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Example

AN ENGINEERING MANAGEMENT VIEW
OF THE GREEN BUILDING DESIGN MOVEMENT AS IT
PERTAINS TO COMMERCIAL BUILDINGS

A dissertation submitted in partial fulfilment
of the requirements for the degree:

MAGISTER INGENERIAE

in

ENGINEERING MANAGEMENT

at the

UNIVERSITY OF JOHANNESBURG

Student Name: CAREL RUDOLPH PIETERS
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February 2013
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I, Carel Rudolph Pieters, hereby declare that the following is my own work as deducted from research and case study investigations. I further declare that I have referenced all relevant sources to the best of my knowledge and have not deliberately infringed on any copyrights.

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C.R. Pieters
ABSTRACT

New and enlarged energy consumption behaviours driven by manufacturing, processing, transportation and an ever growing human population drives the increased extraction and consumption of earths' natural energy sources to such a degree that the energy sources once thought of as infinite now dwindle on the brink of exhaustion.

The earth and all systems related to, and contained within it can be regarded as a finite system in which the different components interact and depend on one another. It is through the recognition of this interdependence and the dire situation thereof that a movement towards renewable energy and ultimately survival has been awakened. A movement powered by numerous commissions and associations working tirelessly to decrease environmental impacts and to improve the lives of all people living on the planet Earth.

The current research investigates the Green Building Design Movement and how it contributes to a safer and healthier work and global environment. The current research not only investigates the background of the movement and reveals it as a multi faceted approach stemming from the depletion of existing energy sources and social consciences, but also provides insight to the direction which Green Design and future technological advancements are moving.

From the conclusions contained in this study the reader will gain a better understanding of the technology, processes and development phases used in Green Building design and how these contribute to lower emissions, lower energy consumption and a more responsible habitation of Earth and its finite systems.

In conclusion, the author employs a product and alternative energy source discussion, along with a case study to practically illustrate how the knowledge gained can be applied to optimize a building and the systems within it, while reducing energy consumption and the environmental impact of the building.
ACKNOWLEDGMENT

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"If I have seen farther it is by standing on the shoulders of giants..." - Isaac Newton
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ABBREVIATIONS AND ACRONYMS

B.C.  Before Christ
BREEAM  Building Research Establishment Environmental Assessment Method
Btu/ BTU  British Thermal Unit
CaGBC  Canadian Green Building Council
CASBEE  Comprehensive Assessment System for Built Environment Efficiency
CFC  Chlorofluorocarbons
CO  Carbon Monoxide
CO₂  Carbon Dioxide
COP  Coefficient of Performance
CSP  Concentrating Solar Power
CSR  Corporate Social Responsibility
EER  Energy Efficiency Ratio
EMF  Electromagnetic Fields
EVA  Environmental Value Analysis
EST  Energy Saving Tips
G  Gauss
GW  Gigawatt
HRVs  Heat Recovery Ventilation system
HVAC  Heating Ventilation and Air conditioning unit
IPCC  Intergovernmental Panel on Climate Change
kW  Kilowatt
kWh  Kilowatt hour
LEED™  Leadership in Energy and Environmental Design
LFG  Land Fill Gas
LiBr  Lithium Bromide
LLD  Lamp Lumen Depreciation
Ly  Langleys
NO  Nitrogen Oxide
NOI  Net Operating Income
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>PEMFC</td>
<td>Proton Exchange Membrane Fuel Cell</td>
</tr>
<tr>
<td>PPM</td>
<td>Parts per Million</td>
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<tr>
<td>PV</td>
<td>Photovoltaic</td>
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<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
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<tr>
<td>SAD</td>
<td>Seasonal Affective Disorder</td>
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<td>SANS:</td>
<td>South African National Standards</td>
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<tr>
<td>SO$_2$</td>
<td>Sulphur Dioxide</td>
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<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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<tr>
<td>USGBC</td>
<td>United States Green Building Council</td>
</tr>
<tr>
<td>VA</td>
<td>Value Analysis</td>
</tr>
<tr>
<td>VE</td>
<td>Value Engineering</td>
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<tr>
<td>VOC</td>
<td>Volatile Organic Compound</td>
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**DEFINITIONS**

<table>
<thead>
<tr>
<th>Term</th>
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<tr>
<td>Anthropogenic factors:</td>
<td>Are actions by humankind that affect the environment and influence climate.</td>
</tr>
<tr>
<td>Brundtland Commission:</td>
<td>A commission appointed by the United Nations, under Chairman Gro Harlem Brundtland, to unite countries in pursuing sustainable development.</td>
</tr>
<tr>
<td>Building Ecology:</td>
<td>The term refers to the physical environment, particularly the air quality, inside a structure.</td>
</tr>
<tr>
<td>Corporate Social Responsibility:</td>
<td>The World Business Council for Sustainable development defines CSR as: &quot;...being the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large.&quot; (Stamm, 2008)</td>
</tr>
<tr>
<td>Chemical energy:</td>
<td>Is defined as influence of electrical forces during the rearrangement of electric charges of electrons and protons in the process of aggregation.</td>
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<tr>
<td>Dehumidifier:</td>
<td>Is a device that reduces the level of humidity in the air.</td>
</tr>
<tr>
<td>Desuperheater:</td>
<td>A “desuperheater” preheats water for commercial and other applications by extracting wasted heat energy from the condensers of air conditioners or refrigeration systems.</td>
</tr>
<tr>
<td>Earth Berms:</td>
<td>Earth berms are barriers constructed through the use of soil, and used as diversion or deflection devices for wind, water and explosions.</td>
</tr>
<tr>
<td>Embodied Energy:</td>
<td>Is the energy needed to grow, harvest, extract, manufacture or...</td>
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<td>Term</td>
<td>Definition</td>
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<td>-----------------------------------------</td>
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<tr>
<td>otherwise produce a product. Some of this energy can be saved through reuse or recycling.</td>
<td>Enthalpy: A measure of the total energy is a thermodynamic system.</td>
</tr>
<tr>
<td>Is a device that cools air through the evaporation of water.</td>
<td>Evaporative Coolers:</td>
</tr>
<tr>
<td>Is a unit used to measure magnetic induction.</td>
<td>Gauss (G):</td>
</tr>
<tr>
<td>Is the warming of the climate as a result of heat trapped by atmospheric gasses.</td>
<td>Global warming:</td>
</tr>
<tr>
<td>The phenomenon whereby the earth's atmosphere traps solar radiation, caused by the presence of Greenhouse gases in the atmosphere that allow incoming sunlight to pass through but absorb heat radiated from the earth's surface.</td>
<td>Greenhouse Effect:</td>
</tr>
<tr>
<td>Any atmospheric gases, such as carbon dioxide, water vapor and methane, that contribute to the Greenhouse Effect</td>
<td>Greenhouse gas:</td>
</tr>
<tr>
<td>Is a device that converts thermal energy to mechanical action.</td>
<td>Heat Engine:</td>
</tr>
<tr>
<td>A device that transfers thermal energy from a source at a lower temperature to a heat reservoir at a higher temperature.</td>
<td>Heat Pump:</td>
</tr>
<tr>
<td>Are systems using equipment to employ a counter flow heat exchange between inbound and outbound air as well as other measures to condition air entering into the building.</td>
<td>Heat Recovery Ventilation System (HRVs):</td>
</tr>
<tr>
<td>Is the energy that an object possesses owing to its motion.</td>
<td>Kinetic Energy:</td>
</tr>
<tr>
<td>Is a protocol of the United Nations Framework Convention on</td>
<td>Kyoto Protocol:</td>
</tr>
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Climate Change and was first adopted in December 1997 in Kyoto Japan. Under the protocol countries commit themselves to reducing emissions of carbon dioxide, methane, nitrous oxide and sulphur hexafluoride. The protocol allows mechanisms such as emission trading.

<table>
<thead>
<tr>
<th><strong>Langley (Ly):</strong></th>
<th>One Langley is the radiation energy equivalent to one calorie falling on one square centimetre. The measurements are taken on a horizontal surface at ground level.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Latent Heat:</strong></td>
<td>Is the heat required to cause a change of state in matter.</td>
</tr>
<tr>
<td><strong>Legionnaires' Disease:</strong></td>
<td>Also known as Legionellosis is an infectious disease caused by aerobic bacteria and is potentially fatal. Symptoms include, fever, chills, coughing and in certain cases muscle aches, headaches, fatigue, diarrhoea and vomiting.</td>
</tr>
<tr>
<td><strong>Light monitors:</strong></td>
<td>Light monitors control the quality and quantity of sunlight inside a building.</td>
</tr>
<tr>
<td><strong>Light shelf:</strong></td>
<td>A light shelf is a white or reflective horizontal shelf, which can be mounted either inside, or outside exterior building windows. It should be mounted near the top of the window, above head clearance. Light shelves reduce window glare and bounce light upwards so it can reach deep into the interior.</td>
</tr>
<tr>
<td><strong>Luminous flux:</strong></td>
<td>Is the quantity of light output from a source of light without regard to the direction of the light. The lumen (lm) is the unit of measure of luminous flux.</td>
</tr>
<tr>
<td><strong>Meter Candle:</strong></td>
<td>A unit of illumination defined as the light given by one standard candle at a distance of 1 meter.</td>
</tr>
<tr>
<td><strong>Parabolic Troughs:</strong></td>
<td>Is a type of solar thermal energy collector, constructed as a long parabolic mirror with a tube running its length at the focal point.</td>
</tr>
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<td>------------------------</td>
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</tr>
<tr>
<td><strong>Potential Energy:</strong></td>
<td>Is the energy assigned to matter owing to its position or arrangement.</td>
</tr>
<tr>
<td><strong>Radiant Barrier:</strong></td>
<td>Radiant Barrier is an aluminized plastic film installed above the insulation and below the roof with the reflective side facing down.</td>
</tr>
<tr>
<td><strong>Radiant Energy:</strong></td>
<td>Is the energy produced by electromagnetic waves or other forms of radiation.</td>
</tr>
<tr>
<td><strong>Rankine Cycle:</strong></td>
<td>Is a cycle used to convert heat in to work energy such as steam operated heat engines found in power generating plants.</td>
</tr>
<tr>
<td><strong>Seasonal Affective Disorder:</strong></td>
<td>Is a type of depression that occurs at a certain time of the year, usually during winter.</td>
</tr>
<tr>
<td><strong>Smog:</strong></td>
<td>Consists of a dense mixture of fog and smoke trapped close to the earth’s surface.</td>
</tr>
<tr>
<td><strong>Specific Heat:</strong></td>
<td>Is the measure of the energy that is needed to raise the temperature of a specific quantity of a substance by a certain amount.</td>
</tr>
<tr>
<td><strong>Sick Building Syndrome:</strong></td>
<td>The phenomenon called “sick building” syndrome, is caused in part by the “out gassing” of chemical compounds from paints, carpets and construction adhesives and part caused by inadequately vented appliances, cigarette smoke, noxious vapours from cleaning compounds, airborne bacteria and microscopic dust mites. Symptoms include sensory irritation of the eyes, throat, nose, skin irritation, odour and taste sensations as well as general health problems.</td>
</tr>
<tr>
<td><strong>Superwindows:</strong></td>
<td>The term “superwindow” refers to double- or triple-paned windows filled with Argon gas and containing an almost invisible “low-emissivity” coating. The low emissive-coating can be on the inner surface of one or more glass panes or on film (or films) suspended between two panes. The glass/film combination allows short-wave radiation to enter while preventing long-wave radiation (infrared or heat) from entering</td>
</tr>
</tbody>
</table>
or leaving.

| Volatile Organic Compounds (VOCs) | Are organic chemicals that have a high vapour pressure resulting from a low boiling point. The low boiling point causes large numbers of molecules to evaporate from the liquid or solid form of the compound and enter the surrounding atmosphere. |
| Water White Glass: | Refers to a type of glass that transmits 98 to 99 percent (%) of light while being anti-glare and anti-reflective. |
CHAPTER 1. DISSERTATION OVERVIEW AND LAYOUT

1.1 INTRODUCTION

“In many ways, the environmental crisis is a design crisis. It is a consequence of how things are made, buildings are constructed and landscapes are used. Design manifests culture and culture rests firmly on the foundation of what we believe to be true about the world.” – Sym Van Der Ryn

Green Design is not a new phenomenon but rather an invention that we as the human species have neglected and forgotten through technological advances and relatively inexpensive energy costs. Ancient civilizations utilized concepts such as heat-reservoirs, day lighting and even harnessed the sun’s energy to power technological advances.

