category if sustainable practices were followed. For several of the options, the number of points earned varies by the extent to which a certain characteristic is improved. Examples include the percent that energy efficiency is increased, the percent of an existing building that is reused, and the percent of energy supplied by renewable resources.

1.7 Applied Example on Green Building.

(The Trump International Hotel and Tower, UAE,2007).

1.7.1 Project Information:

Location: Center part of The Trunk of The Palm Jumierah, UAE.

Project Type: International Hotel and Tower.

Designed by: Atkins global company.

Size: more than 255m tall and 60 stories building.

Year Constructed: under construction.

LEED™ rating: Silver (expected)

The project features a 300-room five-star hotel, 400 residential apartments, offices, retail, and leisure facilities such as a gym, spa, private beaches, and a number of restaurants. The Trump International Hotel and Tower is designed in asymmetrical halves with stainless steel, glass, and stone facades. The open core in the middle of both linked buildings is an innovative feature to minimize the shadows. The building gives the sense of infinity at the top of each tower where the glazed elements blur building. Fig1-18.

Figure 1-8 The Trump International Hotel and Tower
(Source: Atkins company URL: www. Atkinsdesign.com accessed July 2007)

1.7.2 Green design features:

The designer has released an international awareness program on sustainability in construction which emerging plans for integrating green features into the built environment, not only just through design but also all aspects of business.

"Aside from the ecological benefits and positive publicity that a sustainable design approach brings, many of industry's leaders find that sustainability has become an invaluable vehicle for exploring ways to re-invent themselves and reduce costs, manage risks better and drive fundamental internal changes in culture, structure and quality of life,"[1].

According to the design report of The Trump International Hotel and Tower (building physics and sustainability), the building will reduce its impact on the environment through significant design and engineering services. Thus, reducing the consumption level of energy, water, natural resources and the loads on the building are main issues that will be mitigated through applying innovative systems in different aspects of engineering services in the building design. The following strategies present those attempts for

1 B.Abu-Hijleh :URL http://www.Atkins-me.com (accessed July 2007)

sustainable building design which are aimed to reduce the impact on the environment.

1.7.2.1 Economy of Resources.

A. Energy conservation:

- Passive Heating and Cooling

A reduction in air conditioning loads of the building means a reduction in energy consumption as a whole. Thus, shading glass of the facades is a way for reduction the solar gain through the windows and therefore reducing the air condition loads for the building.

Studies had been carried out for optimizing the use of shading through studying sun falls on the building in different times of the year.Fig1-9

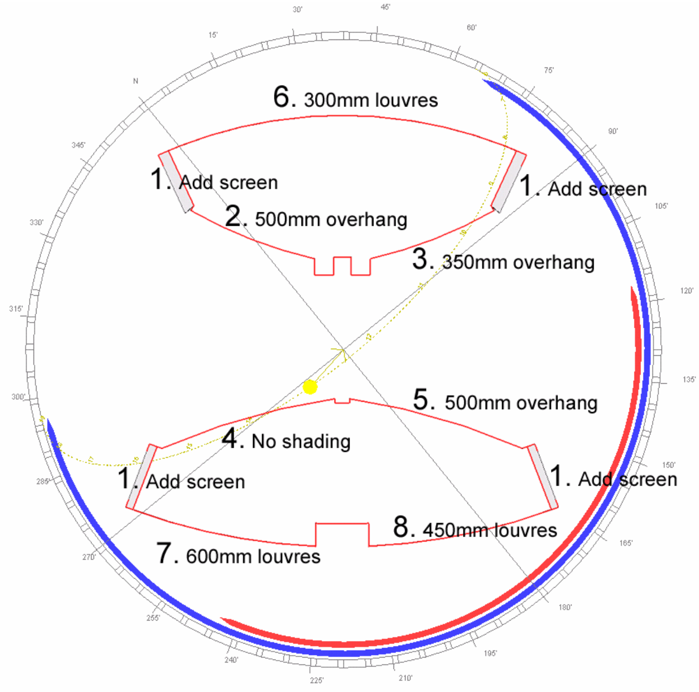

Figure 1-9 Shading design for the towers
(Source: Abu-Safat,O" Sustainability In A Rapid Urban Development" M.Sc. Thesis submitted to KTH, Department of Urban Planning, and Environment, Division of Urban and Regional Studies, Stockholm 2007p.38)

Fig 1-10 shows a sample of the study which presents the optimum use of shading by using louvers with different dimensions during the sun of June 21st.

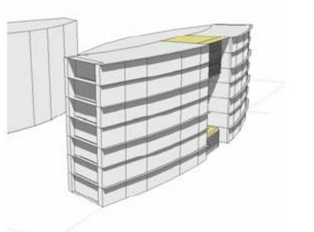	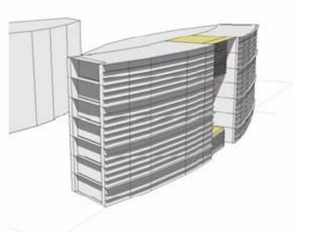	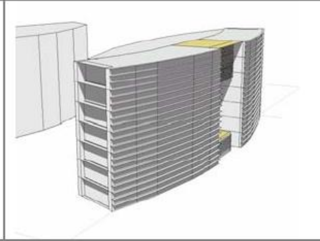
One louvre per floor: 700mm primary floor 400mm secondary floor 15:00h June 21st – little shading	**Intermediate louvres at 1,200mm centres** 700mm primary floor 400mm secondary floor 400mm intermediate 15:00h June 21st – 60% shading	**Intermediate louvres at 1,200mm centres** 600mm for all 15:00h June 21st – 100% shading

Figure 1-10 shading of the south facade of the south tower
(Source: Abu-Safat,O" Sustainability In A Rapid Urban Development" M.Sc. Thesis submitted to KTH, Department of Urban Planning, and Environment, Division of Urban and Regional Studies, Stockholm 2007p.38)

- **Alternate Sources of Energy**

Infiltration is an outside air flowing into the building through the facades. Limiting infiltration especially in the top third of the building where it is generally worst is vital to reduce air conditioning loads and thus, reduce the energy consumption.

- **Insulation**

Insulation of external walls, floors and roofs has also great impact on the reduction of heat gaining and consequently, on the level of energy consumption. In addition, window frames have also significant role of minimizing heat gaining. Thus, designers of the Trump International Hotel and tower realized the importance of insulating window frames and therefore, will limit the thermal transmission through window frames.

- **Daylighting**

Window glass selection according to its properties has a significant effect on the cooling loads of the building and, thereby, on the level of energy consumption. Table1-3 shows the effect of using different glass properties on the cooling loads of the same tested room in the last model. Values of U-value and shading coefficient should be low to ensure minimum cooling loads on the building.

Table 1-3 Glass properties and the impact on the cooling loads
(Source: Abu-Safat,O" Sustainability In A Rapid Urban Development" M.Sc. Thesis submitted to KTH, Department of Urban Planning, and Environment, Division of Urban and Regional Studies, Stockholm 2007p.39)

	U-value	Shading Coefficient	Visual Light Transmission	Peak Total Load	Improvement on minimum
Minimum requirement	2.1W/m²K	0.35	Not specified	4,475W	-
CoolRAY Carat	1.4W/m²K	0.32	52%	4,040W	10%
CoolRAY Galaxy	1.4W/m²K	0.25	40%	3,671W	18%
CoolPANE PB20	1.4W/m²K	0.20	17%	3,436W	23%

- **Energy-Efficient Equipment & Appliances**

Such as refrigerators – are always major consumer of power in apartment- , washing machines and dishwashers should be in the top 10% of their class for energy efficiency. Consequently, this will ensure a reduction in the energy consumption.

B. Water Conservation

Different solar hot water systems have been tested and analyzed in respect of energy and cost efficiency. Thus, solar hot water systems are recommended due to its long term benefits. Table 1-4 shows a comparison between generating hot water from solar hot water with Liquefied Petroleum Gas (LPG) and Electric heaters. The comparison shows that using solar hot water systems are more efficient after 6 years of utilizing.

Table 1-4 A comparison between solar hot water + LPG and Electric heaters
(Source: Abu-Safat,O" Sustainability In A Rapid Urban Development" M.Sc. Thesis submitted to KTH, Department of Urban Planning, and Environment, Division of Urban and Regional Studies, Stockholm 2007p.42)

Solar hot water + LPG	**Cost (AED)**
Boiler cost (1-No)	850,000
Maintenance cost @ 2% p.a.	17,000
5-No 6500 units + 480-No panels @ AED330,000 ea	1,650,000
Piping cost	250,000
Total cost	**2,767,000**
Annual operating costs	**322,560**
Electric heaters	**Cost (AED)**
1,305-No electric heaters @ AED450 ea	587,250
Maintenance cost @ 2% p.a.	11,745
2,500kVA transformer	150,000
Cabling costs	50,000
Total cost	**798,995**
Annual operating cost	**657,720**
Simple payback for Solar Hot Water system	**6 years**

1.7.2.2 Life Cycle Design.

A. Pre-Building Phase

- Using Recycled Materials

According to the sustainable assessment program used the production of construction materials is an energy intensive which has a major environmental impact. By replacing those materials - for instance – Portland cement which are energy intensive with ones that are industrial waste products such as fly ash, this will reduce the carbon dioxide emissions and the energy intensity. Meanwhile, different steel mills use different proportions of recycled steel in their feedstock and the selection of steel by the contractor should consider the recycled content as a matter of contract.

For non-structural concrete, up to 20% of recycled aggregate can be used.

- Using Materials Made From Renewable Resources

All timber and wood, including that used in construction, will be from a certified sustainable source, such as Forestry Stewardship Council (FSC) accredited forests, or be post-consumer re-used timber, or similar.

B. Building Phase

- Employing Nontoxic Materials

Several materials release harmful chemicals into the air. This release is called off-gassing and is a leading cause of sick building syndrome.

Zero- Volatile Organic Compounds (VOCs) paints are readily available on the world market and are the same quality as other paints. Cost implications in Dubai are unknown at this stage. Insolents used in construction will not use ozone depleting substances in their production. Similarly, refrigerants, where used, will have ozone depleting potential of zero and a global warming potential of less than 10.

C. Post-Building Phase

To ensure an effective performance of the environmental initiatives during the operation of the building, an environmental management plan has been drawn in the Trump International Hotel and Tower. This plan contains a formalized monitoring and reporting system that compares performance of a building against industry standards in different area such as energy efficiency and energy management, waste minimization, reuse and recycling and so forth. The plan also sets objectives, targets, and actions to improve performance of the building over time, and reports progress regularly.

1.7.2.3 Human Design.

A. Preservation of Natural Conditions

- Integrating Design with Public Transportation

The public transportation uses thousands of individual vehicles moving in and out of area with the daily commute create smog, congest traffic, and with a huge parking spaces.

- Mixed Use

There is mixing of residential, commercial, office and retail space. The project features a 300-room five-star hotel, 400 residential apartments, offices, retail, and leisure facilities such as a gym, spa, private beaches, and a number of restaurants. This provides a greater sense of community than conventional suburbs. The potential for 24-hour activity also makes an area safer.

B. Design for Human Comfort

Study has been taken place to investigate the effect of shading devices on the cooling loads of the building. The following sample represents this effect of shading on a chosen room facing the south side of the building. Fig 1-11

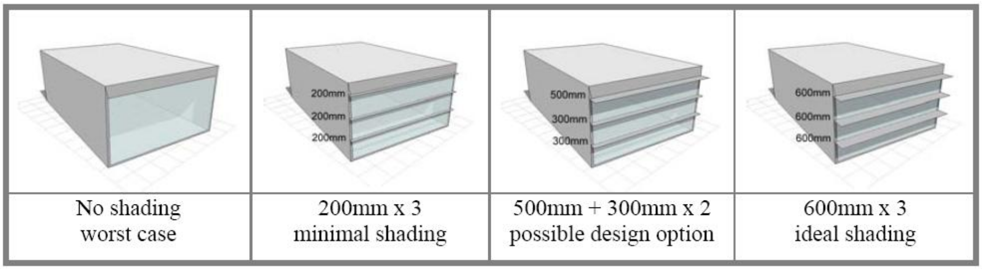

Figure 1-11 The effect of shading devices on a tested room.
(Source: Abu-Safat,O" Sustainability In A Rapid Urban Development" M.Sc. Thesis submitted to KTH, Department of Urban Planning, and Environment, Division of Urban and Regional Studies, Stockholm 2007p.39)

This room has been tested under two different peak conditions on August 15th (peak wet condition with 27°C and peak dry 46°C) where the solar loads are at the peak values. This occurs at 17:00h and 15:00h (the sun is higher and then shading is more effective). Table1-5 shows the improvement on shading loads which minimize the cooling loads - and thereby the cooling energy- , the running costs and the carbon dioxide emissions of the building.

Table 1-5 The resulting shading loads to the room.
(Source: Abu-Safat,O" Sustainability In A Rapid Urban Development" M.Sc. Thesis submitted to KTH, Department of Urban Planning, and Environment, Division of Urban and Regional Studies, Stockholm 2007p.39)

	17:00h Solar Load	% improvement from no shading	15:00h solar Load	% improvement from no shading
No shading	1,729W	-	1,451W	-
200/200/200	1,535W	15%	1,025W	29%
500/300/300	1,311W	27%	755W	48%
600/600/600	1,101W	42%	641W	56%

- **Ventilation**

Ventilation in the car park is to be controlled by pollutant levels so that the jet fans only operate when carbon monoxide levels reach a certain point.

Displacement ventilation is an efficient way to reduce the cooling loads of the building spaces. The advantage of these systems is only the occupied space, for instance, the first 2m above the floor is conditioned rather than conditioning the whole volume which requires more energy. These systems are recommended to be used in high spaces such as the entrance lobby and the restaurant at the top of the trump International hotel and Tower.

1.8 Conclusion

The green architecture principles are guiding lines to understand the needs of a green building, where the benefits of green architecture are measurable in terms of environmental, economic, and social impacts. The economic benefits come from reduced operating costs and improved occupant performance[1]. The social benefits come from the improved health and comfort of the occupants. The environmental benefits derive from the reduced impact of the building's construction and operations on air, water, landfills, and non-renewable energy resources.

Green architecture as a concept of architectural design needs a catalyst to achieve the integrations of the green benefits; sustainable design can be stated as this catalyst.

- Sustainable design is "front loaded" compared with traditional design. Early decisions have the greatest impact on energy efficiency, passive solar design, day lighting, and natural cooling.
- Sustainable design is more of a philosophy of building than a prescriptive building style. Sustainable buildings don't have any particular look or style.
- Sustainable buildings don't have to cost more, nor are they more complicated than traditional construction.
- Integrated design, that is design where each component is considered part of a greater whole, is critical to successful sustainable design.
- Minimizing energy consumption and promoting human health should be the organizing principles of sustainable design. The other elements of design can be organized: energy saving architectural features, energy conserving building envelope, and energy-efficient and health-promoting mechanical, electrical, and plumbing systems.

Buildings are designed and constructed to meet certain green building standards, certification under a rating system will ensure this. There are several classes of benefits can be obtained with design guides and certification systems such as LEED™ and BREEAM, ranging from environmental to financial.

By analyzing the example for green architecture it highlights the importance of the digital technology on the improvement of the green architecture, either by the digital controlling systems for the building, or by using the digital tools in the design stage this by analyzing the model for optimum solution. This technology is no more negligible, it is essential for improving green architectural results.

1 Lewis, M. Special LEED™ Section: "Explaining the need for LEED™. In Environmental Design and Construction", July-Aug., 2002. URL http://www.edcmag.com/CDA (accessed august 2005)

Chapter 2

Digital Technology and Green Design Practice.

2-1 Introduction.
2-2 Digital Technology.
2-3 The Green Design Practice.
2-4 Conclusion.

2.1. Introduction.

Since the 1970s, computer and telecommunication technology have been changing human life. These changes have outpaced the theories guiding such technologies. In the1990s, social and personal life has been affected by computers and telecommunication by making distance irrelevant. Physical spaces and their definitions, as human aspects, have also been affected; meeting rooms, for example, have become virtual, as their physical elements have been computerized. This is simply the integration between the digital computer's abilities and the physical world.

Digital Architecture is a particularly dynamic field that is developing through the work of architecture schools, architects, software developers, researchers, technology, users, and society alike. This chapter will deal with the digital techniques and tools in which were developed in many fields entering the area of green architectural design. Information and digital technologies provide the information for the rapid change in strategies. It is becoming difficult to think of the green architectural design without reference to digital architecture. As green architecture principles are no longer a prominent outsider, but have become embodied inside the digital technology. Where buildings are technology, they accommodate and use technology.

2.2. Digital Technology.

"Having abandoned the discourse of style, the architecture of modern times is characterized by its capacity to take advantage of the specific achievements of that same modernity: the innovations offered it by present-day science and technology. The relationship between new technology and new architecture even comprises a fundamental datum of what are referred to as avant-garde architectures, so fundamental as to constitute a dominant although diffuse motif in the figuration of new architectures."[1]

The major building tasks of society are realized by means of high technology. In its 21st-century incarnation, the vision of inhabitable environments infused with many computational devices has taken the form of computer-controlled temperature, humidity, lighting, security systems,

[1] Branko Kolarevic. "Architecture in the digital age: design and manufacturing," Taylor & Francis, (August 4, 2005) p3.

elevators, doors, even electronic building "skins," creating seamlessly networked and ever-changing electronic landscapes.[1]

As for the design practice technical competence in digital technology has become a condition towards landing a respectable architectural practice. By itself, though, the overwhelming majority of the architectural practice has been forced into the digital domain by the ubiquity of technology itself, the digital file has replaced the drawing as the information backbone in building profession. A few practices are looking beyond the drafting and visualization solutions offered by digital technology and finding themselves reshaped in the course of this interaction. Digital technology has a revolutionary potential in architectural practice. The flow of energy will be unleashed when the legal framework of the industry stretches to accommodate the digital model as a legal appendix to or replacement of the traditional documents. “The Integration of computer-aided design with computer-aided fabrication and construction”; fundamentally redefines the relationship between designing and producing. It eliminates many geometric constraints imposed by traditional drawing and production processes—making complex curved shapes much easier to handle, for example, and reducing dependence on standard, mass-produced components. “It bridges the gap between designing and producing that opened up when designers began to make drawings.”[2]

Any categorizations of digital architecture must connect to the technological skill base. Just as there is a difference between building and architecture, there is also a distinct difference between digitally controlled projects “Intelligent buildings” and digitally generated architecture “using digital tools.”

2.2.1. Intelligent Buildings

Over the years many people have tried to define “the intelligent building” but with little obvious success. This is partly because defining the two constituent parts of the term itself is difficult if not an impossible task – what precisely is meant by a “building”, and what is “intelligence”. But this difficulty is compounded by the fact that there are many diverse advocates

[1] Yehuda E. Kalay, “Architecture’s New Media: Principles, Theories, and Methods of Computer-Aided Design,” The MIT Press. 2004.p79.

[2] Branko Kolarevic.” Architecture in the digital age: design and manufacturing.” Taylor & Francis (August 4, 2005), p57.

for intelligent buildings, who have quite different viewpoints, values, and aims and who therefore perceive intelligent buildings in quite different ways. Illustrating this point, a recent publication listed some thirty-four alternative definitions of “the intelligent building.” [1] A more fruitful effort than definition is to identify the key driving forces leading to the development of the concept of intelligent buildings and to understand what the advocates of intelligent buildings are trying to achieve by turning this concept into reality. Intelligent buildings provide a more profitable line of development. The term "Intelligent Buildings" is viewed by many critics as a sequel to the earlier well-propagated "High Performance Buildings.”

Fundamentally, intelligent buildings are buildings for the digital age. Intelligent Buildings based on computer technology have been around in one form or another for over 20 years. Perhaps the most significant developments were the introduction to building control systems of embedded processors, dedicated networks, and intelligent agent approaches.

2.2.1.1. Intelligent Buildings Generations.

The concept of intelligent buildings has passed by five generations as follow:

- The first-generation of Intelligent Buildings consist of numerous independent self-regulating (automatic) sub-systems. These sub-systems might be relatively sophisticated (e.g. HVAC or security systems), but they are essentially disconnected, and operate independently of each other. The first manifestation relates to improving the management and control of building services. Fig 2-1 .This is the concept of the computer-controlled or automated building. With the rapid development of digital computing, this concept developed naturally from previous building management and control strategies which used technologies such as electro-mechanical and analogue devices. By the mid 1980s[2], the concept of the automated building was well established and it still represents one of the dominant paradigms for the intelligent building.

[1] Wigginton, Michael, and Harris, Jude, "Intelligent Skins.” Architectural Press, London (2002) p17-25.
[2] A. Bezelga ,”Management, Quality and Economics in Building” , Taylor & Francis, 1990 p591

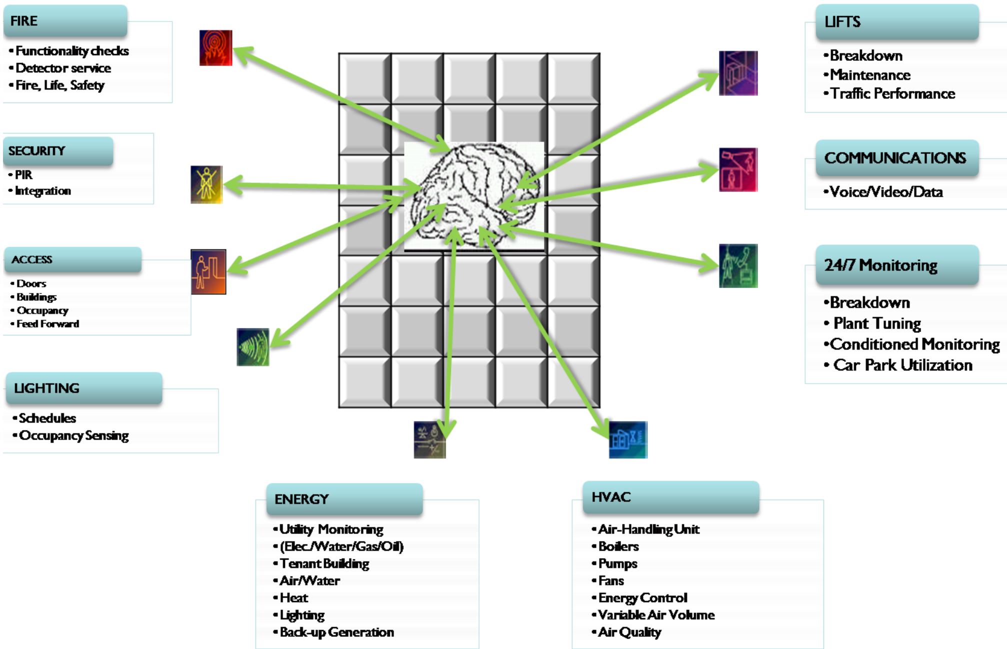

Figure 2-1 The intelligent building concept.

- The second-generation of Intelligent Buildings was formed when building control systems, such as those described in the previous paragraph, are connected together via a network. By interconnecting them in this way, it becomes possible either to control them remotely (from a building services manager's office), or to facilitate some central scheduling or sequencing (such as securing areas, or turning systems on or off at specific times). Several specialized networks, designed for this purpose, are commercially available and fairly widely used. By the mid-1980s, the first intelligent buildings combining the two concepts of the automated building and the digital informed building were being designed and constructed in Europe and Asia. Leading examples include the Lloyds Building in London (1994), the HSBC Building in Hong Kong (1995) and the Rank Xerox International Headquarters (1986). The latter, while not especially well known, was the first commercial building to fully integrate local area networks, wide area networks, and systems to support remote and home working. Concurrently, equivalent buildings were being constructed in Japan such as the Toshiba Headquarters (1984), NTT Twins (1986), and the Umeda Centre (1987)

(Hartkopf et al, 1993).[1] By the end of the 1980s, much of the seminal work on automated and digital informed intelligent buildings was completed. The manner in which those two aspects of the intelligent building relate, and the way in which they would gradually develop into the future, in the influential intelligent buildings pyramid is explained in the following diagram. Fig2-2.

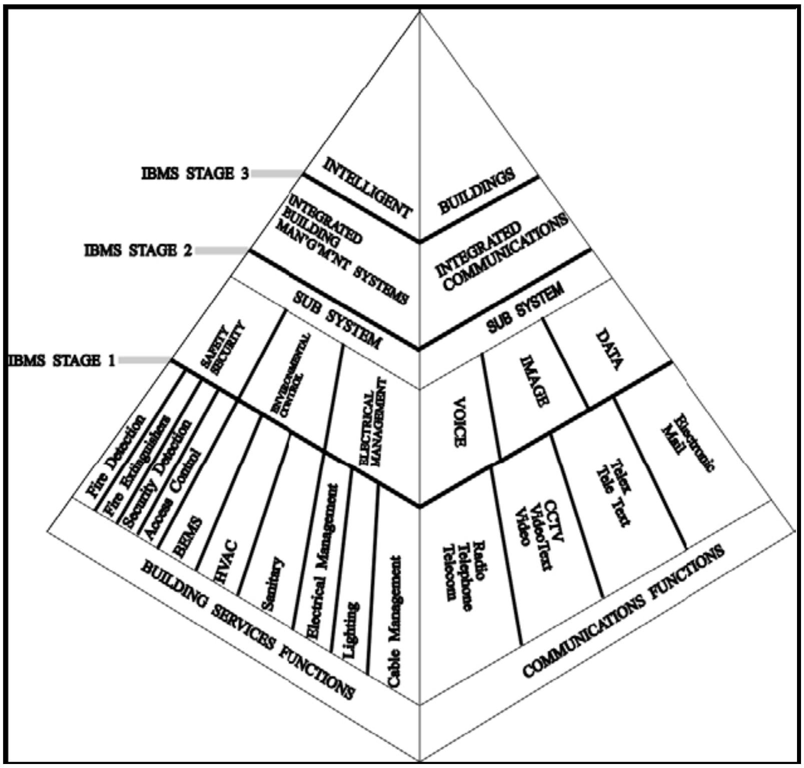

Figure 2-2 The Original Intelligent Buildings Pyramid.
(Source: Alan R Kell, "The Global Development of Intelligent & Green Buildings" i&i limited, London.2005,p 3 URL: www.ibexcellence.org/images/pdfs/akbeijing05paper (accessed November 2005).)

- The third-generation Intelligent Buildings have, in addition to the processors and networks of the first two generations, the capability of learning about the building and its occupants, and hence adapting their control behavior accordingly. This functionality arises from the application of intelligent agent techniques (already widely used in other areas, such as robotics)

Although first- and second- generation Intelligent Building technologies have greatly increased the ease of the operation of building control, they still have not given the building any functions that are akin to human

[1] Alan R Kell, "The Global Development of Intelligent & Green Buildings" i&i limited, London.2005,p 3 URL: www.ibexcellence.org/images/pdfs/akbeijing05paper (accessed November 2005)

intelligence, such as reasoning, learning, or adaptation, that are present in the third generation systems. Only recently, researchers begun facing up to the challenge of giving buildings these third generation capabilities.

- The fourth generation of the intelligent building, which relates to space management but is different, and focuses upon the building structure and form itself. This concept is based upon the proposition that the building itself can manifest "passive" intelligence which is built in through perceptive and high quality design. Such passive intelligence can be used to influence environmental building performance through the building envelope, facades, fenestration, layout, and thermal mass. These features may also be used to influence the internal building environment, and the internal circulation and communications characteristics of the building. Proponents of such passive intelligent buildings, which include structural engineers and architects, argue that investment in the design of the building form and structure can and should replace unnecessary investment in the active intelligent systems that are provided in the automated building. Such arguments have a close affinity with those of the proponents of green buildings. [1]

- The fifth and final generation of the intelligent building, which must not be ignored, focuses upon the organization using the building rather than upon the building itself. No organization's performance will be enhanced by its building unless it has the capability and the intelligence to manage and use the building effectively. History abounds with examples of well-designed buildings which have been misused and mismanaged, were condemned as failing buildings. An intelligent organization is essential to get the most from an intelligent building. This means an organization which understands the importance of managing its buildings strategically, integrating its buildings strategy closely to its business and organizational strategies, while at the same time having the knowledge and the skills available to manage its building services, information services, space management and building structures in a professional and integrated manner. With the emergence of professional facilities management, such organizations are fortunately becoming increasingly common.

[1] Alan R Kell, "The Global Development of Intelligent & Green Buildings" i&i limited, London.2005,p 3 URL: www.ibexcellence.org/images/pdfs/akbeijing05paper (accessed November 2005)

These five concepts of the intelligent building must be seen as complementary and not competitive. Fig 2-3

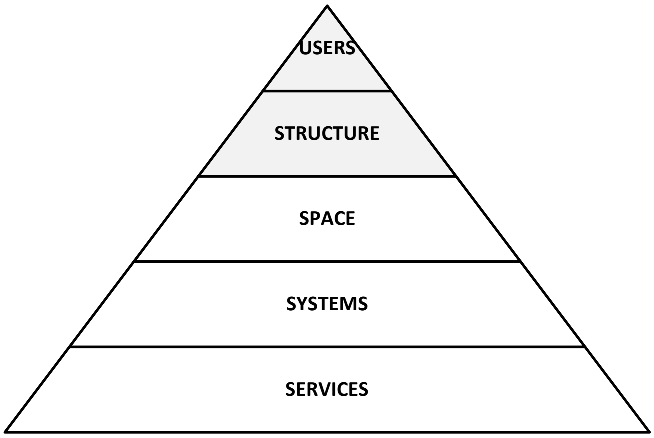

Figure 2-3 The Completed Intelligent Buildings Pyramid.

2.2.1.2. Combining Intelligent & Green.

In general, green buildings are popular with architects and designers since they place a great emphasis upon the structural elements of the building, and look to apply the "passive intelligence" of these elements to improve building performance. This approach reinforces a common antipathy amongst many building designers to reliance upon the "active intelligence" of building services to enhance the management and control of their buildings. As the green building movement has developed, the focus of performance improvement has expanded beyond "green," in its purely environmental sense, towards a broader focus of improving "sustainability." The definition of sustainability now most commonly used is that of the "triple bottom line," which looks to encompass environmental, economic, and social benefits. "It was previously mentioned in chapter1."

It is clear from this that there should be no fundamental conflict between the aims of those advocating intelligent buildings (making the best use of available information) and those supporting green buildings (making the best use of available resources). In reality, however, these two groups have often found it difficult to cooperate in many parts of the world. Because of their different starting points, histories and imperatives (informational and technological verses social and moral)[1] the groups have often displayed disrespect and distrust for each other's positions, a response which has been encouraged by the extremists in each camp – eco-warriors and technology

[1] Alan R Kell, "The Global Development of Intelligent & Green Buildings i&i limited", London.2005,p 6 URL: www.ibexcellence.org/images/pdfs/akbeijing05paper (accessed November 2005)

geeks do not mix well. The goal must be to establish the middle ground in which the alternative propositions can be considered and consolidated, delivering the best of both intelligent and green. Fig2-4.

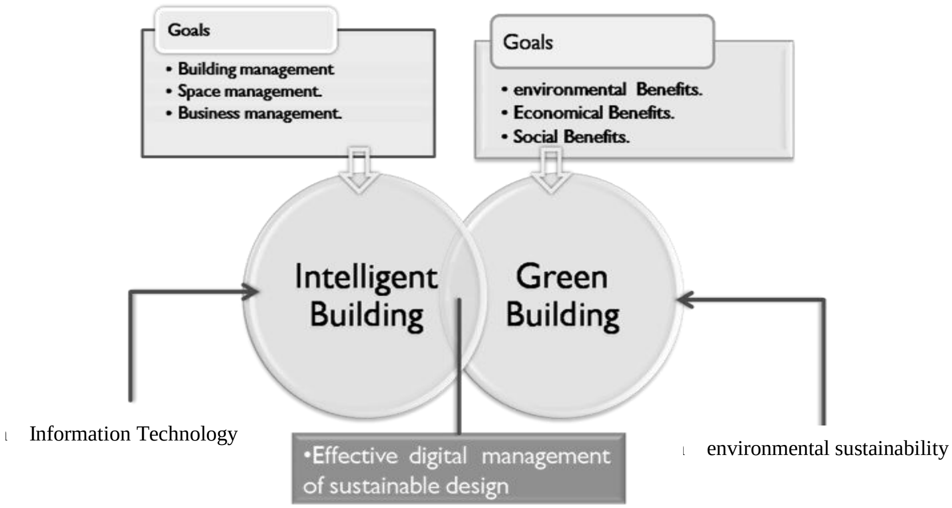

Figure 2-4 Combining intelligent and green.

Schemes to integrate its guiding principles and course of actions are advocated by different interest groups along with designers, all of whom seeking to add more value to the built environment, conserve natural and cultural assets, and enhance the 'quality of life' for users. This trend has reached a positive level where the integration of green practices into the design theory and practice, as well as into construction, is perceived not to impede development but rather as a catalyst for future growth and sound progress: the combined promise of preserving both human prosperity and environmental welfare.

The trend of associating new technologies with green awareness into building management further manifests and endorses the principle green rules.

- **Principle 1: Conserving energy**

Intelligent buildings provide a renewable energy and energy efficient technologies into the building by increasing the energy efficiency and reducing the energy consumption. Fig 2-5. Using zoned energy controls, to control low-usage areas separately, installing an automatic shut-off system for equipment on standby, choosing a 'smart' heating system to automatically turn off at night and on weekends, choosing equipment with 'standby' option.

Figure 2-5the Building Envelope as a communication interface, and feature of expressionism for environmental sensibility and technological sophistication: SUVA Building, Basel; Combined Brise-Soleils and PV panels; and Movable parts in the Helicon, Lond. And Microelectronics Buildings, Duisburg
(Source: Lloyd Jones, David, "Architecture and the Environment: Bioclimatic Building Design". The Overlook Press, New York (1998) p 206).

- Fuel Cells generate night time energy requirements on site. Fuel cells generate power quietly and cleanly by converting a hydrogen-containing gas (natural gas) using a chemical reaction without combustion.

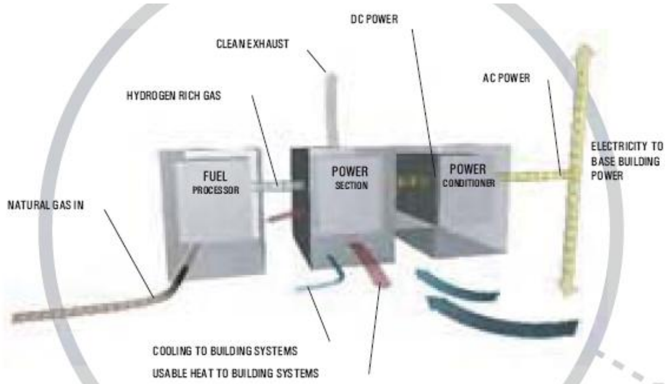

Figure 2-6 Fuel Cell system
(Source: Bruce Fowle, The State Of The Art Of Green Architecture, p5 URL: http:. www.foxfowle.com accessed may 2007)

- Photovoltaic: Thin film photovoltaic panels provide an additional kWh of energy annually.

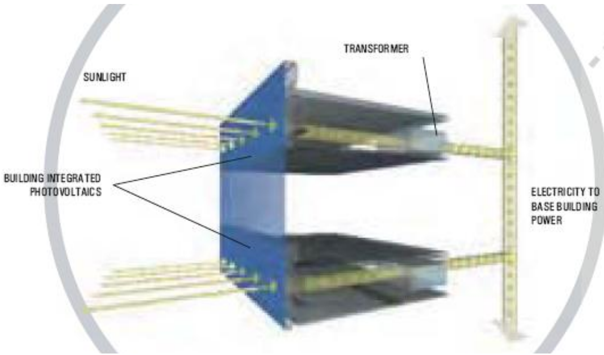

Figure 2-7 The intelligent Photovoltaic design.
(Source: Bruce Fowle, The State Of The Art of Green Architecture, p5 URL: http: www. foxfowle.com accessed may 2007)

- Glazing and lighting: Glazing is low-e glass to provide daylight while improving energy efficiency.
- Lighting: Exit signs contain LED bulbs used as occupancy sensors
- HVAC: Heating and cooling is provided by natural gas absorption chillers/heaters. The high efficiency of the HVAC system is expected to give result in a payback period of years.

- **Principle 2: Working with climate**

The "intelligent skin" is the element which performs the function of enveloping the inhabited interior of an Intelligent Building[1]. This is by working with climate and natural energy sources. Fig 2-8.