The recent rise in energy and fossil fuel costs have stimulated the search for better and more affordable methods of providing energy, leading to a technological research and development frenzy. It is expected that in addition to renewable energy sources, energy conservation and improvements in energy generation will become increasingly important. (Kreider, 2011)

Technological advances ensure that Green Design has become more comparable to conventional construction methods. Green Design makes use of different evaluation methods to those deployed in conventional construction methods, and takes into account factors such as the environmental impact of a construction method, as well as the long term sustainability of the action and the populations affected by it.

1.1.1 Purpose Statement

The aim of the current research is to provide an engineering management view of the Green Building design movement as it pertains to commercial buildings.

From Figure 1 it can be seen that energy consumption through buildings amount to 41 percent (%) of total energy consumption within the European Union. It is with this in mind that Green Designs worth and the relevance thereof begins to show.
1.1.2 Need
The predicted fossil fuel shortages have compelled industries to create energy conservation programs that will reduce energy consumption and generate cost savings. By doing so a company striving to save on energy consumption will need to conduct investigations and research into possible sources of energy wastage. The current research serves as a starting point to broadening companies and individual’s knowledge on sustainable design as well as energy conservation and optimization.

1.1.3 Scope and Limits
The current research is limited to commercial buildings, and although some applications might overlap with residential buildings, these buildings will not be included. All references made in the current research to “Green Buildings” refer to commercial Green Buildings only. It is outside the scope of the current research to supply an in-depth analysis of commercial Green Buildings, the systems applied in each building or processes and materials used.

1.1.4 Defining Sustainable Design
“Sustainable design is the philosophical basis of a growing movement of individuals and organizations that literally seeks to redefine how buildings are designed, built and operated to be more responsible to the environment and responsive to people.” (McLennan, 2004)
The term “sustainable design” is often used to describe strategies, components and technologies that lessen environmental impact and can more precisely be defined as a movement that is actively defining itself, its principles, components and philosophy, focusing all of these into the continued co-existence of earth and its inhabitants. The Brundtland Commission defines sustainability as “…meeting the needs of the present without compromising the needs of the future.” (McLennan, 2004)

The categories included, but not limited to, in sustainable design, are:

- Day Lighting ;
- Site Preservation ;
- Natural Landscaping ;
- Renewable Energy ;
- Solid Waste Management ;
- Commissioning ;
- Water Conservation ;
- Construction Waste Minimization ;
- Embodied Energy ;
- Natural Ventilation ;
- Passive Solar Heating ; and
- Indoor Air Quality.

1.1.5 History

It has been suggested that Archimedes was the first known person to harvest the sun’s energy and reputedly set fire to a Roman fleet at Syracuse in 212 B.C. Galileo and Lavoisier conducted serious studies of the sun’s energy through their research in the seventeenth century and managed to melt diamonds by the year 1700. (Diana Lopez Barnett, 1995)

Since the early 1800s, heat engines could be operated from energy supplied by the sun. The early twentieth century saw solar energy being used to power water distillation plants in Chile and irrigation pumps in Egypt, followed by solar service hot-water heaters in the 1920s. During 1938, the first building to be practically heated with converted solar service-hot-water heaters was constructed at the Massachusetts Institute of Technology.
“...the space age gave solar energy a boost in the United States of America. The success of solar cells in powering service modules of the National Aeronautics and Space Administration (NASA) on terrestrial orbit and lunar excursions led some engineers to propose other uses for solar energy in the space program.” (Diana Lopez Barnett, 1995)

1.1.6 Evolution and Timeline

Sustainable design can be traced back through four distinct evolutionary stages. (McLennan, 2004)

These stages are:

- The biological beginning;
- The indigenous beginning;
- The industrial beginning; and
- The modern beginning of sustainable design.

1.1.6.1 The Biological beginning

The human history of expansion and growth is part of the natural process. It is a case of a species that has so far been intelligent enough to avoid most of the traditional checks and balances in nature. However, the counterbalance cannot be ignored since growth in a finite system (the earth) cannot be infinite.

There are numerous examples in history of cultures that grew and consumed resources until a natural check occurred that ended the growth of the culture. A striking example is that of the inhabitants of Easter Island who denuded their landscape of trees and ultimately created their own demise. It is therefore clear that we as a species are an integral part of the greater scheme, and since we have the ability to live outside the natural parameters set for our species’ it is our responsibility to self-regulate. (McLennan, 2004)

1.1.6.2 The Indigenous beginning

There are a number of people that idealize the designs and innovations of indigenous architecture, which can be found in ancient cultures all over the world. Ruins, such as those of Mesa Verde in New Mexico, show the ingenuity of the people that built this illustrious village.
The village was constructed from stone and is located at the base of an enormous cliff outcrop. In winter the low angle sun would warm the inhabitants and the buildings, while the cliffs provided shade during warmer summer months. The use of massive thermal stones with small windows further increased the benefits of the cliff location. Small windows let in sufficient air and light but not so much that a draft would become problematic. The cliffs and stonework also acted as thermal reservoirs, retaining heat in winter, while staying cool in summer. (McLennan, 2004)

1.1.6.3 The Industrial beginning

The technology gained from the industrial revolution enabled societies to transform the relationship between climates inside buildings and those outside. Building design changed in response to the new technological possibilities.

Before the invention of electricity and electrical lights, buildings were often constructed narrowly to allow as much natural light into the building as possible. Elevators and the proliferation of building materials made it possible to have taller, bigger buildings, which did not limit population densities like their predecessors. Steam engines and automobiles further made it possible to ship materials all over the world and the idea of only building with local material became irrelevant. (McLennan, 2004)

Pollution of air, soil and water closely followed the new inventions and progress. By the eighteenth century, a few very familiar environmental issues such as "smog" began to emerge. Smog consists of a dense mixture of fog and smoke trapped close to the earth’s surface and it was documented to have covered London for periods of up to a month. However, at the time only limited measures were in place to deal with environmental deterioration. The majority of measures available or deployed only acted as temporary solutions and normally sent the problem further afield.

The Sudbury Company can be used as an example. Through the companies nickel mining operations in North America, it was the single biggest contributor to acid rain. Its solution, in the first three quarters of the twentieth century, was to build the world's biggest smokestack and therefore disperse its pollutants over a bigger area. These measures helped halt the decline of the immediate regional environment but spread the problem to a much wider area. (McLennan, 2004)
1.1.6.4 The Modern beginning

Sustainable design can be viewed as a sub-set of the modern environmental movement and is the building industry’s reaction to the realization that the manner in which it conducts business influences environmental problems facing the global community.

During the last couple of decades an increasing number of people became conscious of biological heritage, virtues of indigenous design solutions and even accepted that man made technologies carried certain risks and responsibilities. Countless researchers and developers experimented with energy conservation products and solar energy only to abandon the experiments in preference of more conventional methods. This was mainly due to the lower conventional energy costs associated with the period.

A wide variety of factors such as global warming and the rise in energy costs have necessitated a revised look into sustainable energy and the design thereof. The trend of technological development and buy-in from people has intensified and is stronger than ever. (McLennan, 2004)

1.2 RESEARCH APPROACH

"... research is a systematic and unbiased way of solving a problem (by answering questions or supporting hypotheses) through generating verifiable data." (Lang and Heiss, 1991)

1.2.1 Selection and Formulation of the Research Problem

The accelerated pace of the modern green movement has always been of interest to the author. Through observations the author has identified the need for more costly and environmental friendly energy supply to domestic buildings. After a preliminary literature review and investigation into the limitations of the current research, it was decided to increase the scope of the current research to commercial buildings. These buildings are significant energy consumers while being equipped with energy influencing mechanisms, therefore small changes or improvements to these buildings energy consumptions would be more beneficial to the environment than adaptations to residential dwellings.

1.2.2 Research Aim and Objective

"It's the question - not the method - that should drive the design of education research or any other scientific research. That is, investigators ought to design a study to answer the question that they think important, not fit the question to a convenient or popular design" (Packer, 2011)
The aim of the current research is to answer the following question:

"What measures can be developed, processes followed and mechanisms employed within a commercial building to assist with the decreased energy consumption of commercial buildings and ultimately the reduction of their environmental impact?"

Keeping this in mind, the objective of the current research is to provide insight to the modern green designer on the different components associated with Green Design. It is to show where Green Design originated, where it is heading and which technological advances and organisations drive it.

The author is aware that each topic covered in the current research can be expanded and formulated to such a degree that each one could have filled all of the pages in the current research. The aim of the current research is therefore not to educate the reader in a specific field, but to entice the reader and green designer to dig deeper into the exciting and often overwhelming field of Green Design.

1.2.3 Research Design and Methodology

"A research design is a plan or strategy which moves from the underlying philosophical assumptions to specifying the selection of respondent, the data gathering techniques to be used and the analysis to be done." (Creswell, 2010)

"Qualitative research explores attitudes, behaviour and experiences through such methods as interviews or focus groups. Quantitative research generates statistics through the use of large-scale survey research, using methods such as questionnaires or structured interviews." (Dawson, 2006)

The current research relies heavily on the exploration, examination and assessment of existing literature and can therefore be classified to be more qualitative than quantitative.

The data collection followed a path of conceptualization through the use of coding (forming typologies and taxonomies) which identifies differences in the data, thereby forming subgroups within the data. The process was analytical, requiring the review, selection, interpretation and summarization of data without distorting it. Following the initial step of data gathering was the process of data reduction and analysis. This was done as a sequential and continuous process, becoming more and more complex as the research progressed. The next stage of analysis
consisted of the identification of patterns and themes through which the data collected could be sorted. To assist with finding patterns and themes, data was broken down into smaller, more workable groupings, such as different themes, causes, explanations, relationships and emerging concepts. Once formalized, the data could be moulded and shaped into useful information, discussions and conclusions.

Figure 2: The Research Process (Walliman, 2011)

Figure 2 shows the research process with adoptions as used within the current research.