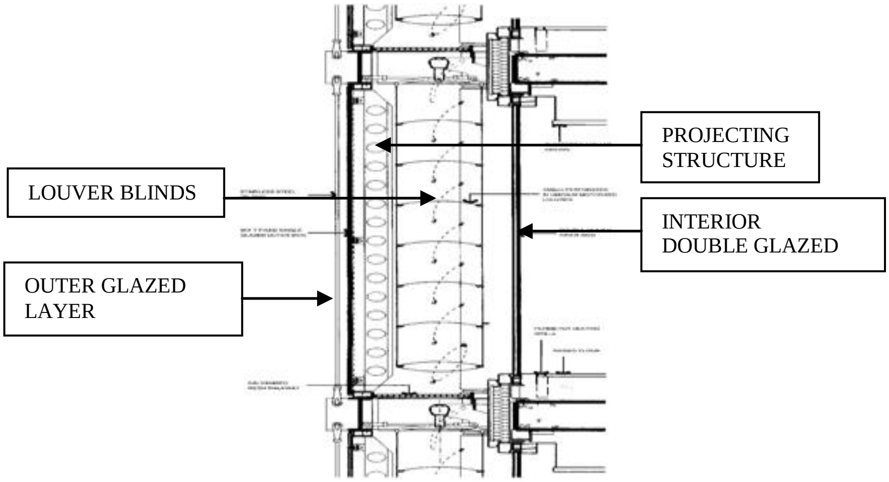

Figure 2-8 the intelligent envelope or skin considered as a regulator-like shell with environmentally interactive membranes, adjustable components, and smart materials: Wall detail of the Helicon; Section of BRE Future Office.
(Source: Lloyd Jones, David, "Architecture and the Environment: Bioclimatic Building Design". The Overlook Press, New York (1998) p181).

[1] Wigginton, Michael, and Harris, Jude, "Intelligent Skins." Architectural Press, London (2002). P 12

- Natural ventilation: This technique is perhaps the most significant energy-saving strategy; it is supplemented with air conditioning. The occupants have operable windows, but when the outdoor temperature is extreme, the windows automatically close and the AC is turned on.
- Layered cladding: It provides the ability to use natural ventilation while shading the building from unwanted heat gain during warmer months.

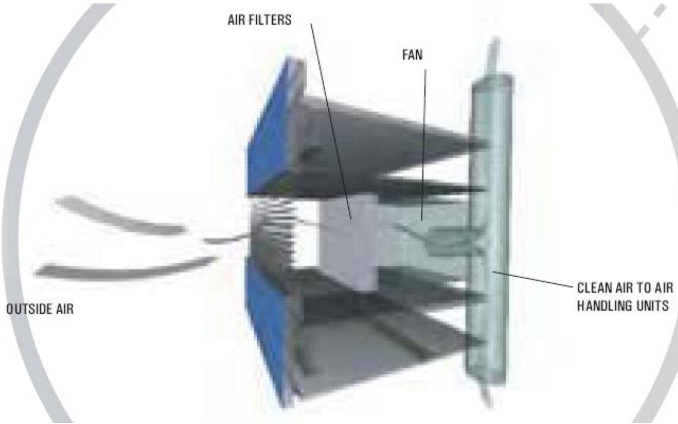

Figure 2-9 Air filtration system.
(Source: Bruce Fowle, The State Of The Art Of Green Architecture, p5 URL: http: www.foxfowle.com accessed may 2007)

- **Principle 3: Minimizing new resources**

Intelligent systems minimize the use of new resources and, at the end of its useful life, form the resources for other, for example the use of Greywater from cooling towers for toilet flushing.

- **Principle 4: Respect for users**

The intelligence includes the use of chilled beams, panels, and ceilings. These can offer significant advantages in terms of energy, thermal comfort, and indoor air quality. The users can have a monitoring of the air quality on a regular basis. Dedicated exhaust must be provided in smoking and copying rooms. These systems can achieve the same comfort range, by supplying air to occupied spaces at higher temperatures and thereby reducing the energy required to cool fresh and return air which in turn reduces the plant and equipment size required.

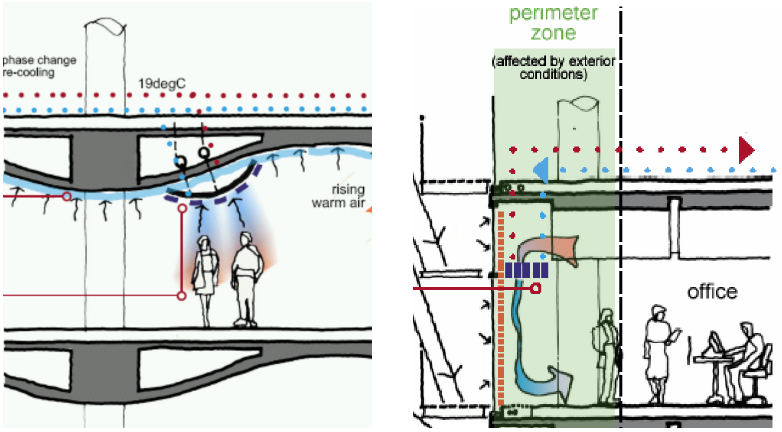

Figure 2-10 Chilled beams and ceiling panels
(Source: Green Star Diffusion, Green Building Council of Australia, p.51 URL http: www.gbcaus.org accessed January 2007)

- **Principle 5: Respect for site**

The metaphor used in the term "intelligent" implies a living envelope able to understand signs, and react in many different ways that benefit the entity it wraps and the functions it encases. Linguistic meaning when associated with a computer terminal, the term "intelligent" denotes such machine as having its own data-processing capability, able to understand, gather, pick out, and read information.[1] Fig2-11. The concept of touching this earth lightly, a building constructed of materials to have no effect on the site. For example a metal building was constructed that sprays countless tiny drops of lake water from thousands of jets. The fleeting sculpture will be even in rain by high-pressure spraying technology as mass of fog that changes from minute to minute. A basic idea about liquid formation in architecture was given that is supposed to respond and be formed according to its users' needs. Intelligent computers were used to adjust spray strength according to the different climactic conditions of temperature, humidity, wind speed, and direction.

Figure 2-11 Blur building.
(Source: URL: http://www.designboom.com/eng/funclub/dillerscofidio.html accessed July 2006)

1 Wigginton, Michael, and Harris, Jude, "Intelligent Skins." Architectural Press, London (2002).p.12

Among these is the central concern for efficiency. The building components were all envisaged as tools that should be studied and employed to achieve sustainable goals. Technical strategies, design guidelines, and applicable means are needed to fulfill these tasks. Achieving an intelligent envelope is a notion that receives broad deliberation, has many premises, and is subject to multiple experimentation and schemes.

2.2.2. Digital Design tools.

Architecture is a subject of personal critical taste and yet a public art, in that people are constrained to use it. That's why it goes beyond the other arts and is called on to function, to modify the climate, provide shelter, and to subdivide and structure space into a pattern that somehow fits the needs of social groups or organizations and cultures, it is always required to fulfill a comprehensive program of social and environmental needs. Various architects today are investigating the digital tools of architectural design, in search of ways to improve processes in the fragmented construction industry.

The term design tool is generally applied to a wide range of techniques, such as the use of tabulated data sheets and manual calculation methods, through to sophisticated computer analysis software. In this context, this term is used to describe computer software developed to replace laborious manual calculations used to inform the design decision-making process. Using a computer to perform the mathematical component makes it possible to study effects not previously considered in many building designs. Designing Environments Historically, the inability of computers to comprehend any design activities that take place outside the computational environment itself, hence the need to design "in" the computer, had the unintended but critical effect of transforming the computer from a design "tool," in the traditional sense of the word, into a design environment: a "place" where design occurs. Instead of following the designer, like a pencil does, allowing architects to design wherever and whenever desired, computers force designers to come to them. Consequently, designers must fiddle with all sorts of knobs, switches, and gadgets to set the machine up so it can begin to support the design activity and, in general, are constrained and shoehorned into the machine's environment. By becoming the environment where design occurs, the computer has changed the culture of the design profession. The addition of Internet communication abilities extended their design environment to encompass not only the individual designer, but also other members of the design team. Which include manufacturers of the objects that are used to assemble the design, the clients, the public, and other interested parties. The Internet has contributed to creating a global design environment, diminishing the importance of collocation, and transcending time zones. As a consequence, there is better integration of the various parts of the design. But there is also a need to accommodate the schedules and work habits of others, to control the flow of information, and sometimes the loss of ownership of the final product.

It was only within the last few years that the advances in computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies have started to have an impact on building design and construction practices.[1] They opened up new opportunities by allowing production and construction of very complex forms that were until recently very difficult and expensive to design, produce, and assemble using traditional construction technologies. The consequences will be profound, as the historic relationship between architecture and its means of production is increasingly being challenged by new digitally driven processes of design, fabrication, and construction.
Fig2-12.
"Architecture is recasting itself, becoming in part an experimental investigation of topological geometries, partly a computational orchestration of robotic material production and partly a generative, and kinematics sculpting of space"[2]

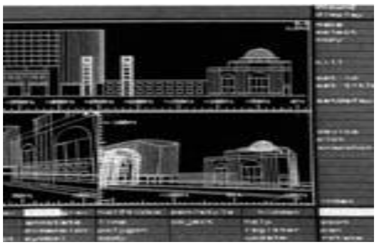

Figure 2-12 WORLDVIEW, an early knowledge-based CAD system, integrating geometric modeling and drafting.
(Source: Yehuda E. Kalay, Architecture's New Media: Principles, Theories, and Methods of Computer-Aided Design by the publisher, The MIT Press. 2004.)

1 Branko Kolarevic, "Architecture in the Digital Age: Design And Manufacturing" Taylor & Francis 2005 P.3
2 Zellner, Peter. Hybrid Space: New Forms in Digital Architecture. New York: Rizzoli (1999). p98

2.2.2.1.The Green Architecture Digital Tools.

Most of green designers have learned to use digital tools as these programs offer feedback on the energy performance of various design scenarios and quantify savings estimates. But it takes time to build models through these tools.[1] Furthermore, these systems ask architects to think like mechanical engineers, usually a losing proposition.

The conceptual stage of design occurs very early in the design process. This is the time when a vast array of competing requirements is shaping the initial building form, when geometry, materials, and orientation are still being formulated. These are the three most important determinants of building performance; this is the most crucial stage of a project. Conceptual design is an iterative process of generating ideas and green principles that then need to be evaluated and tested, for rejection or further refinement.

- **Principle 1: Conserving energy**

The provision of new technologies in this principle minimizes the use of energy. Design in the efficiency options in collaboration with the various relevant engineers (Electrical, Mechanical and Hydraulic), carrying out modeling to determine the effectiveness of various strategies. Fig 2-13.

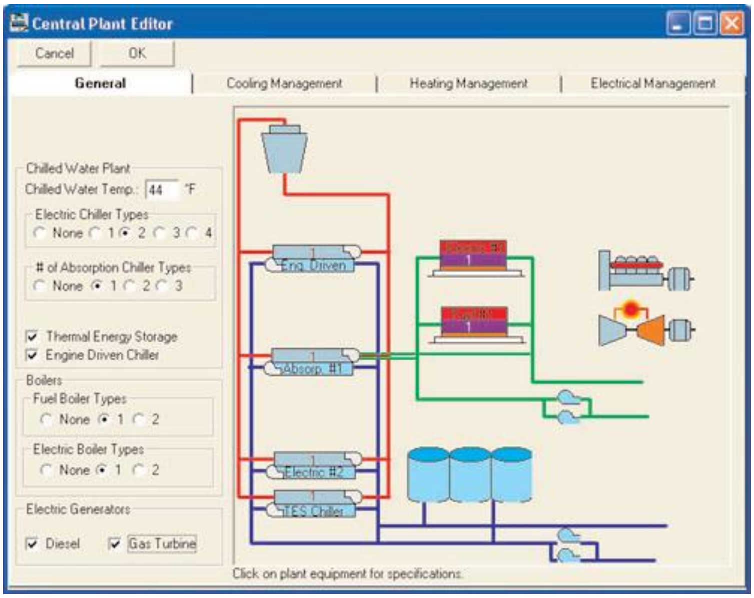

Figure 2-13 Central Plant Editor – Options include air and water cooled chillers, absorption chillers, thermal energy storage and cogeneration.
(Source: visual doe URL: www.archenergy.com/products/visualdoe/vd4_brochure.pdf accessed July 2007)

1 Thomas P. Conlon, Green CAD and 3D Design Survey, ArchitectureWeek, July 2000
URL:http://www.architectureweek.com/2000/0705/tools_2-1.html (accessed December 2005)

Computer modeling allows the energy consumption of a building over a year to be assessed. The effects of a range of designs of glazing and solid elements within a building envelope design can be tested in modeling to identify optimal performance.
With sufficient information on the materials concerned, such as U values (the rate at which heat is transmitted through a material), determinations can be made through modeling of cooling or heating loads on a building. Information required for accurate modeling consists of building elevations and plans and the usages of each room. From this information, window options related to size and materials can be tested for their contribution to the overall energy performance of the building.[1]

- **Principle 2: Working with climate**

The way in which a building is oriented has a marked effect on the energy consumption of the building. Charts can be produced to show the technologies which are most effective given temperature and humidity. Passive solar heating is effective if the Dry Bulb Temperature (DBT) is between 15 and 22 and the air has an Absolute Humidity (AH) between 5 and 12 (i.e. cold and relatively dry). Fig 2-14.

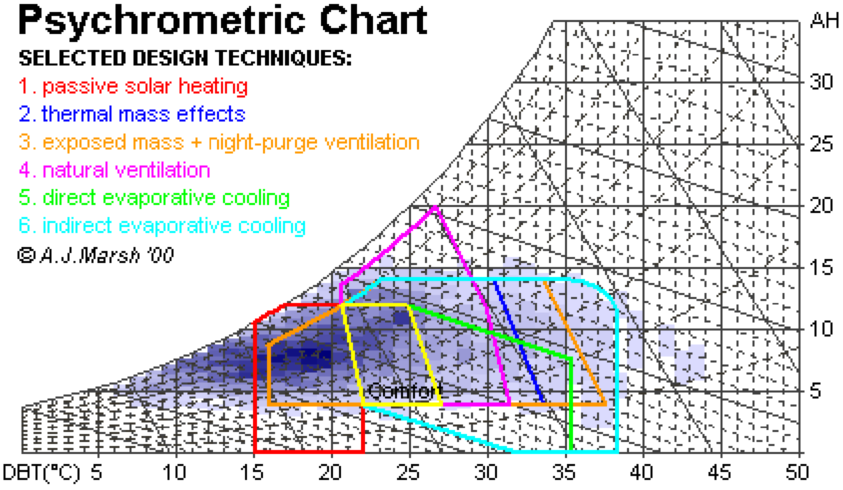

Figure 2-14 Effectiveness of Passive Techniques.
(Source: Dr Andrew Marsh of Square One Research Pty Ltd www.squ1.com
URL:http://www.squ1.com/climate/climate-passive.html)

From a range of factors, the thermal environment can be modeled in a building. From this a PPD [2] map can be created for the occupied areas.

1 Bruce Fowle, "The State Of The Art of Green Architecture," p29. URL: http: www. foxfowle.com (accessed may 2007)
[2] PPD: is the Predicted Percentage of Dissatisfied people.

Problems can be identified and remedied before the building is actually built and occupied. In digital modeling information required includes:

- Location of heating and cooling elements;
- Location of vents and extracts;
- Location of windows;
- Equipment and occupation density; and
- Geometry of floor plan including ceiling height.

From this and climatic data, the temperatures and air movement are assigned for each of the design elements. The sources, such as lights, may have differing hours of operation. This would result in a map of how comfort people would feel in the area. Fig 2-15

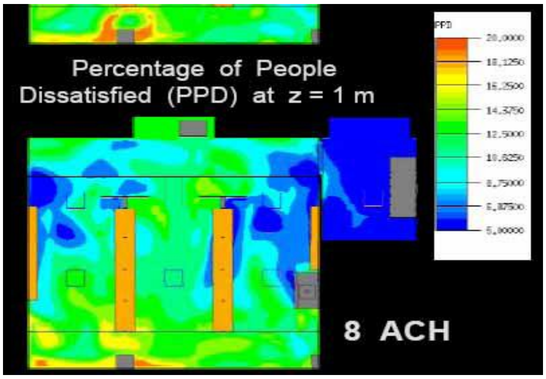

Figure 2-15 Different version of PPD contour map
(Source: Laboratories for the 21st Century Modeling Session E-3
URL: http:/labs21.lbl.gov/DPM/Assets/e3_maine.pdf)

- **Principle 3: Minimizing new resources**

The importance of managing the waste product of the project is to minimize the use of new resources and, at the end of its useful life, to form the resources for other. This is by using a project management tool.

- **Principle 4: Respect for users**

Design flexible floor plans, which can be rearranged and reconfigured easily in the future and reduce, churn costs include enough space for recycling, in convenient, easy-to-use areas. It is important for the user to participate in the design and construction process. In designing the indoor thermal environment the occupant satisfaction is the first thing that has to be considered. Fig 2-16.

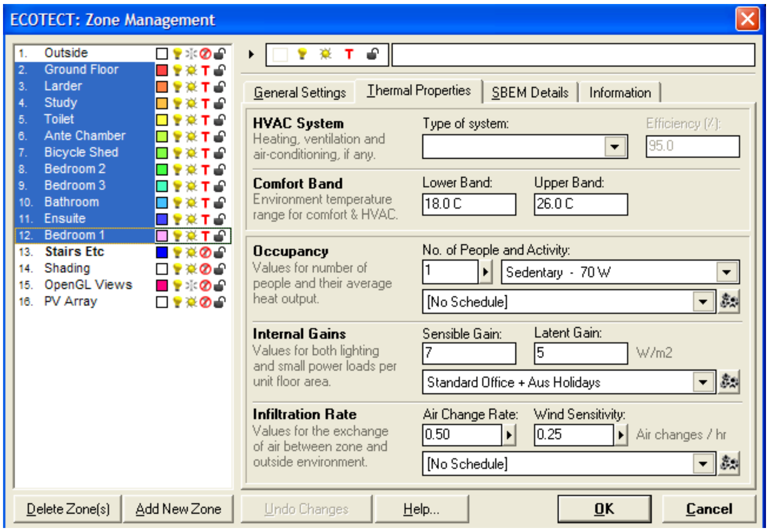

Figure 2-16 zone management window

A climate analysis will determine what proportion of the year some conditioning to the external environment is required. Data can be obtained from weather stations to analyze when modifications need to occur. Typical year data should be used warily as this may not take into account extremes experienced on a year to year basis. Other considerations such as microclimate in which the building is located should be identified in modifying open field weather station data. Fig 2-17.

The climatic properties of the project location.

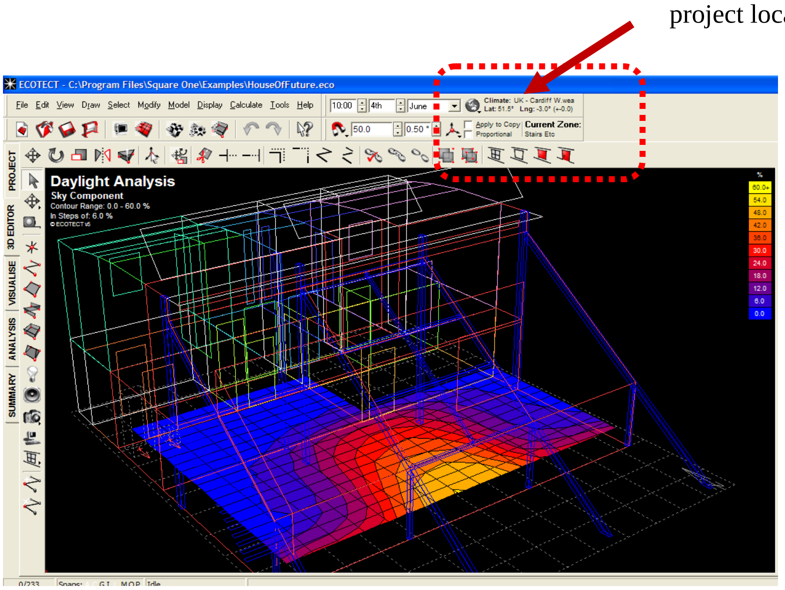

Figure 2-17 the model identifies its location and orientation using the weather data

This value should be further developed in a way that could increase the level of satisfaction with the construction of a building. In parallel to that, people should freely engage into the process of design and creating a building.

- **Principle 5: Respect for site**

The interaction between a building and its site is the key word for this principle. Fig 2-18

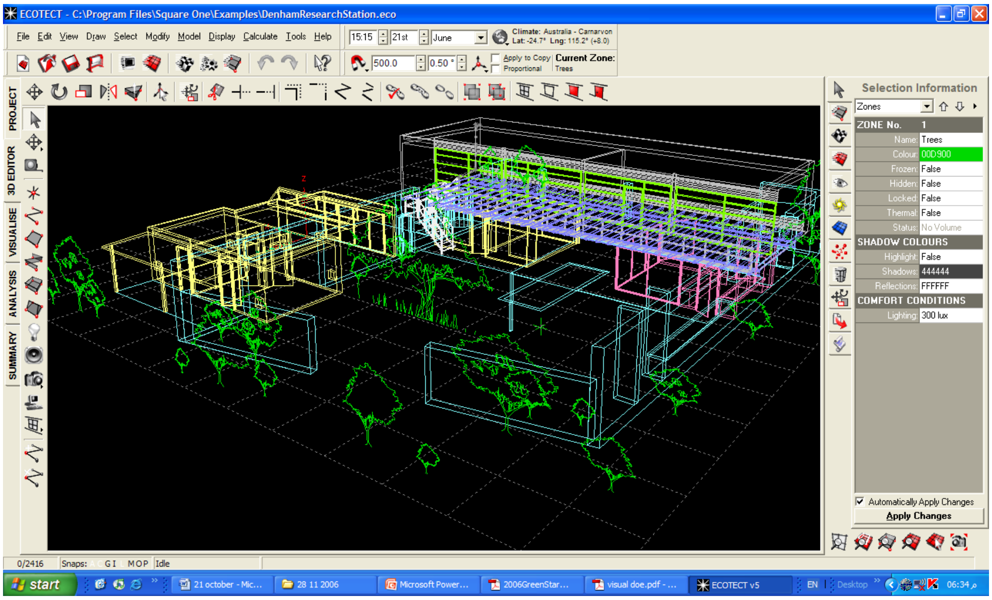

Figure 2-18 The interaction between site and the building.

- **Principle 6: Holism**

Traditional methods of testing an idea or a principle involve quick perspective sketches, simple geometric analysis on a drawing board, or even small hand-calculations. The main criteria for these tests is speed. Being able to quickly reject impractical ideas can save significant amounts of time. Each newly rejected idea providing one more clue to a more acceptable one.[1] In order to make environmental performance a practical consideration at this early stage, thereby informing the decision-making process as much as any other consideration, real and useful feedback has to be produced from what is often ill-defined and abstract information. To use these tools, the designer must first enter the small amount of hard data they do have, and then arbitrarily quantify whatever else is needed before a result can be produced. Overcoming this requires a completely different approach from the concise, solution-based nature of existing digital tools.

[1] Akin, "How do architects design, Artificial Intelligence and Pattern Recognition in Computer-Aided Design," ed. by J-C Latombe, North Holland, New York, pp. 65-104

The Green Architecture Digital tool is investigating the use of a single unified digital model of the building to help resolve these problems by bringing greater intelligence to bear at the earliest 'form generating' phase of the design process when the user's requirements are still being specified and when both physical design and user expectations are most easily modified. The aim is to help narrow the gap between what users hope to obtain and what they eventually receive from a building project.

Although the use of 2D drafting software is now pervasive in architectural practice, the building design professions are only just beginning to use 3D object modeling and more advanced digital representation techniques. Advances in industrial simulation technologies hold promise for architecture in both process and product. They need to understand how CAD is currently being used in the real world and prepare for the digital transformations that are just around the corner.

2.2.2.2. The use of 3D CAD

The most commonly used tools for 2D drafting and 3D modeling are not the same tools as those considered "most effective" by practitioners who do 3D modeling in schematic design.[1] This is important for energy tool users because sustainability-related issues must be addressed by designers at the earliest phases. "Greening" cannot be applied during the construction documents phase, where most mainstream CAD is performed. The Energy Performance Analysis Tool Project must develop a software module designed for XML-based energy analysis integration with existing 3D CAD architectural software tools.

To find out how designers use 3D CAD in practice, a recent survey found that the average architects uses 3D for 24.3% of its work.[2] That's almost 1 in 4 CAD files that are 3D based[3], presumably at least a 2D drafting program. Thirty-six percent use 3D tools. At present the most sophisticated 3D drafting tools are used more for marketing presentation to create a snazzy rendering or animated walkthrough rather than for building design.[4] Large projects use 3D CAD during conceptual design; the vast majority of mid-

[1] Thomas P. Conlon, Green CAD and 3D Design Survey, architectureweek, July 2000 URL:http://www.architectureweek.com/2000/0705/tools_2-1.html accessed December 2005

[2] Nigel Davies, CAD Managers' Survey 2006 Results URL: www.evolve-consultancy.com

[3] Ibid.

[4] Thomas P. Conlon, Green CAD and 3D Design Survey, architectureweek, July 2000 URL:http://www.architectureweek.com/2000/0705/tools_2-1.html accessed December 2005

size and smaller projects do not. As a result, larger firms tend to report higher percentages of CAD use. It was found that amount of detail in a model differs at various phases of the design process early in design; "simple" 3D models are preferred over "detailed" models, by a factor of 2 to 1. Over 68% of the respondents reported always using a simple 3D CAD model early in their new construction design process. Some reported to be occasionally using a simple model in the early phase of design while the use of detailed 3D modeling is less common. However detailed modeling is more popular late in design, over two-thirds of the represented projects receive some form of CAD-assisted presentation. Table 2-1

Table 2-1 the Levels of 3D CAD Assisted Presentation.
(Source: Thomas P. Conlon, Green CAD and 3D Design Survey, architectureweek, July 2000
URL:http://www.architectureweek.com/2000/0705/tools_2-1.html accessed December 2005)

Levels of 3D CAD Assisted Presentation	Mean %
Basic Computer-Rendered Skills	44%
Photorealistic Computer-Rendered Skills	25%
Recorded Walkthrough Animation	8%
Live Walkthroughs	6%
3D CAD not used for Presentation	31%

As seen in a comparison of Table 2-2, many frequent 3D users, like those surveyed, prefer to use different programs for 2D drawing/drafting and 3D modeling.

Table 2-2 CAD Tools Used Currently for 3D Modeling Tasks
(Source: Thomas P. Conlon, Green CAD and 3D Design Survey, architectureweek, July 2000
URL:http://www.architectureweek.com/2000/0705/tools_2-1.html accessed December 2005)

CAD Tools Used Currently for 3D Modeling Tasks		
Rank	Program	%
1	AutoCAD	42
2	Form Z	12
3	DesignWorkshop	9
5	Vector Works	6
6	Micro Station	5
7	TriForma	4
8	DataCAD	4
9	All Other (those under 3%)	20

The most frequently mentioned tools for 2D tasks are shown in Table2-3. Together, AutoCAD and its successor outpace the rest. Bentley's Micro Station comes in third. Notably absent are ArchiCAD and Architectural Desktop, which can be used for both 2D and 3D but are evidently not being used much by this group for 2D drawing/drafting. AutoCAD remains far ahead of its closest competitor, form-Z.

Table 2-3 Percent of Each Products Users Who "Always" Use Simple 3D Models Early in the Design Process

(Source: Thomas P. Conlon, Green CAD and 3D Design Survey, architectureweek, July 2000
URL:http://www.architectureweek.com/2000/0705/tools_2-1.html accessed December 2005)

Percent of Each Products Users Who "Always" Use Simple 3D Models Early in the Design Process		
Rank	Program	%
1	ArchiCAD	60.6
2	DesignWorkshop	44.4
3	Vector Works	36.8
4	Form Z	33.3
5	DataCAD	33.3
6	TriForma	30.0
7	3D Studio Max	25.7
8	Micro Station	23.1
9	AutoCAD 2000	20.0
10	Architectural Desktop	14.3
11	3D Studio Viz	13.5
12	AutoCAD R14	11.6
13	Accurender	2.0

The tools most often used for simple modeling "early in the design process" affect energy use, CAD tools need to be applied early in design. Users who said they "always" use simple 3D CAD models early in design were asked which 3D CAD tool their firm uses most extensively. Again, ArchiCAD turns up on top with the majority of its users reporting they "always" build simple models during conceptual design.

The Previous tables demonstrate a mismatch between 2D and 3D use and between frequency and perceived effectiveness of common tools. For energy-related software tools to be most effective in schematic design, they should aim at integration with 3D modelers that architects already find to be effective at that phase. These results ensure the importance of integration of energy analysis with effective 3D modelers for schematic design. As for the energy performance simulation programs will be shown and reviewed in detail in the next chapter.

2.2.2.3.Virtual Environments

Three-dimensional CAD models; sometimes called virtual buildings or parametric design systems are intended to accelerate workflow through integrated data management and automated extraction of working drawings, schedules, bills of materials, and so on. It was observed that 3D modeling programs "allow the designers to input countless details into the model and to simultaneously update and track information across multiple-linked drawing files."[1]

The use of computer modeling and simulation enable person to interact with an artificial three-dimensional visual or other sensory environment. VR applications immerse the user in a computer generated environment that simulates reality through the use of interactive devices, which send and receive information and are worn as goggles, headsets, gloves tracking devices, CAVES and other media. Fig 2-19

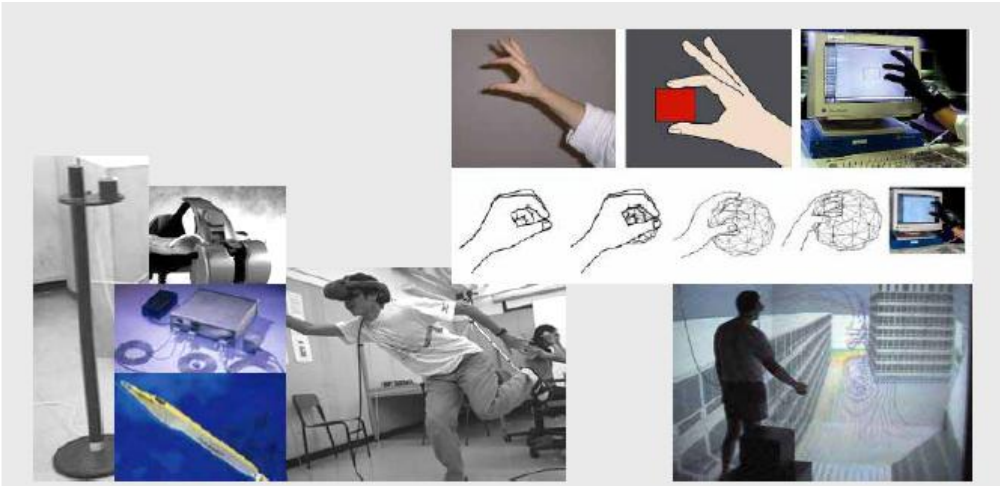

Figure 2-19 Virtual environment devices.

Besides performance evaluation, there is migration of high-tech visualization techniques into architecture. Lightweight, portable augmented-reality domes for simulation are now emerging; these give architecture firms

1 Jerry Laiserin, FAIA, "Getting onto the digital fast track," architectural record, Digital Architect February 2002

new possibilities for design, analysis, and client presentations. The potentially most radical effect of computers assuming a role of inhabitable environments is the advent of cyberspace — a term denote the information space created by the Internet — and its steady assertion of itself as a "place."[1] Although it can only be experienced through the mediation of computers and can only be inhabited by proxy, cyberspace is fast becoming an extension of our physical and temporal existence, offering a common stage for everyday economic, cultural, educational, and other activities. Making places for human inhabitation in a nonphysical space raises interesting questions concerning presence, authenticity, adaptability, orientation, and suspension of disbelief. What kind of activities can be supported by nonphysical spaces and what will it take to support them in a socially and psychologically appropriate manner. Already video conferencing, e-commerce, and video entertainment are migrating to cyberspace. The new "space" is virtual, the construction of computers. But humans have not changed, nor have their relationships with other human beings. The opening of a new kind of space made possible by computers and networks promises to revolutionize their perception of reality like no other invention before it and challenges the professions of architecture, town planning, and interior design which have been striving to accommodate human activities in the physical domain for thousands of years. The roles of computing, with regard to architecture, are thus multifarious and have varying degrees of impacts. They range from being tools that can augment certain traditional design activities, with little impact on the activities themselves, to more pervasive impacts as environments within which design and even inhabitation itself occurs.

2.3. The Green Design Practice.

One of the most challenging aspects of green architectural project delivery is coordination and integration of various consultant and expert input. Quite often it is the coordination and integration within a project team that determines the success of a project and hence the increasing emphasis on an integrated designs process.[2]

1Ghent Urban Studies Team, “The Urban Condition: space, community, and self in the contemporary metropolis” 010 Publishers 1999,P423-424

2 Green Star Diffusion, Green Building Council of Australia, p.11 URL http: www.gbcaus.org (Accessed January 2007)

- **Briefing and Concept Design**

During the pre-design stage before the architect commences with building design, the first step for any type of project should always be the setting of a project brief. The complexity of a project brief largely depends on the nature of the project, the stakeholders and the project team involved. Green building design increasingly has become a central element of a project brief due to the number of building design and services aspects it has influence on (directly or indirectly). The project brief once established also sets the initial context and parameters that all aspects of the project must relate to.

Concurrent to the briefing process is the Concept Design process. Concept design and the project brief go hand in hand so that the resultant brief is practical and the concept design progresses acknowledging the constraints and can therefore be more effective in the search for alternative solutions and innovative ideas. Some of the key architectural aspects important to the setting of the brief and to progress the concept design include:[1]

- Informing the client on the potential of green building opportunities and the broader benefits of taking such actions.
- Designing for the macro-climate, and for the microclimate and orientation of the site.
- Specification to be based on needs analysis to avoid under- or over specification.

- **Sketch Design, Design Development, and Documentation.**

The design and analysis process for developing integrated building designs includes:[2]

- Establishing a base case—for example, a performance profile showing energy use and costs for a typical facility that complies with code and other measures for the project type, location, size, etc.
- Identifying a range of solutions—all those that appear to have potential for the specific project.
- Evaluating the performance of individual strategies—one by one through sensitivity analysis or a process of elimination parametric.
- Grouping strategies that are high performers into different combinations to evaluate performance.

1 Green Star Diffusion, Green Building Council of Australia, p.12 URL http: www.gbcaus.org (Accessed January 2007)

2 Ibid.

- Selecting strategies, refining the design, and reiterating the analysis throughout the process. Fig 2-20

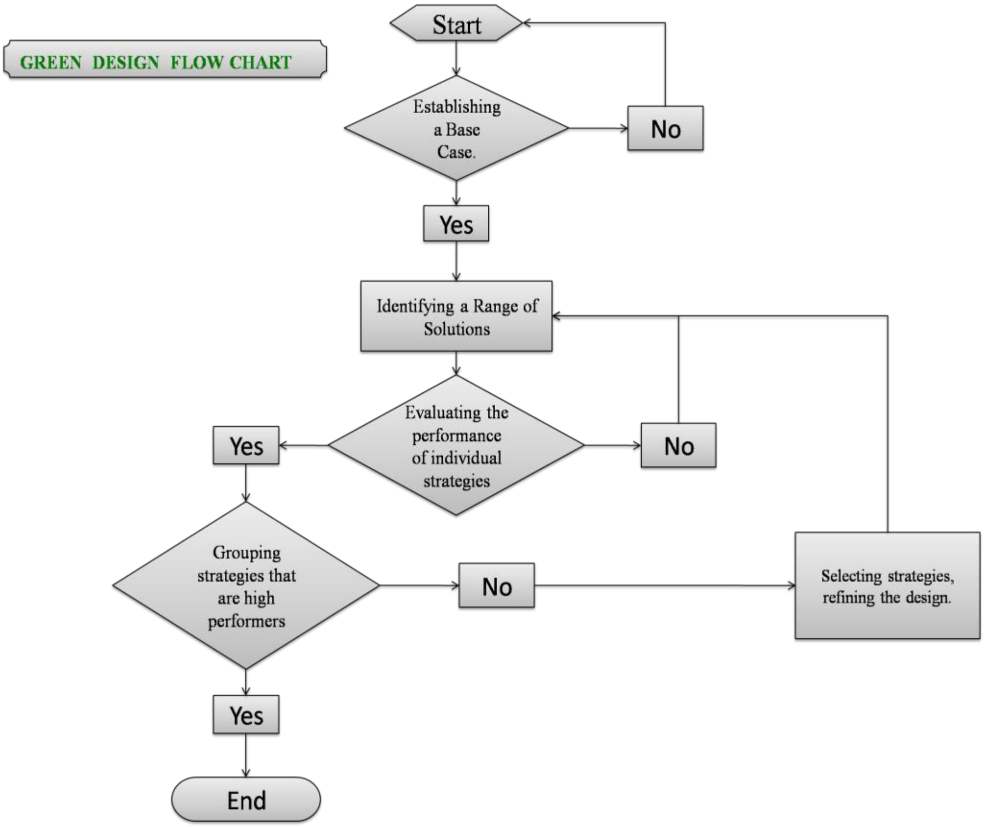

Figure 2-20 The green design flow chart.

Finding the right building design initiatives through an integrated design process can be challenging. However, continuing to explore design integration opportunities can sometimes yield incredible results, in which the design team breaks through the cost barrier. The building design begins with an analysis of the required spaces. With an eye toward the green building targets established in pre-design, the individual spaces should be clearly described in terms of their function, occupancy and use, daylight and electric light requirements, indoor environmental quality standards, acoustic isolation needs, and so on. Spaces then can be clustered by similar function, common thermal zoning, need for daylight or connection to outdoors, need for privacy or security, or other relevant criteria.