Following the casual process theory, the current research makes use of interrelated sets of definitions and statements which define theories as well as describe when and where such processes or theories are expected to occur. In this theory form, immeasurable concepts and limits are drawn on which the theory will be applicable. (Walliman, 2011)

1.2.4 Selecting the Research Tools

The research followed the path of an in-depth literature review, strengthened by case studies as available in the texts. The current research further refers to SANS codes of practice and product related literature. Some information, as captured in the interview with Mr. Allister Devine from ABB, has been documented in a field book and is formally represented in Annexure A.
1.2.5 Current Research Outcomes

From the onset of examining the research, a vast number of unformulated research questions appeared. This necessitated the author to broaden the scope of the research to address as many of these questions as possible by including and communicating as much relevant information.

It is anticipated that the following outcomes can flow from the current research:

- Readers of the current research will be able to form a better understanding of the Green Design movement and the direction, both historical and future, which the movement has taken;
- The organisational environment might be altered and better influenced;
- Perspectives and opinions of key role players will be affected, either for better or worse;
- The reader of this current research will by no means be completely schooled in all matters pertaining to Green Design; and
- The designers and architects of technological advanced products will be educated as to where there are fields of study still to be conducted.

1.2.6 Related Research

Through the current research it was found that an extensive amount of information is available on Green Design as a topic. The author was able to examine some very assertive and informative sources. It was, however, discovered that many of the texts available used older statistics -statistics that might not be as relevant today as it was when published.

From the investigations conducted within the current research it was found that there are limited sources available on technological advances currently being made on green products.

1.2.7 Section Conclusion

The current research covers a number of topics pertaining to Green Buildings. Each topic is set out with a brief or in-depth discussion assisted with formula and a conclusion summarising the point of discussion. Different trade-offs, advantages and disadvantages are shown and compared, with the aim of leaving the reader more informed and equipped.
The author has included relevant questions as Annexure and referenced these within the body of the current research. Please refer to Chapter 6 for a more complete and detailed discussion on the relevant findings and conclusions.

1.3 ACADEMIC BACKGROUND

This section is included for the benefit of the reader and aim to secure the readers academic understanding of certain terms or processes that are used or discussed within the current research.

“James Prescott Joule, a nineteenth century English businessman, is accredited with performing the experiments that led to the principle of the conservation of heat and mechanical energy. Joule, in 1840, was able to determine the mechanical equivalent of heat, now appropriately referred to as Joule’s constant (4.184 joules/calorie)” (Krenz, 1984)

1.3.1 Different forms of Energy

Reference (Devins, 1988) states the following as different forms of energy:

- Kinetic Energy – The energy of relative motion;
- Gravitational Potential Energy – The energy of position of mass in a gravitational field;
- Electric and Magnetic Energy – The energy of position of electric charges in electric and magnetic fields;
- Electromagnetic Energy – The radiant energy resulting from acceleration of electric charges;
- Chemical Energy – The energy of position of electrical charges in the electric fields of atoms;
- Mass Energy – The binding energy resulting from interactions of strong nuclear forces between nucleons;
- Thermal Energy – The kinetic energy of electrons, atoms and molecules.

1.3.2 The First and Second Law of Thermodynamics

Thermodynamics deals with the transfer of heat through two principal laws. The first law is concerned with the conservation of energy and states that energy can neither be created nor destroyed, only converted from one state of energy to another. The second law deals with the equalization and transfer of energy from a higher to a lower state. Simply stated, energy is always
transferred from a higher potential or state to a lower potential or state, until the energy sources achieve exact equilibrium. (Angrist, 1976)

The energy of a closed system can be expressed as:

\[ E = me + \frac{(mu)^2}{2g} + \frac{mgz}{g_c} \]

**Equation 1**: First law of Thermodynamics (Jan F. Kreider, 2001)

Where:
- \( E \) is the total energy of the system
- \( e \) is its internal energy per unit mass \((m)\) and the last two terms are the kinetic and potential energy (Jan F. Kreider, 2001)

### 1.3.3 Heat Transfer

"In general heat is energy in transfer state because it does not stay in any specific position and constantly moves from a warm object to a cooler one until such time that, as per the second law of thermodynamics, both bodies reach heat equilibrium." (Gevorkian, 2009)

Heat travels in one of three forms: radiation, conduction or convection. As radiation, heat is transferred in a wave form, while conduction occurs through physical contact and convection is the flow of heat between air, gas, liquid and a fluid medium. The volume, size and mass of an object are irrelevant in the heat-transfer process, however the rate of heat transfer is directly proportional to the difference in temperature between the two objects.

### 1.3.4 Defining Wavelengths and Energy Transfer

The energy of a photon of radiation, \( E_{\text{photon}} \), is proportional to the frequency of the radiation, \( \nu \). (Angrist, 1976)

\[ E_{\text{photon}} = h\nu \]

**Equation 2**: Energy of a Photon of Radiation (Angrist, 1976)

Where
\[ h = 6.625 \times 10^{-34} \text{ J/s (Planck's constant)}. \]
Utilizing the relationship between frequency and wavelength \( \lambda \), an expression for energy in terms of wavelength is obtained.

\[
v = \frac{c}{\lambda}
\]

**Equation 3: Energy as Wavelength** *(Angrist, 1976)*

Where

\[
c = 3 \times 10^8 \text{ m/s (velocity of light)}.
\]

Therefore:

\[
E_{\text{photon}} = \frac{hc}{\lambda}
\]

**Equation 4: Energy of a Photon** *(Angrist, 1976)*

From this, it is clear that light with different wavelengths will have different values of energy.

1.3.5 Molecular Agitation

Dependent on the state of heat energy within the substance, most substances exist in vapour, liquid, or solid states. Therefore, a substance’s state can be altered by adding to or removing heat from the substance. For example, steam will condense back to water if heat energy is removed from it, and in turn, the liquid will change into its solid state when sufficient further heat is removed from it.

This state of change is related to the fact that in various substances, depending on the presence or absence of heat energy, a phenomenon referred to as atomic thermal agitation causes expansion and contraction in molecules. A close contraction of molecules forms solids, while large separation between molecules transforms the substance into a liquid. *(Angrist, 1976)*

1.3.6 Coefficient of Performance (COP)

“A ton of cooling energy equates to 12 000 Btu/h, which is the energy required to remove heat from a space through melting a ton of ice. One ton or 12 000 Btu, is equal to 3413 W of electric power.” *(Gevorkian, 2009)*

An air conditioners’ energy efficiency is defined by a coefficient of performance (COP), which is the ratio of energy consumed (kW) versus cooling energy supplied (Btu). Also expressed as:
1.3.7 Energy Efficiency Ratio (EER)

The term Energy Efficiency Ratio (EER) is an industry designation for energy conservation efficiency. The higher the EER, the greater the efficiency and the more likely savings will become over the life cycle of the system.

\[
EER = \frac{\text{BTU (heat transferred)}}{\text{Watt (electricity used)}}
\]

Equation 5: Coefficient of Performance (Angrist, 1976)

\[
COP = \frac{\text{CoolingEffect}}{\text{HeatInput}}
\]
CHAPTER 2. GREEN DESIGN MOVEMENT

2.1 AIM AND OBJECTIVES

“A Green Building is one that considers and then reduces its impact on the environment and human health.” (Yudelson, 2008)

The ultimate goal of Green Building design is a design culminating in a building that is bright and well lit, warm in winter and cool in summer, comfortable and healthy, energy- and resource-efficient, functional, has longevity and promotes the well being of its occupants and the earth. In short, it is to produce buildings that take less from the earth, while giving more to the people inhabiting the buildings.

Therefore a Green Buildings should:

- **Save Energy:**
  Modern energy efficiency technology enhances most buildings comfort, beauty, quietness, performance, bottom line and worker productivity;

- **Save Water:**
  Water efficient plumbing fixtures reduce water, energy and sewage treatment bills;

- **Promote Economic Development:**
  Resource efficient buildings strengthen local and national economies through owners and tenants spending less on imported energy and utilities and more on local readily available resources;

- **Improve Health and Productivity:**
  Green Buildings provide improved worked productivity and reduced absenteeism;

- **Reduce Pollution:**
  Saving energy directly saves units of fuel, generally coal, from being consumed to generate electricity. Consuming less fuel results in less CO₂ emissions which is the primary Greenhouse gas as well as less SO₂ and NOₓ emissions which contribute to acid rain; and
• Protect the Environment:

    Carefully designed Green Buildings restore and enhance natural habitats while the use of recycled or sustainably sourced building materials help protect forests and endangered species.

Green Design is gaining ground through the revelations of current research showing that organisational aims have shifted, away from purely economical considerations, to include factors such as human capital, social implications, environmental impact and issues of sustainability. (Stamm, 2008)

### 2.2 BENEFITS

To be commercially, socially and environmentally effective, sustainable design needs to have measurable outcomes and benefits. These benefits can be sub-divided between direct and indirect benefits. (Diana Lopez Barnett, 1995)

**Direct benefits:**
- Lower long-term exposure to environmental or health problems for workers;
- Greater workforce productivity;
- Protection of ecosystems;
- Savings in energy bills; and
- Market advantage.

**Indirect benefits:**
- Reduced emissions that cause Global Warming;
- Less ozone layer depletion;
- Increased biodiversity; and
- Reduced recycling.

**Further benefits:**

<table>
<thead>
<tr>
<th>Number</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Utility cost savings for energy and water, typically 30 to 50 percent (%), along with a reduced &quot;carbon footprint&quot; from energy savings.</td>
</tr>
<tr>
<td>2</td>
<td>Maintenance cost reductions from commissioning, operator training and other measures to improve and ensure proper systems integration and ongoing performance</td>
</tr>
<tr>
<td></td>
<td>Benefits of Green Buildings (Yudelson, 2008)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>Increased value from higher Net Operating Income (NOI) and increased public relations for commercial buildings.</td>
</tr>
<tr>
<td>4</td>
<td>Tax benefits for specific Green Building investments such as energy conservation and solar power; and local incentives depending on location.</td>
</tr>
<tr>
<td>5</td>
<td>More competitive real estate holdings for private sector owners, over the long run, including higher resale value.</td>
</tr>
<tr>
<td>6</td>
<td>Productivity improvements for long-term building owners, typically 3 to 5 percent (%).</td>
</tr>
<tr>
<td>7</td>
<td>Health benefits, including reduced absenteeism, typically 5 percent (%) or more.</td>
</tr>
<tr>
<td>8</td>
<td>Risk management, including faster lease up and sales for private developers and less risk of employee exposure to irritating or toxic chemicals in building materials, furniture and furnishings.</td>
</tr>
<tr>
<td>9</td>
<td>Marketing benefits, especially for developers, large corporations and consumer products companies.</td>
</tr>
<tr>
<td>10</td>
<td>Public relations benefits, especially for developers and public agencies.</td>
</tr>
<tr>
<td>11</td>
<td>Recruitment and better retention of key employees and higher morale.</td>
</tr>
<tr>
<td>12</td>
<td>Fund raising for colleges and nonprofits.</td>
</tr>
<tr>
<td>13</td>
<td>Increased availability of both debt and equity funding for developers.</td>
</tr>
<tr>
<td>14</td>
<td>Demonstration of commitment to sustainability and environmental stewardship as well as shared values with key stakeholders.</td>
</tr>
</tbody>
</table>

In addition to the health and environmental benefits of living and working in a Green Building, worldwide many governments and other entities are now offering rebates, tax breaks, and other incentives to encourage the incorporation of eco-friendly elements in proposed building projects. (Sam Kubba, 2010)

Green Buildings further offer a wide framework of non-tangible benefits such as economic, financial, productivity, risk management, public relations, marketing and funding benefits. These benefits differ from project to project due to ownership, type of building use, level of investment and other similar drivers. Please refer to Section 2.7 of the current research for a more complete discussion on Green Building economics.