Whenever one green strategy can provide more than one benefit, there is a potential for design integration. Sometimes the most effective solutions also have the lowest construction costs, especially when they are part of an integrated design. The built form is the primary mechanism for reducing energy loads. A proactive approach is for the energy efficiency aspects to set the constraints against which the building components can be developed. Such constraints may include the building plan depth, the proportion of glazed façade, solar shading requirements, and thermal massing.[1]

A range of environmental design tools such as building thermal modeling, daylighting assessment, indoor environment quality assessment, and plant and systems modeling, may need to be employed and commence assessment during the sketch design stage to evaluate and guide the building and services design. Fig 2-21.

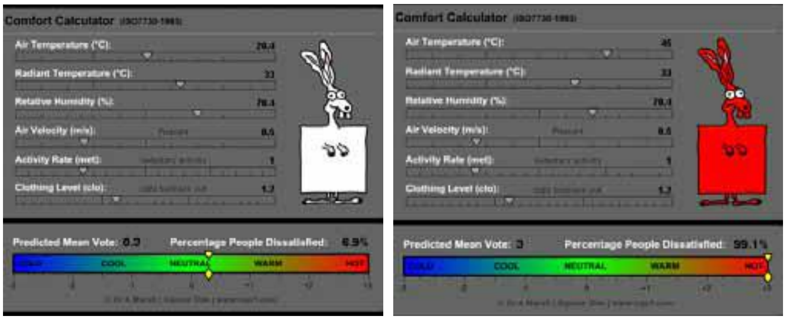

Figure 2-21 Interactive tool for giving an idea of comfort.
(Source: Square One Research Pty Ltd URL: http://www.squ1.com/comfort/prediction.html accessed July 2006)

This is the core of the integrated design process and requires extensive communication, coordination, and integration of assessment outcomes and adjustment required amongst the architect, services engineers, and various consultants.

It is often during conceptual design that existing accepted practices are challenged as part of the design process in search of the most suitable system for a building. This further intensifies the inter-disciplinary coordination required to fully understand the practicality and financial feasibility of a proposed system. The assessment outcome, especially the cost-and-benefit analysis, needs to be presented to the client for informed decision-making.

In principle, as design development progresses with the building and services design taking shape, so does architectural documentation including specifications. Part of the design development process would include material selection for construction materials, interior and exterior finishes.

1 Green Star Diffusion, Green Building Council of Australia, p.13 URL http: www.gbcaus.org (Accessed January 2007)

There are opportunities for further examination of the construction practices and processes to minimize the use of new materials. This may involve investigating alternative construction technologies, introducing or increasing the recycled content of building materials such as recycled concrete, timber, and steel.

2.4. Conclusion.

Architectural design requires a knowledge and understanding of the theories and principles of environmental technologies, and an awareness of their impact upon human comfort, well-being, and protection. It requires an understanding of the relationship of these to the climate, the development of a sustainable environment, and the impact that design decisions may have upon the natural world and its resources.

New technology has always been a catalyst for new ideas in Architecture. It is presently engaged in an impatient search for solutions to critical questions about the nature and the identity of the discipline, and digital technology is a key agent for prevailing in innovations in architecture.

Most of digital architecture projects still come to life through the lens of a familiar architectural process as a critical problem solving activity that results in projects represented with a rigor and depth of the idea and intention, even though with a highly sophisticated digital tool skill set.

Digital architecture requires proficiency with a specific foundation set of digital skills such as: 2D composition, vector graphics, image manipulation, 3D modeling: surface modeling, solid modeling, video editing, motion graphics, rendering, animation, parametric, drafting, communications, layout, printing, presentation, database operations, web interface, performance analysis: lighting, structures, systems, etc. However, this conclusion provides a useful link into the next chapter, in which the driving forces and the aims of green buildings are considered using the digital tools "energy performance simulation programs."

According to the green design practice the digital tools are involved in its all stages which help the designer in determining the factors and properties of the design. These tools are used to provide environmental simulation data, which the building designer can then use as a basis of the cognitive analysis in determination of the building's optimum green design, which can only be achieved by satisfying its predefined objectives, i.e. capital costs, operation, and maximizing daylight. These digital tools are called energy performance simulating programs which will be reviewed in details in the next chapter.

Chapter 3

Capabilities of Building Energy Performance Simulation Programs

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3-1 Introduction
3-2 Energy Performance Simulation Programs.
3-3 Different Types of Energy Performance Simulation Programs.
3-4 Overview on Projects used Energy Performance Simulation Programs.
3-5 Conclusion.

3.1. Introduction.

The evolution of computer-aided design in architecture can be viewed as the search for technology that can fulfill certain preconceived roles, such as drafting and modeling. However, a second view may be of greater interest to the profession and discipline of architecture, possibly even to society at large. In this second view, digital technology is something that can actually change how the built environment is conceived, constructed, and used. More than any other tools, computers can change the tasks they are applied to, creating new roles for themselves along the way. Digital assistants could elaborate details, watch out for known problems and resolve them.

The energy performance simulation programs are becoming increasingly important in green building design, particularly during the conceptual design phase.

This chapter attempts to explain the concept of 'energy performance simulation programs' as an analytical tool for the evaluation of architectural design, by specifically focusing on its current operation and implementation into the design process.

This chapter also provides a brief overview on some of these programs, which depend on the zonal modeling approach. Then it will be followed by a comparison table of the capabilities for each simulation program in the following areas: Supporting, Depend on features of other Programs or softwares, Availability, user interface file format, import from \export to CAD, the outputs and Links to Other Programs,. The software programs are listed alphabetically in the tables. Then, green projects will be analyzed according to their use of the energy performance simulation programs in their early design stage, in order to reach the sustainable design.

3.2. Energy Performance Simulation Programs.

Since the early 1960's, the use of computer modeling and simulation tools within the building industry has steadily increased.[1] These tools have progressed from simple single-task applications with limited input and output requirements, to quite sophisticated modeling systems that can simultaneously analyze a range of performance parameters.

1 Gaithersburg, MD , "Modeling and Simulation: A NIST Multi-Laboratory Strategic Planning Workshop" URL:http://math.nist.gov/spw.html (accessed December 2005)

The use of most advanced simulation tools begins with the entry of a very detailed model; the results produced at least appeared to be more specific to the actual problem they are being applied to and more accurate than manual calculations or rules of thumb. Some doubt does exist over the true validity of computer simulation methods when compared directly with real buildings.

The real challenge is to make these tools applicable to the earlier stages of design, where a more informed analysis of possible alternatives can yield the most benefit and the greatest cost savings, both economic and environmental.[1] Specialist skills may still be required, but just as important is the ability to translate the loosest architectural sketch into a valid input model and translate the result into fundamentally solid design feedback.

This is where computer modeling and simulation can really lead to better and more efficient buildings, both in terms of their internal environment and the environmental impact on their surroundings.

However, there are legislative laws issued to help promote the good design of buildings, taking into account the rights and comfort of the users and the public, as well as the environmental impacts. Therefore, it is important to understand the physical properties and behavior of the buildings, in order to cater for it in their design.

Based on the modeling approach, energy performance simulation programs can be categorized into two categories: zonal and computational fluid dynamics.[2]

- **Zonal Approach.**

This approach can be sub divided into two other categories, the steady state or the dynamic approach. But generally, programs based on the zonal approach, are simplified in an attempt to reduce computation time and complexity. The zonal approach breaks down the object into zones, where each zone is considered to be in a thermal state.[3] Fig 3-1

Examples: EnergyPlus, ECOTECT, TAS, DOE.

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[1] The three benefits of green architecture Chapter1.

2 Mourshed, M. K., D. Keane, M. 2003, “Integrating simulation in design”, the International Building Performance Simulation Association News,2003 Vol. 13(1): p.21-26.

[3] Ibid.

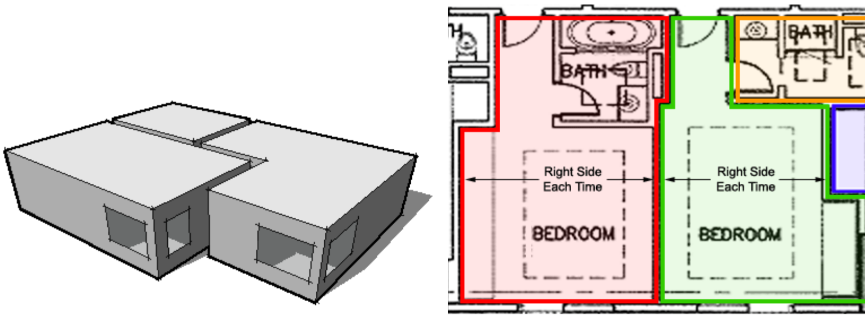

Figure 3-1 Thermal model with gaps between zones
(Source: Andrew J. Marsh “Thermal Modeling: The ECOTECT Way” URL: http://www.cmis.csiro.au/cfd/. (accessed November 2005)

- **Computational Fluid Dynamic Approach.**

This approach is the quantitative process of modeling fluid flows by the numerical solution of governing partial differential equations, or other mathematical equations of motion,[1] mass, and enthalpy conservation.

3D space is divided into grids, where each node on the grid is given an initial value for different environmental parameters. This approach represents real-life situations more accurately than the zonal approach. Fig 3-2. For this reason, there is a need to spend a lot more time and effort in simulation preparation.

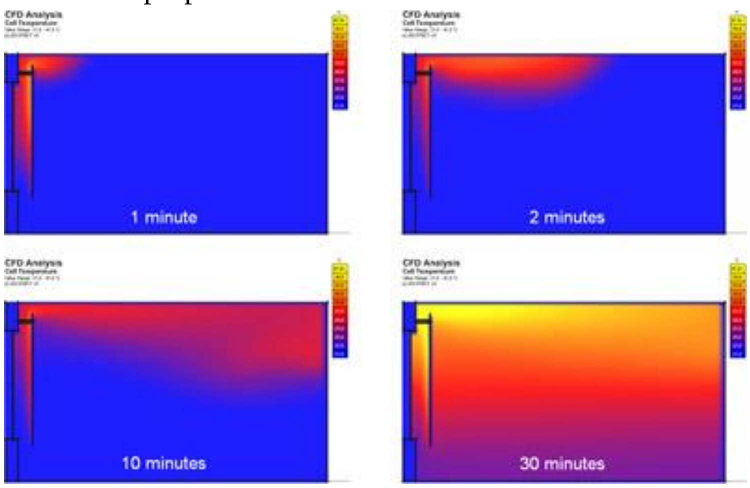

Figure 3-2 A time-sequence using computational fluid dynamics (CFD) to show the effect of thermo-siphoning on room air temperatures.
(Source: Andrew J. Marsh “The Thermal Effects of Solar Gain” URL: http://www.cmis.csiro.au/cfd/. (accessed November 2005)

3.2.1. Variables

The accuracy of computer based energy performance simulation program models, are dependent on the appropriate use and validity of weather files in order to arrive at realistic representative climatic simulations.[1]

1 Csiro, 'Computational Fluid Dynamics website', URL: http://www.cmis.csiro.au/cfd/. (accessed November 2005)

There are a variety of weather files available to be specifically used for energy performance simulation programs. These range from locally recorded measured weather data, to pre selected 'typical' data sets.

• WYEC2 (developed by ASHRAE)
• TMY2 (updated by NREL[2])
• CWEC (developed by the WATSUN Simulation Laboratory')

TMY2 and WYEC2 data sets will result in predicted energy consumption and energy costs that are closer to the long-term average. The newer versions of these data sets are based on the improved solar models and more closely match the long term average climatic conditions.[3]

3.2.2. Sub Simulating Tools.

The invention of the air-conditioning system is seen by many as having liberated the architect from the constraints of climate. The capability of mechanical services to produce a controllable and comfortable internal environment within any building is almost unquestioned in modern architecture. This capability is well understood by architects and together with artificial lighting technology, underpins the majority of building design. However, there is still a significant demand for non-mechanically serviced and naturally lit buildings as the social and economic benefits of passive environmental controls gain recognition amongst both architects and clients. There is concern regarding the finite capacity of natural systems, compared to the perceived infinite capacity of mechanical systems. This makes designers wary of passive design solutions unless they can be rigorously validated and clearly shown to work in each specific case. This is where energy performance tools plays its part, making it more viable to use windows and vents instead of electric lights and air-conditioning by providing some assurance that the same levels of occupant comfort can be achieved. Such tool must consist of sub simulating tools as follows.Fig3-3

1 Crawley, D. B. and Y. Joe Huang, 'Does It Matter Which Weather Data You Use in Energy Simulations' Building Energy Simulation User News 18, 1997, P. 2-12.

2 National Renewable Energy Laboratory.

3 Ibid.

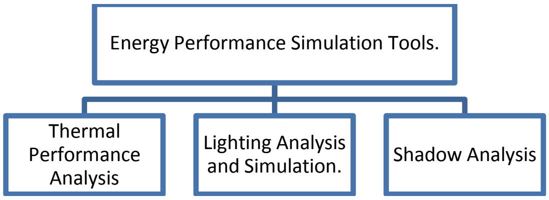

Figure 3-3 The sub simulating tools of energy performance tools.

- **Thermal Performance Analysis Tools.**

The aim of thermal analysis is to accurately predict the internal temperatures of spaces within a model, to calculate heating and cooling loads. There are a wide range of simulation techniques with varying levels of sophistication and accuracy. By accurately modeling the physical processes of heat and air flow, it is possible to simulate more complex thermal systems such as under-floor heating, chilled beams, displacement ventilation, passive solar elements, and natural ventilation systems. Such tools can also calculate sensible and latent loads, radiant temperatures, inter-zonal exchange, and internal solar gains tracked through multiple zones.Fig3-4.

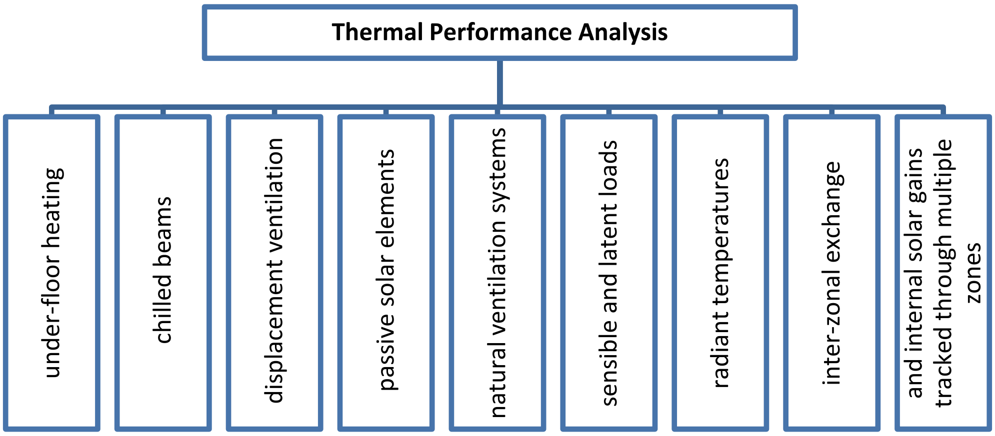

Figure 3-4 Thermal performance tree of simulations.

The most basic method of heat load analysis is based on the Building Loss Coefficient which is a function of the U-Value and surface area of each element in the building fabric. Climate data can then be used to determine incident solar radiation on surfaces and then calculate heating and cooling loads required if some static internal conditions are to be maintained.

Such methods are known as steady state calculations as "there is no accounting for the thermal response of the building fabric to cyclical fluctuation in temperature," and the non-steady state or dynamic response of a building, "This is based on a steady state calculation but simulates the dynamic performance as fluctuations about a mean."[1]

The main use of thermal performance tools has been in the design and analysis of air-conditioning plant. Once a geometric model is created and internal spaces zoned, internal temperatures and plant load for any space or group of spaces can be determined from actual recorded weather data. Loads can be applied to a plant schematic and the effects of diversity, pull-down and coincident loads more accurately considered when sizing air-handling units or even individual A/C outlets.

Standard practice is to size the required plant by summing the peak loads in each zone and applying a simple diversity factor to account for occupancy and sun movement. Using more sophisticated tools, peak heating and cooling loads can be determined from maximum hourly loads in each zone, taken over the entire year. Such loads take full consideration of fresh air requirements based on actual outside air conditions as well as changes in occupancy level and usage throughout each day. This level of accuracy, and the potential for increased efficiency at each component, can result in significant energy savings.

- **Lighting Analysis and Simulation.**

The aim of any form of lighting simulation is to be able to predict lighting levels at points within a space or over an entire surface.Fig3-5

1 Andrew J.Marsh,1997 "Performance Analysis and Conceptual Design" published thesis submitted to The University of Western Australia School of Architecture and Fine Arts December 1997

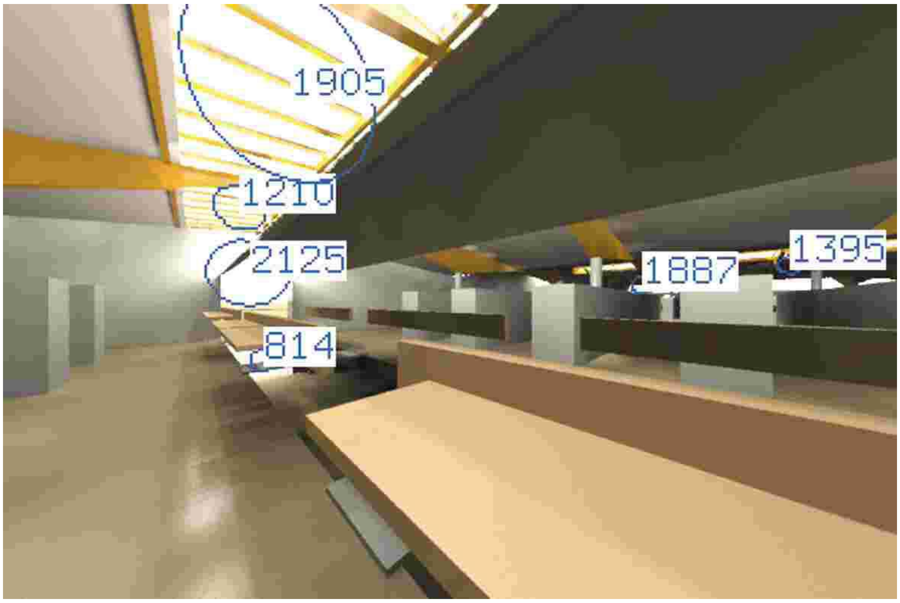

Figure 3-5 The lighting analysis allows qualification of luminance distribution by providing three dimensional displays that are made according to the eye's sensitivity.
(Source: Energy Conservation in Buildings & Community Systems Programmer)

The process of accurately calculating these levels can become quite involved given the complex nature of surface inter-reflection. As a result, there exist a range of methods of varying sophistication for lighting analysis and simulation.

- The point-by-point method:

It is the simplest means of calculating light levels by summing the contribution of each visible light source and taking account of the distribution pattern of each source. Indirect light and diffuse reflections off surrounding surfaces are not considered. This is a useful method for examining the distribution of light from multiple sources. The resulting levels significantly underestimate actual levels; however they offer important feedback at the design stage of a lighting system.
Calculating natural light levels is more difficult as diffuse light from the sky dome itself is often the main source, not just the direct sun. As cloud cover is a significant variable, a model of the distribution of light over the sky has to be used. ‘The Daylight Factor is the ratio of the daylight illumination at a point on a given plane due to light received directly or indirectly from a sky of assumed or known luminance distribution, to the illumination on a

horizontal plane due to an unobstructed hemisphere of this sky. Direct sunlight is excluded for both values of illumination[1].

- More sophisticated methods:

It makes use of full rendering techniques. The aim when using more advanced lighting simulation tools is to produce realistic images of the spaces within a geometric building model that correspond as closely as possible to what would actually be found if that space was real. There are many applications that produce rendered images from three dimensional models. However, there is a major difference between photo-realistic rendering and actual lighting simulation.[2]

"Photo-realistic rendering" places emphasis on the appearance of its output rather than the techniques used to derive it. Anything goes, basically, as long as the final image looks nice. There is no attempt to use physically realistic values for the light sources or the surface reflectance. In fact, the light sources themselves often have physically impossible characteristics like 1/r falloff [3] (as opposed to $1/r^2$),[4] or there is a lot of ambient lighting that comes from nowhere but somehow manages to illuminate the room. The renderers use the ambient level as the main source of illumination. Also surfaces typically have colour but there is no reflectance given, so all the surfaces appear to have the same brightness."

"Ray-tracing." This technique is adequate for representing the effects of direct lighting and low order reflection, but does not represent high order antireflection or diffuse light well at all. This tends to be the technique used by most photo-realistic rendering applications used for artistic visualization.

"Physically-based rendering," on the other hand, follows the physical behavior of light as closely as possible in an effort to predict what the final appearance of a design might be. This is not an artist's conception any more, it is a numerical simulation. The light sources start in the calculation by

1 Longmore, J., BRS "Daylight Protractors", Department of Environment Building Research Station, Her Majesty's Stationary Office (HMSO), London 1968.URL: http://www.bioimages.org.uk/HTML/B147498.HTM (accessed July 2004)

2 Greg Ward "Tools for Lighting Design and Analysis" URL: http://radsite.lbl.gov/radiance/refer/sg96crs.pdf (accessed October 2006)

3 r : Is the radius of the falloff light source

4 Andrew J.Marsh,1997 "Performance Analysis and Conceptual Design" published thesis submitted to The University of Western Australia School of Architecture and Fine Arts December 1997

emitting with a specific distribution, and the simulation computes the reflections between surfaces until the solution converges.[1]

Light levels shown in images generated from detailed simulations of the physical processes of light are actual levels that can be read directly. This means that they have direct relevance to a particular design, indicating if levels are too low or if sources of glare discomfort are present. Post-processing of such image can be used to overlay contour lines or even to derive more complex information such as illuminance levels, daylight factors, glare indexes, and even visual comfort.

"Radiosity" is the most sophisticated of lighting simulation techniques involves the analysis of flux transfer between surfaces. This technique requires that all surfaces be divided into small patches that exchange light energy within a closed system. The computation is iterative, progressively refining the energy exchange until the variance between iterations is insignificant. A comprehensive account of this technique and its practical application was given[2].

Hybrid techniques which combine radiosity with ray-tracing are used in some simulation tools. These involve tracing light rays in the reverse direction, from a point on the surface of an object back to its sources of direct and indirect light. RADIANCE is an example of a tool that uses a hybrid technique. It uses geometric rays to determine the portion of other surfaces visible from sample points. Ambient light levels are then iteratively calculated for all points by interpolating between sample points.Fig3-6

Figure 3-6 Radiance Rendering
(Source: URL:http://www.archenergy.com/services/sda/tools//radiance/ accessed July 2007)

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[1] Andrew J.Marsh,1997 "Performance Analysis and Conceptual Design" published thesis submitted to The University of Western Australia School of Architecture and Fine Arts December 1997

2 Ashdown, I, "Radiosity: A Programmer's Perspective", John Wiley & Sons, Inc, New York 1994.

- **Shadow Analysis**

An adjunct to lighting simulation is the analysis of sun penetration and solar shading. Whilst there are a number of dedicated shadow and reflection analysis applications available, shadow analysis is mainly performed using CAD-based rendering and visualization tools.Fig3-7 Applications such as ArchiCAD and Micro station are examples of CAD packages with in-built solar position routines. Many thermal analysis tools include functions for calculating and displaying shadows.

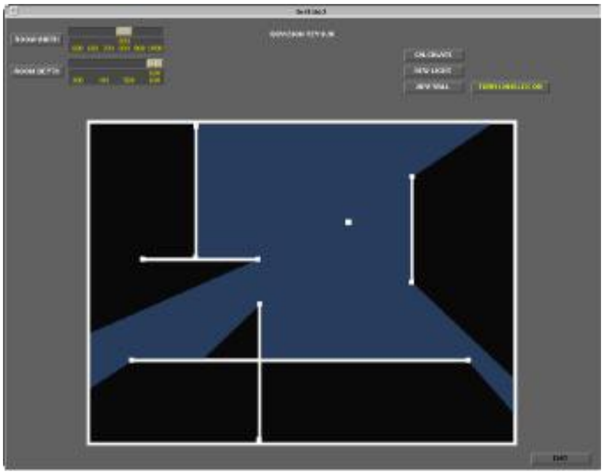

Figure 3-7 Tcl-Shadow displays an isovist by casting shadows.
(Source: Do, Ellen Yi-Luen, and M.D. Gross Computer Assisted Architectural Design Futures ‘Kluwer Academic Publishers, Dordrecht97, R. Junge(ed) pp. 196)

3.3. Different Types of Energy Performance Simulation Programs.

For the past 50 years, a wide variety of building energy simulation programs have been developed, enhanced and are in use throughout the building energy community. This chapter provides a comparison of the features and capabilities of some major building energy simulation programs: BLAST, BSim, DOE- 2.1E, ECOTECT, Ener-Win, Energy Express, Energy-10, EnergyPlus, eQUEST, ESP-r, PowerDomus, SUNREL, TAS, and TRACE. This comparison is based on information provided by the program developers[1]. Computer simulations are important tools that help direct building design and cost decisions. There are a number of software tools for building design and simulation that are available in helping design like.

1 Drury B. Crawley “Contrasting the Capabilities of Building Energy Performance Simulation Programs,” U S Department of Energy Washington, DC, USA, JULY 2005.

3.3.1. BLAST.

The Building Loads Analysis and System Thermodynamics (BLAST)[1]

Aim of the tool

BLAST can be used to investigate the energy performance and cost of new or retrofit building design options of almost any type and size.

Main inputs / main outputs

User inputs are weather data and building construction and operation, for the calculation of Space Loads. In addition, to run the Air System Simulation, the user must define the building air-handling.

Which passive solution can be calculated?

Space loads

Advantages

- BLAST tool is predicting energy consumption and energy system performance and cost in buildings.
- It investigates the energy performance of new or retrofit building design options of almost any type and size.
- It performs peak load (design day) calculations necessary for mechanical equipment design.

Disadvantages

- BLAST is no longer under development, and no new versions have been released since 1998.

Limits

- It estimates the annual energy performance of the facility, which is essential for the design of solar and total energy (cogeneration) systems and for determining compliance with design energy budgets.

The subprograms:

BLAST contains three major subprograms: Fig 3-8

- Space Loads Prediction.
- Air System Simulation.
- Central Plant.

[1] Building Systems Laboratory , Version 3.0 Level 334, August 1998URL: www.bso.uiuc.edu/(accessed October 2006)

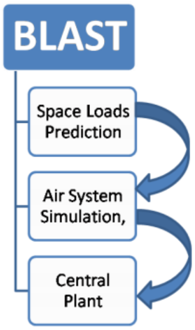

Figure 3-8 The subprogram of BLAST

3.3.2. BSim Version 4.4.12.11[1]

BSim has been used extensively over the past 20 years, previously under the name tsbi3. Today BSim is the most commonly used tool in Denmark, with an increasing interest abroad, for energy design of buildings and for moisture analysis.

Aim of the tool

BSim is a user-friendly package of simulation programs that provide means for detailed, combined hydro-thermal simulations of buildings and constructions.

Which passive solution can be calculated?

Simulations of buildings and constructions.

The subprograms:

The software comprises several modules: Fig 3-9.

- SimView (graphic model editor and input generator),
- Tsbi5 (hydro-thermal building simulation core),
- SimLight (tool for analyses of daylight conditions in simple rooms),
- XSun (graphical tool for analyses of direct sunlight and shadowing),
- SimPV (a simple tool for calculation of the electrical yield from PV systems),
- NatVent (analyses of single zone natural ventilation)
- SimDxf (a simple tool which makes it possible to import CAD drawings in DXF format).

[1] Danish Building Research Institute, 2004, URL: www.bsim.dk (accessed October 2006)

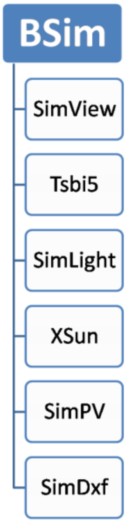

Figure 3-9 The subprogram of BSim

3.3.3. DOE-2.1E Version 121

DOE-2.1E[1] has been used in the design or retrofit of thousands of well-known buildings throughout the world. The private sector has adapted DOE-2.1E by creating more than 20 interfaces that make the program easier to use.

Aim of the tool

The calculation program DOE-2.2 is an up-to-date, unbiased computer program that predicts the hourly energy use and energy cost of a building, given hourly weather information and a description of the building and its HVAC equipment and utility rate structure. It is a widely used and accepted freeware building energy analysis program that can predict the energy use and cost for all types of buildings.

Main Inputs / main outputs

Using DOE-2.2, designers can determine the choice of building parameters that improve energy efficiency while maintaining thermal comfort and cost-effectiveness. The purpose of DOE-2 is to aid in the analysis of energy usage in buildings; it is not intended to be the sole source of information relied upon for the design of buildings: the judgment and experience of the architect/engineer still remain the most important elements of building design.

[1]Winkelmann et al. URL:http://simulationresearch.lbl.gov/(accessed October 2006)

DOE-2.2 uses a description of the building layout, constructions, usage, conditioning systems (lighting, HVAC, etc.) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills. Outputs of the program are air flow and coil loads, behavior of boilers, chillers, cooling towers, storage tanks, etc., in satisfying the secondary systems heating and cooling coil loads. It takes into account the part-load characteristics of the primary equipment in order to calculate the fuel and electrical demands of the building.

Advantages

- Designers can determine the choice of building parameters that improve energy efficiency, while maintaining thermal comfort and cost-effectiveness.

The subprograms:

DOE-2.1E has one subprogram for translation of input (BDL Processor), and four simulation subprograms (LOADS, SYSTEMS, PLANT and ECON). LOADS, SYSTEMS and PLANT are executed in sequence, with the output of LOADS becoming the input of SYSTEMS, etc. Fig 3-10.

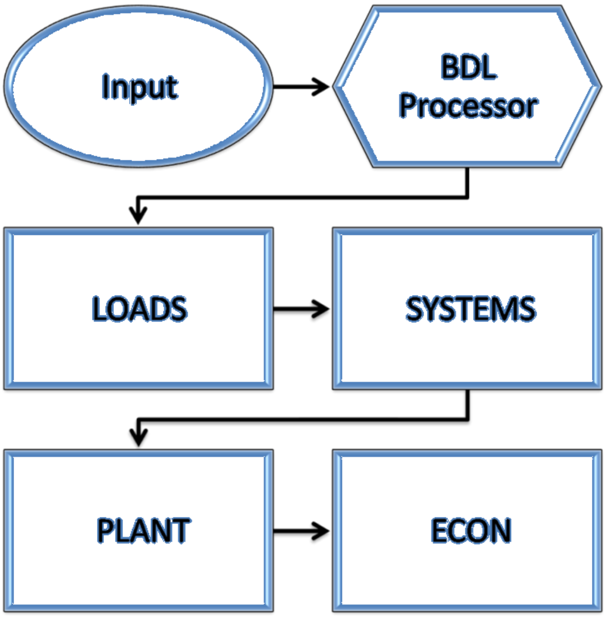

Figure 3-10 The process of executing the DOE-2.1 program

Each of the simulation subprograms also produces printed reports of the results of its calculations.

3.3.4. ECOTECT Version 5.50

ECOTECT[1] has modeling and analysis capabilities can handle geometry of any size and complexity.

Aim of the tool

ECOTECT is a highly visual building simulation tool with a wide range of performance analysis functions covering thermal, energy, lighting, shading, acoustics, resource use and cost aspects. The intent is to allow designers to take a holistic approach to the building design process, making it easy to create a truly low energy building.

Main inputs / main outputs

As well as the broad range of internal calculations that Ecotect can execute, it also imports/exports to a range of more technical and focused analysis engines, such as Radiance, EnergyPlus, ESP-r, NIST FDS and others, and for general data import/export facilities, it includes an array of formats suitable for use alongside most leading CAD programs.

Advantages

- A holistic approach to the building design process, making it easy to create a truly low energy building. And it will be mentioned in detail in the case study.

3.3.5. Ener-Win Version EC

Ener-Win[2] is an hourly energy simulation model for assessing annual energy consumption in buildings. Design data, tabulated by zones, also show duct sizes and electric power requirements

Aim of the tool

Ener-Win EC software produces annual energy consumption, peak demand charges, peak heating and cooling loads, and solar heating fraction through glazing, daylighting contribution, and a life-cycle cost analysis.

Advantages

- The program also has the capability of simulating the floating space temperature (passive designs) for comfort analyses in unheated or uncooled spaces.

The user interface:

It contains an interface module; Ener-Win requires only three basic inputs:

- the building type,

[1] ECOTECT URL:www.ecotect.com (accessed October 2006)
[2] Enerwin, URL: http://enerwin.com/ (accessed October 2006)

- the building ' s location,
- The building's geometrical data.

3.3.6. Energy Express Version 1.0[1]

Aim of the tool

Energy Express can be used for the analysis of alternative designs of new buildings and their mechanical and electrical systems, or in the assessment of retrofit options being considered for existing buildings.

There are two different versions for Energy Express: one for architects and another one for engineers. With this separation, Energy Express allows architects to evaluate building facade options without having to specify details about the air-conditioning.

Main inputs / main outputs

Both versions have the ability to compare a range of alternative designs and calculate savings. The tool also comprises a built-in 2D CAD facility for fast geometric data input and editing.

Disadvantages

- Data libraries only cover Australia, New Zealand, and South East Asia.

The subprograms:

Energy Express includes a Dynamic multi-zone heat transfer model coupled to an Integrated HVAC model see figure 30 so that zone temperatures are immediately impacted by any HVAC shortcomings.

Import/Export with other softwares.

Read 8760 hour weather files. Read data files from Energy Express for Architects.

3.3.7. Energy-10 Version 1.8

Energy-10[2] is a user-friendly early design stage building energy simulation program.

Aim of the tool

- Energy-10 integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient shell design and mechanical equipment.

[1] CSIRO, Energy Express URL: www.ee.hearne.com.au (accessed October 2006)
[2] Energy10 URL: www.nrel.gov/buildings/energy10 (accessed October 2006)

- The program is geared toward small commercial and residential buildings of 10.000 ft2 or less.
- The program runs an hourly thermal network simulation while allowing users to rapidly explore a wide range of energy efficiency strategies and plot the results in a number of ways.

Which passive solution can be calculated?

- Daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient shell design and mechanical equipment.

limits

- For small commercial and residential buildings of 10.000 ft2 or less.

The user interface

Energy-10 takes a baseline simulation and automatically applies a number of predefined strategies ranging from building envelope (insulation, glazing, shading, thermal mass, etc.) and system efficiency options (HVAC, lighting, daylighting, solar service hot water and integrated photovoltaic electricity generation). Full life-cycle costing is an integral part of the software. Starting from building location, footprint, usage type and HVAC type

The output result

It can generate reference and low-energy target cases in seconds based on full annual hourly simulation.

Ranking graphs for individual strategies can guide early design analysis. Built-in graphs including an embedded version of "DVIEW" allow flexible review of summary and hourly results.

However, overall energy use may be underestimated because HVAC interactions between multiple zones may not be accurately represented. Energy-10 allows rapid exploration of broad design issues effecting energy performance early in design based on a ENERGY PERFORMANCE SIMULATIONTEST (ASHRAE Standard 140- 2001) validated thermal simulation engine.

3.3.8. EnergyPlus Version 1.2.2

Aim of the tool

EnergyPlus[1] is a modular, structured software tool based on the most popular features and capabilities of BLAST and DOE-2.1E.

1Crawley et al. URL:www.energyplus.gov (accessed October 2006)

Main inputs / main outputs

It is primarily a simulation engine: input and output are simple text files.Fig3-11

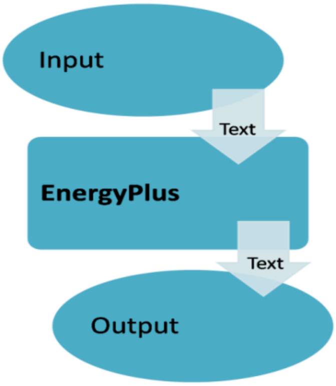

Figure 3-11 Input and output are simple text files.

The subprograms:

EnergyPlus has two basic components—a heat and mass balance simulation module and a building systems simulation module. The building systems simulation manager handles communication between the heat balance engine and various HVAC modules and loops, such as coils, boilers, chillers, pumps, fans, and other equipment/components. EnergyPlus grew out of a perceived need to provide an integrated (simultaneous loads and systems) simulation for accurate temperature and comfort prediction. Loads calculated (by a heat balance engine) at a user- specified time step (15-minute default) are passed to the building systems simulation module at the same time step. The EnergyPlus building systems simulation module, with a variable time step (down to 1 minute as needed), calculates heating and cooling system and plant and electrical system response. This integrated solution provides more accurate space temperature prediction—crucial for system and plant sizing, occupant comfort and occupant health calculations. Integrated simulation also allows users to evaluate realistic system controls, moisture adsorption and desorption in building elements, radiant heating, and cooling systems, and interzone air flow.