### 2.2.1 Developer and Tenant Benefits

Green Buildings benefit the developers and tenants through being:

- Healthier to work in;
- Having psychological advantages; and
- Enhancing company profiles and images.
2.2.1.1 Healthier to work in
The use of more natural light, solar energy for heating and cooling as well as more organic materials during construction all add up to healthier buildings than conventional air conditioned buildings.

2.2.1.2 Psychological advantages
People seem to respond better to buildings where they can open windows, pass through well planted atria, feel a breeze or see a plantation directly outside their windows. All these, contribute to a hyphenated sense of well being and thereby increased productivity. (Edwards, 2003)

2.2.1.3 Enhanced company image
Sustainable design provides the impression that a company has an open, flexible and holistic way of thinking and conducting business.

2.2.1.4 Repayment Benefit
Financially, sustainable design offers a major advantage to developers. The developer should take a long term view realising that, if designed and implemented correctly, the lower running and maintenance cost of a Green Building will pay for itself several times over for the greater initial investment.

For a more complete list of Green Building benefits, please refer to Annexure B.

2.3 PRINCIPALS

“We shape our environments, thereafter, they shape us – Winston Churchill.” (McLennan, 2004)

It should be noted that sustainable design in itself is not a new building style. Instead, it is representative of an evolution in designing, constructing and operating buildings so as to lessen the environmental and other harm poorly designed buildings can cause. This evolution can only be obtained by using the best building approaches in logical combination with the best technological advances available. (McLennan, 2004)

Sustainable design does not revert back to the past, but rather calls for the responsible co-operative long-term usage of technology in combination with modern and innovative design. It further suggests that technological fixes be applied only after all natural measures have been employed to
their full extent, and it encourages celebrating and protecting unique characteristics of the building location.

Though being in its early stages of development it should be noted that the modern sustainable design methodology and philosophy does not have one author or divine source. It is the work of hundreds of thousands of individuals often fighting the status quo on how the design and implementation should be done.

Figure 3 shows the layout of some of the most basic Green Design principles.

![Figure 3: Framework for Achieving Green Design (Stamm, 2008)](image)

### 2.3.1 Core Fundamentals

The sustainability design movement has, as its core, two fundamental beliefs, namely:

- That we humans, as a civilization, along with our actions, have a negative impact on the environment and are therefore putting our own existence and that of other species at risk; and
- That we have a responsibility to shape our societies and technologies in such a way as to ensure our future existence as well as the existence of other species on earth.
2.3.2 Natural Sustainable Design

“The human race is challenged more than ever before to demonstrate our mastery – not over nature – but of ourselves.” - Rachel Carson (McLennan, 2004)

Six major principles on the sustainable design movement have emerged to flesh out the philosophy of sustainable design:

- Respect for the wisdom of the Natural Systems;
- Respect for People;
- Respect for Place and Location;
- Respect for the Circle of Life;
- Respect for Energy and Natural Resources; and
- Respect for Process.

2.3.2.1 Respect for the Natural System

This principle is based on taking inspiration from the designs present in nature, through the use of an ecological standard to judge the rightness of innovations and valuing what can be learned versus what can be extracted. Almost all major discoveries in engineering and medicine have a direct link to lessons learnt from nature. These include inventions such as Velcro; which was derived from seeds sticking to animals' fur; and even painkillers and anaesthesia derived from tropical plants and animals such as the curare vines and tree frogs.

The design concepts should therefore strive to align with nature’s innovations having in common the following:

- Use of sunlight as energy;
- Using only the energy needed;
- Fitting form to function;
- Recycling;
- Rewarding co-operation;
- Banking on diversity;
-Demanding local expertise; and
- Curbing excesses from within.
2.3.2.2 Respect for People

“Sick building syndrome is defined as a sustained state of unhealthy indoor environmental conditions. It is caused by prolonged unhealthy air quality that can come from a variety of sources including the chemical off-gassing of materials, mould and mildew growth, and elevated carbon dioxide levels caused by poor ventilation.” (McLennan, 2004)

It might be surprising to learn that the sustainable design movement and philosophy is in fact as much about people as it is about the environment. People tend to forget that it is possible to elevate the concerns of other species without negatively influencing our own. (McLennan, 2004)

2.3.2.3 Respect for Place and Location

“...place is used as a word to describe the complex interplay of climatologically, biological and topographical features that create the differences we see around us” (McLennan, 2004).

In the unwavering search for greater comfort and security, the technologies and philosophies developed changed the way people interact with their immediate surroundings. Inventions such as air conditioning, central heating, elevators and the industrial production processes made it possible to create comfortable conditions regardless of the regional climate.

Sustainable designers take into account building orientation and functioning when assessing factors such as sun movements, natural breezes etc. These natural factors should ultimately determine the buildings location, orientation, shape, size and energy consumption. Having applied all these factors correctly should make major energy savings possible.

2.3.2.4 Respect for the Circle of Life

“What stupidity is it that compels us to design packaging that lasts a thousand years when the food contained in it is meant to last only for a few days?” (McLennan, 2004)

Respecting the Circle of Life means finding the appropriate fit between a products' life expectancy and the use it was created for. Human civilization is guilty of an irresponsible over-engineering tendency, while at the same time encouraging the throw-away-culture and consumption of such materials.
Planet earth sustains life within a narrow range of parameters, such as an atmospheric oxygen level of 21 percent (%) and a fairly constant 1.7 parts per million of methane. The methane in the atmosphere reacts with sunlight to form carbon dioxide and water. It is therefore clear that all organisms or systems on earth are interconnected with one another and interdependent on each other for survival. (McLennan, 2004)

Years have been spent removing harmful elements such as asbestos and lead from environmental surroundings while a large range of toxic materials still remain. Some materials have not yet been proven harmful and include substances such as Polyvinyl Chloride (PVC), fibreglass and Mercury.

2.3.2.5 Respect for Energy and Natural Resources
The convenience and affordability of modern energy supply and its use, has consequences and responsibilities which are not always recognised. These consequences and responsibilities are not always clear off hand and therefore energy should always be used as a valuable resource, which is limited and expensive. (McLennan, 2004)

2.3.2.6 Respect for Process
Sustainable design is a progressive subject dealing from the understanding that all elements are interconnected and that changes on some might adversely affect others.

2.4 INTEGRATED DESIGN
The process of integrated design for a high performance building is relatively simple. Firstly, the developer should make a commitment to integrated design and hire a design team that has experience in such ventures or at least wants to participate. Secondly, the design team needs to be closely managed so as to incur a zero cost increase over a conventional budget. By closely managing the design team “cost transfers” or “cost tradeoffs” can be identified from the onset of the project. Thirdly, “stretched” goals should be set for each member of the team as well as the entire team as a whole. Appraisal of the overall project success can then be measured against the goals previously set. Lastly, enough time for research, feedback and revisions should be allowed for before committing to a final design concept. (Yudelson, 2008)

Since the focus of integrated design should be on the long term functionality and health of an entire building system or group of systems, not just specific elements, the interrelation of different systems within the building should be viewed as critical.
"In system science, a system is a set of elements interacting with one another purposefully to achieve some common goals making the whole functionality greater than the sum of the individual parts." (Chang, 2011) Therefore there are relationships between two or more elements, that serve to define the subsystems or the organization of the whole system. The boundary of a system separates it from the rest of the universe, which is known as the surroundings. (Chang, 2011)

Figure 4 illustrates how different elements and subsystems interact with each other within a system.

2.4.1 Integrated Design

There are ten key steps in the facility delivery process where extra care and deliberation should be taken. Reference(Sandra Mendler, 2006) states these steps as:

- Project Definition
- Team Building
- Education and Goal Setting
- Site Evaluation
- Baseline Analysis
- Design Concepts
• Design Optimization
• Documents and Specifications
• Bidding and Construction
• Post-occupancy

2.4.1.1 The Integrated Design Team
An integrated design team will normally comprise of persons that bring specific skill sets to the project. There should however be some key participants such as the following, in the design team:

• The building or project owner;
• The architect;
• The mechanical engineer (typically including HVAC and plumbing designers);
• The civil and/or structural engineer;
• The project manager; and
• The general contractor, consisting of landscape architect, interior decorator, etc.

A design teams’ experience will have a substantial influence on the actual design fees, firstly since a “risk premium” is normally assigned by teams with little or no experience and secondly, experienced teams have developed shortcuts, written standard specifications, researched alternative materials and generally have learned to compile a design team with similar experience.

2.4.1.2 Team Structure
When key personnel such as the contractor and key sub-contractors understand how high performance projects come together and are well integrated into the building team from the beginning, cost premiums tend to evaporate.

2.4.1.3 Cost-Benefit Analysis
Most project teams will be facing “cost versus benefit” questions for the various measures proposed in a Green Building development. Without a solid quantifiable set of metrics to assess a project against, environmental initiatives normally tend to take a back seat to traditional project forces such as schedule constraints and budget-related issues.
2.4.2 Managing Conservation Programs

Monitoring and tracking energy consumption as well as keeping track of trends and measuring performance are viewed as the most important tasks in energy management plans. By applying sound accounting principles the energy cost trend could be an effective way to control costs and increase profits. (Krenz, 1984)

The effectiveness of an energy management plan should be evaluated by plotting the rate of energy consumption, per unit of production, over a period of time. Keeping track of energy usage by itself is not sufficient since it will not reflect the effect of production on energy use. For example, the energy use over a two year period might have shown a gradual decrease, therefore a manager might assume the situation is under control, however if plant output was decreasing more rapidly over this period of time a comparison with energy usage per unit of output would have shown an increase rate that could be cause for alarm.

If several forms of energy enter the plant, it may be desirable to keep track of total energy consumption over a specific time period, rather than tracking one specific energy source.

2.4.3 Section Conclusion

The foundation of Green Building success lies in the entire design team utilizing the skills of all the disciplines to accurately understand the different impacts a Green Building might have, as well as to achieve high performance results without increasing initial building costs.

Design and construction costs are “hard costs” because these costs occur in the present, whereas benefits such as projected energy savings, water savings and productivity gains are “soft” because they will be speculative and occur over a longer period of time in the future.

A benefit-cost breakdown should be compiled and will be essential for each project to convince building developers, design teams and investors to proceed with sustainable design measures and the certification effort thereof.

2.5 DESIGN PROCESS

In the last few decades Green Building initiatives have been driving substantial innovation in product and material development as well as building design. A fundamental change in the process of how
buildings are designed and built, called integrated design, has helped developers deliver on the “Green Promise”. (Yudelson, 2008)

When planning the design of a Green Building the following should be considered:

- The importance of thorough planning and definition of the outcome;
- The view that sustainable design is more philosophical than an actual building style;
- Green Buildings do not need to be inordinately expensive or complicated; and
- Minimizing energy consumption should serve as a central goal when designing a Green Building.

2.5.1 Initiation

The starting point of all green projects should be a visioning session among project stakeholders with the discussion aimed at allowing the project owner or developer to develop a set of goals which the project design and construction team can refer to as needed during the design and development process.

The various design elements of a Green Building can be divided into three broad categories namely: energy-saving architectural features, an energy-conserving building shell and energy-efficient lights and mechanical systems including furnaces, air conditioners and water heaters.

2.5.2 Conceptual and Schematic Design

During the conceptual and schematic design phases, the high-performance design team would typically investigate major system alternatives for the project. Investigating free natural resources such as solar-, wind- and geothermal energy, climate control schemes, façade alternatives and building massing as well as building orientation. By the end of this phase, the design team should have defined the major building systems, pending detailed analysis in the design development phase, along with further costing and constructability reviews.

The design and decision making processes are illustrated in figure 5 and should roughly follow the design loop stipulated in reference (Todd, 1996) as:

- Identifying and defining problems - Investigating needs and opportunities;
- Developing the Design Brief - Clarifying the results you want to achieve;
- Exploring possible alternatives - Searching for solutions and information;
• Accumulating and Assessing the alternatives - Developing and choosing the best solution;
• Trying out the best solution - Experimenting and developing solutions, building models and prototypes; and
• Evaluating the results - Testing the Solution and Assessing the Process

Figure 5: The Decision Making Process (Crundwell, 2008)

For possible questions to act in assistance with this phase, please refer to Annexure C.

2.5.3 Defining Objectives

It is common for sustainable design projects to involve a myriad of considerations ranging from seeking higher levels of energy efficiency and using recycled-content material to incorporating day lighting.

Ideally, a sustainable building project should take into account factors such as:

• The appropriate and best suited use of land;
• The efficient use of natural resources such as water, energy, lumber and others;
• Enhancing human health and productivity;
• Strengthening local economies and communities through trade and interactions;
• Conserving, as far as possible, flora and fauna, endangered species and natural habitats;
• Protecting agricultural, cultural and archaeological resources;
• Being economical to build, operate and maintain;
• Reducing energy loads wherever possible;
• Providing energy input as efficiently as possible; and
• Minimizing plant operation times by incorporating a sleep or standby mode.

A good design will address key areas of performance such as lighting, psychological well-being, visual comfort and passive control of the working environment.

2.5.4 Triple Bottom Line

“Sustainability and its application to Green Buildings can be defined by the concept of the Triple Bottom Line. The Triple Bottom Line concept is based on concerns in three main areas of impact: Planet, Profit and People.” (Yudelson, 2008)

To the conventional Triple Bottom Line areas can be added areas such as environmental, economic and social impacts. Having clearly defined impact areas, can assist the design team to articulate a design path aimed at reaching the goals specified.

Once the goals and boundaries have been defined, the team should evaluate the list for synergies among the Triple Bottom Line elements. For example, “reduce energy consumption” and “reduce Greenhouse emissions”, listed under Planet, are linked to one another as well as to “reducing energy cost” under the Profit category. This connection can then be maintained to align with the People category of “be a good Corporate Citizen” and “reduce Greenhouse emissions”.

Table 2 shows an example of the interactions possible between the different Triple Bottom Line elements.

<table>
<thead>
<tr>
<th>PLANET/ENVIRONMENTAL</th>
<th>PROFIT/ECONOMIC</th>
<th>PEOPLE/SOCIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce energy consumption by 50 percent (%)</td>
<td>Reduce energy costs by 50 percent (%)</td>
<td>Be a good corporate citizen</td>
</tr>
<tr>
<td>Reduce Greenhouse gas emissions by 50 percent (%)</td>
<td>Reduce water costs by 50 percent (%)</td>
<td>Provide a healthy work environment</td>
</tr>
<tr>
<td>Reduce water usage by 50 percent (%)</td>
<td>Reduce maintenance costs</td>
<td>Reduce Greenhouse gas emissions</td>
</tr>
<tr>
<td>Reduce waste produced during construction and operations</td>
<td>Increase productivity</td>
<td>Maximize utilization of resources</td>
</tr>
</tbody>
</table>
Protect Biodiversity | Reduce risk of sick building-related issues | Reduce overall carbon footprint

<table>
<thead>
<tr>
<th>CONSTRAINTS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Site is already selected</td>
<td>Owners payback targets are &lt;10 years</td>
<td>Limited experience internal to owners’ team</td>
</tr>
</tbody>
</table>

Table 2: Triple Bottom Line Goals for a Project Visioning Session (Yudelson, 2008)

### 2.5.5 Environmental Value Analysis (EVA)

After completing the above-mentioned analysis, the team will have a greater understanding of the developers’ vision and how to approach the project to achieve the set of goals expected. The design team should then evaluate the various LEED™ or other rating systems and sustainable design solutions that support the owners’ Triple Bottom Line requirements for the building. The elements or benefits that the developer has stipulated should become part of the Environmental Value Analysis (EVA) log. Ensuring the project teams understanding of the owners’ point of view will ultimately determine the success of a project. (Yudelson, 2008)

Unlike Value Analysis (VA) or Value Engineering (VE) the EVA log is meant to retain sustainable elements in the building that have an important role in delivering the financial, as well as environmental results the client expects from a specific project. The design team can then present a set of solutions that is tailored to the developers’ specific needs and best aligned with the triple Bottom Line goals established at the beginning of the process. (Yudelson, 2008)

### 2.6 BUILDING ECOLOGY AND HUMAN HEALTH CONSIDERATIONS

Reference (Noyes, 2001) states that “there is a growing awareness of the importance of considering the human factor in system and product development and operation.”

A building’s ecology can be affected by a number of factors, such as the kind of materials used during construction, the finishes employed in the building, the quality of heating, cooling and ventilation systems as well as operation and maintenance practices. (McLennan, 2004)

For possible questions that act in assistance to this topic, please refer to Annexure D.
2.6.1 Air Quality

“The term “building ecology” refers to the physical environment, particularly the air quality, found inside a structure.” (Diana Lopez Barnett, 1995)

Generally, a “healthy building” should strive to obtain, at least a 50 percent (%) reduction of normal levels of known contaminants such as fumes out gassed from paint and other contaminants. To achieve this goal, the designer will have to be very particular about which paints and finishes are specified. Oil based paints and other solvent based finishes, like polyurethane, will expel fumes that can cause nausea, tremors and headaches. It is with this in mind that many Green Building products have been formulated especially to reduce out gassing.

2.6.1.1 Sick Building Syndrome

The phenomenon called “sick building” syndrome, is caused in part by the “out gassing” of chemical compounds from paints, carpets and construction adhesives and part by inadequately vented appliances, cigarette smoke, noxious vapours from cleaning compounds, airborne bacteria and even microscopic dust mites.(Diana Lopez Barnett, 1995)

Normally, older, less energy efficient buildings had more infiltration of air into the building through leaks and drafts than their newer counterparts and therefore avoided sick building syndrome. Some previously built energy efficient buildings trapped indoor pollution inside at greater concentrations and literally made personnel, working in these buildings, sick.

Standards for reducing Volatile Organic Compounds (VOCs), found in paints, stains, furniture, carpets and other finishes, are actively being supported by the sustainable design movement. It is through standards such as these that a measure of improved air quality has been achieved. Products such as asbestos and lead are no longer allowed on new construction sites and the possibility exists that materials such as vinyl and certain types of arsenic and chromium treated wood products will be banned in the future.

2.6.1.2 Air Duct Placement

Incoming air ducts should always be located as far away from driveways, loading docks, exhaust air ducts and garbage dumpsters as possible to ensure that the air entering a building is clean and of good quality. If needed a filtration system can be installed to remove contaminants or pollutants.
2.6.1.3 Air Changes
Historically air quality has meant a certain amount of “air changes” per hour. However, a set number of air changes, will not always ensure adequate air mixing or might even induce unnecessarily high ventilation rates. CO₂ sensors should be used to monitor CO₂ levels that increase as people inhabit an area or space. These levels can be managed by increasing or decreasing ventilation rates as needed without wasting energy by over ventilating.

Reference (Thumann, 1989) states that the number of air changes per hour has a wide variation due to a number of factors such as:
- The number and size of openings around doors and windows;
- The average wind speed blowing against the structure and the protection of the structure against this;
- The number and size of chimneys, vents and exhaust fans and the frequency of their use;
- The number of operations for doors and windows; and
- How the structure is utilized.

2.6.1.4 Heat Recovery Ventilation Systems
Heat Recovery Ventilation Systems (HRVs), more commonly known as air-to-air heat exchangers, can be deployed to preserve indoor air quality. HRV units will exhaust particulates and Volatile Organic Compounds (VOCs) while recovering up to 80 percent (%) of the temperature difference between incoming and exhaust air. HRVs are a better solution to ventilating a building than windows in the case where the outside air is of poor quality or if the weather is undesirable.

2.6.2 Acoustics
Smaller Heating Ventilation and Air Conditioning units (HVACs) not only save energy costs, but will also reduce noise pollution. So too does better designed air distribution fans and noise blocking superwindows.

2.6.3 Climate Change
“The hole in the ozone layer over the south pole is now the size of the USA. This hole is caused in large part by chlorofluorocarbons (CFC’s) escaping from air conditioning systems and from some other commercial uses and ending up in the upper atmosphere where it is reacting to destroy the ozone that protects all of us from the deadly effects of the sun’s ultraviolet radiation. Recently the
"growing ozone hole extended for the first time over land in southern Argentina that is inhabited by people, putting thousands at serious risk." (McLennan, 2004)

Current research has found that there is a close link between the increase in anthropogenic pollution, global temperature rise and the occurrences of diseases related to elevated temperatures. It is further speculated that extreme global temperature rise can in future directly cause loss of life and promote environments for the growth of pathogens that cause serious diseases.

Through global warming the risk of certain infectious diseases, such as West Nile Viral Infection, Cholera, Malaria and Lyme Disease will increase. Lyme Disease is spreading rapidly throughout North America and Europe and is caused by increased temperatures in these areas, allowing disease carriers such as mosquitoes, ticks and mice to thrive and reach areas previously uninhabitable by these organisms.

2.6.4 Electromagnetic Fields

Although it has not yet been conclusively proven, there is some evidence to suggest that Electromagnetic Fields (EMF) may be linked to cancer, miscarriages and other disorders. Electromagnetic Fields (EMF) are invisible, weaken over distance and occur whenever alternating current runs through an operating appliance or wire.

Due to the lack of research and evidence to support the claim that EMFs are harmful, a practice of “prudent avoidance” is widely adopted by Green Designers and developers. If concern exists, a Gauss meter should be acquired and used to measure EMF levels in the building, or on the building site.

2.6.5 Productivity and Comfort

Current research show that the average person spends about 90 percent (%) of his or her life indoors. Many modern buildings provide little exposure to natural daylight, and only limited views of the outdoors. Some nutrients can only be processed if the body is exposed to sunlight. Therefore, long-term lack of exposure to natural sunlight can contribute to ailments such as Seasonal Affective Disorder (SAD). (Montoya, 2010)

Reference (Murrell, 1965) states that temperature and humidity affects employees and their productivity in a number of ways. Through research conducted it was found that skilled performance deteriorated sharply if the effective temperature passed beyond the region of 27°C to 30°C. In a
warm-moist environment, heat is mainly conected and work becomes more difficult because of high humidity, which reduces the evaporation of sweat, which in the absence of convection is the main method in which the body can reduce heat.