The user interface

User-configurable heating and cooling equipment components give users flexibility in matching their simulation to actual system configuration. HVAC air and water loops are the core of the building systems simulation manager—mimicking the network of pipes and ducts found in real buildings. The air loop simulates air transport, conditioning and mixing, and includes supply and return fans, central heating and cooling coils, heat recovery, and controls for supply air temperature and outside air economizer. The air loop connects to the zone through the zone equipment. Users can specify more than one equipment type for a zone.

Based on other softwares

The heat and mass balance calculations are based on IBLAST—a research version of BLAST with integrated HVAC systems and building loads simulation. The heat balance module manages the surface and air heat balance modules and acts as an interface between the heat balance and the building systems simulation manager. The surface heat balance module simulates inside and outside surface heat balances; interconnections between heat balances and boundary conditions; and conduction, convection, radiation, and mass transfer (water vapor) effects. The air mass balance module deals with various mass streams— ventilation and exhaust air, and infiltration— accounting for zone air thermal mass and direct convective heat gains. EnergyPlus inherits three popular windows and daylighting models from DOE–2.1E—fenestration performance based on WINDOW 5 calculations, daylighting using the split-flux inter reflection model, and anisotropic sky models. Fig3-12.

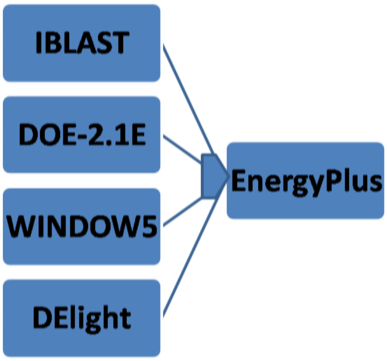

Figure 3-12 Energy plus depend on the above programs.

3.3.9. eQUEST Version 3.55

Aim of the tool

eQUEST 1is an easy to use building energy use analysis tool which provides professional-level results with an affordable level of effort. This is

1 the QUick Energy Simulation Tool URL:www.doe2.com/equest (accessed October 2006)

accomplished by combining a building creation wizard, an energy efficiency measure wizard, and a graphical results display module.

Main inputs / main outputs

A building creation wizard, an energy efficiency measure wizard, and a graphical results display module.

Which passive solution can be calculated?

- Control external heat gains at the external surface of the envelope
- Control and modulate heat transfer through the envelope
- Reduce internal gains
- Use high efficiency active conventional cooling plants

Advantages

- Easy to use.
- The tool allows the user to perform multiple simulations and view the alternative results in side by side graphics.

The user interface

It is accomplished by combining a building creation wizard, an energy efficiency measure (EEM) wizard and a graphical results display module with an enhanced DOE-2.2-derived building energy use simulation program. eQUEST features a building creation wizard that walks through the process of creating an effective building energy model. This involves following a series of steps that help to describe the features of the design that would impact energy use, such as architectural design, HVAC equipment, building type and size, floor plan layout, construction materials, area usage and occupancy, and lighting system. After compiling a building description, eQUEST produces a detailed simulation of building, as well as an estimate of how much energy it would use.

Based on other softwares

Although the results are generated quickly, this software utilizes the full capabilities of DOE- 2.2. Within eQUEST, DOE-2.2 performs an hourly simulation of the building design for a one-year period. It calculates heating or cooling loads for each hour of the year, based on the factors such as: walls, windows, glass, people, plug loads, and ventilation. DOE-2.2 also simulates the performance of fans, pumps, chillers, boilers, and other energy-consuming devices. During the simulation, DOE-2.2 also tabulates your building's projected energy use for various end uses.

The output result

eQUEST offers several graphical formats for viewing simulation results. For instance, graphing the simulated overall building energy on an annual or monthly basis or comparing the performance of alternative building designs.

3.3.10. ESP-r Version 10.1 [1]

Aim of the tool

ESP-r is a general purpose, multi domain building thermal, interzone air flow, intra zone air movement, HVAC systems and electrical power flow-simulation environment.

Main inputs / main outputs

It works with third party tools as Radiance to support higher resolution assessments as well as interacting with supply and demand matching tools.

Which passive solution can be calculated?

Multi domain building thermal, interzone air flow, intra zone air movement, HVAC systems and electrical power flow-simulation environment.

Advantages

- ESP-r has a strong research heritage (e.g. it supports simultaneous building fabric/network mass flow and CFD domains).
- It is used as Consulting tool by architects, engineers, and multidiscipline practices and as the engine for other simulation environments.
- It is multi-domain—building thermal, inter- zone air flow, intra-zone air movement, HVAC systems and electrical power flow—simulation environment which has been under development for more than 25 years.

limits

- It follows the pattern `simulation follows description` where additional technical domain solvers are invoked as the building and system description evolves.
- Users have options to increase the geometric, environmental control and operational complexity of models to match the requirements of particular projects.

[1] ESRU 2005, Clarke 2001URL: www.esru.strath.ac.uk/Programs/ESP-r.htm(accessed October 2006)

- It supports an explicit energy balance each zone and at each surface and uses message passing between the solvers to support inter-domain interactions.

The user interface

Support modules include: climate display and analysis, an integrated (all domain) simulation engine, environmental impacts assessment, 2D-3D conduction grid definitions, shading/insulation calculations, view factor calculations, short-time step data definitions, and model conversion (e.g. between CAD and ESP-r) and an interface to the visual simulation suite Radiance.

3.3.11. PowerDomus Version 1.5

Aim of the tool

PowerDomus, is a whole building simulation tool for analysis of both thermal comfort and energy use.

It models heat and moisture transfer in buildings when subjected to any kind of climate conditions.

Which passive solution can be calculated?

Power Domus allows users to visualize the sun path and inter-buildings shading effects and provides reports with graphical results of zone temperature and relative humidity.

Advantages

- PowerDomus has been conceived to be very user-friendly software in order to stimulate a larger number of users to use building simulation software.

3.3.12. SUNREL Version 1.14

SUNREL[1]is an hourly building energy simulation program developed by NREL's Center for Building and Thermal Systems.

Aim of the tool

SUNREL aids in the design of small energy efficient buildings where loads are dominated by dynamic interactions between the building’s envelope, its environment, and its occupants. The program includes algorithms

[1] SUNREL,Deru et al. 2002 URL: www.nrel.gov/buildings/sunrel (accessed October 2006)

specifically for passive technologies, such as Trombe Walls, programmable window shading, advanced glazing, natural ventilation and rock bins.

Main inputs / main outputs

Algorithms

Which passive solution can be calculated?

Trombe Walls, programmable window shading, advanced glazing, natural ventilation and rock bins.

Limits

- For small energy efficient buildings.

Import/Export with other softwares.

SUNREL can read TMY, TMY2, BLAST, and SUNREL weather files. A graphical interface can be used to create and revise the text input files. The interface allows a single run or parametric runs for a single variable at a time.

3.3.13. Tas Version 9.0.7, May 2005[1]

Aim of the tool

TAS is a suite of software products, which simulate the dynamic thermal performance of building and their systems, integrating natural and forced airflow.

Advantages

- It has a 3D graphics based geometry input that includes a CAD link.
- Tas combines dynamic thermal simulation of the building structure with natural ventilation calculations which include advanced control functions on aperture opening and the ability to simulate complex mixed mode systems.

Limits

The software has heating and cooling plant sizing procedures, which include optimum start. It has a reputation for robustness, accuracy and a comprehensive range of capabilities. There is an extensive Theory Manual detailing simulation principles and assumptions. Developments are regularly tested against ASHRAE, CIBSE[2] and ISO[3] /CEN[4] standards.

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1 Environmental Design Solutions Limited 1989, URL:www.edsl.net (accessed October 2006)
2 Chartered Institution of Building Services Engineers
3 International Standards Organization
4 European Committee for Standardization

The subprograms:

The main module is Tas Building Designer, which performs dynamic building simulation with integrated natural and forced airflow. It has a 3D graphics based geometry input that includes a CAD link.

Tas Systems is a HVAC systems/controls simulator, which may be directly coupled with the building simulator. It performs automatic airflow and plant sizing and total energy demand.

The third module, Tas Ambiens, is a robust and simple to use 2D CFD package which produces a cross section of micro climate variation in a space. Simulation data (shading, surface information etc) is extracted from the Tas 3D model, including an automatically generated air flow network.

3.3.14. TRACE 700 Version 4.1.10

Aim of the tool

It is a whole- building simulation tool for analysis of both thermal comfort and energy use.

The subprograms:

The TRACE 700 program is divided into four distinct calculation phases: Design, System, Equipment, and Economics. The user can choose from several different load methodologies: TETD, CLTD/CLF, ASHRAE RTS, and others. Fig3-13

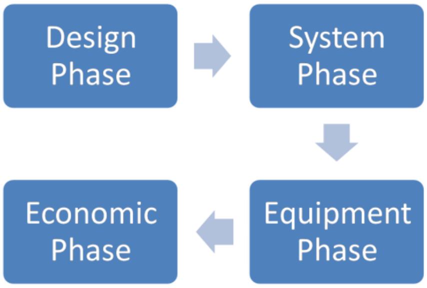


Figure 3-13 The phases of trace700

3.3.15. Comparison Table

Table 3-1 a comparison table between energy performance simulation programs.

3.4. Overview on Projects Used Energy Performance Simulating Programs.

Energy performance simulation programs are used to evaluate, select, integrate, and refine energy, daylighting, and green sustainable design strategies for both new and existing buildings.

In this part of the chapter, an overview will be done on some projects that were designed to reach the green goal using the energy performance simulating programs, these projects will be analyzed according to the categorization of simulation programs (thermal, lighting, and shadow analysis). That is by highlighting the appropriate tool which was selected for the particular analysis task, based on the phase of design and the complexity of the alternative design solutions to be evaluated. All of these projects had reached a LEED™ rating, which indicates the greens of the projects.

3.4.1. Old National Bancorp Headquarters ,2003.

Figure 3-14 The Old National Bancorp Headquarters
(Source: Old National Bancorp Headquarters
URL: http://www.archenergy.com/services/sda//onb/ accessed July 2007)

- **Project Information:**

Location: Evansville, Indiana, USA.
Project Type: Office Building
Designed by: Architects: Veazey Parrott Durkin & Shoulders
Evansville, Indiana - HOK St. Louis, Missouri
Energy/Daylighting/Sustainable Design Consultant
Architectural Energy Corporation Boulder, Colorado
Designed for: Old National Bancorp

Size : 225,000 square feet
Year Constructed / Occupied: 2003 - 2004 / 2004
LEED™ rating: Silver.

- **Sustainable Design Features:**

An integrated energy and environmental design achieves high levels of energy conservation and efficiency, and reduces environmental impact through using the energy performance simulation programs.

- **Energy Performance Simulation Programs**

Thermal Simulation:

The high-rise design incorporates numerous energy and sustainable design features, through modeling the project in Doe-2 program. Fig 3-15

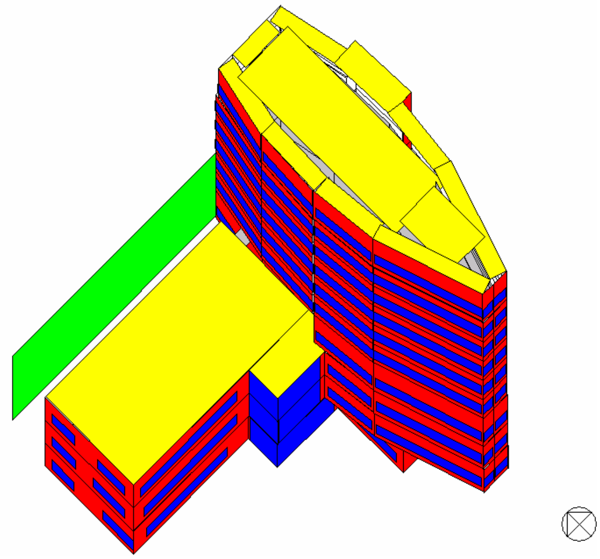
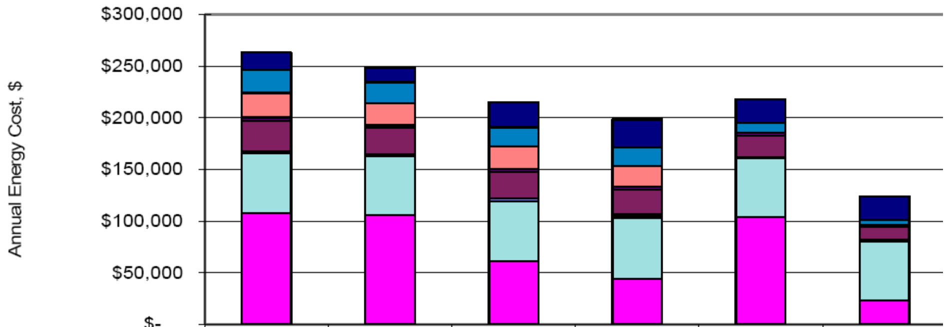


Figure 3-15 Graphic Representation of the DOE-2 Energy Model for the Old National Bancorp Headquarters

(Source: Old National Bancorp Headquarters URL: http://www.archenergy.com/services/sda//onb/ accessed July 2007)

- Improve comfort and indoor air quality, the under floor air distribution system supplies conditioned air to most building spaces, enhancing comfort and air quality.
- Reduce environmental impacts, through choosing Low environmental impact materials and products used throughout interior finishes to reduce indoor pollutants and conserve natural resources.

- High efficiency HVAC system design uses variable frequency drives, enthalpy economizer control, CO2 ventilation supply air control, and direct digital controls to maximize efficiency.
- Enhance worker productivity and well-being by decreasing the solar gain– high performance glazing.
- Reduce annual operating costs. Fig 3-16



	Baseline	Envelope	Lighting	Daylighting	Mechanical	Combo
Gas DHW	$-	$-	$-	$-	$-	$-
Gas Heat	$17,123	$13,346	$24,445	$26,702	$22,941	$22,650
Source Uses	$-	$-	$-	$-	$-	$-
Fans	$21,872	$20,400	$18,871	$17,986	$9,513	$4,800
Pumps & Humidification	$23,902	$20,549	$21,480	$20,323	$433	$315
Tower	$3,011	$2,687	$2,662	$2,567	$2,605	$1,663
DX Cooling	$30,034	$26,398	$26,086	$24,489	$20,659	$12,506
Electric Heat	$1,541	$1,252	$2,337	$2,767	$1,521	$1,849
Plug Loads	$57,981	$57,141	$58,269	$59,114	$56,198	$56,546
Ext. Lighting	$-	$-	$-	$-	$-	$-
Area Lighting	$107,559	$106,031	$61,166	$44,392	$104,310	$23,640

Figure 3-16 Annual Energy Cost Prediction for Various Energy Saving Design Strategies for the Old National Bancorp Headquarters (source: Old National Bancorp Headquarters
URL: http://www.archenergy.com/services/sda//onb/ accessed July 2007)

Lighting and Shadow Analysis and Simulation:

Radiance Analysis tool was used for Electric Lighting Design

- The program was used to design an aggressive daylighting design, with daylighting strategies tuned by orientation.
- The Light Louver Daylighting System redirects daylight onto the open office space ceilings to meet ambient lighting requirements.
- High performance glazing tuned by function and orientation.
- Ambient-task electric lighting design reduces electric lighting energy use, and associated cooling loads; and dimming ballasts with photo sensor controls harvest daylight. Fig 3- 17

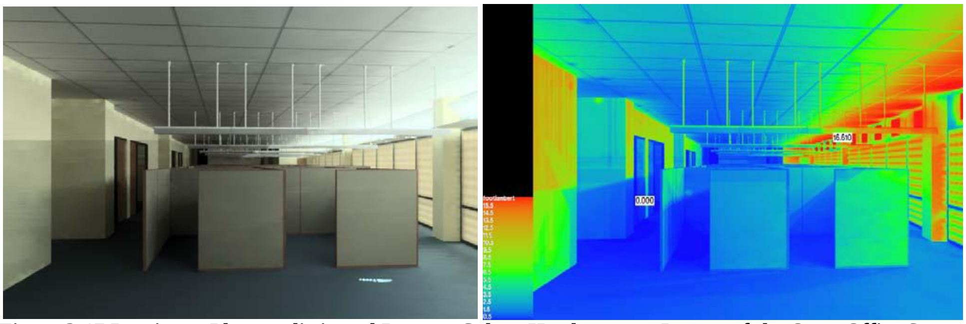


Figure 3-17 Daytime – Photorealistic and Reverse Color –Headquarters Images of the Open Office Space of the Old National Bancorp.
(Source: Old National Bancorp Headquarters
URL: http://www.archenergy.com/services/sda//onb/ accessed July 2007)

3.4.2. Phipps Conservatory and Botanical Gardens Welcome Center, 2005.

- **Project Information:**

Location: Pittsburgh, Pennsylvania, USA.
Project Type: Office Building
Designed by: Architects: IKM, Inc. Energy/Daylighting/Sustainable Design Consultant Architectural Energy Corporation Boulder, Colorado
Size: 11,500 square feet
Year Constructed / Occupied: 2005
LEED™ rating: Silver

Figure 3-18 Welcome Center
(Source: Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ accessed July 2007)

As part of a major renovation and expansion of the historic Phipps Conservatory and Botanical Gardens, a new Welcome Center has been designed and built as the new entry to the site. The Welcome Center contains a cafe, gift shop, coat check, ticket purchasing, restrooms and vertical circulation to the Conservatory, all organized around a central glazed atrium. The architectural design is in keeping with the historical conservatory, while employing state-of-the-art energy efficiency.

- **Sustainable Design Features:**

A partial earth-sheltered structure with gentle sloping walkways was designed. Low or no VOC paints adhesives and other interior finishing materials were used, with high efficiency HVAC and lighting systems with advanced energy management and control system.

- **Energy Performance Simulating Programs:**

Thermal Simulation:

Fluent Computational Fluid Dynamics was used to analyze the Natural Ventilation. Fig 3-19, 3-20.

Vector cuts show the flow regime in the space, with 5 mph wind blowing from the south. Air enters in vertical south-facing vents and lower north-facing vent. Air exits through top north-facing vent and part of the top south-facing vent.

High inlet velocity at lower inlet (400+ fpm) may result in noise and discomfort for occupants.[1]

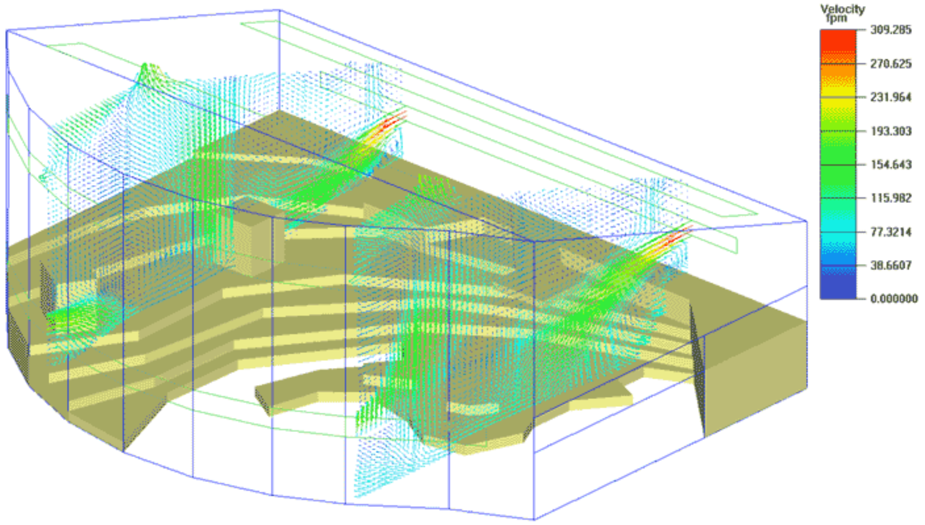


Figure 3-19 The Analysis of Airflow Vectors of the Phipps Conservatory welcome center.
(Source: Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ accessed July 2007)

1Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ accessed July 2007)

Natural ventilation design provides sufficient ventilation to avoid excessive overheating –interior conditions = ambient conditions.

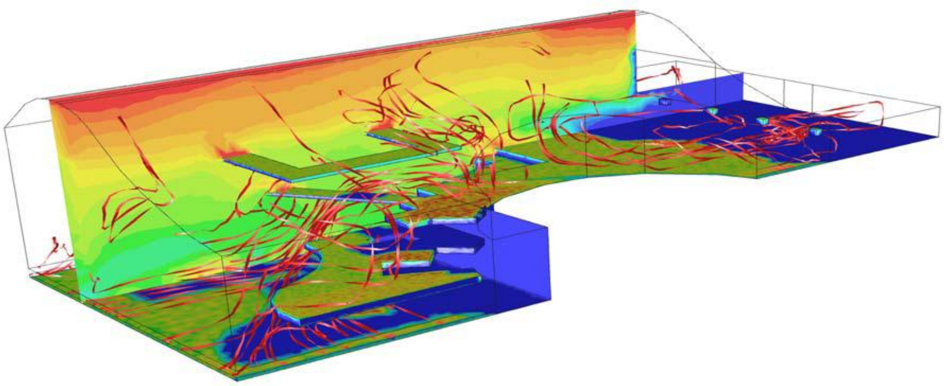


Figure 3-20 The Analysis of Natural Ventilation of the Tropical Forest Building of the Phipps Conservatory and Botanical Gardens Addition
(Source: Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ accessed July 2007)

Solar gains modeled with solar temperatures (accounts for conductive/convective solar gains) and instantaneous direct gain on the floor. No occupant or lighting loads modeled. Glass modeled as 1/4" clear (vertical U = 1.0 Btu/hr-ft-F) (sloped U = 1.15 Btu/hr-ft-F). Opaque walls modeled. [1] Fig 3-21, 3-22.

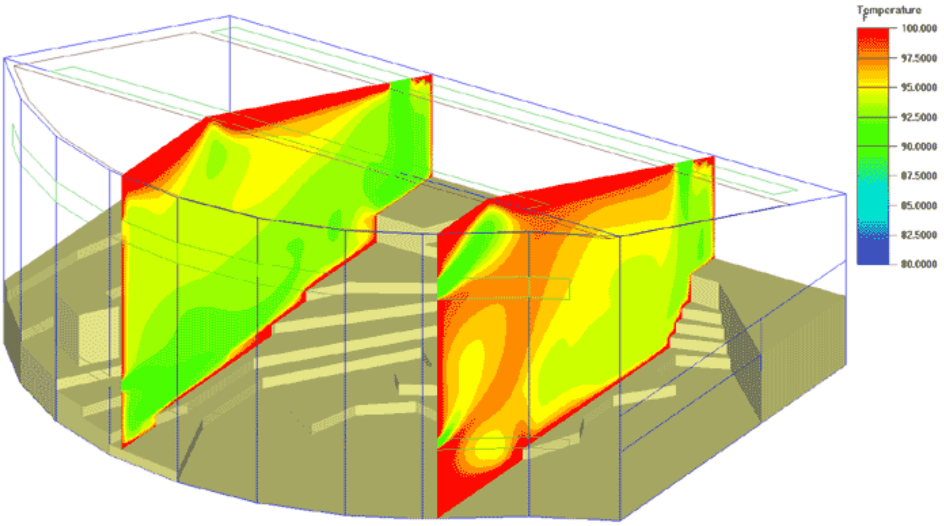


Figure 3-21 The Analysis Temperature Contour Maps of the Phipps Conservatory welcome center.
(Source: Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ accessed July 2007)

1 Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ (accessed July 2007)

Under peak summer conditions, the space will be uncomfortably warm without additional shading. South corner of the building is somewhat stagnant and therefore maintains higher temperatures relative to the rest of the space. Adding vents to the east side of the building may help
The high floor temperature is due to lack of shading modeled high in the space.

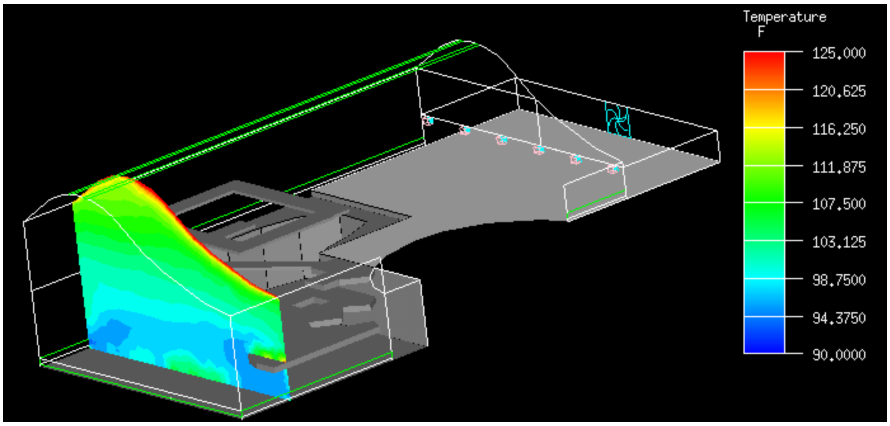


Figure 3-22 The Analysis of Temperature Stratification in the Tropical Forest Building of the Phipps Conservatory and Botanical Gardens Addition
Source: Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ accessed July 2007)

And through the simulation the following points were concluded:

- Horizontal shade cloth provides important solar heat gain control, while still promoting temperature stratification.
- Increasing inlet and outlet areas do not significantly improve conditions, but can improve local ventilation coverage.
- Big screens cut the ventilation rate in half, and thus must be accounted for in the sizing of the inlet and outlet vents.

<u>Lighting and Shadow Analysis and Simulation:</u>

Radiance Analysis tool was used for lighting and shadow simulation for:
The 34-foot high glass atrium, which provides daylighting to the visitor lobby and ticketing areas. A dramatic setting for the stairway up to the Conservatory. Fig 3-23

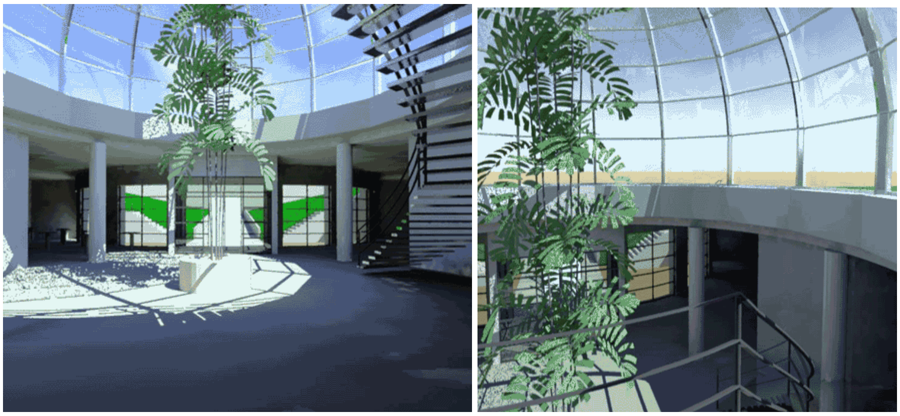


Figure 3-23 Radiance Image of the interior of the Phipps Conservatory Welcome Center
(Source: Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ accessed July 2007)

- A high performance glazing, tuned by orientation, with varying frit density to control solar heat gain and daylighting.
- The control system which automatically opens and closes operable windows at two levels in the atrium to release stratified heated air and to induce natural ventilation. Fig 3-24

Figure 3-24 Radiance Image of the Interior of the Tropical Forest Building of the Phipps Conservatory And Botanical Gardens Addition
(Source: Phipps Conservatory and Botanical Gardens Welcome Center
URL:http://www.archenergy.com/services/leed//phipps/ accessed July 2007)

3.4.3. National Museum of the U.S. Marine Corps, 2007.

- **Project Information:**

Location: Quantico, Virginia, USA.

Project Type: Museum.

Designed by: Architect: Fentress Bradburn Architects Denver, Colorado - Energy/Daylighting/Sustainable Design Consultant Architectural Energy Corporation Boulder, Colorado

Size: 137,000 square feet

Year Constructed: Currently under design

LEED™ rating: Silver

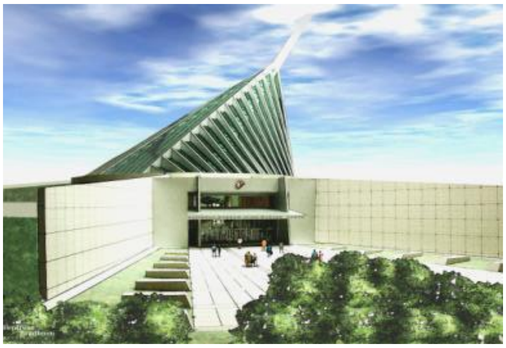



Figure 3-25 National Museum of the U.S. Marine Corps
(Source: URL:http://www.archenergy.com/services/sda/tools//vmfacfd/index3.html accessed July 2007)

- **Sustainable Design Features:**

Sustainable design features was used to fulfill green design by using the following:

  - Earth covered exhibit halls
  - Large Central Gallery, with high performance glazing and ventilation systems
  - High performance glazing throughout Energy Performance Simulating Programs.

- **Energy Performance Simulating Programs:**

Thermal Simulation:

By using Computational Fluid Dynamics Analysis model using the following features:

Standard HVAC sizing and modeling based on mixed air in space (uniform temperature). If space is stratified, these methods over predict air flow requirements.CFD analysis provides more accurate design information. Fig3-26

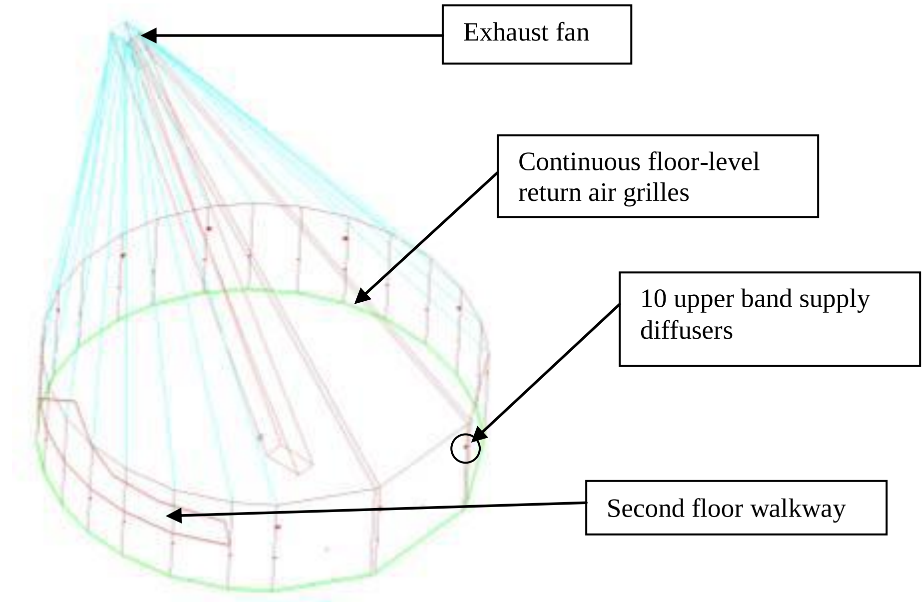


Figure 3-26 CFD Building Model
(Source: URL: http://www.archenergy.com/services/sda/tools//cfdmodeling/ accessed July 2007)

- Lower cooling supply air flow rate will satisfy the design cooling load
- Lower heating supply air flow rate will satisfy the design heating load
- Air exhaust from the top of the Central Gallery during the summer is required to control temperatures and radiant heat transfer
- In the summer, Central Gallery air temperatures will stratify between 20 and 45 degrees from the top of the "drum" to the top of the skylight, depending on exhaust flow rate. Fig 3-27, 3-28.

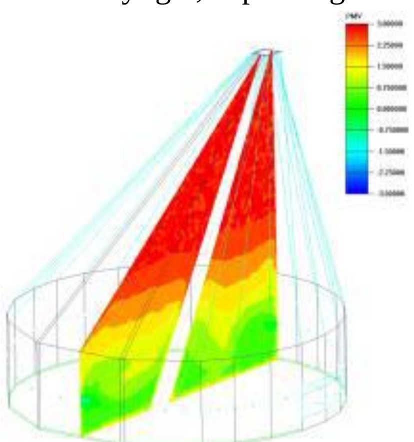


Figure 3-27 Predicted Mean Vote Comfort Calculation
(Source: URL: http://www.archenergy.com/services/sda/tools//cfdmodeling/ accessed July 2007)

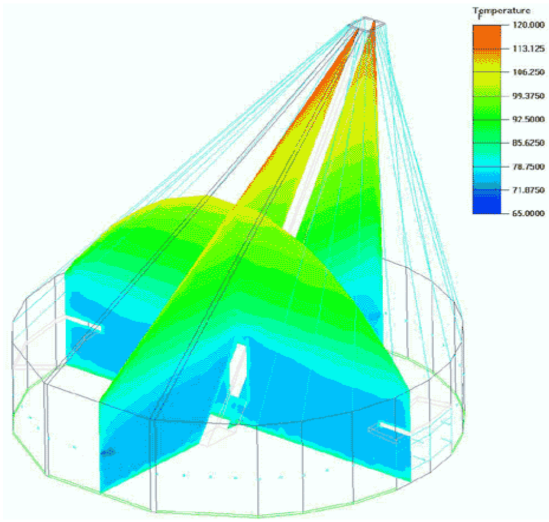


Figure 3-28 AirPak Analysis of Temperature Stratification in the Museum.
(Source: URL: http://www.archenergy.com/services/sda/tools//cfdmodeling/ accessed July 2007)

<u>Lighting and Shadow Analysis and Simulation:</u>

Using Radiance in the early stages of the design process not only improve the lighting performance of buildings, but also lead to the production of better architecture and energy savings Analysis tool was used for lighting and shadow simulation. Fig 3-29

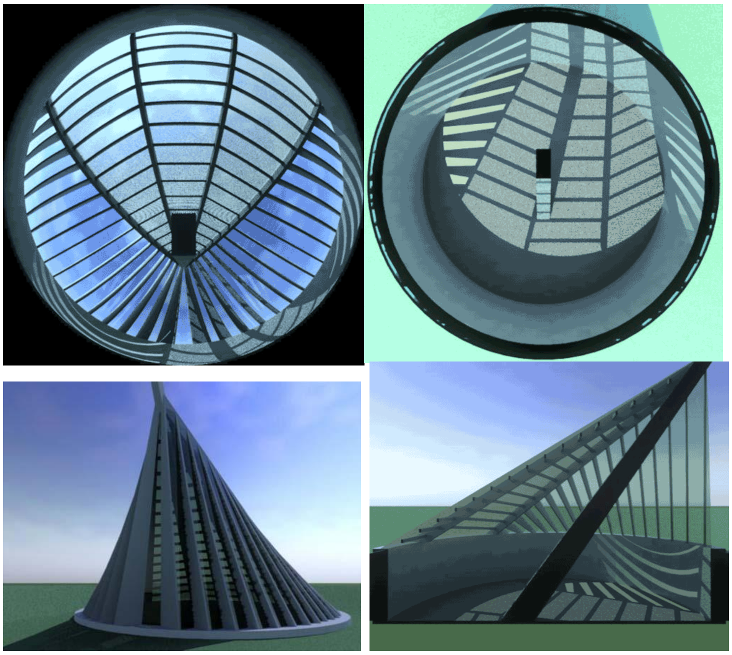


Figure 3-29 Different views for the lighting shadow analysis model.
(Source: URL:http://www.archenergy.com/services/sda/tools//vmfacfd/index3.html accessed July 2007)

3.4.4. Indianapolis International Airport Mid-Field Terminal,2007.

Project Information:

Location: Indianapolis, Indiana,USA.

Project Type: Airport Terminal and Concourses.

Designed by: Architect: AeroDesign Group Hellmuth, Obata + Kassabaum, Inc. - Energy/Daylighting/Sustainable Design Consultant Architectural Energy Corporation Boulder, Colorado

Size: 1.2 million square feet

Year Constructed: Currently under design.

LEED™ rating: Silver

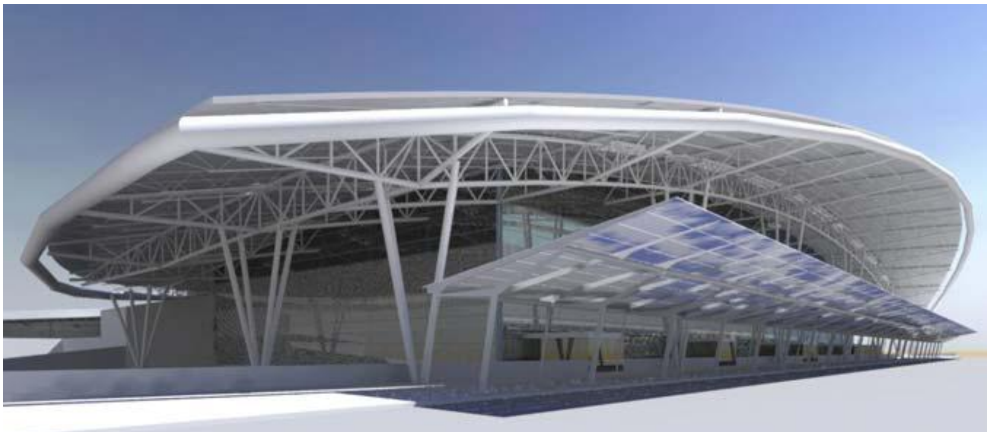


Figure 3-30 Indianapolis International Airport
(Source: Indianapolis International Airport URL: http://www.archenergy.com/services/leed//indyairpt_leed/ accessed July 2007)

- **Sustainable Design Features:**

A whole-building integrated sustainable design process has been used to identify, evaluate, select, and incorporate energy efficiency and sustainable design strategies. The primary sustainable design concepts integrated into the terminal and concourse design by using the energy performance simulation programs.