The normal amount of heat developed by a human body is approximately 500 Btu per hr. 100 Btu are used up in maintaining the body during operation while the remaining 400 Btu have to be dissipated, otherwise the body would overheat. Under normal conditions, a proper balance is maintained by nature in accordance with the following table of heat dissipation:

- 190 Btu per hr by radiation
- 110 Btu per hr by convection and evaporation
- 100 Btu per hr by exhalation
- Total 400 Btu (Shoemaker, 1954)

Intuitive logic suggests that inhabitants of a building will be more productive in comfortable surroundings. Current research shows that production increases between 6 to 15 percent (%) are achievable through making a building more environmentally responsive.

2.6.6 Section Conclusion

“The issue of creating healthy places for people is very much ingrained in the US Green Building Council’s LEED™ rating system. This system offers a large portion of its points to building features such as indoor air quality, day lighting, thermal comfort, connection to the outside and general user control that all enhance indoor environmental quality.” (McLennan, 2004)

Particulate matter such as soot and dirt particles which cause respiratory failure are arguably the leading cause of air pollution-related deaths. Lead emissions are another significant health concern as it can cause neurologic damage and the educational impairment of children.

The percentage of health problems related to building ecology, can not yet be proven scientifically, but there remains little doubt that many work related illnesses, headaches and eye strain are directly related to poor lighting, inadequate fresh air, harsh acoustics and the gloomy surroundings that prevail in many office spaces.

The depletion of the stratospheric ozone layer has led to increased ultra violet (UV) radiation, which in turn has numerous adverse effects on human health. These effects include an increased risk of
various forms of skin cancer, a weakening of the human immune system and an increased risk of eye disorders such as cataracts.

In the past sustainable design improved on thermal control, lighting and other environmental factors, to such a degree that Green Buildings are today expected to have healthier and more productive occupants than their traditional counterparts.

An average reduction of 40 percent (%) in bad health symptoms can be achieved by implementing measures to improve indoor environmental quality such as increased ventilation, day lighting and views to the outdoors as well as low toxicity finishes and furniture.

### 2.7 ECONOMICS

“...most Green Buildings pay when measured through strict financial criteria, in that the extra construction costs of sustainable design are retrieved through reduced running costs in the first eight to ten years.” (Edwards, 2003)

#### 2.7.1 Green Barriers

The biggest barrier to Green Buildings is the perception that these buildings are more expensive to construct than conventional buildings. Current research conducted in the United States of America revealed that 89 percent (%) of respondents, comprising of experienced executives and participants in the building, design and construction industry, felt that Green Building construction is more expensive than conventional construction. (Jan F. Kreider, 1989)

“The world business Council has current research results in surveys conducted on sustainable development. Respondents to a 1400 person global survey estimated the additional cost of building Green Buildings at 17 percent (%) above conventional construction. At the same time, survey respondents put Greenhouse gas emissions from buildings at 19 percent (%) of world total, while the actual number is 40 percent (%), if both residential and commercial buildings are included.” (Yudelson, 2008)

#### 2.7.1.1 Cost drivers

Key cost drivers identified for Green Buildings include the following:

- The experience of the design team with regards to LEED™ or other similar certification systems ;
• The level of certification required by the project;
• How a design team is compiled and the structure thereof;
• Design process and scope;
• Certification documentation; and
• Design fees.

2.7.1.2 Adoption barriers
Some barriers to the widespread adoption of Green Building techniques include the perceived complexity and cost of LEED™ or other rating system documentation. Long payback periods further discourage developers from employing green technologies even though these technologies will be more economical in the long term.

Additional reasons why developers shy away from Green Buildings include:
• A lack of will on behalf of the developer and/or designers to change current development cycles and/or construction processes and procedures;
• A lack of understanding the full range of costs and benefits inherent in making the changes required by a green development; and
• A lack of comprehension of the life cycle cost benefits that result from implementing Green Building practices within the context of the project requirements.

Some other barriers to Green Building has very little to do with cost but rather with design teams that are set in their ways, do not like to venture outside conventional thinking or lack the relative experience needed for Green Design.

2.7.2 Property Value
With proper maintenance and planning more competitive leasing arrangements, which allow for larger profit margins, can be obtained by reduced water and energy consumption in Green Buildings. A 50 percent (%) reduction in energy from a building’s conventional energy system to a green system should be relatively easy to achieve, while as much as an 80 to 90 percent (%) reduction should be possible with good design. (Diana Lopez Barnett, 1995)
2.7.3 Cost Shifting

The cost of constructing a Green Building is generally the same as their conventional counterparts. However, cost-shifting within Green Buildings might not always be reflected by the bottom line. For example, efficient superwindows are more expensive than standard windows. However, installing superwindows will reduce heat gain in hot climates, net a lower heat loss in cold climates and reduce lifetime energy costs. The reduction in unwanted heat flows allows a building designer to downsize the heating and/or cooling system. A smaller Heating-Ventilation-and-Air Conditioning (HVAC) system in turn will cost less to purchase and might even offset the immediate additional price of the superwindows. The initial cost saving along with the reduced running cost will result in long term energy and cost savings. (Diana Lopez Barnett, 1995)

Green Buildings will further account for some measure of the life cycle impact of building materials, furniture and furnishings. These benefits result from better site development practices; design and construction choices and the cumulative effects of operation, maintenance, removal and possible reuse of building materials and systems.

2.7.4 Economic Benefits

“A review of current research by Lawrence Berkeley National Laboratory showed that the payback from building commissioning in terms of energy savings alone was about 4 years, while the payback fell to about 1 year when other benefits were considered, such as fewer call backs to address thermal comfort complaints.” (Yudelson, 2008)

Increasing economic benefits are the primary driver of change towards Green Buildings. Current research has documented that a properly commissioned Green Building should show energy cost savings of 10 to 15 percent (%). By conducting comprehensive functional testing of all energy-using systems before occupancy, potential problems will be eliminated in advance and therefore savings will occur from the onset. (Smith, 1979)

2.7.5 Other Economic Considerations

Specific consideration should be given to factors which negatively affect the use of Green Building applications and materials. Reference (Jan F. Kreider, 1989) identifies such factors as:

- Material transport and storage;
- Possible taxes;
- Labour and wages;
• Construction drawings and reproduction;
• Permit fees;
• Maintenance training manuals and instructor time;
• Maintenance, casualty insurance and warranties;
• Spare parts and components;
• Testing and commissioning;
• Overheads; and
• Construction bond and liability insurance.

2.7.6 Carbon Credits

Participants and signatories of the Kyoto Protocol, in evaluating the merits of credits versus taxation, chose carbon credits as a superior alternative to tax. By treating carbon emissions as a marketable item, carbon credits becomes a business transaction and management tool allowing traders to predict future pricing fluctuations and adjustments. Moreover, the pricing mechanism established by the Kyoto Protocol provides added insurance that economic transactions will be verifiable, thus promoting carbon dioxide reductions.

The main advantages of tradable carbon credits are as follows:

• The price is more likely to be perceived as fair by those paying it because the cost of carbon is set by the market and not by politicians;
• Investors in credits have more control over their own costs; and
• The flexible mechanisms of the Kyoto protocol ensure that all investment goes into genuine, sustainable carbon-education schemes through its internationally agreed upon process.

In the past, all environmental Greenhouse gas emissions restrictions have been voluntarily imposed on business through regulation. Even though the concept of carbon cap and trade has found acceptance by a vast number of countries, market based carbon trading is still being scrutinized and rejected by some. South Africa agreed to the Kyoto Protocol in March 2002.

2.7.7 Life Cycle study

Engineering economics are built on the premise that money has a time value and therefore a given amount of money today will be worth less at a specific future date. The application of engineering
economics to energy systems is known as life cycle costing. In life cycle costing the energy costs of the building are added to the costs of purchase and installation, maintenance, repair and insurance for the solar investment. Therefore providing a global view of costs associated with a specific system. (Jan F. Kreider, 1989) Reference (Mitchell, 1983) states that life-cycle cost techniques are necessary in order to accurately evaluate energy conserving improvements. These methods allow for an accurate determination of the true cost of energy and of owning a device or system over its useful life-cycle. The total life costs should include taxes, interests payments and changes during the life-cycle.

Rapidly increasing energy costs will in many cases justify the use of energy conservation apparatus even those priced at a higher initial cost.

The modern world places an increasing demand on natural fuel resources, causing an increase in fuel prices which in turn results in rapidly increasing energy costs with no foreseeable end in sight. Life cycle studies will therefore become increasingly important to determine the best alternative mechanical system designs. (Smith, 1979)

The conventional method of selecting the system that has the lowest initial cost can no longer be viewed as the correct decision. The objective in system selections should be to evaluate the anticipated overall system life costs and not only initial costs.

Figure 6 illustrates some of the elements involved in a life cycle perspective as well as the process direction thereof.
2.7.7.1 Capital Recovery Factors

In utilizing life cycle techniques to select between two systems, simple formulae can be used to determine whether or not long term savings warrant the additional initial costs of a more expensive system. Capital recovery factors are primarily influential on a future date at which the cost of the system employed will be fully recovered. (Smith, 1979)

To forecast costs over an extended period, the effect of inflation on labour, materials and energy should be assumed. If it can be illustrated that costs savings will occur from the options chosen, measures implemented and reasonable assumptions made, the project will be worth pursuing. It is also prudent to mention the consideration which should be given to factors such as the ease of maintenance, greater reliability and future availability of energy.

It should be noted that the useful-life time employed in life cycle costing should be no greater than the remaining useful life of the building or system involved. This makes sense since the system employed in the building cannot outlast the building itself.
2.7.7.2 Cost vs. Benefit Measures

The two most commonly used cost-benefit measures are Payback Period and Return on Investment (ROI), both of which can be used to evaluate the relative merits of a given investment. In some alternate project types or accounting systems other methods such as Present Value Analysis may be preferred. (Smith, 1979)

\[
PaybackPeriod = \frac{investmentamount}{(netannualsavings - annualdepreciation)}
\]

Equation 7: Payback Period (Gerald J. Thuessen, 2004)

\[
ROI = \frac{(netannualsavings - annualdepreciation)}{investmentamount}
\]

Equation 8: Return on Investment (Gerald J. Thuessen, 2004)

Where:

- The initial cost, or investment amount, is viewed as the full cost of installing the particular equipment or equipment modification;
- Net annual savings can be defined as the difference between the cost of the energy that will be saved by the improvement, minus all annual costs of owning and operating the equipment, such as interest on borrowed funds, maintenance costs, insurance and taxes if applicable; and
- Lastly, straight line annual depreciation is recommended for this calculation.

2.7.7.3 Payback Period

The payback period can be defined as the time required to recover the initial investment as well as all interests and costs incurred with a system through accumulated energy savings.

2.7.7.4 Return on Investment

This method is most useful for comparing energy investments with alternative investments and in ensuring that the annual savings will be sufficient to pay back the principal investment, interest as well as other annual costs incurred where borrowed funds are used.
2.7.7.5 Present Value

Present Value, or Present Worth, is the value of an investment needed presently to realize annual returns in the future. This method of analysis is generally preferred when the annual savings are low compared to the capital investment involved. (Thumann, 1989)

Since the savings involved in the calculation is limited to the useful life of the improvement, depreciation of the system should be taken into account. At the end of the systems useful life, a new Present Value determination can be done for a replacement system.

\[
P = \frac{F}{(1 + i)^N}
\]

Equation 9: Present Value (Gerald J. Thuessen, 2004)

Where:

- P is the present worth;
- F is the future value;
- i is the interest rate; and
- N is the number of periods.

The reliability of the present value method depends heavily on the reliability of forecasts made regarding fuel cost, inflation as well as other costs and therefore should be applied with some caution when evaluating energy management projects. (Smith, 1979)

2.7.7.6 Detailed economic analysis methods

For commercial buildings detailed economic calculations should take into account factors such as:

- Initial capital cost increment less investment tax credit;
- Interest charges;
- Operating energy costs;
- Property taxes;
- Replacement of solar energy system components during economic lifetime;
- Maintenance; and
- Insurance.
2.7.8 Capital and Funding

When examining conservation measures and their respective costs it should be kept in mind that energy management is an evolutionary process. The initial focus should be on measures that appear feasible within the level of available staff and in house expertise. It would be foolish for a company to attempt accomplishing or implementing all options immediately. Rather respond deliberately and carefully, choosing measures that have the greatest current impact and can be applied and managed by the existing organization. This step-by-step approach will ensure greater control over energy management and will assist in building the credibility needed to stimulate further funding of an energy management program. (Diana Lopez Barnett, 1995)

The evaluation of a project is a multidisciplinary task involving elements of engineering economics, capital budgeting, financial management and strategic planning. The projects ability to consume and produce funds for each year of the projects life must be determined in order to assess the merits of a project. Reference (Crundwell, 2008) states that there are five basic inputs to the project financials that should be considered when evaluating a project:

- **Revenue** - The revenue is the money that is made through activities.
- **Costs** - These consists of the operating and overhead costs of the project.
- **Taxes and Royalties** - Taxes include income and capital gains tax. Royalties may be charged for the use of natural resources, such as in mining and oil extraction.
- **Capital Expenditure or Fixed Capital** - Is the sum of money required to develop and install a manufacturing facility.
- **Working capital** - Can be defined as the net amount of money required for stock, debtors and creditors, the money needed to fund day-to-day operations.

### 2.7.8.1 Fund Availability

All potential sources of funds for an energy management program should be defined and listed. Funds that may be available for general upkeep and maintenance, as well as capital funds for major refit and systems convert undertakings, should be investigated individually.

Funding sources normally involves borrowers, lenders and financial institutions. Borrowers wish to raise capital from investors while lenders wish to earn a return on savings and investments. In return for the investments provided by lenders, borrowers will issue securities. Lenders and borrowers can conclude financial arrangements directly with each other or through a financial institution or an
intermediary. A financial intermediary collects money from lenders and issues its own securities, while providing money to borrowers in exchange for the borrowers own securities. (Crundwell, 2008)

Figure 7 illustrates the financial system of lenders, borrowers and financial intermediaries.

![Financial System Diagram](image)

**Figure 7**: The Financial System (Crundwell, 2008)

Important funding source information to be collected includes:

- Name of the source providing funds and person in charge;
- Types of funds disbursed such as loans, etc;
- Types of programs funded, including maintenance, upkeep or refit ;
- Restrictions imposed on the loan ;
- Format of request ;
- Data required to lend support to the request for funding ; and
- Time requirements imposed by the source of the funds.

**2.7.9 Section Conclusion**

Current research has revealed that even experienced construction industry participants are poorly informed and have false perceptions about green development and the associated costs.

It has been documented in the United States of America that Green Buildings have a higher market value than their conventional counterparts in regions such as Davis, California, Sacramento as well as at the Green Building program in Austin Texas and Prairie Crossing in Illinois. Green Buildings
with their improved aesthetics, comfort and performance therefore translate into higher initial sales and rents and later into lower operation costs since these building are less expensive to heat, cool and light.

The financial market created by carbon credits aims to reduce global Greenhouse emissions and works on the premise of a company that has a surplus of carbon credits offering these to a client that generates emissions above their quota. In these dealings, the buyer would pay the seller, in local or international currency, the equivalent amount of carbon credit value with regard to annual metric tons of carbon dioxide emissions.

Specific energy reduction actions and modifications applicable to a building depend on the buildings size and complexity.

Correct financial planning of energy conservation measures are critical to ensuring payback of the system in the allocated long term time frame.

2.8 CLASSIFICATION AND RATINGS

2.8.1 The LEED™ Rating System

The Leadership in Energy and Environmental Design (LEED™) rating systems was developed by the United States Green Building Council (USGBC) to serve as a rating system for the performance of new commercial, institutional and multi-family residential buildings, as well as projects involving substantial renovations. (Diana Lopez Barnett, 1995) In essence, the LEED™ system is a point based rating system that allows vastly different Green Building attributes to be compared with one another and compiled into a resulting aggregate score.

The LEED™ system is based on a series of credits measuring performance in five areas namely:

- Sustainable sites;
- Energy and atmosphere;
- Water;
- Materials and resources; and
- Indoor environmental quality.

To facilitate with certification and sustainable practices in projects with unique design criteria, the USGBC has developed or is developing guidelines specific to many special subsets of project application types.
These include but are not limited to:

<table>
<thead>
<tr>
<th>LEED-NC</th>
<th>New Construction and Major Renovations</th>
<th>Released 2009</th>
</tr>
</thead>
</table>
| LEED-EB          | Existing Building operations and maintenance | Approved 22/10/2004  
|                  |                                        | Current version 3.0 |
| LEED-CI          | Commercial Interiors                    | Approved 17/11/2004  
|                  |                                        | Current Version 3.0 |
| LEED-CS          | Core and Shell                          | Approved July 2006  
|                  |                                        | Current Version 3.0 |
| LEED-Homes       | Homes                                  | Released January 2008  
|                  |                                        | Errata updated to January 2010 |
| LEED-ND          | Neighbourhood Development               | In Pilot |
| LEED for Schools or Existing Schools | Schools | Launched in April 2007  
|                  |                                        | Current Version 3.0 (Existing Schools under development) |
| LEED for Retail or Retail Interiors | Retail construction | In Pilot |
| LEED for Healthcare | Healthcare facilities                    | Under development |
| LEED for Labs    | Facilities with laboratories             | Under development |

(All information correct at the time of publishing, February 2010.)

Table 3 : LEED Rating Guidelines (Haselbach, 2010)

2.8.1.1 LEED™ Levels of Certification

The LEED™ rating system provides teams with a framework of Green Building focal points, while each credits performance is tied back to the Triple Bottom Line.

In the aim to move to higher LEED™ rating levels a large number of studies will have to be conducted in the design phase, including natural ventilation analyses, computational fluid dynamic studies and more frequent energy modelling, all adding to increased initial cost aimed at achieving higher LEED™ ratings. Higher cost elements such as Green roofs, photovoltaics and certified wood products are also introduced when aiming to move to higher levels of certification, while ratings such
as Gold or Platinum requires consideration of factors such as sustainable-site criteria and the conservation of materials and resources.

The LEED™ rating system was first used in the year 2000 and is regulated by the U.S. Green Building Council (USGBC) as well as the Canadian Green Building Council (CaGBC). The system is heavily weighted toward saving energy, saving water and providing higher levels of indoor environmental quality in commercial buildings. It collects and incorporates a wide variety of “best practices” across many disciplines including architecture, engineering, interior design, landscape architecture and construction and then measures these against previously recovered data.

The LEED™ rating system is widely adopted and is currently being used in 13 countries. It can be viewed at www.usgbc.org/leed.

### 2.8.2 ENERGY STAR® Rating System

ENERGY STAR® for Buildings and Plants was developed as a voluntary program of the U.S. Environmental Protection Agency (EPA) and Department of Energy (DOE). Launched in 1995, and limited to buildings within the United States of America, the system offers two ENERGY STAR labels for commercial projects: ENERGY STAR and Designed to Earn the ENERGY STAR. The ENERGY STAR® label is awarded to new or existing buildings after one year of utility bills have been reported and actual energy use assessed. (Reeder, 2010)

The program gives an incomplete overview of a building’s true environmental impact since it solely represents a building’s energy usage compared with other buildings of the same type in a given region.

The ENERGY STAR® program can be viewed at www.energystar.gov

### 2.8.3 Building Research Establishment Environmental Assessment Method (BREEAM)

The BREEAM system is of British origin and serves as a benchmark system against which a design team can measure overall environmental credentials included in a building. BREEAM assigns buildings a rating on a scale of fair, good, very good or excellent. This system not only deals with a building’s energy performance, but also includes issues ranging from global atmospheric pollution
and the impact of the building upon local environments to incorporating the comfort and health of building users.

### 2.8.3.1 Factors Assessed

The main factors assessed by BREEAM are:

- CO₂ emissions ;
- Air quality and ventilation ;
- Healthy building features ;
- Minimization of ozone depletion and acid rain ;
- Ecology of the site ;
- Recycling and reuse of materials ;
- Water conservation ;
- Risk of Legionnaire’s disease ;
- Noise ;
- Hazardous materials ; and
- Lighting.

### 2.8.3.2 Benefits Provided

The following benefits are provided to the construction industry by BREEAM:

- Managers can reassure and prove to workers that their work environment is healthy to work in, and of high quality ;
- Property owners can audit the property from an environmental point of view ;
- Designers can demonstrate the environmental achievements of their work ; and
- Developers can promote sales with the environmental performances of rated buildings.

### 2.8.4 Other Green Building Rating Systems

Some other Green Building rating systems used over the world include Green Globes, a program of the Green Building Initiative in America, the Japanese CASBEE system and the Australian Green Star.
2.9 OPTIMIZATION

"It can be safely predicted that, because of the urgency and increasing expansion of the environmental movement, architecture will probably change more radically over the next two decades than it has changed in the past 100 years. Far beyond the usual self-conscious motivations of style and theory, the shape of buildings will finally be forced to respond to the demands of limited resources and earth-centric imperatives. This is potentially one of the most challenging periods of architectural innovation in history." (Wines, 2008)

Sustainable design aims to cause minimal environmental harm. Ecological disruptions caused by construction can be dramatically reduced, if not eliminated entirely, through restraint and careful planning.

2.9.1 Site Selection

Effective sustainable design greatly depends on accurate and correct site selection. Ideal green development sites would need to offer abundant clean air, water and soil as well as access to sufficient solar energy and other possible forms of renewable energy. As a secondary consideration the location of public transport, residential areas, schools, libraries, shopping centres and other community services should be considered. Considerations such as these will assist in reducing the overall carbon footprint of the building as well as the workers and community supported within it. (Yudelson, 2008)

The evaluation of a suitable site should be conducted in an open minded and practical way, asking relevant questions such as:

- Is the site under consideration suitable for the specific planned green development?
- Could the site be better utilized?
- Does the site have cultural, historical or archaeological significance?
- Is redevelopment and rehabilitation possible?
- What are the sites values in terms of natural resources?
- How does the sites topography, geology and hydrology lend it to sustainable design?
- Are strong Electromagnetic Fields (EMF) present?
- Can existing structures be incorporated or redeployed?
- Will future development on adjacent lands affect the project?
CHAPTER 2 GREEN DESIGN MOVEMENT

2.9.2 Building Placement

A Green Building should always be orientated as to maximize its beneficial use of the sun and other renewable resources and to minimize its impact on the natural environment. Consideration of this might involve searching for the most attractive micro-climate or even plotting surrounding buildings' shadow patterns. If possible, advantage should be taken of existing land forms and vegetation to improve the buildings energy performance and comfort. Something as trivial as earth berms can be beneficial to the project by being employed to provide shelter from blizzards or to deflect noise. Deciduous trees can block the hot summer sun while allowing solar gain in the winter.