- **Energy Performance Simulating Programs:**

Thermal Simulation:

Using DOE-2 analyzes design alternatives that improve energy efficiency while maintaining thermal comfort and cost-effectiveness of buildings. By providing simple or increasingly detailed description of a building design or alternative design options, accurate estimates of the proposed building's energy consumption, interior environmental conditions, and energy operation cost can be obtained. Fig 3-31, 3-32.

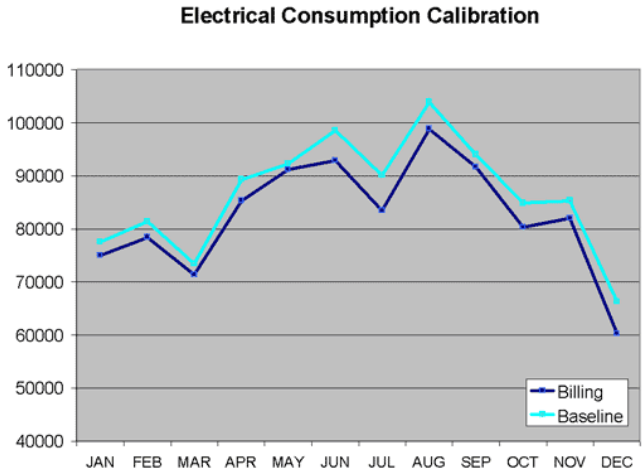
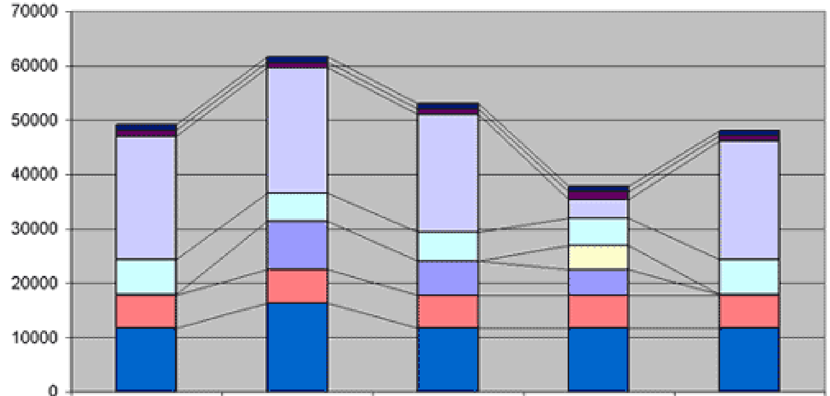


Figure 3-31 Electrical and Gas Consumption Graphs Used for Energy Model Calibration.
(Source: Indianapolis International Airport
URL:http://www.archenergy.com/services/sda/tools//doe2gallery/index9.html accessed July 2007)



	VAV w/CO2 Sensors	ASHRAE	Evap	GSHP	VAV w/OA Unit
Hot Water (Gas)	982.3282	982.3282	982.3282	926.7272	982.3282
Pumps & Aux.	1030.249308	1016.676398	1017.894605	1404.598369	1030.249308
Space Heat (Gas)	22762.0906	23146.7809	21676.6162	3432.1656	21681.0906
Vent. Fans	6469.703343	5116.871052	5274.051705	5060.261335	6551.722627
Space Heat (Elec)	0	0	0	4556.707511	0
Heat Reject.	0	0	104.422497	0	0
Space Cool	62.15146522	8960.763872	6221.847111	4600.612851	62.15146522
Misc. Equip.	6068.569647	6068.560072	6068.568279	6068.569647	6068.569647
Area Lights	11745.88023	16393.2701	11745.88132	11745.88023	11745.88023

Figure 3-32 Energy Modeling Parametric Analysis Graph " Illustrating the Effect of Applying Various Energy Saving Measures to a Minimally Code Compliant ASHRAE Baseline Model.
(Source: Indianapolis International Airport
URL:http://www.archenergy.com/services/sda/tools//doe2gallery/index9.html accessed July 2007)

- High efficiency mechanical systems throughout with displacement air distribution and a radiant floor system in the Civic Plaza.

Fig 3-33

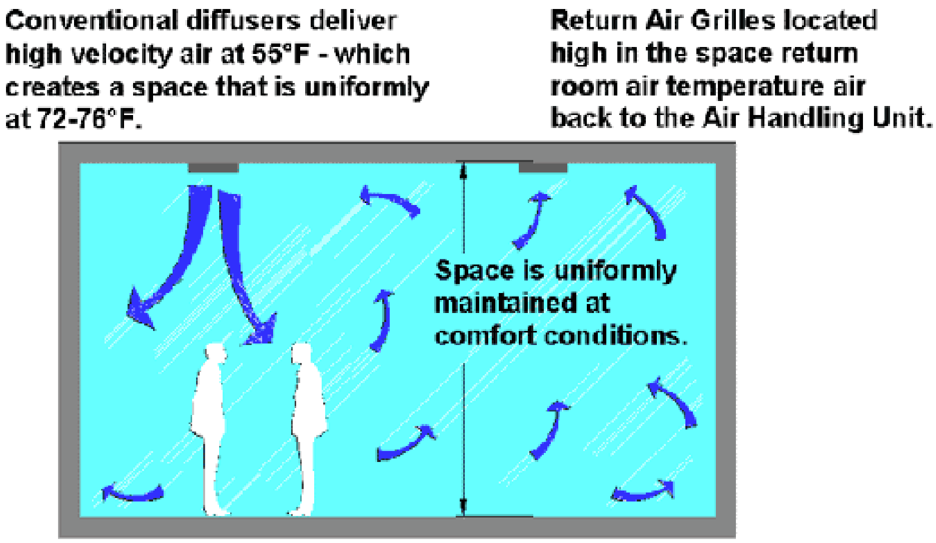


Figure 3-33 Diagrams Illustrating the Benefit of a Displacement Air Delivery System Over a Conventional Delivery System

(Source: Indianapolis International Airport
URL:http://www.archenergy.com/services/sda/tools//doe2gallery/index9.html accessed July 2007)

- Low environmental impact materials used throughout for all primary and secondary systems and interior finishes.

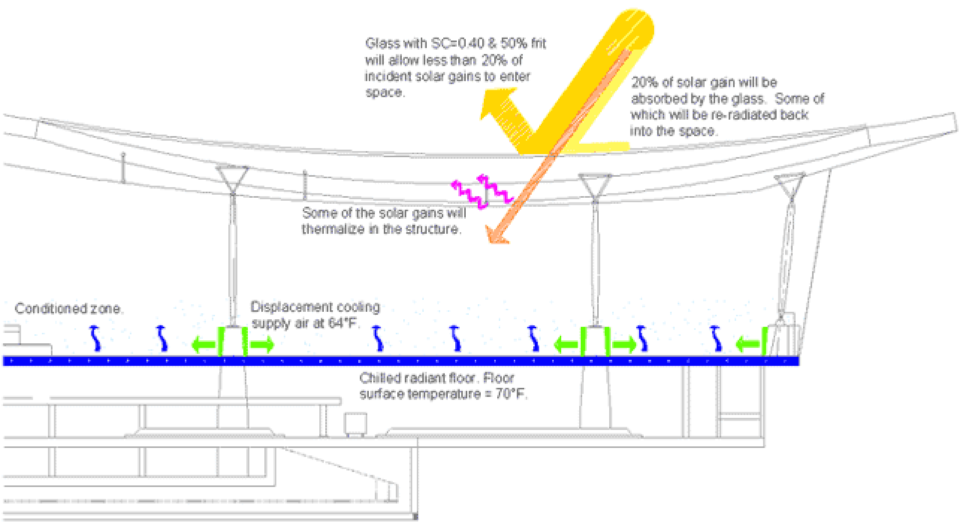


Figure 3-34 Diagram of Radiant Cooling Design Alternative for Indianapolis Airport Midfield Terminal Complex

(Source: Indianapolis International Airport
URL:http://www.archenergy.com/services/sda/tools//doe2gallery/index9.html accessed July 2007)

Lighting and Shadow Analysis and Simulation:

An aggressive daylighting design strategy is employed throughout the Terminal and Concourses, with linear daylights used in the Departure Hall and Security Halls; side-daylighting strategies used in the Departure Hall and the concourses, and a large circular skylight above the Civic Plaza. Radiance Analysis tool was used for Electric Lighting Design .Fig 3- 35.

Figure 3-35 Radiance analysis of an innovative daylighting distribution strategy for the Indianapolis International Airport

(Source: Indianapolis International Airport URL: http://www.archenergy.com/services/leed//indyairpt_leed/ accessed July 2007)

- High performance envelope including increased insulation levels, and high performance glazing "tuned" by function and orientation.
- High efficiency electric lighting system throughout with dimming controls in day lit zones.

3.4.5. Science Museum of Minnesota – Science House,2003.

- **Project Information:**

Location: along the banks of the Mississippi River, USA.

Project Type: Science House.

Designed by: Architect: Barbour/LaDouceur Architects -The Weidt Group

Size: 1,500 square feet

Year Constructed: Design of the project was completed in 2002 and the building construction completed in 2003.

LEED™ rating: registered

Figure 3-36 Science Museum of Minnesota.
(Source :Andersen Continuing Education Architectural Record, August 2003)

- **Sustainable Design Features:**

The inception of Science House began with a donation to the Science Museum of Minnesota to begin the design and construction of a building that would be a net electrical producer. Science House and Science Park began with several overarching goals that defined the building in its role and context. Science House will:

- Serve the Science Museum of Minnesota as a dynamic working model for energy efficiency and renewable energy.
- Serve as a beacon for the Science Museum's environmental initiatives.
- Serve as an interpretive center for environmental programming.
- Serve as a headquarters building in a landscape that inspires the imagination, teaches Earth-systems science, and connects people to each other and to their natural and built environment.

Through the program refinement and conceptual design processes, more specific green goals were set. The sustainable design features for the building were to[1]:

- Demonstrate the integration of building design concepts with state of the art energy efficiency and renewable energy features.
- Reduce annual energy consumption requirements.

[1] Andersen "Continuing Education," Architectural Record, August 2003.

- Function as a net energy producer by using an integrated photovoltaic (PV) roof system to generate excess energy on an annual basis and supply it back to the Science Museum.

- **Energy Performance Simulating Programs:**

The design development stage of the project focused on evaluating a wide range of energy efficiency strategies, using computer energy simulation modeling, to balance the annual energy consumption requirements of the building with the electric generation capacity of the photo-voltaic system attached to the building's roof. Fig3-37

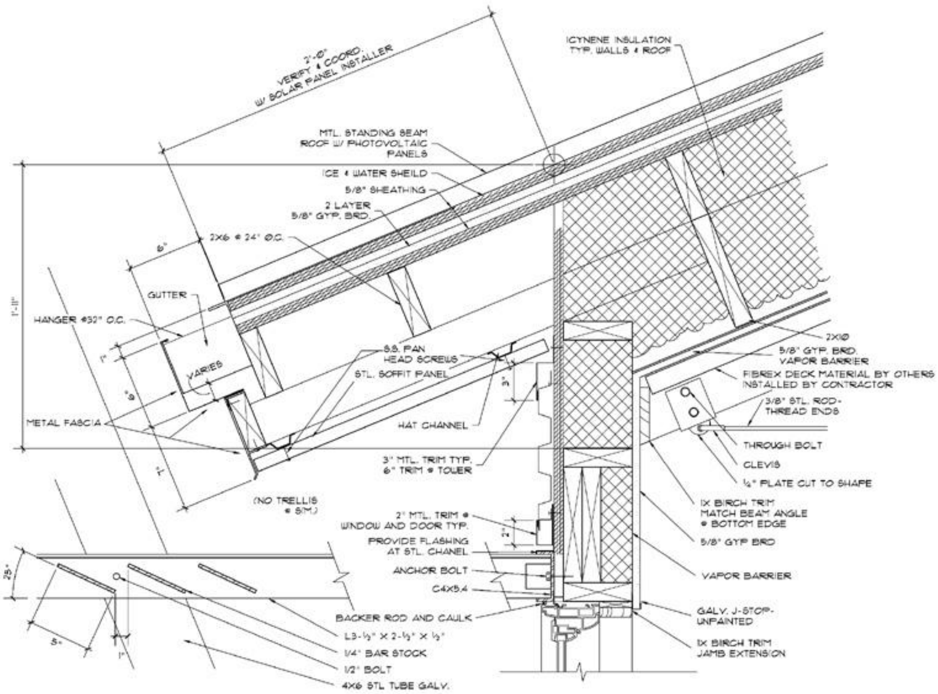


Figure 3-37 Photovoltaic system design.
(Source: Science House URL:http://www.eere.energy.gov/buildings/database/viewbigpix.cfm?BinaryID=2337. Accessed July 2005)

<u>Thermal, Lighting and Shadow Analysis and Simulation:</u>

DOE-2 is a sophisticated thermal and luminous building simulation program, so it was also used in the lighting simulation.

- Thermal calculations are made on an hour-by-hour basis, using typical yearly climatic data, to determine the building's energy loads and system requirements the computer models are simulated using the DOE-2. Parameters include outdoor dry and wet bulb temperature, wind velocity, cloud cover, solar radiation, and incidence angle for each hour of the year.

The evaluation process during the design phase included the following steps:

- Develop a baseline energy code model of the schematic design. Fig3-38

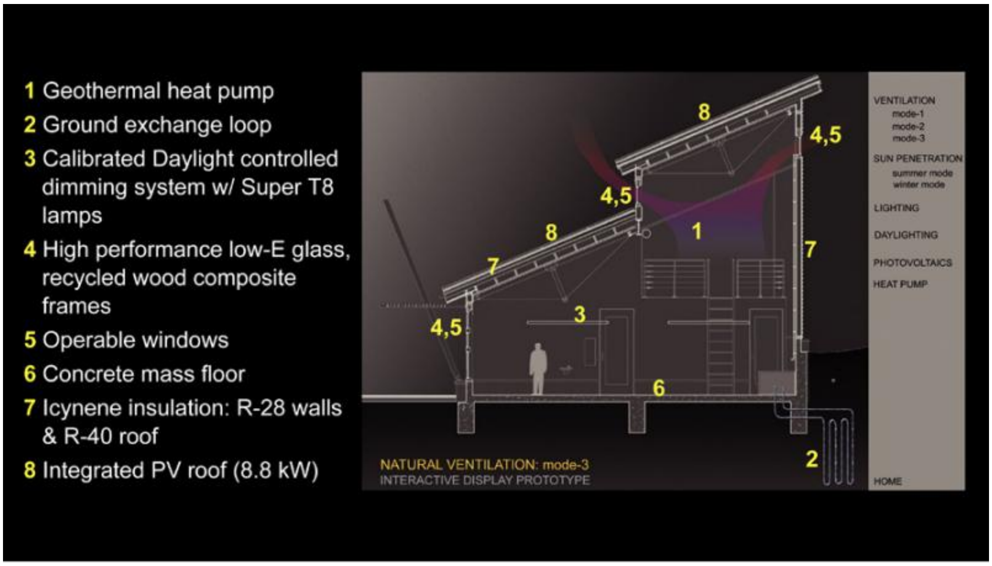


Figure 3-38 Developing the schematic design.

(Source: Science House URL:http://www.eere.energy.gov/buildings/database/viewbigpix.cfm?BinaryID=2337. Accessed July 2005)

- Identify a range of isolated energy efficiency strategies for all building system categories, architectural, mechanical and electrical and plumbing.
- Simulate the energy performance of each isolated energy efficiency strategy. Fig 3-39.

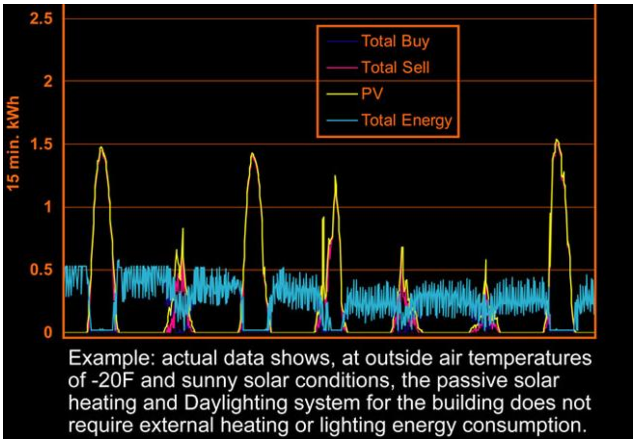


Figure 3-39 Weekly energy use simulation results.
(Source: URL:http://www.eere.energy.gov/buildings/database/images.cfm?ProjectID=284 Accessed July 2005)

- Identify the cost-effectiveness for each isolated energy efficiency strategy.
- Design workshop with design team and owner to create bundled sets of the most promising isolated strategies. Fig 3-40

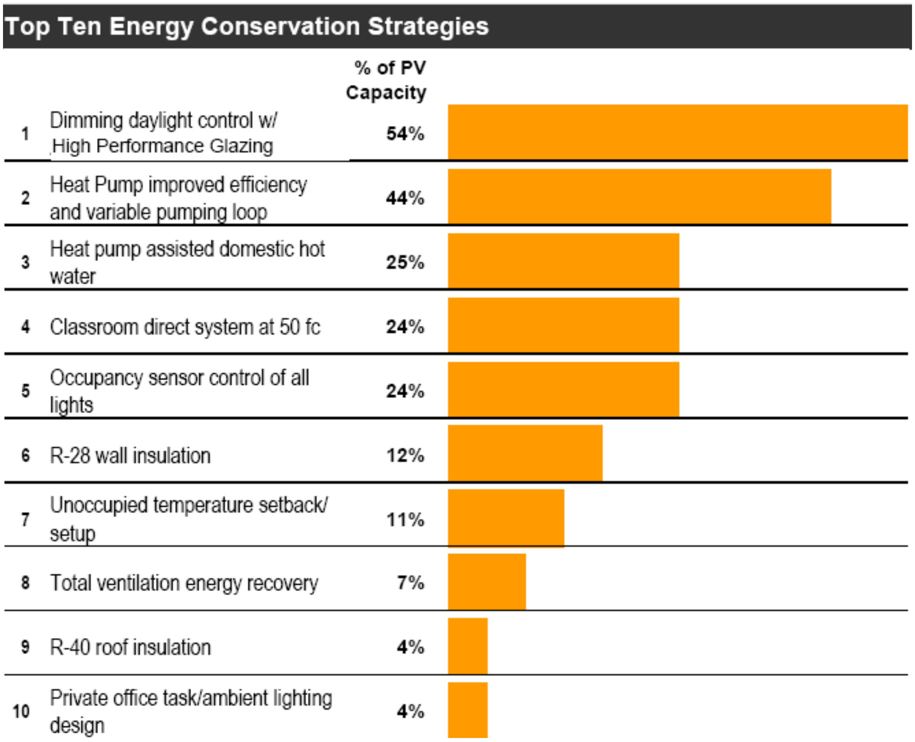


Figure 3-40Top ten conserving energy strategies.
(Source: Andersen "Continuing Education," Architectural Record, August 2003.)

- Simulate the energy performance of the bundled strategy sets. Fig 3-41.

Strategy Description	Bundle		
	1	2	3
Envelope			
Daylight dimming controls w/ igh Performance Glazing	●	●	●
North clerestory glazing	●	●	●
4 foot overhang on south side	●	●	●
R-40 roof insulation - icyenene	●	●	●
R-28 wall insulation - icyenene	●	●	●
Lighting			
Occupancy sensor control of all interior lighting systems	●	●	●
Dual level or manual dimming switching in the classroom and office	●	●	●
Classroom direct lighting system at 50 foot candles	●	●	●
Office task/ambient lighting system at 25 to 30 foot candles	●	●	●
Storage, Vestibule and Restroom lighting at 15% better than code	●	●	●
HVAC			
High efficiency ground source heat pumps with variable pumping	●	●	
Premium efficiency ground source heat pumps with variable pumping			●
Unoccupied temperature control 55F heating / 85F cooling	●	●	●
CO2 control of outside air – interlocked with bathroom exhaust	●	●	●
Total ventilation energy recovery	●	●	●
Domestic hot water			
Electric resistance only	●		
Heat pump assisted DHW w/ electric resistance back-up		●	●

Figure 3-41 Identification of Bundles
(Source: Andersen "Continuing Education," Architectural Record, August 2003.)

- Select a final bundle to implement. Fig 3-42.

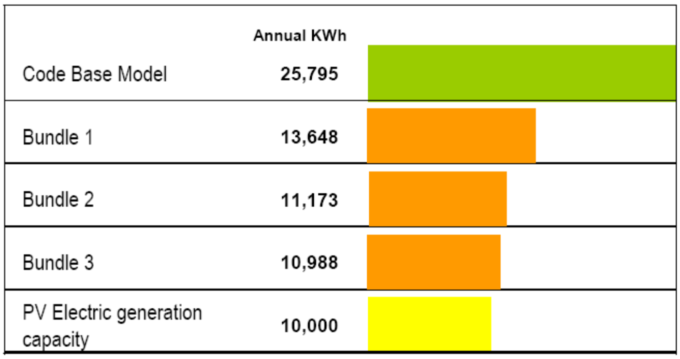


Figure 3-42 : Annual Energy Consumption` for Bundles by End Use KWH/year
(Source: Andersen "Continuing Education,"Architectural Record, August 2003.)

3.5. Conclusion

Architects make decisions which address the complex interactions between people, the environment, and the building systems that serve them.

The use of Energy performance simulation programs in the design stage of the project focuses on evaluating a wide range of energy efficiency strategies, throughout the project's various lifecycle stages.

As a result of the comparison performed throughout this chapter the following points were concluded.

- There is a weak common language between the energy performance and other programs.
- The input/output files vary a lot from one program to another.
- The Energy performance simulation programs mainly consist of Sub-programs or depend on features of other softwares.
- Two programs were having the most useful features by combining the thermal, lighting, and shadow simulations together in the same simulation tool 'DOE-2 & ECOTECT'.

Only one program will be selected to use for the next chapter in the case study. The selection was based on the benefits through the graphic interface, ease of design, flexibility of definitions and breadth of analysis; outweigh the awareness of adapting to the thermal framework, and extensive help files.

And by analyzing the examples, it was concluded that inspite of the existence of the thermal, lighting, and shadow simulation inside the same energy performance simulation programs, designer still use program for thermal simulation and another program for lighting and shadow analysis.

Chapter 4

Simulation Analysis for Thermal Performance

4.1. Introduction.

At the conceptual stage, building geometry is fluid and subject to constant change, with solid quantitative information relatively scarce. A range of energy performance programs such as building thermal modeling, daylighting assessment, indoor environment quality assessment, and plant and systems modeling, may need to be employed and commence assessment during the sketch design stage to evaluate and guide the building and services design. This is the core of the integrated design process and requires extensive communication, coordination, and integration of assessment outcomes and adjustment required amongst the architect, services engineers, and various consultants. This chapter presents ECOTECT software, which has a unique approach to conceptual building design. It features a designer-friendly 3D modeling interface fully integrated with a wide range of performance analysis and simulation functions. It is used in the thermal simulation for the case study at three different locations in Egypt. The evaluation will depend on the thermal comfort factor simulation for the building, regardless of any other simulations that can be used.

4.2. The Digital Design Modeling Tool.

“ECOTECT” software was chosen because of its Intelligent and flexible interface, capable of satisfying the following requirements:

- Reducing the perceived input requirements to define a model.
- Maximum utilization of whatever information is input, for example: knowing the internal temperature of any space at a certain time is so easy.
- Allowance for constant development and refinement of the model, for example: adjusting the thermal properties of the zone (natural-ventilation, occupancy, and comfort band) increase the accuracy of the results.
- Reducing input requirements and making the maximum use of whatever is input requires a step beyond traditional geometric interfaces that focus on geometric entities.
- Interoperability with CAD systems can be achieved by supporting the DXF file format Fig 4-1, a standard format amongst such

applications .which supports: 2D and 3D information either ASCII or binary formats simple geometric description.

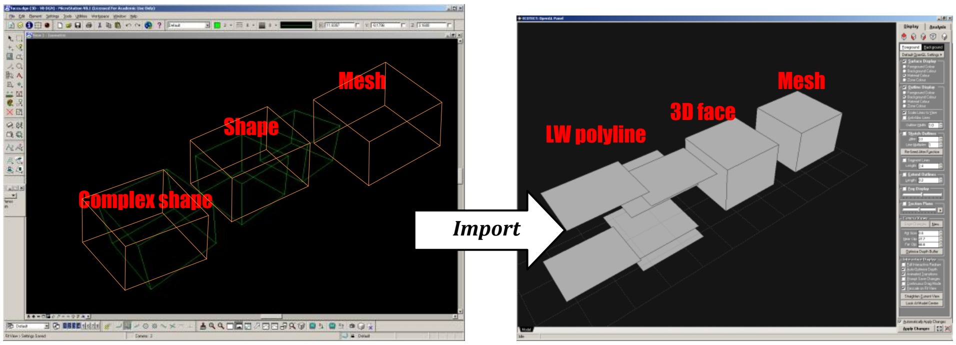


Figure 4-1 The insertion from CAD DWG to ECOTECT file.

Temperatures in ECOTECT are not straight air temperatures. They are actually environment temperatures, formed from a component of mean radiant temperature (basically area weighted surface temperatures) and air temperature. This makes them a better indicator of comfort than a simple air temperature. Whilst it is possible to quantify comfort or discomfort at a particular time, longer-term comfort levels are more difficult. For example, it is simple to calculate the **Total Discomfort Hours** (the total time each month that the internal zone temperature is outside the comfort band), then a single hour 1deg above counts exactly the same as an hour 10deg above. Hence it is more useful to display **Comfort Degree Hours** (the sum of the number of degree above and below the comfort band that the internal zone temperature is for each hour of each month).

- The thermal graph or diagram defines what thermal state the building design is currently in, which allows comparing it with many other states. That way, any changes that move the current performance more towards the desired thermal performance are steps in the right direction – provided with a clear validation mechanism by which an objectively judge could be done for the subsequent design decisions.
- In a free running building such as residential buildings it can be useful to see just how often an occupant is likely to be uncomfortable in any of its spaces. This is simply a matter of establishing a set of comfort conditions and then seeing how often and by how much each space departs from these conditions. The used software allows

choosing the algorithm by which the current comfort temperature is calculated, including both fixed band and adaptive comfort methods. This measures the running monthly average temperature with the hourly variation in degree hours.

4.3. Case Study

There are large amounts of materials used and energy consumed during the construction and operation of an average building. One of the growing areas of interest is the implementation of green technologies when designing new buildings that are more energy efficient and have less impact on the natural environment during operation. The emphasis to reach greenness of the building on this case study was mainly placed on the technical issues such as materials, building components. These are also an energy related design concepts.

In addition, there is awareness that the key for applying this demand is linking resource efficiency to:

- **lower operating costs** – homes that use less heating/cooling and use less water have lower monthly utility bills. Also more durable building components reduce upkeep and replacement costs.
- **increased comfort** – homes that are resource-efficient have more even temperatures throughout the home, with less drafts and better humidity control.
- **lower maintenance** – in most families today, free time is a precious commodity—lawns that require less watering and decks that require no sealing/staining are more than welcomed.
- **increased resale value** – more and more homeowners are reporting better selling value with documented lower monthly utility bills.
- **improved environmental quality**—in and out of doors – builder attention to moisture control construction details, low VOCs paints, and air exchange/filtration can contribute to a more comfortable and healthy indoor environment. Builder attention to overall resource-efficiency can contribute to a better local environment.

4.3.1. Choosing the Case Study.

The focus of this case study is currently new residential construction. It touches on the larger issue of land development and recognizes the potential and importance represented by modeling but mainly deals with issues relating to construction of a new home on an individual plot of land.

4.3.2. Methodology of Applying the Case Study.

The case study follow a chain of design strategies starts by stating the project's information, the case study program "digital design modeling tool" used, the building thermal simulation plan, then the thermal simulation modeling.

4.3.3. Case Study Information:

Location: Different locations in Egypt.

Project Type: Residential House.

Designed by: Architect: Hossam Mohamed Abd-Elaziz, the Housing and developing Bank, Cairo, Egypt.

Year Constructed: Design of the project was completed in 2004

- **Green Design Features:**

The design approach adopted for low- income family House is an excellent example of integrated design. One of the unique aspects of the project was that building was designed to be built at different locations in Egypt[1]. Use of integrated design process, eco-friendliness, minimal ecological footprint, energy efficiency, use of renewable energy sources and rain harvesting, waste recycling and reuse, and 'green' material-based construction.

The design of the building focuses on the following key green principles:

- **Principle 1: Conserving energy**.

Improving energy efficiency at the very beginning of the design process by:

- The entire building should be regarded as a system in which passive and active features interact. Provide a broader range of other passive comfort design elements where passive and low energy cooling contributes substantially to comfort.
- Consider intrinsic building comfort performance inherent in the building form, irrespective of energy and systems availability.
- Design elements are integral to the building form to create comfort outcomes rather than through attached mechanical solutions. The achieved comfort contribution is through design elements integral to building superstructure cost centers.
- Design elements can interact with related design elements; notably safari roof for increased thermal insulation from the building interior,

[1] Housing and Developing Bank URL: http://www.hdb-egy.com/ (accessed October 2006)

humidification and shading associated with understory. Invest in improving understanding of technology and building science.

- Understand the application of whole of life impact and cost concepts. Understand life cycle costs and financial parameters which affect investment in energy efficiency.

- **Principle 2: Working with climate.**

Thermal comfort is related to the building occupant's experience and reaction to the indoor environment. The success or failure of a building is often measured by how comfortable people feel in the building. The climate conditions and the comfort zone for that location must be established. The amount of days that require conditioning such as heating, cooling, humidification or dehumidification should be established. Therefore, in designing this case study in Egypt -which has different climatic regions- the climatic analysis, must be considered. A climate analysis will determine what proportion of the year some conditioning to the external environment is required. Typical year data should be used warily as this may not take into account extremes experienced on a year to year basis. Other considerations such as microclimate in which the building is located should be identified in modifying open field weather station data[1].

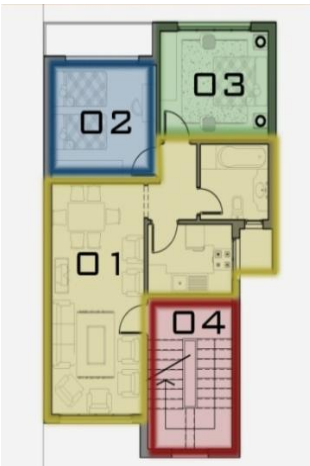
- **Principle 3: Minimize new resources.**

Every time a new green building is built the designers find new ways to recycle the demolition waste. Recycling material can save money, help the environment, and increase the chance of receiving a positive green building rating.

- **Principle 4: Respect for users.**

This is by understanding the following points in the design:
The needs of the user, number of people who will be using the building, and the type of people using the building. The objectives of the user will be cooperated, by understanding the functions that will be undertaken in the building. The building was designed to be executed in phases the first phase is the heart of the building where it is suitable for two Persons. The next phases are going to be the future extensions when the number of users increases. Fig 4-2.

1 Weather data is available from the internet URL: www.EnergyPlusWeather Data egypt.html. (Accessed October 2006).



Phase 01:
Kitchen +Bathroom + Living room
(Bedroom +Living)
Phase 02:
Phase 01+ Bedroom
Phase 03:
Phase 02+ Bedroom
Phase 04:
Multiple floors.

Figure 4-2 The different phases of the selected building,
(Source: Housing and developing Bank URL: http://www.hdb-egy.com/ accessed October 2006)

- **Principle 5: Respect for site.**

Evaluate site resources is the solution for respecting it, the asses of the soil type, vegetation, water, and wetlands. Do not disturb important natural areas. Implement a landscaping scheme that reinforces the plant and animal populations that exist there.

Check for solar orientation for natural light, passive heat gain and ventilation.

4.4. The Testing Parameters.

Thermal comfort relates to the building occupant's experience and reaction to the indoor environment. Occupant thermal comfort is not only about the actual air temperature of a space but also air movement, humidity, radiant temperature. Fig 4-3. The success or failure of a building is often measured by how comfortable the people feel in the building. Research indicates there is variation from person to person and even the same person on different days.[1] There are however a range of attributes that can be incorporated in the design to facilitate occupant comfort.

- The climate conditions and the comfort zone for that location must be established.
- The amount of days that require conditioning such as heating, cooling, humidification or dehumidification should to be established.

[1] Green Star Diffusion, Green Building Council of Australia, p.13 URL http: www.gbcaus.org (Accessed January 2007).

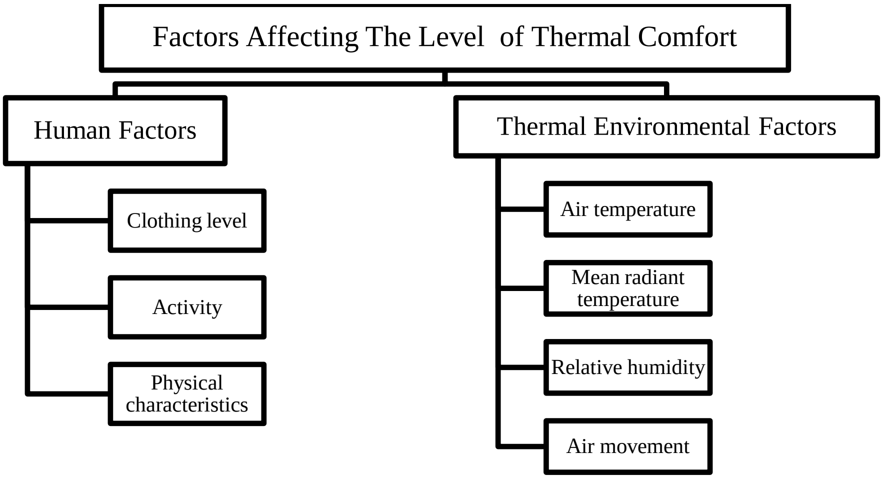


Figure 4-3 Factors affecting thermal comfort.

4.4.1. The Thermal Simulation Method.

This simulation deals only with occupant thermal comfort and does not address other important factors such as indoor air quality, glare, and noise. Considering the following points:

- Solar radiation can help keep building occupants warm even when the air temperature around them is considerably lower. Seasonal variation is taken up in part by the way people dress. In winter people tend to wear more clothes.
- If building occupants are able to control their environment by opening windows, switching on heaters and lights, occupants are more tolerant of their thermal environment. The use of thermostatic valves on radiators could help occupants keep control of their local thermal environment.
- Radiant systems should be considered as well as the usual convective systems as they provide a more even distribution of heat that is more perceptible to the occupants than conductive or convective systems.

There are other examples including air movement for perceived cooling but common sense must be used in the designing of systems. It is important to understand that the comfort zone is a range of conditions rather than a specific design temperature.

4.4.2. Modeling Setting:

From a range of factors, the thermal environment can be modeled in a building. In computer modeling information required includes:

1. Location of heating and cooling elements.
2. Location of vents and extracts.

3. Location of windows.
4. Equipment and occupation density.
5. Geometry of floor plate including ceiling height.

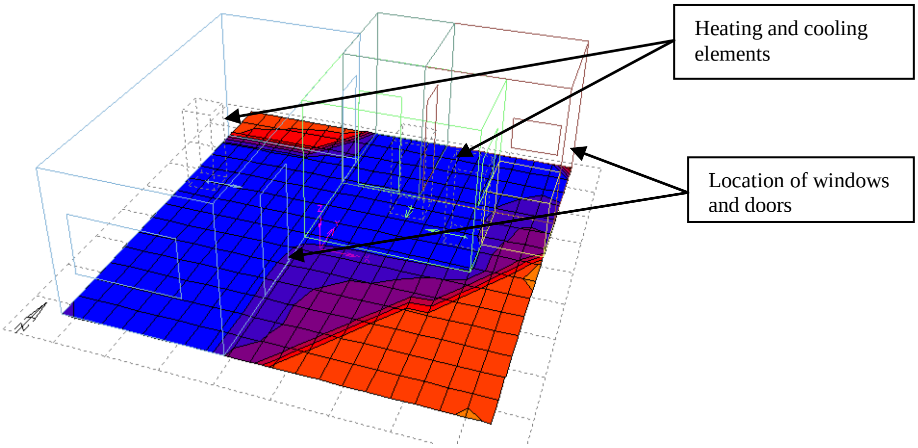


Figure 4-4 The thermal model.

4.5. The Climatic Data Used in Simulation.

A large amount of researches had been done to classify Egypt into several climatic zones depending on geographical and climatically base, in order to help the architect to design buildings more suitable for each climate.[1] Table 4-1.The simulation for the case study will be applied at three out of six climatic zones in Egypt (Cairo, Alexandria, and Aswan) , these cites are main cites in Egypt . Fig 4-5.

Figure 4-5 The three locations for the case study.

1 سوزيت ميشيل عزيز ، "تقييم السلوك الحراري كأداء لتصميم التجمعات السكنية في مصر" رسالة دكتوراة، كلية الهندسة–جامعة القاهرة1989، صـ91-158

Table 4-1 The climatic zones of Egypt.
(Source: Housing and Building Research Center "Egyptian map of building materials and the manufactories depending on it" Manufacturing of Building Materials Department. 2001.)

Climatic Zone	The Cities	The Climatic Data Through The Summer Period					
		The Shaded Air Temperature		Solar Energy		Wind Velocity m\sec	Relative Humidity %
		Max. Temp. ^0C	Min. Temp. ^0C	Horizontal Planes Watt\m^2	Vertical Planes Watt\m^2		
High Hills Zone	Saint Catrine	30	9	Varies 154-640.	950	Varies	5.0 - 10
The North Coast	Salom, Sedy-Brany, Marsa Matroh, El Dbaah, Alexandria, Rashid, Damitta, Port Saied, El Arish	30.6	15.8	Varies 155-645	950	7.8 North West	59-80
The East Cost	El Toor, Hurgada, Safaga	35	17.5	Varies 155-645	1028	12.3 North West	40-60
Cairo and The Delta	Zagazig, Tanta, Banha, Mansoura, Fayed, Ismalia	35	14	Varies 155-645	1000	5.3 North West	50-80
Middle Egypt	Giza, Fayoum, Bny Swife, Asuit, Siwa, Frafra, El Dakhla, El Khrga	40	15.3	Varies 164-645	1025	4.6 North West	20-70
Far South Egypt	Naga Hmady, Mllawy, Komombo, Luxer, Aswan	45	17.4	Varies 170-645	1030	7 North West	10_40

Detailed climate data is vital to any energy efficient and responsive passive building design, and thermal simulation. There are a wide range of climatic factors that can be recorded. However, many are interrelated and can often be derived from a combination of other measures. In terms of hourly data, the following is the minimum required for both pre-design site analysis and post-design thermal performance simulation:

1. Dry-Bulb Temperature (°C or °F)
2. Relative Humidity (%)

3. Solar Radiation (W/m²)
4. Wind Speed (km/h, mph, or m/s)
5. Wind Direction (Deg, 1/4, 1/8 or 1/16ths)
6. Cloud Cover (%, tenths or octal)
7. Rainfall (mm or in)

All these data can be found in the weather file, which can be downloaded from the internet URL: www.EnergyPlusWeather Data egypt.html. [1]This was used for the case study simulation.

4.6. Spatial Analysis of the Base Case.

The case study is the first phase of the building, in which it consists of living, bathroom, and kitchen. This building will be divided into 5 zones.
The orientation of the building will be north south direction .Fig 4- 6. This phase is suitable for two persons to live in; some of the external walls will be changed to be internal walls on applying the next phases.

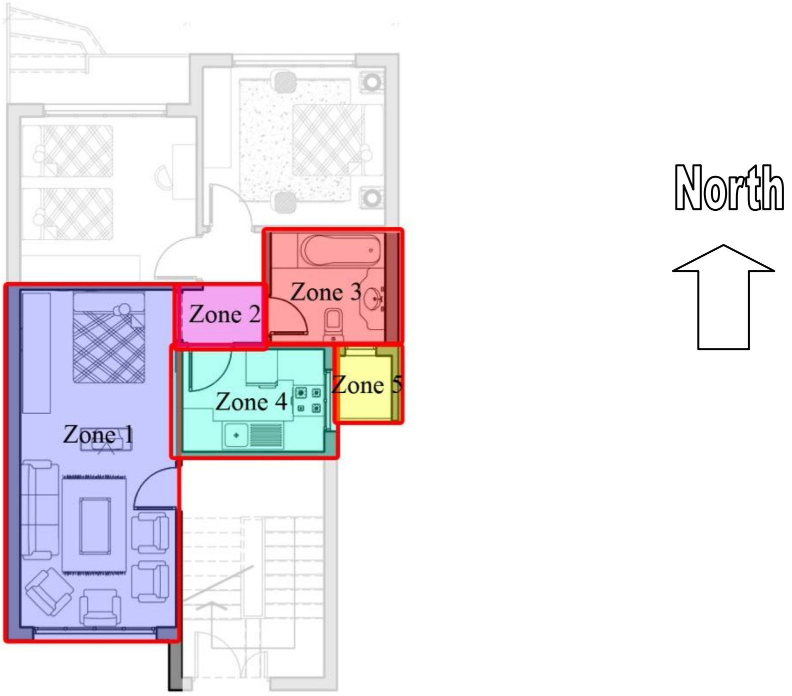


Figure 4-6 The case study zones and orientation.

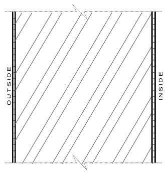
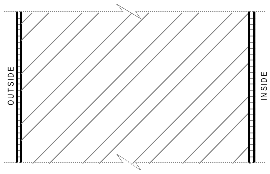
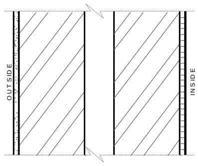
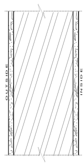
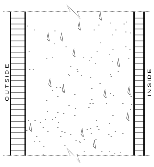
1 (Accessed October 2006).

4.7. The Thermal Simulation.

The base case will have the same properties and components, the only variable will be the wall material, five kinds of wall materials will be applied and measured for their effect on the thermal performance of the building. Table 4-2.

This simulation will be applied at three locations in Egypt as mentioned before. Each location will apply that base case using the same variables.

Table 4-2 The wall materials which will be applied in the thermal simulation

Wall material description.	*Cross section*
25cm red bricks with 2 cm plaster from inside and 3cm plaster from outside.	
50cm stone bricks with 2cm plaster from inside and 3cm plaster from outside.	
12cm double bricks with cavity 5cm in-between with 2cm plaster from inside and 3cm plaster from outside.	
12cm brick Egyptian fire with 2cm plaster from inside and 3cm plaster from outside.	
25cm concrete blocks with 2cm plaster from inside, 3cm plaster from outside.	

All cases will be modeled, and then the thermal performance will be calculated. The results will be shown through:

- The total monthly solar exposure for the building modeled in which it affects on the thermal comfort. Fig 4- 7

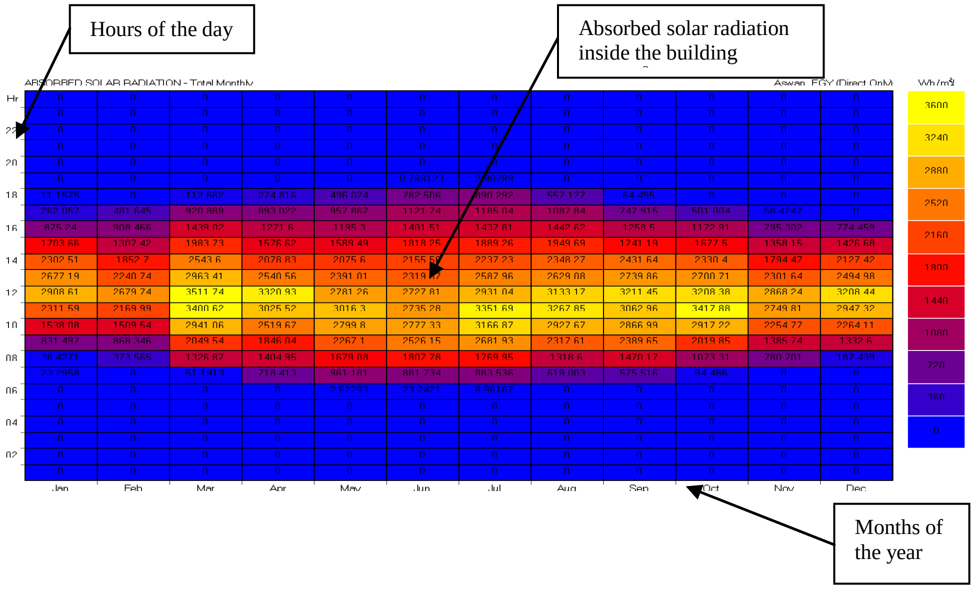


Figure 4-7 The graph analysis of the solar exposure.

- The monthly total degree hours of thermal discomfort (sums the number of degrees above and below the comfort band for each hour of each month, not only the time). Fig 4- 8.

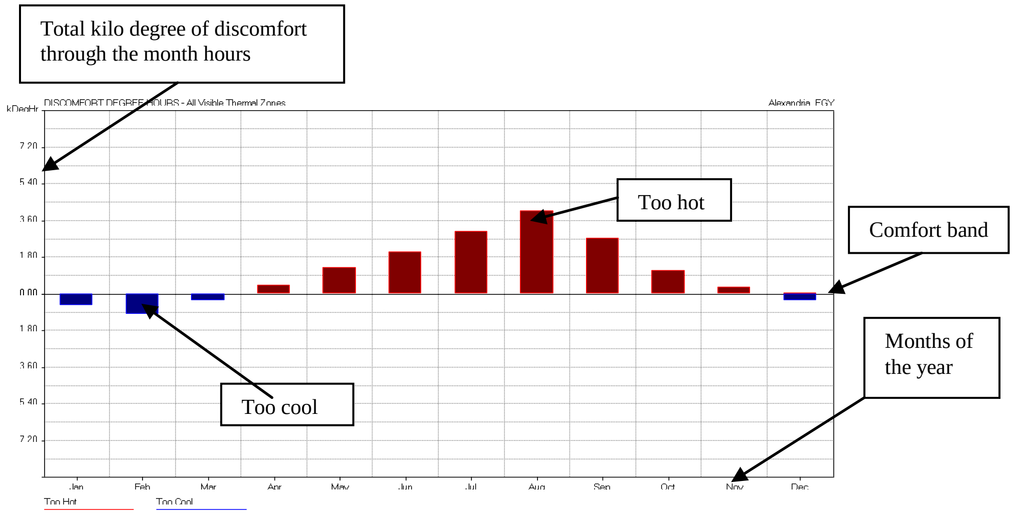


Figure 4-8 The graph showing the total discomfort through the whole year.

4.7.1. Base Case A -1

- Location: Cairo – Egypt.
- Number of users: 2 inhabitants
- Material used:

  Walls are 25 cm red bricks with 2cm plaster from inside and 3cm plaster from outside

  Ceilings are 12cm of reinforced concrete covered by 2cm humidity insulation,5cm foam insulation then 7cm concrete layer then 5cm sand 2cm mortar and final finish is cement tiles.

  Floor is concrete slab with ceramic floor tiles.

  Windows are single glazed glasses and hold by timber frames.

  The doors are solid core door and made of oak timber.
- Internal loads:

  Cooker, fridge, T.V.

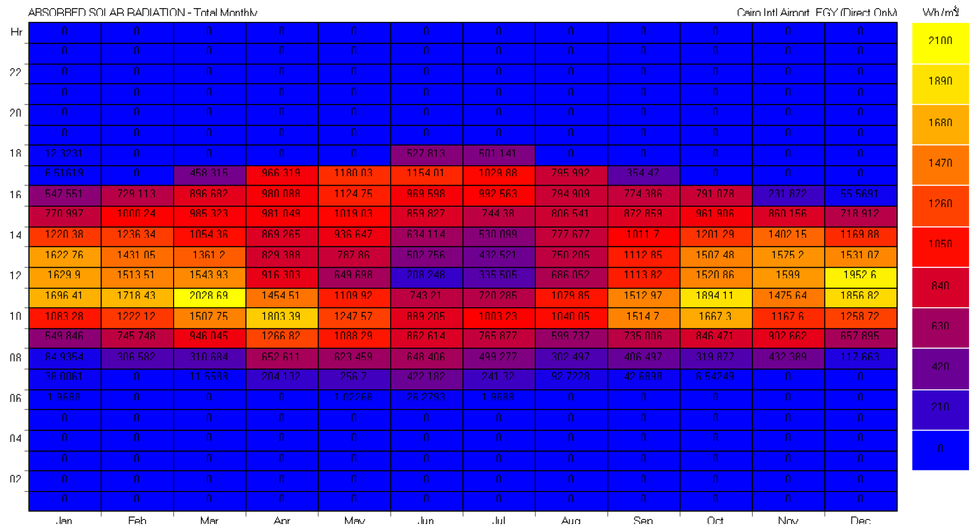


Figure 4-9 The amount of absorbed solar radiation by the walls per month for the base case A-1.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 114329 watt\m^2. Fig 4-9 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-10 shows the total sum of discomfort degree of the whole hours of the month. July is the month which has the biggest discomfort time with total 2.5 kilo degree hours of discomfort.

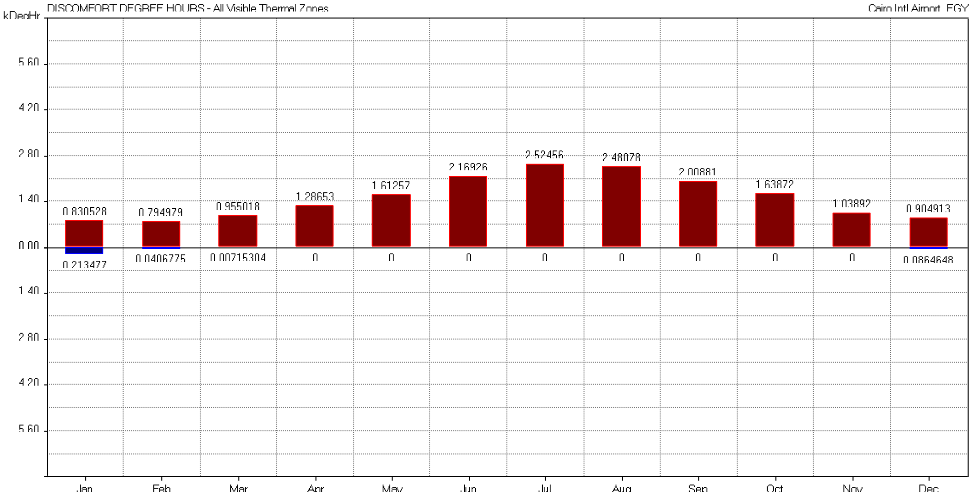


Figure 4-10 The total discomfort degree hours of the building through the year for the base case A-1.

4.7.2. Case A-2

- Location: Cairo – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 50 cm stone bricks with 2cm plaster from inside and 3cm plaster from outside

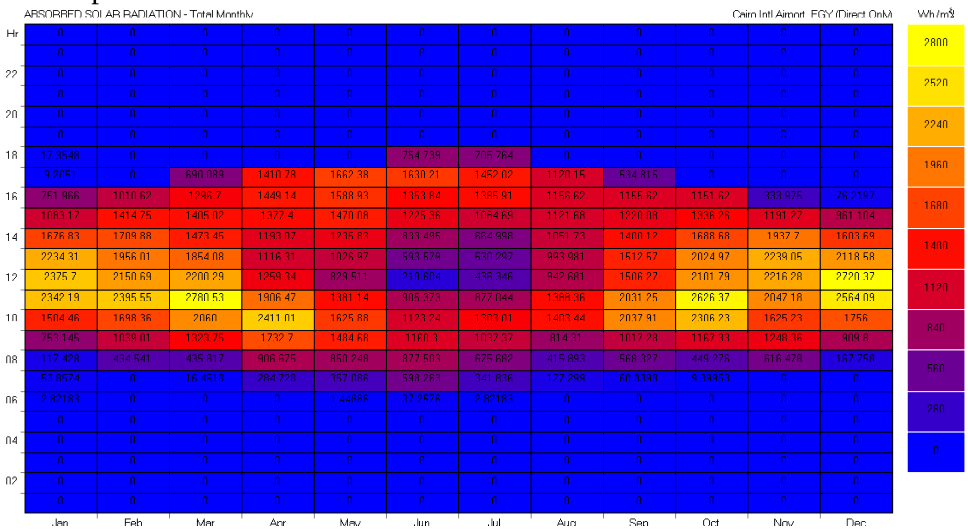


Figure 4-11 The amount of absorbed solar radiation by the walls per month for case A-2.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 157408 watt\m^2. Fig 4-11 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-12 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 4.7 kilo degree hours of discomfort.

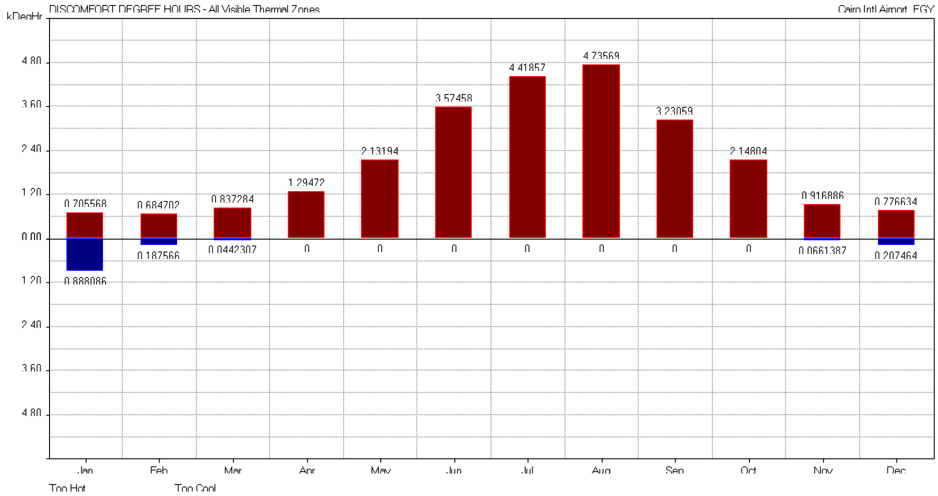


Figure 4-12 The total discomfort degree hours of the building through the year for case A-2.

4.7.3. Case A- 3

- Location: Cairo – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 12 cm double red bricks with cavity 5cm in-between with 2cm plaster from inside and 3cm plaster from outside.

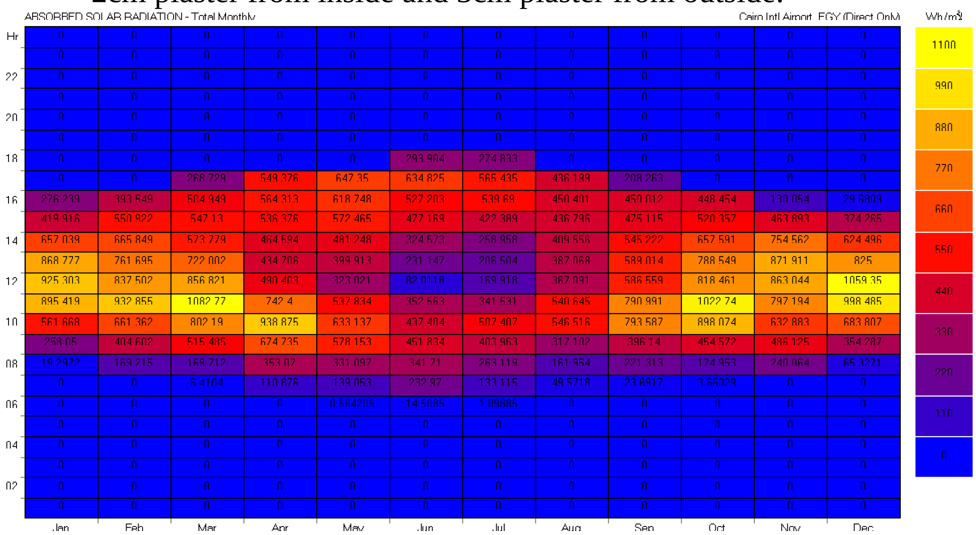


Figure 4-13 The amount of absorbed solar radiation by the walls per month for case A-3.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 61146 watt\m^2. Fig 4-13 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-14 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 4.6 kilo degree hours of discomfort.

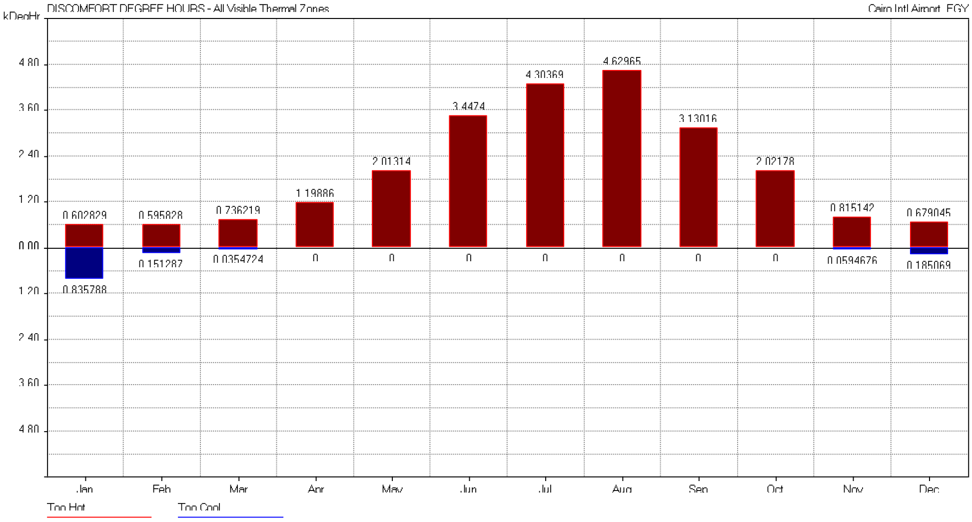


Figure 4-14 The total discomfort degree hours of the building through the year for case A- 3.

4.7.4. Case A-4

- Location: Cairo – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 12 cm brick Egyptian fire with 2cm plaster from inside and 3cm plaster from outside

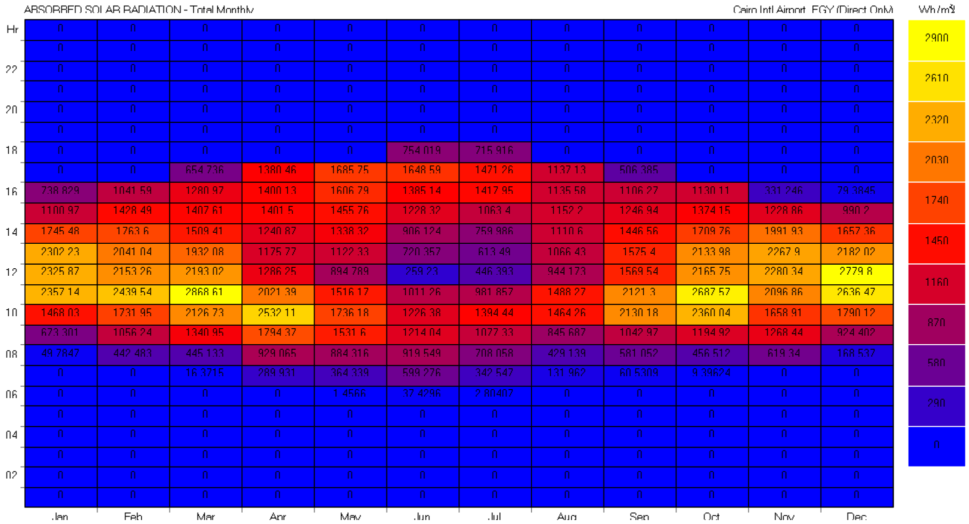


Figure 4-15 The amount of absorbed solar radiation by the walls per month for case A-4.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 161597 watt\m^2. Fig 4-15 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-16 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 5.2 kilo degree hours of discomfort.

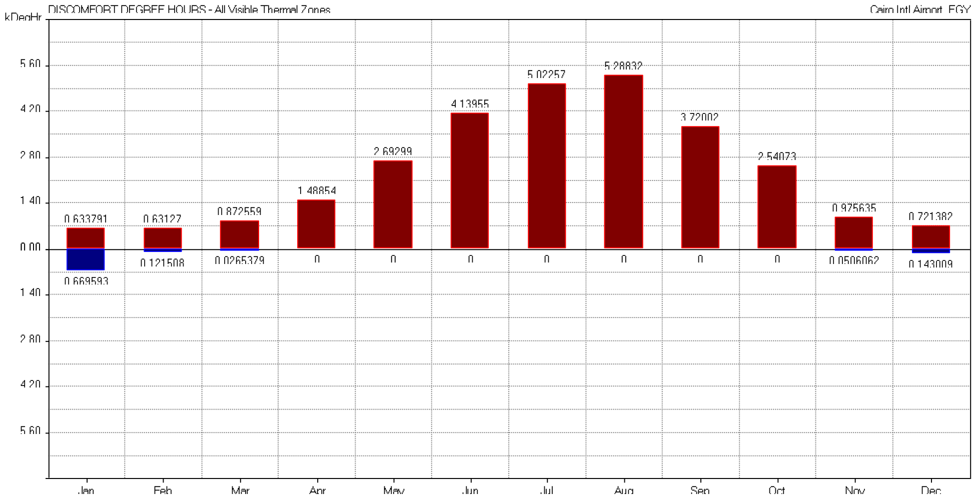


Figure 4-16 The total discomfort degree hours of the building through the year for case A-4.

4.7.5. Case A-5

- Location: Cairo – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 25cm concrete blocks with 2cm plaster from inside, 3cm plaster from outside.

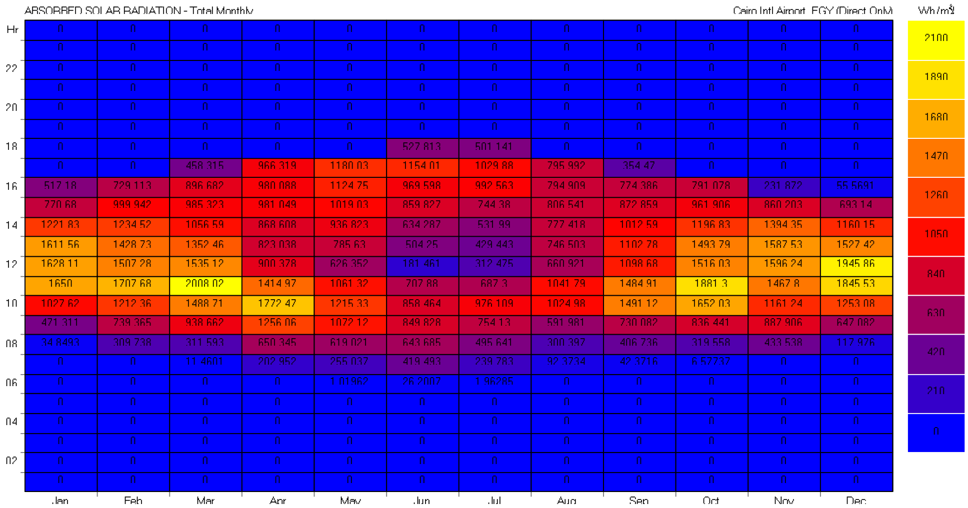


Figure 4-17 The amount of absorbed solar radiation by the walls per month for case A-5.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 113118 watt\m^2. Fig 4-17 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-18 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 5.4 kilo degree hours of discomfort.

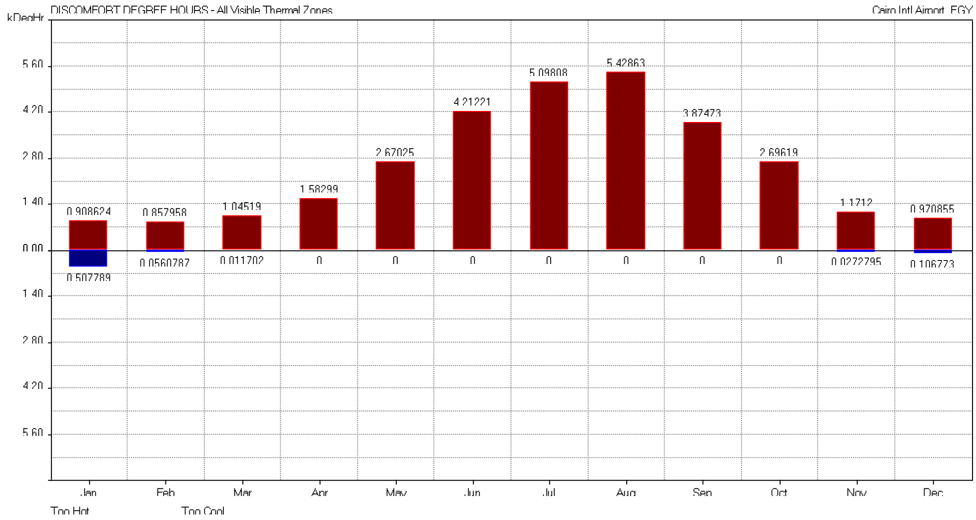


Figure 4-18 The total discomfort degree hours of the building through the year for case A-5.

4.7.6. Base Case B-1

- Location: Alexandria – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 25 cm red bricks with 2cm plaster from inside and 3cm plaster from outside

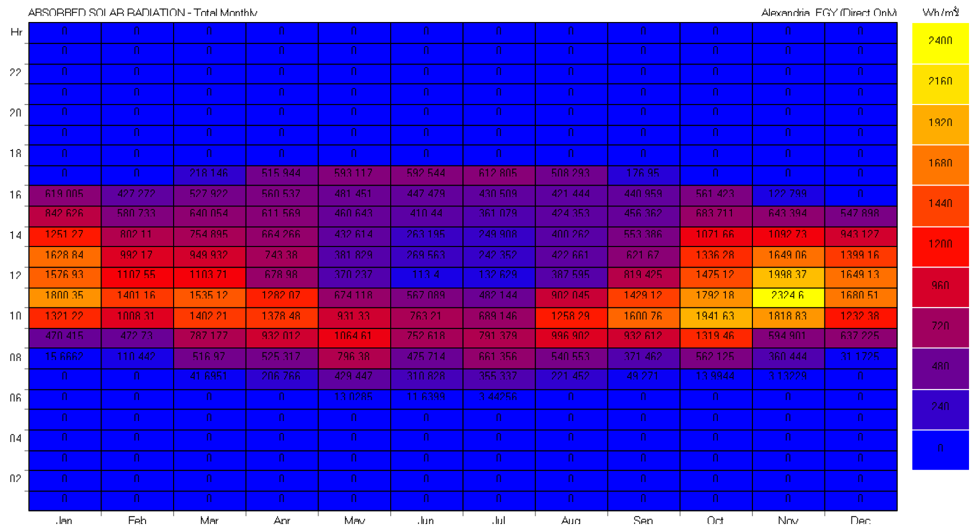


Figure 4-19 The amount of absorbed solar radiation by the walls per month for the base case B-1.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 93047 watt\m^2. Fig 4-19 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-20 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 4.3 kilo degree hours of discomfort.

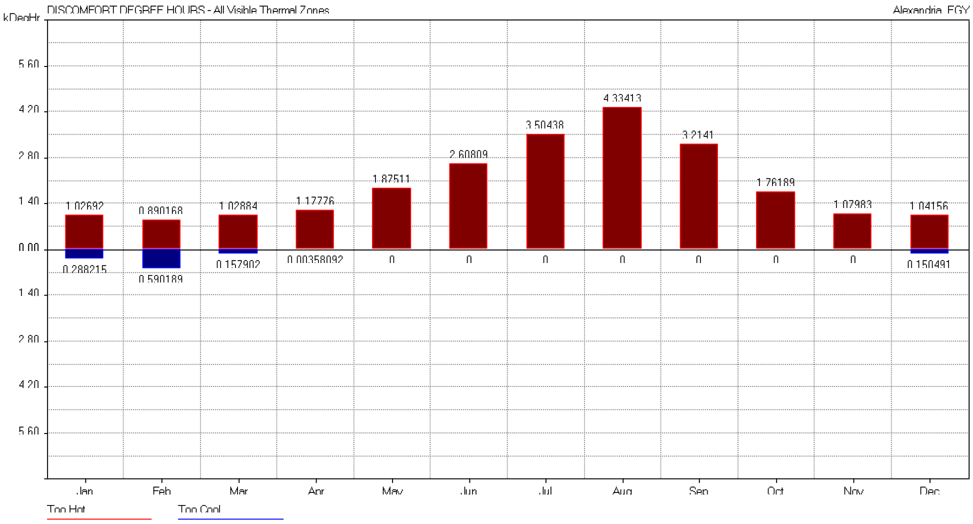


Figure 4-20 The total discomfort degree hours of the building through the year for the base case B-1.

4.7.7. Case B-2

- Location: Alexandria – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 50 cm stone bricks with 2cm plaster from inside and 3cm plaster from outside

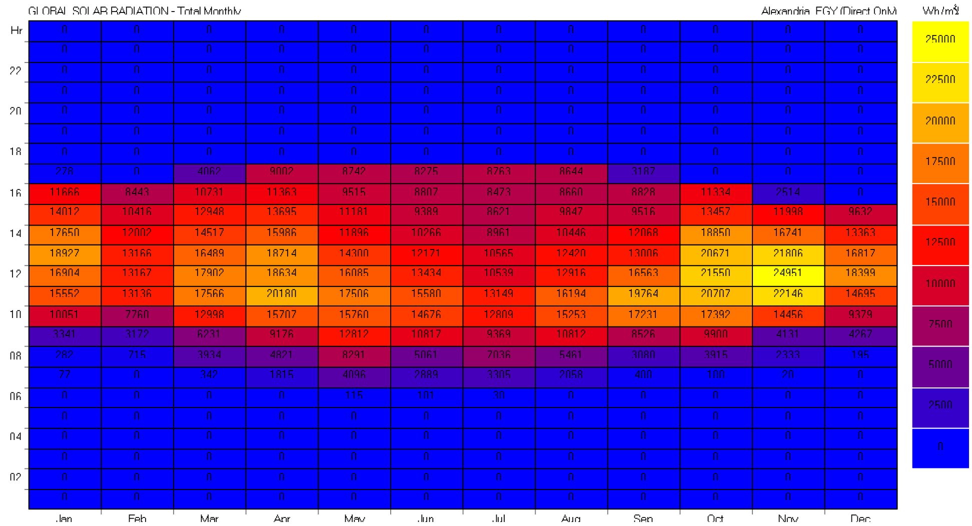


Figure 4-21 The amount of absorbed solar radiation by the walls per month for case B-2.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 128764 watt\m^2. Fig 4-21 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-22 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 3 kilo degree hours of discomfort.

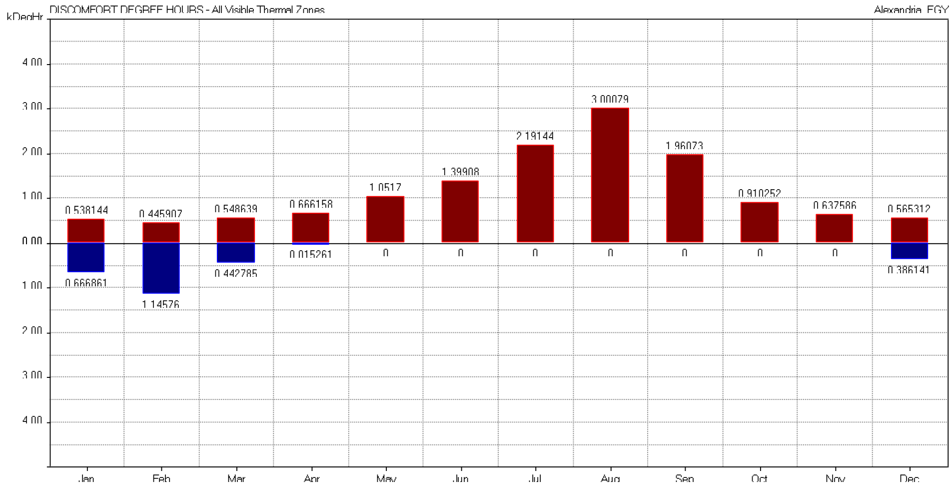


Figure 4-22 The total discomfort degree hours of the building through the year for case B-2.

4.7.8. Case B-3

- Location: Alexandria – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)

  Walls are 12 cm double red bricks with cavity 5cm in-between with 2cm plaster from inside and 3cm plaster from outside

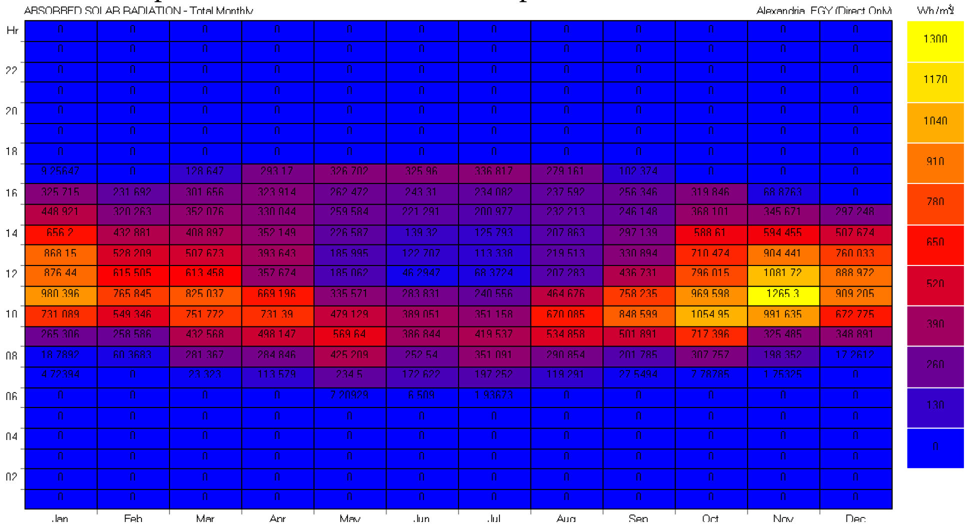


Figure 4-23 The amount of absorbed solar radiation by the walls per month for case B-3.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 50142 watt\m^2. Fig 4-23 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-24 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 4.3 kilo degree hours of discomfort.

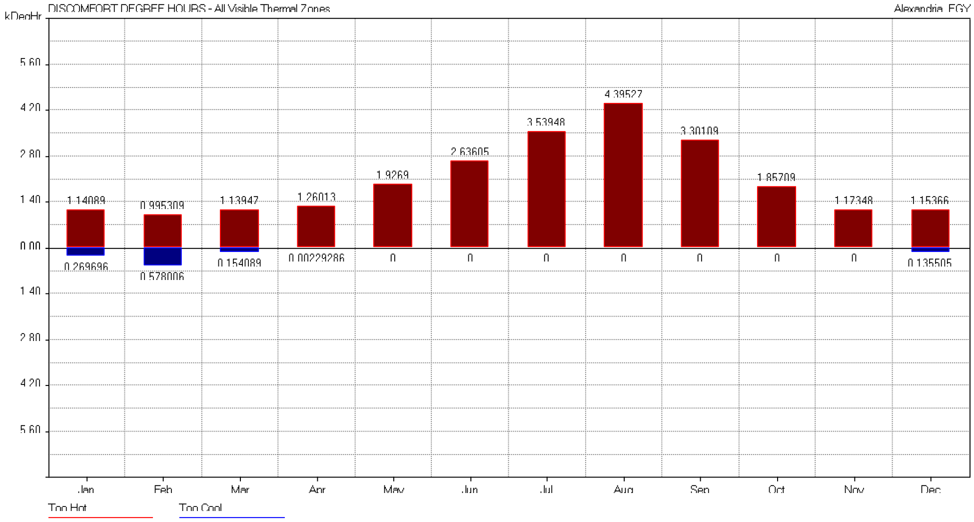


Figure 4-24 The total discomfort degree hours of the building through the year for case B-3.

4.7.9. Case B-4

- Location: Alexandria – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 12 cm brick Egyptian fire with 2cm plaster from inside and 3cm plaster from outside

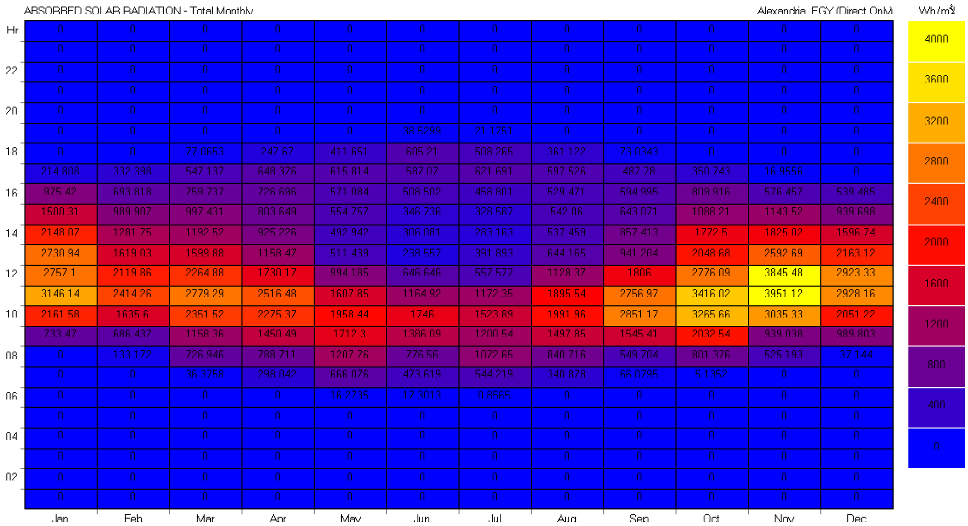


Figure 4-25 The amount of absorbed solar radiation by the walls per month for case B-4.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 160249 watt\m^2. Fig 4-25 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-26 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 4.5 kilo degree hours of discomfort.

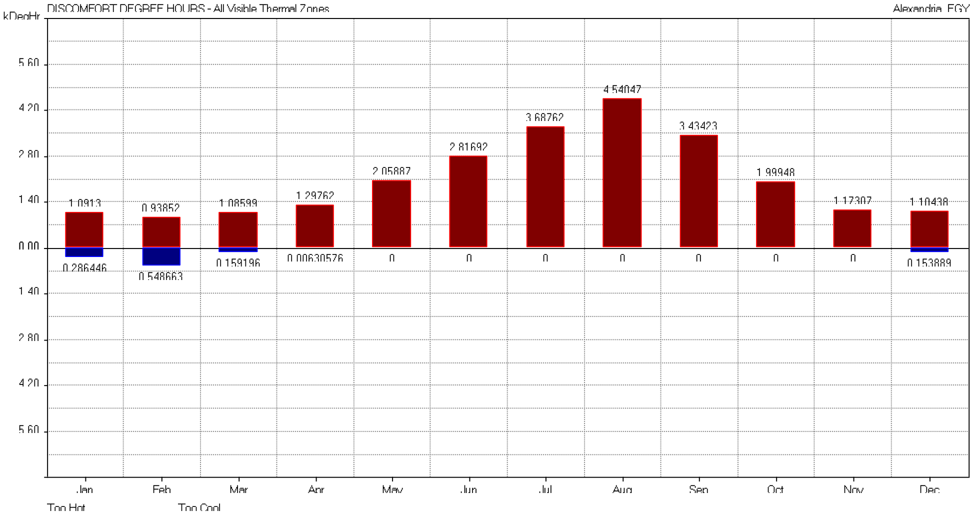


Figure 4-26 The total discomfort degree hours of the building through the year for case B-4.

4.7.10. Case B-5

- Location: Alexandria – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 25cm concrete blocks with 2cm plaster from inside, 3cm plaster from outside.

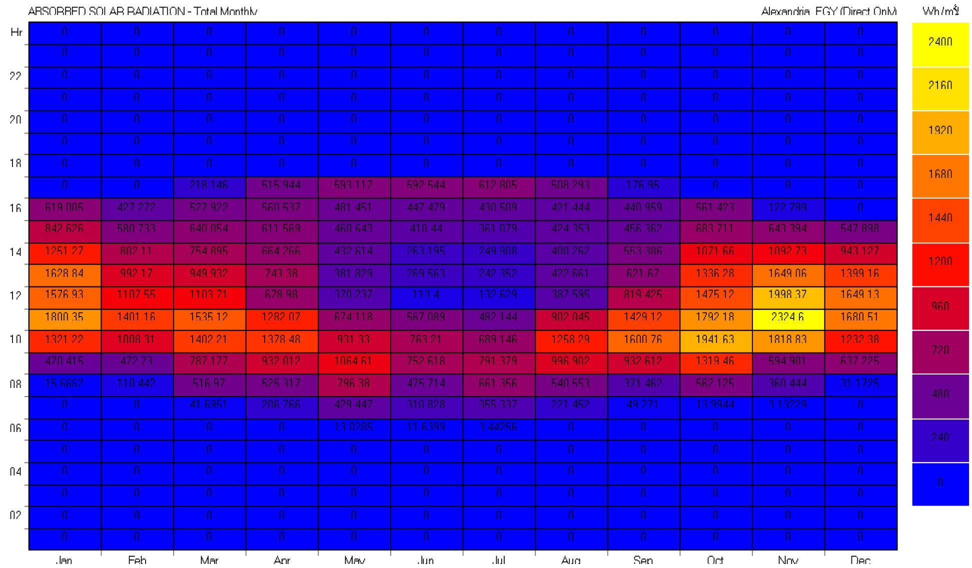


Figure 4-27 The amount of absorbed solar radiation by the walls per month for case B-5.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 93047 watt\m^2. Fig 4-27 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-28 shows the total sum of discomfort degree of the whole hours of the month. August is the month which has the biggest discomfort time with total 4.1 kilo degree hours of discomfort.

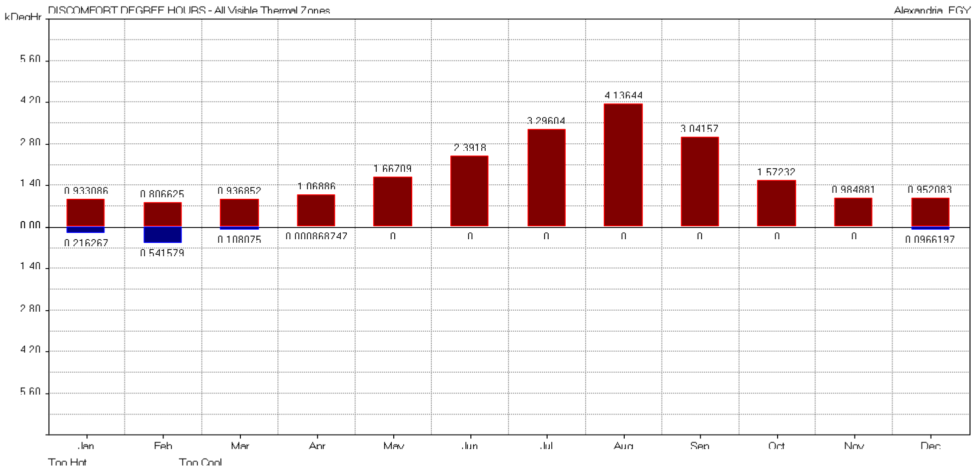


Figure 4-28 The total discomfort degree hours of the building through the year for case B-5.

4.7.11. Base Case C-1

Location: Aswan – Egypt.

- All properties are the same of Base case.
- Material used: (Only variable)

  Walls are 25 cm red bricks with 2cm plaster from inside and 3cm plaster from outside

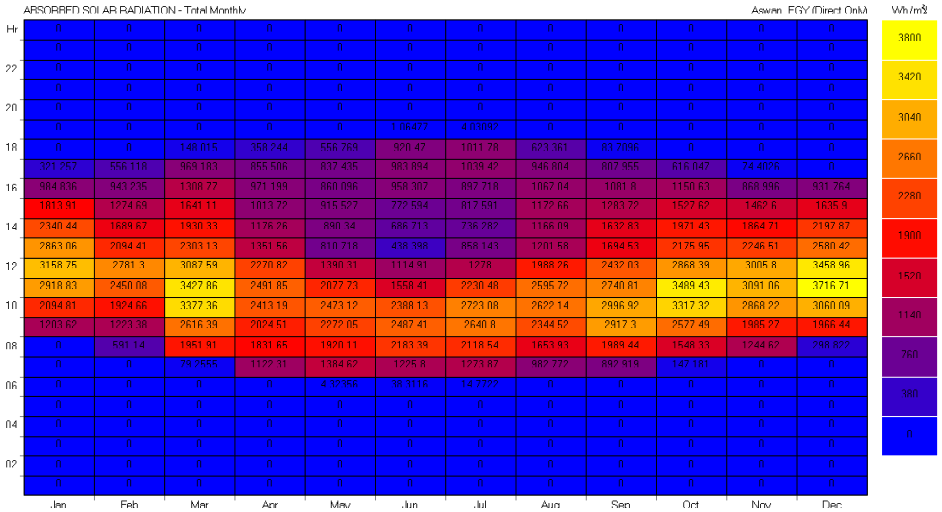


Figure 4-29 The amount of absorbed solar radiation by the walls per month for the base case C-1.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 222613 watt\m^2. Fig 4-29 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-30 shows the total sum of discomfort degree of the whole hours of the month. July is the month which has the biggest discomfort time with total 9.1 kilo degree hours of discomfort.

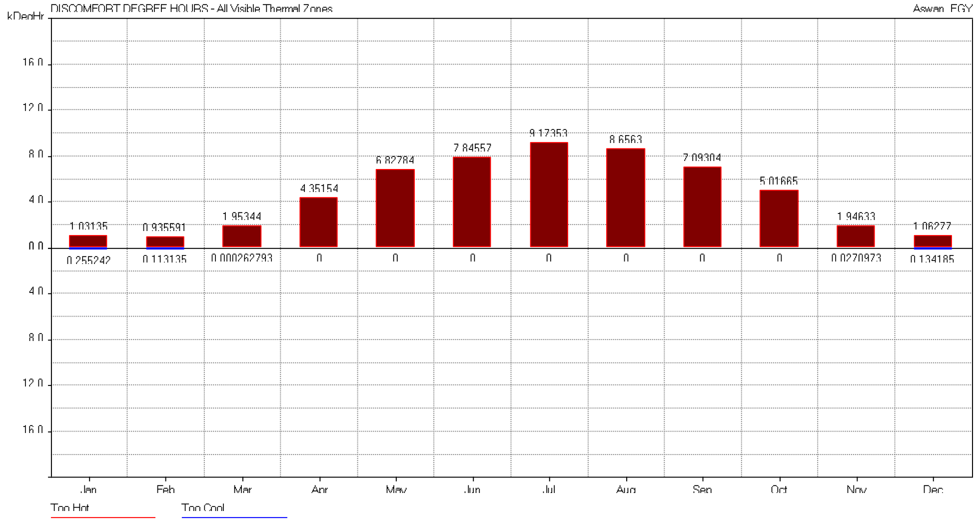


Figure 4-30 The total discomfort degree hours of the building through the year for the base case C-1.

4.7.12. Case C-2

- Location: Aswan – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 50 cm stone bricks with 2cm plaster from inside and 3cm plaster from outside.

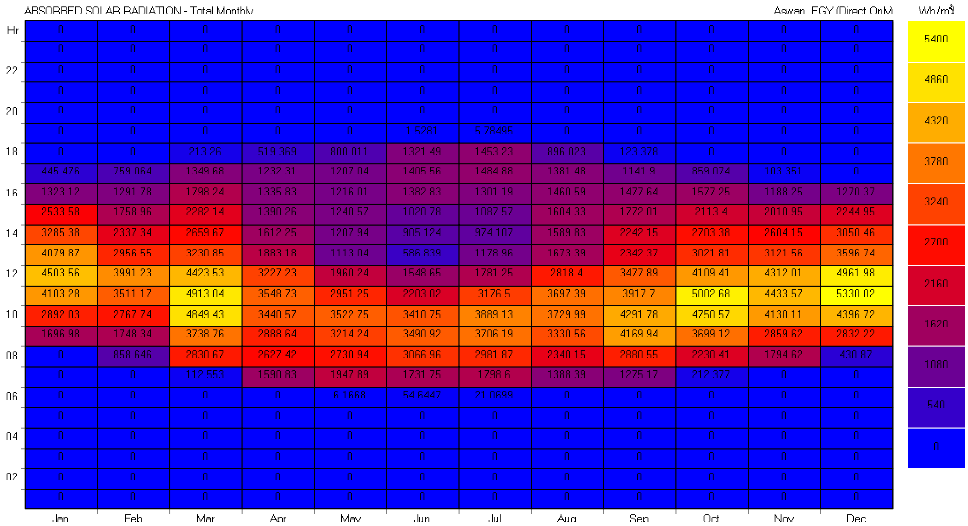


Figure 4-31 The amount of absorbed solar radiation by the walls per month for case C-2.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 322990 watt\m^2. Fig 4-31 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-32 shows the total sum of discomfort degree of the whole hours of the month. July is the month which has the biggest discomfort time with total 7.9 kilo degree hours of discomfort.

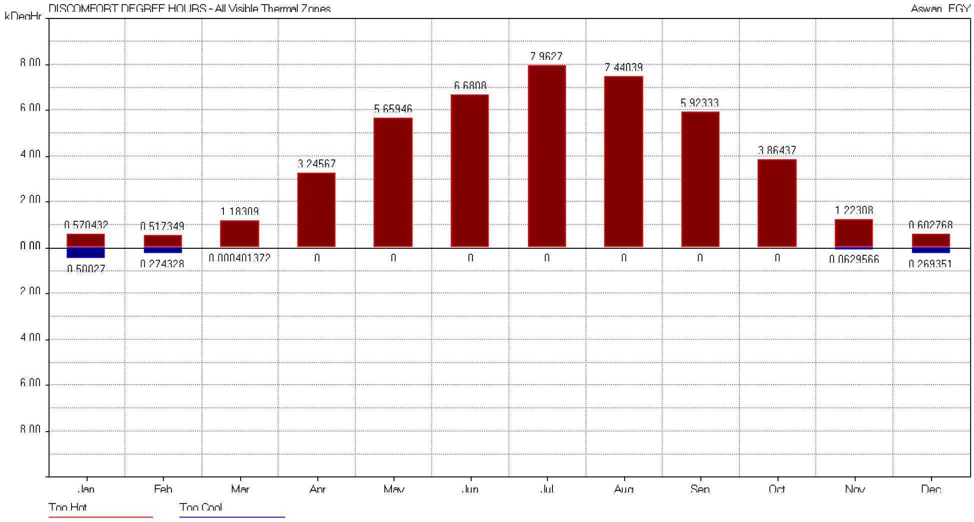


Figure 4-32 The total discomfort degree hours of the building through the year for case C-2.

4.7.13. Case C- 3

- Location: Aswan – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 12 cm double red bricks with cavity 5cm in-between with 2cm plaster from inside and 3cm plaster from outside

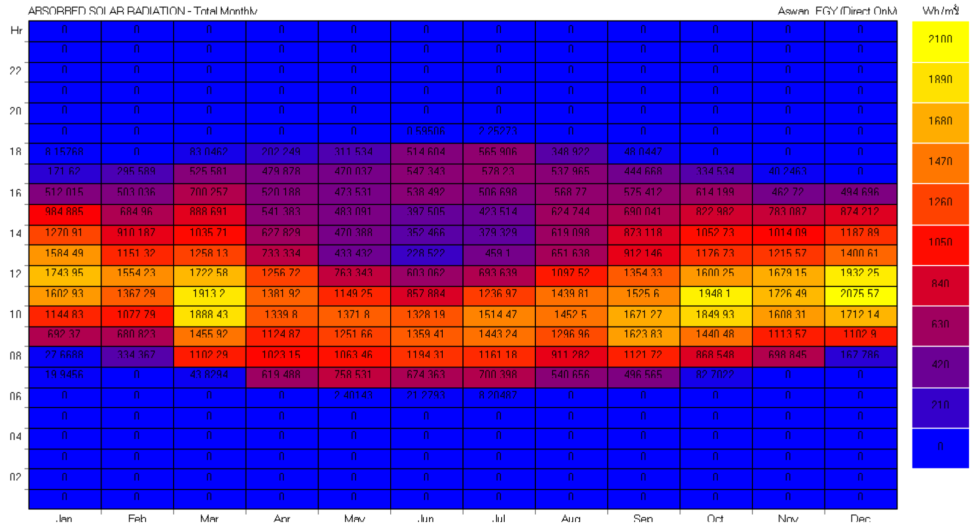


Figure 4-33 The amount of absorbed solar radiation by the walls per month for case C-3.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 122593 watt\m^2. Fig 4-33 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-34 shows the total sum of discomfort degree of the whole hours of the month. July is the month which has the biggest discomfort time with total 9.3 kilo degree hours of discomfort.

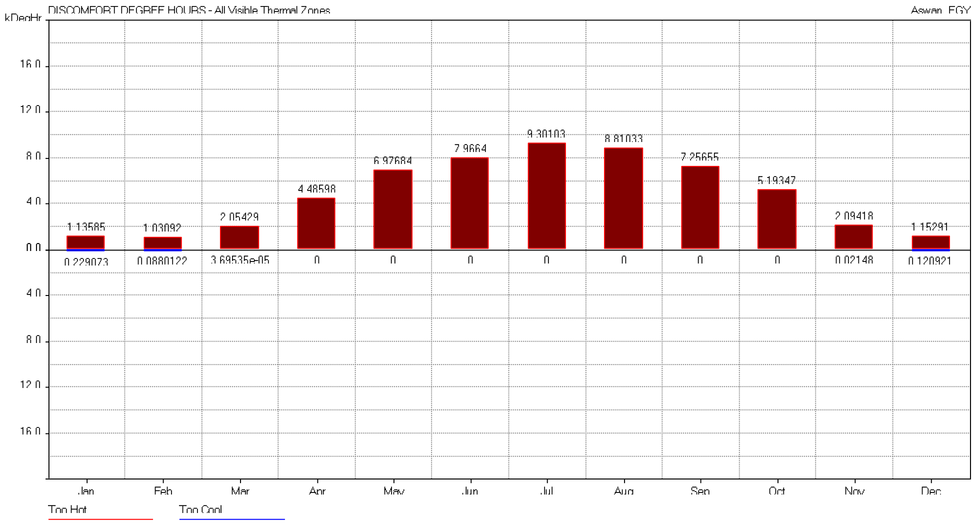


Figure 4-34 The total discomfort degree hours of the building through the year for case C- 3.

4.7.14. Case C-4

- Location: Aswan – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 12 cm brick Egyptian fire with 2cm plaster from inside and 3cm plaster from outside

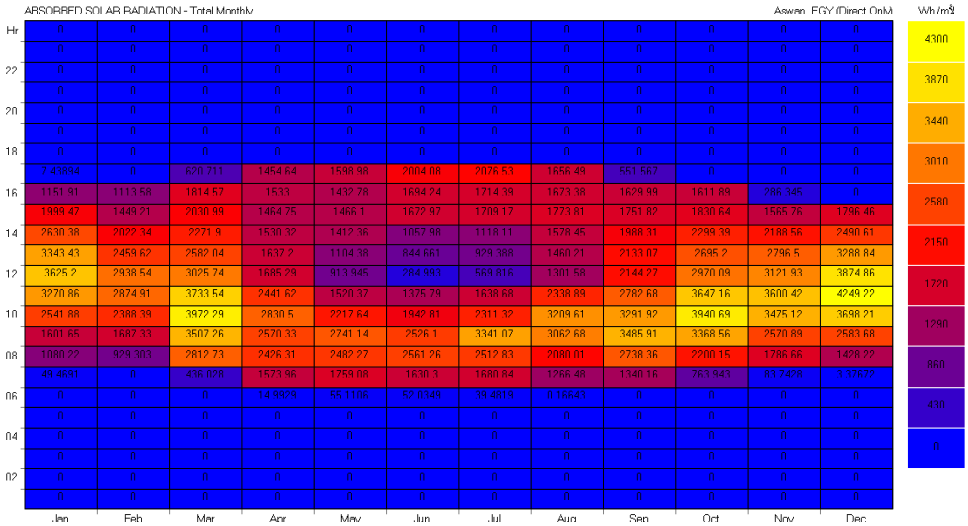


Figure 4-35 The amount of absorbed solar radiation by the walls per month for case C-4.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 58586 watt\m^2. Fig 4-35 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-36 shows the total sum of discomfort degree of the whole hours of the month. July is the month which has the biggest discomfort time with total 9.8 kilo degree hours of discomfort.

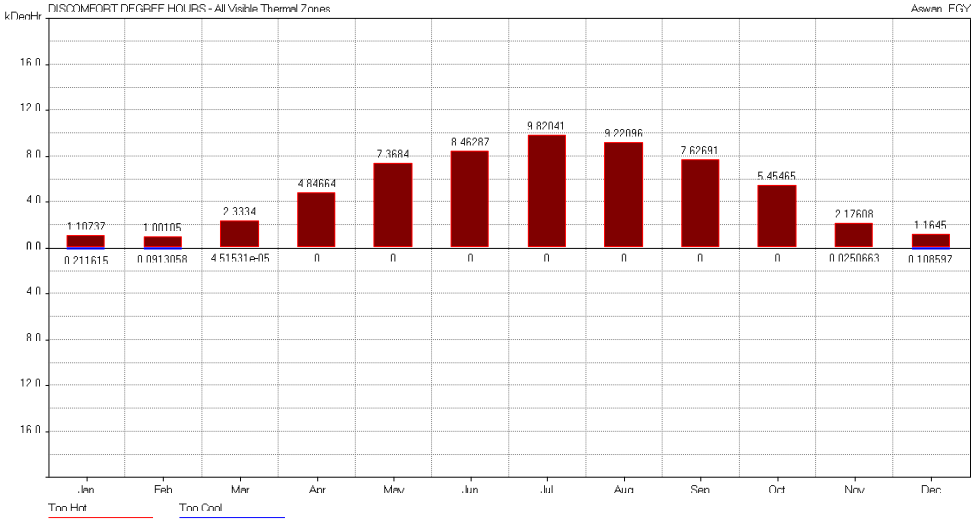


Figure 4-36 The total discomfort degree hours of the building through the year for case C-4.

4.7.15. Case C-5

- Location: Aswan – Egypt.
- All properties are the same of Base case.
- Material used: (Only variable)
  Walls are 25cm concrete blocks with 2cm plaster from inside, 3cm plaster from outside.

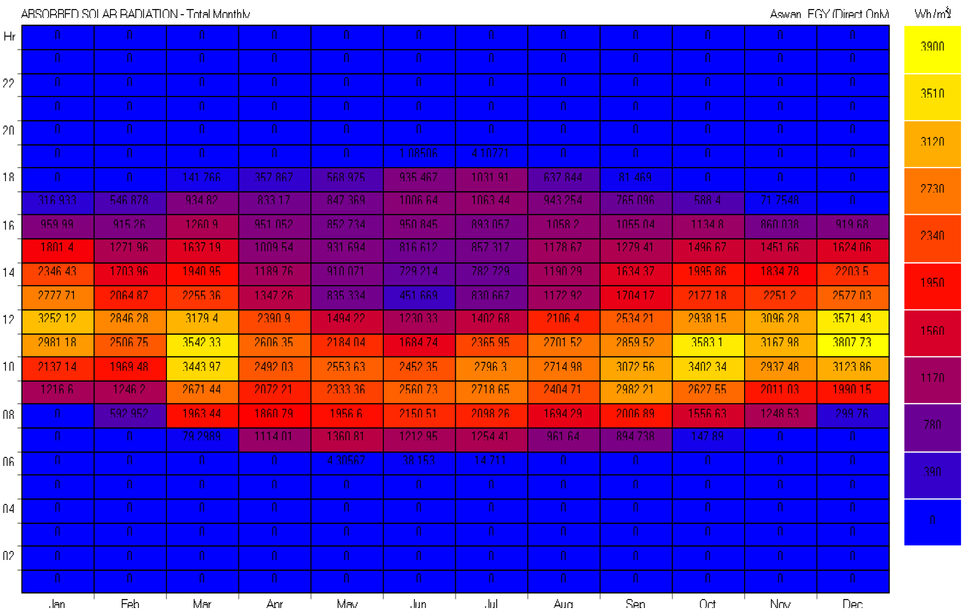


Figure 4-37 The amount of absorbed solar radiation by the walls per month for case C-5.

From the result of the simulation, the total solar radiation absorbed by the building walls through the year is 226229 watt\m^2. Fig 4-37 shows the total amount of solar radiation absorbed at every hour of the day through every month of the year.

The thermal analysis in this case is measured by the total discomfort time per month that the internal zone temperature is outside the comfort band. Fig 4-38 shows the total sum of discomfort degree of the whole hours of the month. July is the month which has the biggest discomfort time with total 9 kilo degree hours of discomfort.

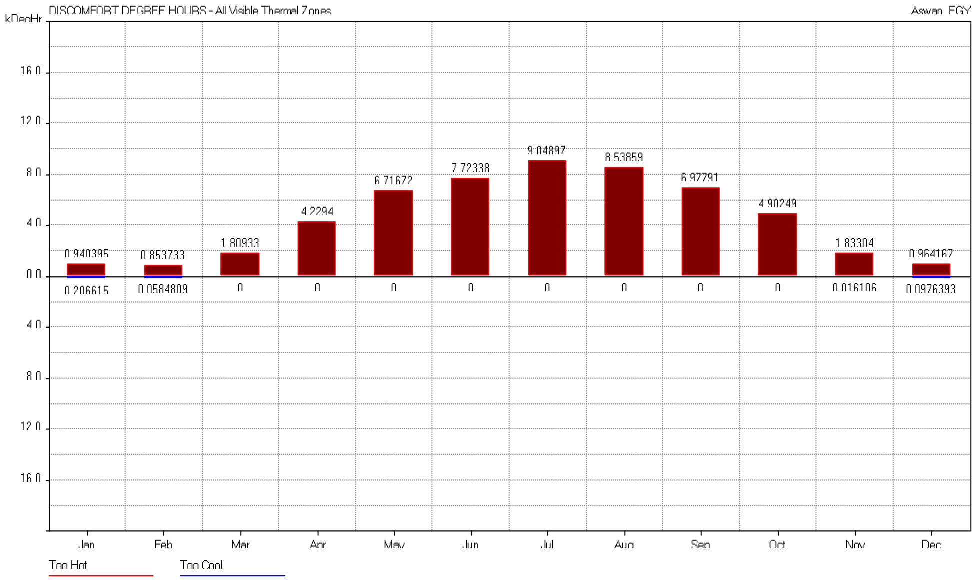


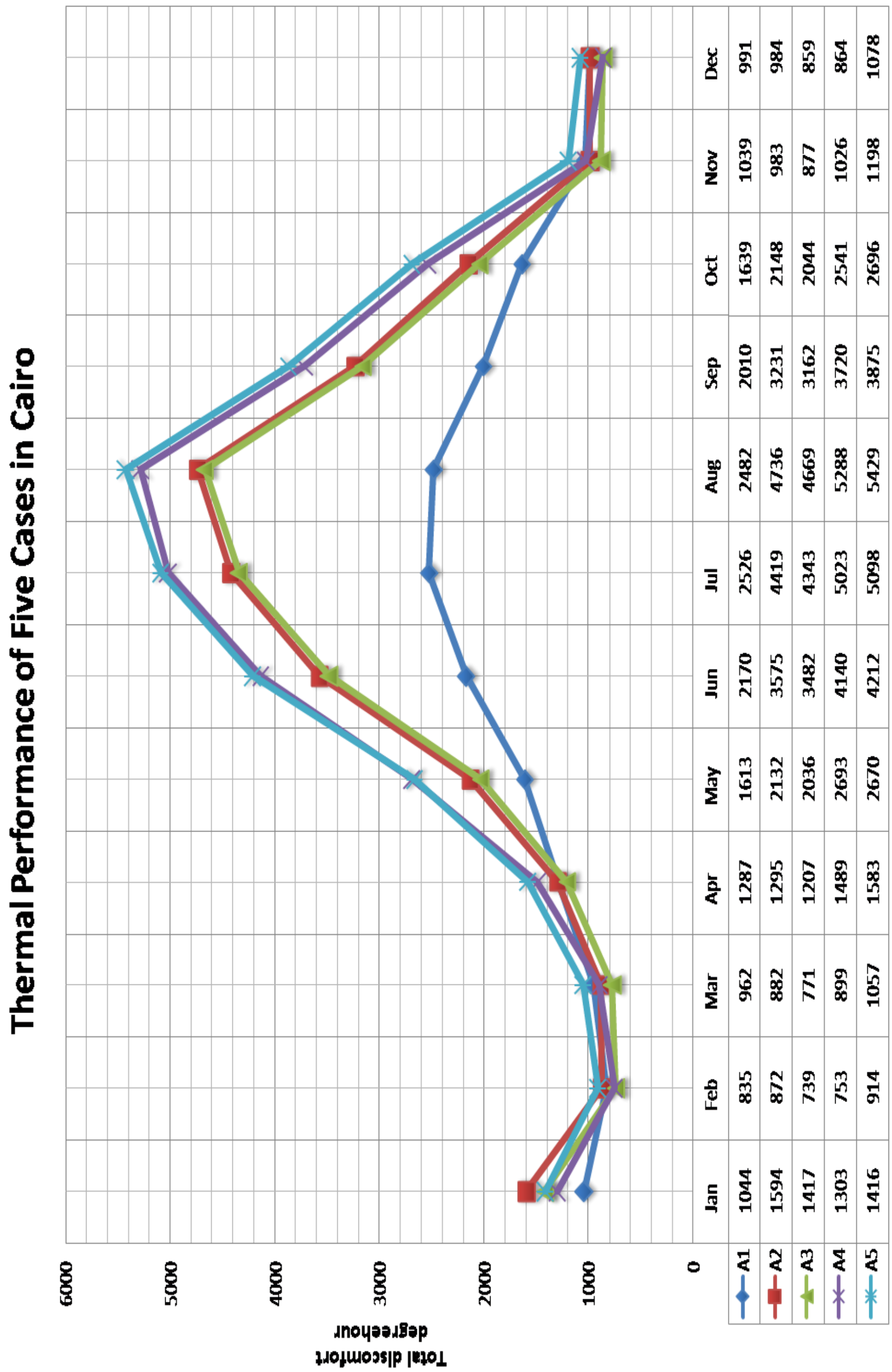
Figure 4-38 The total discomfort degree hours of the building through the year for case C-5.

4.8. Simulation, Analysis, and Discussion:

After performing the thermal simulation for all cases the following graphs are the comparison of the total discomfort degree hours of different wall materials buildings at each location separately.

- At Cairo location the cases from A-1 to A-5, the thermal performance of case A-1 results the less thermal discomfort total degree hours by 34% of the average performance of all the other materials, which means that the wall material used in this case is the most suitable material from the other used in the simulation of this case. This material was 25cm. red bricks with 2 cm plaster from inside and 3cm plaster from outside. Fig4-39.

- At Alexandria location the cases from B-1 to B-5, the thermal performance of case B-2 results the less thermal discomfort total degree hours by 22% of the average performance of all the other materials, which means that the wall material used in this case is the most suitable material from the other used in the simulation of this case. This material was 50 cm stone bricks with 2cm plaster from inside and 3cm plaster from outside. Fig4-40.
- At Aswan location the cases from C-1 to C-5, the thermal performance of case C-2 results the less thermal discomfort total degree hours by 20% of the average performance of all the other materials, which means that the wall material used in this case is the most suitable material from the other used in the simulation of this case. This material was 50 cm stone bricks with 2cm plaster from inside and 3cm plaster from outside. Fig4-41.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A1	1044	835	962	1287	1613	2170	2526	2482	2010	1639	1039	991
A2	1594	872	882	1295	2132	3575	4419	4736	3231	2148	983	984
A3	1417	739	771	1207	2036	3482	4343	4669	3162	2044	877	859
A4	1303	753	899	1489	2693	4140	5023	5288	3720	2541	1026	864
A5	1416	914	1057	1583	2670	4212	5098	5429	3875	2696	1198	1078

Figure 4-39 The effect of the wall materials on the total discomfort degree hours of the building at Cairo.

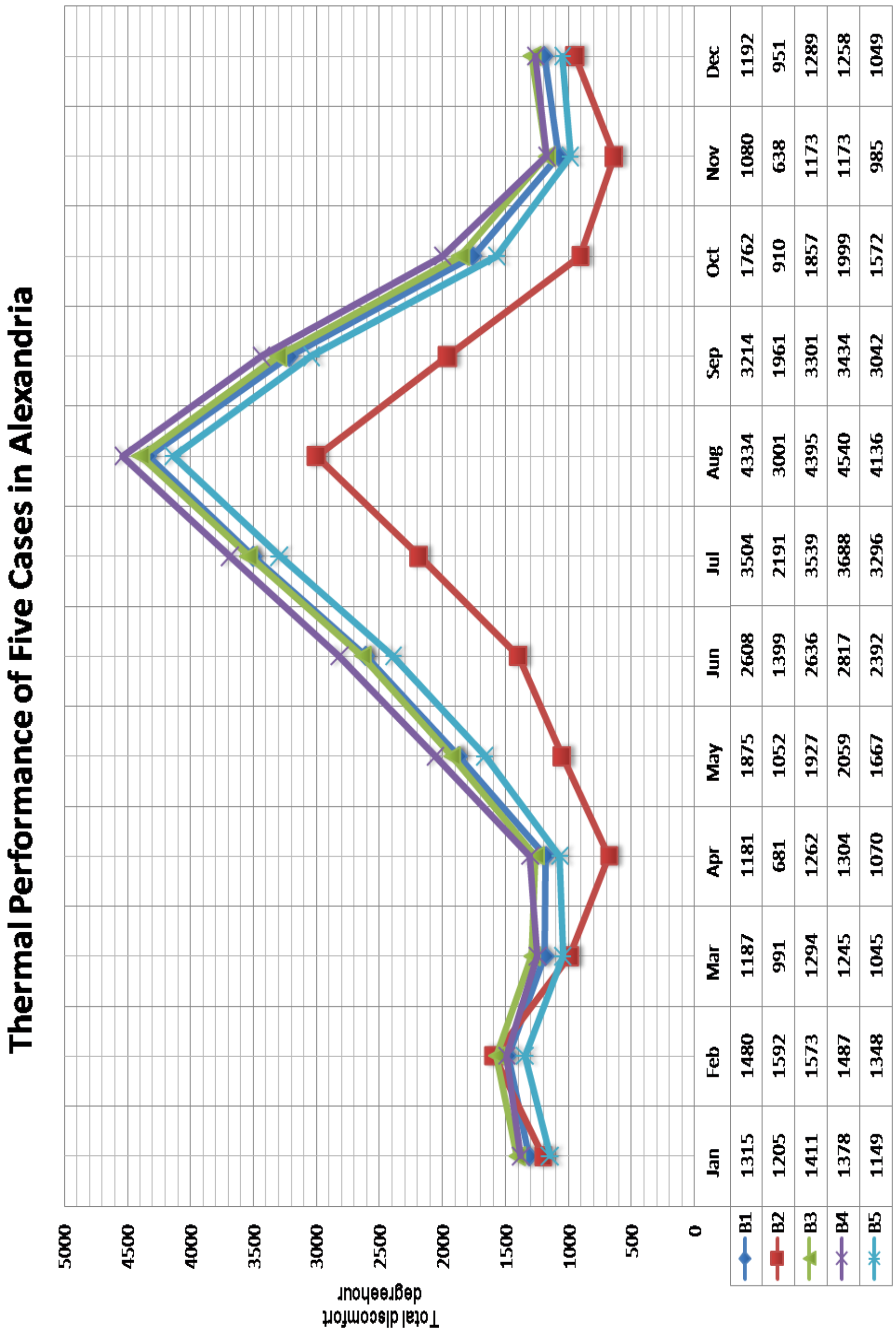
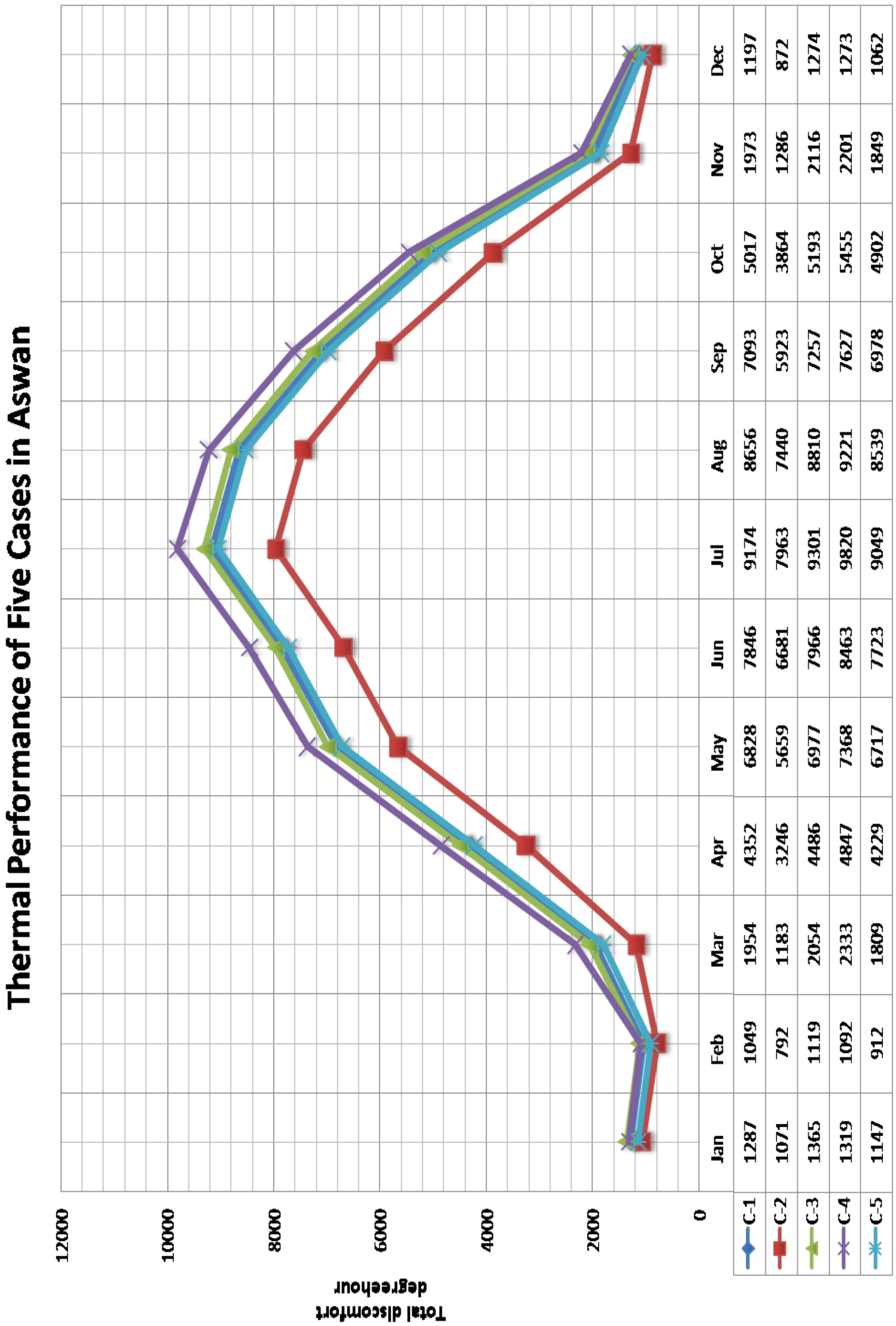


Figure 4-40 The effect of the wall materials on the total discomfort degree hours of the building at Alexandria.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
C-1	1287	1049	1954	4352	6828	7846	9174	8656	7093	5017	1973	1197
C-2	1071	792	1183	3246	5659	6681	7963	7440	5923	3864	1286	872
C-3	1365	1119	2054	4486	6977	7966	9301	8810	7257	5193	2116	1274
C-4	1319	1092	2333	4847	7368	8463	9820	9221	7627	5455	2201	1273
C-5	1147	912	1809	4229	6717	7723	9049	8539	6978	4902	1849	1062

Figure 4-41 The effect of the wall materials on the total discomfort degree hours of the building at Aswan.

4.9. Conclusion.

The fundamental theme of this chapter is about the building thermal performance concerns, are best addressed by architects at the most conceptual stages of design, where many methods, graphs are available to represent the thermal analysis for the building. All these methods have their application and are useful in some way. Architects will have the variety to work with different types of graphs produced by using such program "ECOTECT" because it fits their particular conception of the process more and they are able to gain as much information as they need from it.

A range of graphical displays are presented and discussed, such as the solar radiation energy absorbed by the walls, and the thermal comfort analysis of the whole building.

The application of this experimental study emphasizes that building performance simulation programs enrich the design with more accurate concrete results, that even if the building is having the same concept of design, properties and orientation just by changing its location (climate) the best kind of wall material - for having the best thermal performance- differ from one location to another, by giving the amount of this difference in numbers.

Chapter 5

Conclusions and Recommendations

5.1. Conclusions.

Through the Theoretical and the Practical study of the research, the following conclusion points were reached:

- An innovative digital solution offers some unexpected new conduits to an attentive discipline of architecture that integrates both digital technologies and green architecture design practice. The processes of design demands knowledge and understanding of structural and constructional principles, the properties and meanings of materials, and the ways that these may inform and influence design decisions. Similarly, design makes a respect of the effect of statutory instruments for environmental health, safety, and comfort, both during the construction and subsequent occupation of a project.

- Projects which implement the use of energy performance simulation programs, usually do so during the detailed design stage, when most critical decisions (i.e. building azimuth, mass, etc) that will affect the overall building efficiency, have been finalized by the lead designer. This neglects the verity that most energy savings could be achieved if energy performance simulation programs are employed during the initial stages of design.

- Each of the software applications has great potential as an educational tool. With a moderate learning curve, and some relationships to existing software in the workplace, these powerful tools can be integrated with relative ease. Each design will contribute exponentially to the next design in terms of knowledge, judgment and design skill. Still, it is important to emphasize that as is the case with any digital simulations, the inputs and goals must be considered for repercussions and appropriateness.

- For architects in small practice, or those not yet contributing in an integrated design process, the benefit to modeling with any of these integrated tools is the savings in consultant fees where initial decisions can be made in-house. Such an approach may circumvent consultant tendencies of finding systems specifications in a table based on a limited scope of data, and may provide an opportunity to design more innovative lighting and mechanical systems. Energy performance simulation programs would provide a suitable platform for designing buildings with lowered overall and peak loads, regardless of the limitations imposed by the mechanical system designations, allowing a consultant to design a more efficient mechanical system once general building performance has been optimized.

- Energy performance simulation programs guide engineer to design more sustainable buildings in the future. Especially for the designing stage because engineer can simulate the performance of the design plan before the constructor turn the design to the real object. The engineer can analysis thermal comfort, solar and others building performance in 3D viewing based on their design, material usage, and the orientation of the building.

Finally, the objectives of this research are achieved by using one of the energy performance simulation programs. The thermal comfort analysis of buildings is done and displayed in this research.

5.2. Recommendations.

To achieve Green Architecture, architects must be educated about environmental, economical, and social issues during their professional training.

- Faculties have to foster environmental awareness, introduce students to environmental ethics, the economy of the projects and developing their skills and knowledge-base in sustainable design. Both environmental and economical awareness are so attached with each other.

- A digital future in architecture requires a clearer definition of principles and skills necessary to maintain a rigor in emerging digital projects.

- Enhancing the abilities of these specialist programs and operators, is a better for Architects .The architectural designers will only feel comfortable by using green architectural digital tools if the interfaces are designed to suit their techniques of design/drawing. Thus, reducing the time needed for training, and limit the need to contact other specialists.

- Clearly, A large portion of this research is yet to be implemented, and must be executed by designers themselves, as each design provides a unique datum set. With an increasing number of designers employing such software in the future, valuable conclusions could be drawn from a study of the collected testing of many buildings. While using a huge data set, one could normalize data for varying perspectives and then begin to assess for trends and other characteristics of sustainable design. Therefore, dissemination of strategies and good practice would be possible.

The depicted research topic might help other researches to define energy performance simulation programs, and it still can be continued in the future. Possible extensions to this research could include a more careful testing of simple buildings, across multiple platforms, followed by testing of accurate full-scale models. This is also a scope of research in the future. Material costing and the cost of the construction also can be further increased by using this simulation program.

Appendixes

Agenda 21

A program run by the United Nations (UN) related to sustainable development. It is a comprehensive blueprint of action to be taken globally, nationally and locally by organizations of the UN, governments, and major groups in every area in which human's impact on the environment. The number 21 refers to the 21st century.[1]

Chapters of Agenda 21 Driving force indicators state indicators response indicators[2]

Category: Social

Chapter 3: Combating poverty
-Unemployment rate
-Head count index of poverty
-Poverty gap index
-Squared poverty gap index
-Gini index of income inequality
-Ratio of average female wage to male wage
Chapter 5: Demographic dynamics and sustainability
-Population growth rate
-Net migration rate
-Total fertility rate
-Population density
Chapter 36: Promoting education, public awareness and training
-Rate of change of school-age population
-Primary school enrolment ratio (gross and net)
-Secondary school enrolment ratio (gross and net)
-Adult literacy rate
-Children reaching grade 5 of primary education
-School life expectancy
-Difference between male and female school enrolment ratios
-Women per hundred men in the labour force
-GDP spent on education
Chapter 6: Protecting and promoting human health
-Basic sanitation: Percent of population with adequate excreta disposal facilities
-Access to safe drinking water
-Life expectancy at birth
-Adequate birth weight
-Infant mortality rate
-Maternal mortality rate
-Nutritional status of children
-Immunization against infectious childhood diseases
-Contraceptive prevalence
-Proportion of potentially hazardous chemicals monitored in food
-National health expenditure devoted to local health care

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[1] URL: http://en.wikipedia.org/wiki/Agenda_21(accessed October 2006).
2 Indicators of Sustainable Development URL: www.un.org/esa/sustdev/natlinfo/indicators/worklist.html (accessed October 2006).

-Total national health expenditure related to GNP

Chapter 7: Promoting sustainable human settlement development
-Rate of growth of urban population
-Per capita consumption of fossil fuel by motor vehicle transport
-Human and economic loss due to natural disasters
-Percent of population in urban areas
-Area and population of urban formal and informal settlements
-Floor area per person
-House price to income ratio
-Infrastructure expenditure per capita
Chapter 10: Integrated approach to the planning and management of land resources
-Land use change
-Changes in land condition
-Decentralized local-level natural resource management
Chapter 12: Managing fragile ecosystems: combating desertification and drought
-Population living below poverty line in dry land areas
-National monthly rainfall index
-Satellite derived vegetation index
-Land affected by desertification
Chapter 13: Managing fragile ecosystems: sustainable mountain development
-Population change in mountain areas
-Sustainable use of natural resources in mountain areas
-Welfare of mountain populations
Chapter 14: Promoting sustainable agriculture and rural development
-Use of agricultural pesticides
-Use of fertilizers
-Irrigation percent of arable land
-Energy use in agriculture
-Arable land per capita
-Area affected by salinization and water logging
-Agricultural education
Chapter 11: Combating deforestation
-Wood harvesting intensity
-Forest area change
-Managed forest area ratio
-Protected forest area as a percent of total forest area
Chapter 15: Conservation of biological diversity
-Threatened species as a percent of total native species
-Protected area as a percent of total area
Chapter 16: Environmentally sound management of biotechnology
-R & D expenditure for biotechnology
-Existence of national bio-safety regulations or guidelines
Chapter 9: Protection of the atmosphere
-Emissions of greenhouse gasses
-Emissions of sulphur oxides
-Emissions on nitrogen oxides
-Consumption of ozone depleting substances
-Ambient concentrations of pollutants in urban areas
-Expenditure on air pollution abatement

Chapter 21: Environmentally sound management of solid wastes and sewage-related issues
-Generation of industrial and municipal solid waste
-Household waste disposed per capita
-Expenditure on waste management
-Waste recycling and reuse
-Municipal waste disposal
Chapter 19: Environmentally sound management of toxic chemicals
-Chemically induced acute poisonings
-Number of chemicals banned or severely restricted
Chapter 20: Environmentally sound management of hazardous wastes
-Generation of hazardous wastes
-Imports and exports of hazardous wastes
-Area of land contaminated by hazardous wastes
-Expenditure on hazardous waste treatment
Chapter 22: Safe and environmentally sound management of radioactive wastes
-Generation of radioactive wastes

Category: Economic

Chapter 2: International cooperation to accelerate sustainable development in countries and related domestic policies
-GDP per capita
-Net investment share in GDP
-Sum of exports and imports as a percent of GDP
-Environmentally adjusted Net Domestic Product
-Share of manufactured goods in total merchandise exports
Chapter 4: Changing consumption patterns
-Annual energy consumption
-Share of natural-resource intensive industries in manufacturing value-added
-Proven mineral reserves
-Proven fossil fuel energy reserves
-Lifetime of proven energy reserves
-Intensity of material use
-Share of manufacturing value-added in GDP
-Share of consumption of renewable energy resources
Chapter 33: Financial resources and mechanisms
-Net resources transfer / GNP
-Total ODA given or received as a percentage of GNP
-Debt / GNP
-Debt service / export
-Environmental protection expenditures as a percent of
GDP
-Amount of new or additional funding for sustainable development
Chapter 34: Transfer of environmentally sound technology, cooperation and capacity-building
-Capital goods imports
-Foreign direct investments
-Share of environmentally sound capital goods imports
-Technical cooperation grants

Category: Environmental

Chapter 18: Protection of the quality and supply of freshwater resources
-Annual withdrawals of ground and surface water
-Domestic consumption of water per capita
-Groundwater reserves
-Concentration of faucal coliform in freshwater
-Biochemical oxygen demand in water bodies
-Waste-water treatment coverage
-Density of hydrological networks
Chapter 17: Protection of the oceans, all kinds of seas and coastal areas
-Population growth in coastal areas
-Discharges of oil into coastal waters
-Releases of nitrogen and phosphorus to coastal waters
-Maximum sustained yield for fisheries
-Algae index
Chapter 8: Integrating environment and development in decision-making
-Sustainable development strategies
-Program of integrated environmental and economic accounting
-Mandated Environmental Impact Assessment
-National councils for sustainable development
Chapter 35: Science for sustainable development
-Potential scientists and engineers per million population
-Scientists and engineers engaged in R & D per million population
-Expenditure on R & D as a percent of GDP
Chapter 37: National mechanisms and international cooperation for capacity-building in developing countries
Chapter 38: International institutional arrangements
Chapter 39: International legal instruments and mechanisms
-Ratification of global agreements
-Implementation of ratified global agreements
Chapter 40: Information for decision-making
-Main telephone lines per 100 inhabitants
-Access to information
-Program for national environmental statistics
Chapter 23-32: Strengthening the role of major groups
-Representation of major groups in national councils for sustainable development
-Representatives of ethnic minorities and indigenous people in national councils for sustainable development
-Contribution of NGOs to sustainable development

Pre Evaluation – ECOTECT					
No	Criteria	Options	✓	Issues	Notes
Section 1: Tool Background					
1	Name		✓	Name of tool.	ECOTECT
2	Source/Developer		✓	(Include address where possible)	Square One Research Pty Ltd Centre for Research in the Built Environment Building Welsh School of Architecture Cardiff University King Edward VII Avenue Cardiff, Wales CF10 3NB UK Tel: +44 (29) 2087 5977 Fax: +44 (29) 2087 4623 Email: support@squ1.com and sales@squ1.com Web: www.squ1.com
3	Date of Availability	Latest version	✓	From what date was the tool available?	The first commercial release of ECOTECT was in Sydney in late 1996. The software has undergone some major changes since then. Version 2.5 was the first commercial release in 1997, followed by version 3.0 in 1998, version 4.0 in 2000, and version 5.0 in June 2002. Version 5.2 builds significantly on the functionality of previous versions introducing a range of new analysis functions and real-time hidden line and sketch visualization. It also refines some of the major algorithms such as the thermal and daylight factor calculations.
		First version	✓		

Pre Evaluation – ECOTECT

No	Criteria	Options	✓	Issues	Notes
4	Description		✓	Brief description of the model, tool, or toolkit.	ECOTECT is an environmental design tool which couples a 3D modeling interface with solar, thermal, lighting, acoustic, and cost analysis functions. The tool is driven by the concept that environmental design principles are most effectively addressed during the conceptual stages of design. The software provides visual and analytical feedback from sketch models, progressively guiding the design process as more detailed information becomes available. The model is saleable and can handle simple shading models to full-scale cityscapes.
5	Type	Metric			ECOTECT is an environmental design tool.
		Model			
		Toolkit	✓		
6	Role	Policy/Strategy		What is the primary role of the model, tool, or toolkit?	ECOTECT is designed to assess and control such issues as overshadowing, solar access, thermal comfort etc of a building through analyzing the performance of a design.
		Planning			
		Monitoring			
		Evaluating			
		Auditing			
		Other (describe) Assessment, Certification	✓		
7	Object of Assessment:	Product		If the assessment object is a product, does the tool assess new and/or refurbished products?	The object of assessment of the ECOTECT design tool is a building. The ability of ECOTECT to assess refurbished buildings was not discussed in the literature available.
		Urban Region			
		Infrastructure			
		Building (domestic, office, retail, industrial)	✓		
		Building element			
		Process (e.g. stakeholder involvement, supply chain management.)			

Pre Evaluation – ECOTECT

No	Criteria	Options	✓	Issues	Notes
8	Spatial Dimension	Component/Element/ Material		What spatial scale are impacts considered over?	The ECOTECT environmental design tool is completely scalable. It can handle simple shading models through to full-scale cityscapes. Its extensive export facilities also make final design validation much simpler by interfacing with Radiance, EnergyPlus (merger of DOE2 and BLAST) and many other focused analysis tools.
		Building	✓		
		Estate	✓		
		Neighborhood	✓	Can it work on micro and macro scale?	
		District	✓		
		City/Metropolitan	✓		
		Regional			
		National		Likability to other toolkits?	
		Trans-National			
		Global			
9	Geographically Specific	Yes		Tool is or is not geographically specific. (e.g. city wide tool but only for a named city)	No.
		No	✓		
10	Time scale	Short 0-5 years	✓	Time scale over which assessment is valid?	The time scale over which the assessment is valid is less than 5 years due to the regular updating of the tool and the increasing efficiency buildings.
		Medium 5-20 years			
		Long 20+ years			
11	Sustainability Dimension	Environmental	✓	What sustainability dimensions does it consider?	ECOTECT is an environment design tool which focuses on environmental issues. Some aspects of the economic side of sustainability are considered is so far as, ECOTECT provides instant access to initial capital outlays, ongoing running costs and life cycle assessment at all stages in the design process.
		Social			
		Economic			
		Environmental – Social			
		Environmental – Economic			
		Social – Economic			
		Environmental – Social – Economic			
12	Life Cycle Phase Covered	Feasibility		What is the most appropriate stage in the development process for it to be fully utilized?	The ECOTECT tool is driven by the concept that environmental design principles are most effectively addressed during the conceptual stages of design development.
		Conception	✓		
		Scheme			
		Detailed	✓		
		Manufacturing			
		Construction			
		Operation (heating, illumination, air-conditioning etc.)			
		Maintenance			

Pre Evaluation – ECOTECT					
No	**Criteria**	**Options**	✓	**Issues**	**Notes**
		Decommissioning: demolition			
		Decommissioning: disposal (recycling, landfill, incineration for energy recovery etc)			
13	Component Methodologies		✓	Which (if any) pre-existing frameworks / models / systems is the tool based on, or uses?(E.g. tool is based on LCA. It uses eco-points).	The original ECOTECT software was written as a demonstration of some of the ideas presented in PhD thesis by Dr. Andrew Marsh at the School of Architecture and Fine Arts at The University of Western Australia. The fundamental theme of this thesis was that building performance concerns are best addressed by architects at the most conceptual stages of design, not at the very end of the process where nothing but a few cosmetic changes are possible.
14	Data Requirement	Quantitative (e.g. census data, monetary)	✓	Is it imperative it functions with accurate quantitative data? Can it be supplied with reliable, relevant accurate data? Who assembles it the data there is a lack of it? How is the data entered?	The input required for this tool to properly function is simply quantitative data such as dimensions, locations, positioning etc of the building elements. The user needs to be aware of the different modeling and data requirements before commencing. For example, for thermal analysis, weather data and modeling geometry in an appropriate manner is important, and appropriate and comprehensive material data is required for almost all other types of analysis. 'Garbage in, garbage out'.
		Qualitative (e.g. morphological, perception)			
15	Stakeholders considered by tool	Developer/Owner		Are the following considered?	The purpose of ECOTECT is to assess and control such issues as overshadowing, solar access, thermal comfort etc of a building through
		Lenders			
		Insurers			
		Professional advisors			

Pre Evaluation – ECOTECT					
No	Criteria	Options	✓	Issues	Notes
		Architect/Design team	✓		analyzing the performance of a design in order to make the building environmentally sustainable. The decisions made based on the assessment will have a beneficial impact on energy and waste reduction, for both the end user of the building and people worldwide.
		Contractors	✓		
		Manufacturers			
		Raw materials producers			
		End users	✓		
		Facility managers			
		Deco missioners			
		Central government			
		Local government			
		Regulator			
		Local community			
		People worldwide	✓		
16	Stakeholders involved in the use of the tool	Developer/Owner	✓	Are the following involved? What is the process by which this involvement occurs?	The stakeholders involved in the use of the tool are architects and contractors and the developer. The process of involvement is not known.
		Lenders			
		Insurers			
		Professional advisors			
		Architect/Design team	✓		
		Contractors	✓		
		Manufacturers			
		Raw materials producers			
		End users			
		Facility managers			
		Deco missioners			
		Central government			
		Local government			
		Regulator			
		Local community			
		People worldwide			
17	User		✓	The main actor(s) who will use the tool? The main actor(s) who will use the outcome of the tool?	There are over 2000 individual licenses world wide, ECOTECT is taught at approximately 60 universities mainly in Australia, UK, and USA. The main users of the tool are architects and building designers, with application also to engineers and planners. The outcome of

Pre Evaluation – ECOTECT					
No	Criteria	Options	✓	Issues	Notes
					ECOTECT will be used by the developer / owner and the designer.
18	Usability		✓	Training required? Tool's user interface type? (E.g. software or handbook, and complexity).	CAD and environmental design experience would be useful but not essential. ECOTECT is good at teaching the novice environmental designer many of the important concepts necessary for efficient building design. Extensive help files and tutorials are provided. The tool's user interface type is a 3D modeling software package.
19	Costs	Buy and maintain		The decision maker purchases the tool and undertakes the assessment.	
		Buy the service	✓	The decision maker purchases the services of an other party who uses the tool to undertake the assessment.	
20	Output	Identification of drivers / pressures		More questions may be posed if the tool is used as part of a bigger assessment process. Weighting and scoring convention used if any. (E.g. during issue aggregation or issue prioritization).	ECOTECT's own analysis functions use a wide range of informative graphing methods which can be saved as Metafiles, Bitmaps or animations. Tables of data can also be easily output. For more specific analysis or validation output can be exported into other simulation software packages.
		Identification of present states			
		Identification of responses			
		Decision guidance (advice)			
		Decision(s)			
		Visualization	✓		
		Qualitative output			
		Quantitative (numeric) output	✓		
		More questions			

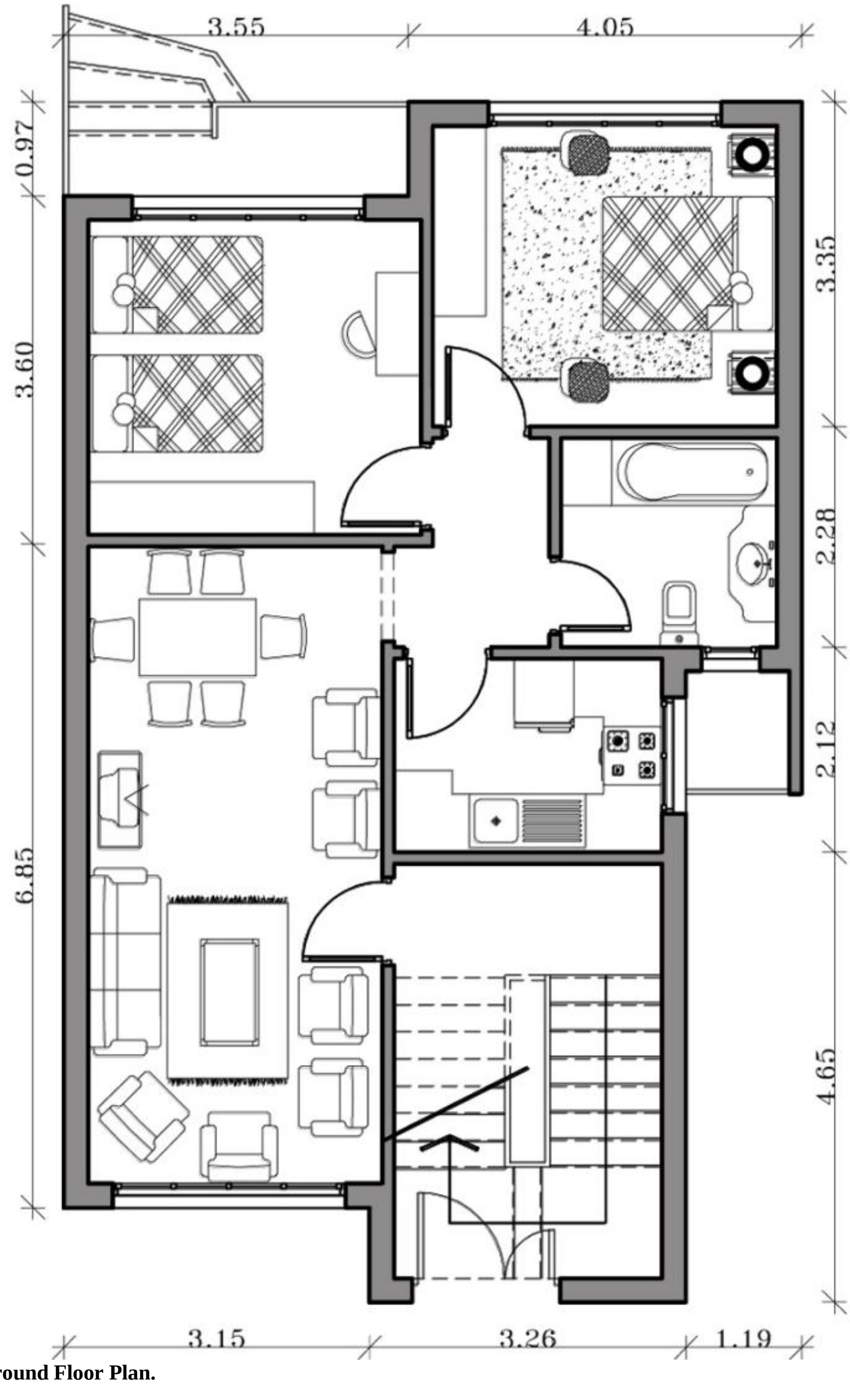
Pre Evaluation – ECOTECT					
No	Criteria	Options	✓	Issues	Notes
		Other (describe)			
21	Benchmarks and Targets	Past performance		Outcome is measured with respect to:	The outcomes assessing and controlling such issues as overshadowing, solar access, thermal comfort etc are quantitatively assessed with respect to good practice.
		Good practice	✓		
		Absolute sustainability measures (e.g. eco-footprint)			
		Past performance		Targets are made in reference to:	The target for ECOTECT is to make a building be as environmentally efficient as possible based on the information available.
		Good practice	✓		
		Absolute sustainability measures (e.g. eco-footprint)			
22	Post Decision Assessment		✓	To what extent does the tool evaluate the outcome of the decision?	The outcome of the tool is an overall quantitative assessment of building issues such as overshadowing, solar access, thermal comfort etc
				To what extent does the tool "learn" from its past use and/or from past decision outcomes?	The ECOTECT tool does not learn after each period of implementation. It uses the up to date data from its libraries of building element information to base its results on.
23	Legislation			Is there legislation requiring the use of this specific tool?	No.
Section 2: Tool Characteristics					
A	Characteristics	Flexibility	✓	Can tool adapt during an assessment to changes in a project?	The ECOTECT tool is designed to be used in the initial, schematic phases of design to analyze the likely performance of a building, therefore, the tool should be able to adapt if there are modifications in the design.
B		Upgrading		Can tool adapt as legal, commercial, cultural contexts change?	No information

Pre Evaluation – ECOTECT					
No	Criteria	Options	✓	Issues	Notes
C		Compatibility with other tools	✓	At input (i.e. uses the output of other tools as an input). At output (i.e. other tools can use its output). During operation (i.e. is used in conjunction with other tools to assess an aggregate impact). Is it used with a 'sustainability management' system?	Intuitive 3D CAD interface allows validation of the simplest sketch design to highly complex 3D models. ECOTECT can also import 3DS and DXF files. The output of ECOTECT can be used for more specific analysis and validation in RADIANCE, POV Ray, VRML, AutoCAD DXF, EnergyPlus, AIOLOS, HTB2, CheNATH, ESP-r, ASCII Mod files, and XML.
D		Aggregation/Disaggregation		Ability to 'add up' (over scales, issues, lifecycle phases) impact streams to give aggregate impacts. Ability to 'unpack' impacts into component streams.	No information.
E		Holistic	✓	Does it cover all life cycle phases? (scoring: possibly a ratio 4/10 based on the 10 stages identified in criteria 12)	2 / 10
F		Multidimensional	✓	Does it cover all sustainability dimensions? (criteria 11)	1 / 3
G		Inclusive	✓	Considers all stakeholders (criteria 15) Involves all stakeholders (criteria 16)	4 / 16 3 / 16

Pre Evaluation – ECOTECT					
No	Criteria	Options	✓	Issues	Notes
H		Scale able	✓	Does it consider impacts over a number of spatial scales? (criteria 8)Is it applicable at a number of product scales?(e.g. can be applied to both a building and a urban region; criteria 7)Is it applicable over a number of time scales?(criteria 10)	5 / 101 / 41 / 3

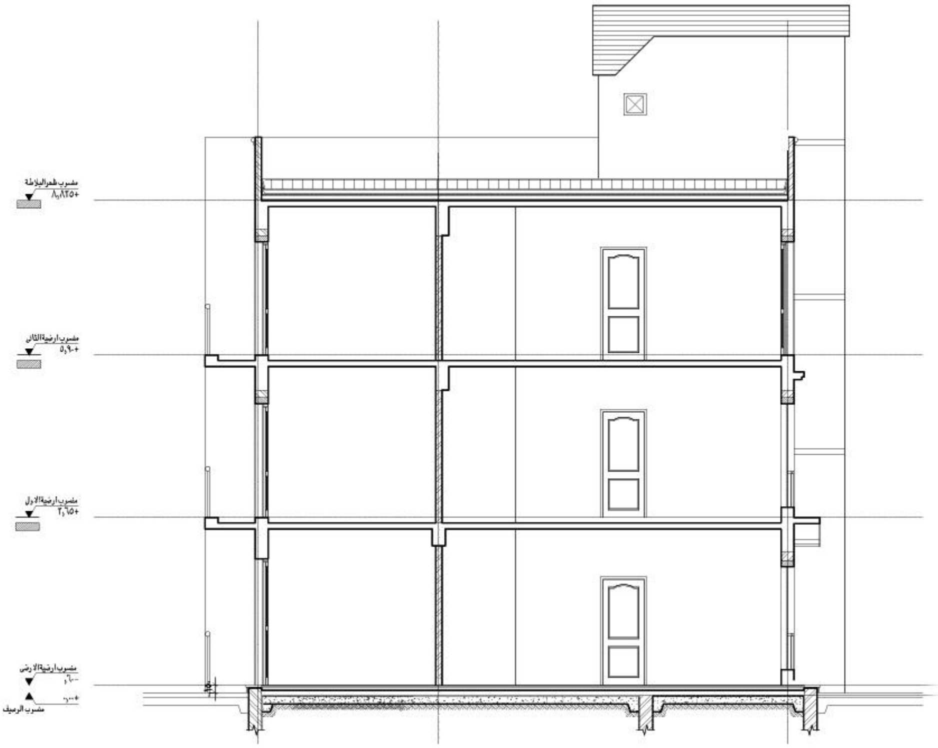
Source :URL:www.uclan.ac.uk/other/sds/rae/documents/ECOTECT.xls (accessed January 2005)

The Case Study Drawings

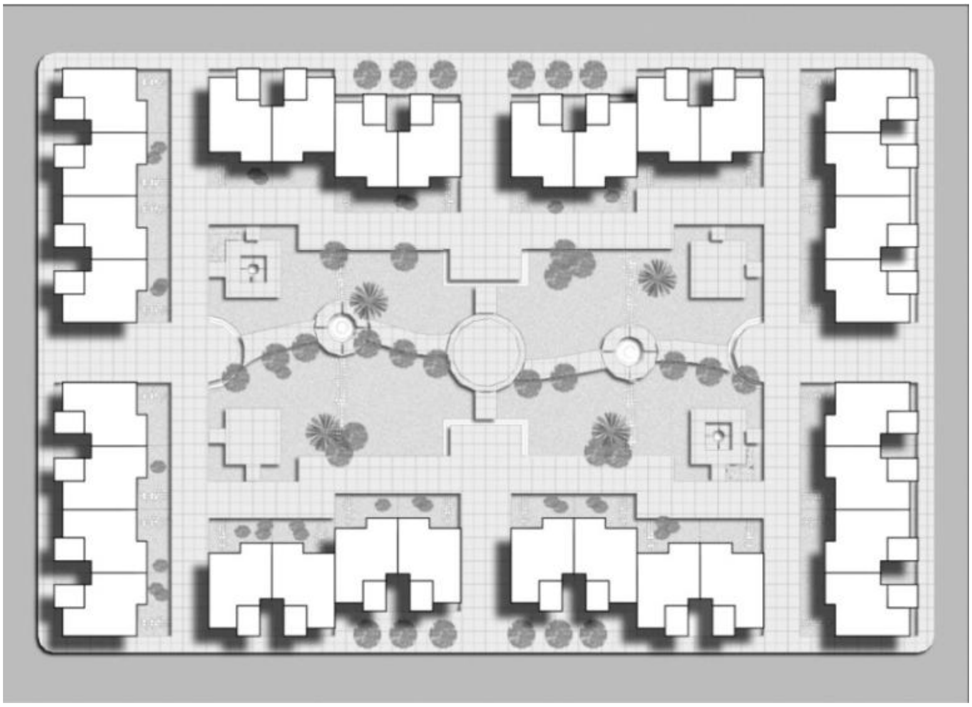


Ground Floor Plan.
(source: Housing and developing Bank URL: http://www.hdb-egy.com/)

The Main Elevation.
(source: Housing and developing Bank URL: http://www.hdb-egy.com/)



Cross Section
(source: Housing and developing Bank URL: http://www.hdb-egy.com/)



Layout.
(source: Housing and developing Bank URL: http://www.hdb-egy.com/)

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