Seasonal winds can have a significant effect on comfort and cooling, therefore the designer should consider prevailing winds when orientating the building aiming to block winter gales while still capturing summer breezes.

2.9.3 Building Configuration

2.9.3.1 Building Shape

A building's shape, interior layout, size and solar orientation all affect its energy consumption. General considerations when designing an energy efficient building shape should include taking into account the natural resources, topography and climate of the site.

2.9.3.2 Climates

In cold climates the buildings form should be as compact as possible to reduce heat loss due to winter winds while slightly elongated on the east-west axis to maximize solar exposure and heat absorption. The opposite is true in hot, humid climates where natural ventilation and shading should be maximized and heat gain through windows should be kept at a minimum.

2.9.3.3 Natural Lighting

Natural light also called day lighting is both utilized as a design element as well as an environmental resource. Natural light used as a design element can enhance aesthetics and qualitative aspects of buildings.

Among the reasons for considering the use of day light as a lighting source are:

- Better quality of lighting;
• Importance of daylight as a design element;
• View from the building;
• Energy conservation resulting from daylight systems;
• Electricity peak demand reduction;
• Psychological and physiological benefits of daylight; and
• Genuine desire to have natural light in a room.

Maximizing the sun's energy in the form of heat and light is a central principle in Green Design, regardless of climate. Day lit buildings use substantially less energy while providing a welcome subconscious connection to the outdoors. Natural day lighting contributes to reduced operating costs, increased worker productivity and increased health and well-being of the occupants.

Apparatus such as light monitors, light shelves, atria, courtyards, glass or glass topped partitions, top silvering or venetian blinds (to bounce light off ceilings) and light coloured paints and furnishings all assist in distributing natural light deep into the building. Poorly designed day lighting should be avoided since it can cause glare and ultimately discomfort to the occupants.

2.9.4 Building Shell

The building shell consisting of walls, windows, doors and the roof, should be designed to optimize thermal performance. Heat transfer through the shell of a building occurs in three ways:

• Conduction;
• Infiltration; and
• Radiation.

The exposed surface area, consisting of walls and floor, for a given volume or floor area of a compact building will be less than that of a building with a larger surface area. As a result, the heat exchange by conduction between the building and the ambient air is less than that of a spread out building which surface area causes a greater heat gain or loss and therefore a greater energy expenditure of the air conditioning equipment. (Givoni, 1998)

In general, the shell should be designed to minimize conduction losses, resist the infiltration of hot air in the summer and prevent as far as possible the radiation of heated air in the winter. Some specific technologies may be employed to achieve these goals in different climates. For example, in
Chapter 2 Green Design Movement

Hot climates, installing a radiant barrier can boost a building's energy performance through limiting unwanted heat penetration. This thin film reflects radiant heat and can reduce cooling loads by 7 to 15 percent (%).

2.9.5 Windows

The biggest breakthrough in Green Building products over the past two decades is arguably the technological advances made in window construction. Windows along with other glazing materials are a critical component of the thermal envelope, day lighting system and ventilation system. (McLennan, 2004)

The introduction of superwindows with a high insulation value and light transmittance marks a dramatic improvement in the construction of windows, saving great amounts of heating and cooling energy, which in turn makes it possible to downsize on heating or air conditioning units. This in turn reduces initial capital and installation costs.

Superwindows add advantages such as the ability to block out noise, increase comfort and protect furnishings from ultraviolet damage. Operable windows should be incorporated along with the superwindows to assist with passive cooling strategies that emphasize cross ventilation.

Modern windows can be equipped with a different glazing options such as those listed in the table 4.

<table>
<thead>
<tr>
<th>GLAZING TYPES</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Glass</td>
<td>Clear glass transmits the highest amounts of all the wavelengths of the solar spectrum.</td>
</tr>
<tr>
<td>Heat Absorbing Glass</td>
<td>Heat-absorbing glass selectively absorbs a higher fraction of the infrared (heat) part of the solar spectrum, compared with its absorption of visible light.</td>
</tr>
<tr>
<td>Heat Reflecting Glass</td>
<td>Heat-reflecting glass is produced by deposition of a very fine semitransparent metallic coating on the glass surface, which selectively reflects a larger part of the solar infrared radiation.</td>
</tr>
<tr>
<td>Low Emissivity Glass</td>
<td>Low-Emissivity glass is produced by coating the glass with a layer of selective low-emissivity long-wave radiation.</td>
</tr>
<tr>
<td>Super insulating Glass</td>
<td>Super-Insulating glass often has three glazing layers, the interior layer with low-Emissivity coating and the spaces between the layers filled with a gas of lower conductivity than air, such as Argon.</td>
</tr>
<tr>
<td>Grey or Coloured Glass</td>
<td>Gray or coloured glass absorb more visible than infrared light.</td>
</tr>
</tbody>
</table>

Table 4: Glazing Types (Givoni, 1998)
2.9.6 Building Materials

Conventional selection criteria for building materials include strength, cost, appearance and suitability. In a modern sustainable design environment, these can be expanded to include environmental impact, durability and toxicity. (Diana Lopez Barnett, 1995)

A materials’ durability, as measured through its life cycle cost, might have profound environmental ramifications. Extending the useful lifetime of a product therefore becomes critical in reducing environmental impacts and carbon footprints.

An apt adage to keep in mind when choosing building material is: “reduce, reuse, recycle”

- Reduce: A smaller and/or more efficient building will require less concrete, less wood products, fewer litres of paint, etc.;
- Reuse: Reusing building materials or re-deploying a complete building, reduces the amount of new materials needed for construction; and
- Recycle: Minimize construction waste as far as possible through onsite recycling.

2.9.7 Water

Water has always been abundantly available on earth, however the quality and distribution of usable water has become a great concern in the last few decades. The earths surface comprises of 70.8 percent (%) water of which 97 percent (%) is salt water. Of the remaining 3 percent (%) as much as 90 percent (%) is locked up in glaciers, leaving very little water for consumption by humans and other species. (Diana Lopez Barnett, 1995)

Therefore the supply of clean unpolluted water as well as wastewater treatment capacities should be viewed as finite. Installing water efficient plumbing fixtures in a Green Building will reduce the clean water consumption of a building while also reducing the load on sewage treatment plants.
Figure 8 shows the Hydrological Cycle where:

- 1: The sun - Powers the hydrological cycle;
- 2: Clouds - Forms due to evaporation and condensation;
- 3: Evaporation - From land and sea;
- 4: Precipitation - Returning the water to earth; and
- 5: Runoff - Accumulating in oceans and ponds.

As water precipitates it comes into contact with pollutants that humans have released into the atmosphere. It also gathers more pollutants as it filters through soil and drains into rivers and the sea. (Vale, 1991)

For possible questions to assist with this topic, please refer to Annexure F.

2.9.7.1 Water-efficient Landscaping

Since water is connected to a wide array of economic and environmental issues, the efficient usage of water should be of primary concern in the development of a landscaping plan for a Green Building or development. (Edwards, 2003)
The following should be considered when employing water-efficient landscaping:

- The appropriate selection of plants, irrigation equipment and irrigation scheduling can significantly reduce waste water;
- Installing a drip irrigation system to water trees, bushes and shrubs will reduce water use;
- An automatic sprinkler system should always be programmed correctly to maximize the benefits of irrigation and minimize waste water;
- It is recommended to water deeply every 4 hours rather than shallow every 2 hours. This is more beneficial to plants and reduces total water consumption; and
- Some irrigation timers also include buried moisture sensors that enable the user to deliver the absolute correct amount of water to the root zone at the precise time.

2.9.7.2 Rain Water Collection

A Green Building can reduce its need for treated water by collecting rainwater on the roof of the building and then relaying it by gutters or pipes to a cistern or a manmade catchment area. Such an improvement will increase a building's supply of landscaping water and might reduce a building's potable water consumption.

2.9.7.3 Graywater

The vast majority of waste water, called graywater, is from sinks, showers, baths, dishwashers and washing machines. This water can be captured and safely reapplied for other uses such as the flushing of toilets or landscaping.

Since graywater amounts to such high volumes of water used, reapplying this water can offer significant savings. Concerns have been raised about health and safety of graywater, however Australian researchers concluded, that there was little evidence for disease spread from graywater used in ornamental landscaping. (Sorvig, 2008)

2.9.7.4 Blackwater

Sewage or “blackwater” from toilets must be treated, either on site or at a commercial treatment plant, with the resulting effluent that can then be used to water golf courses, parks or other landscaping areas.
2.9.7.5 Alternative sewage systems

There are a number of alternatives to conventional sewage systems that don't save water per se, but have many other environmental and economical benefits. Biological systems can be set up to work as an interlinked series of wetlands and marshes through which sewage water passes. Water filters through a series of wetlands where it is purified by water loving plants and microorganisms, eventually emerging as clean drinking water. This system is low cost, low maintenance and low tech, however the major drawback of this system is the space required to employ it efficiently.

The obstacle of space requirement by systems such as the marsh system can be overcome by introducing a Greenhouse approach, where waste water passes through a series of tanks and is gradually purified by plants, bacteria, invertebrates, fish and sunlight.

2.9.8 Section Conclusion

Fossil fuels are becoming scarce and expensive. The same holds true for other resources, for example, aggregates, steel, aluminium. The long term solution should be to design and construct buildings that allow for ready dismantling and reuse, as well as incorporating the maximum amount of recycled material. Buildings should be viewed as reservoirs of resource investments which are carried over from one generation to another.

A sites natural resources such as wetlands, woodlands, trails, lakes and streams can be powerful amenities if considered during the design phase and protected during construction. Not only natural but also manmade features might be of importance to neighbours and inhabitants of the site. The importance of these structures should be taken into consideration and incorporated into discussions with the local community.

A well designed and controlled natural lighting system can significantly reduce energy consumption and peak energy demand. Natural lighting can significantly reduce a commercial buildings energy consumption since 20 to 50 percent (%) of the energy used in commercial buildings are normally contributed to illumination.

Water should not only be saved due to its scarcity, but also due to the large amounts of embodied energy contained in the water. As water travels from river or dam storage to urban use to sewage plant, energy is used to pump it, treat it and heat it. It is through processes such as these, that water accumulates large amounts of embodied energy. Saving water can be easy and inexpensive by installing features such as low flush toilets, efficient showerheads and faucet aerators. Catchment
areas which are landscaped to look like ponds or marshes can be supplied with water collected from roofs or drained from paved areas such as parking lots.

Graywater should preferably be passed through a commercial filter or a site built sand filter before being used as irrigation water.

The Marsh and Greenhouse water treatment systems share the following advantages:

- The use of much less energy, capital and fewer chemicals, than conventional sewage plants;
- These systems are cheaper to operate and maintain than conventional plants;
- These systems can be made surprisingly attractive; and
- A natural habitat for plants and other organisms are created and food might even be produced in some cases.
CHAPTER 3. ENVIRONMENTAL IMPACT

Calculating Total Environmental Impact:

\[
\text{Total Environmental Impact (I)} = \text{Population (P)} \times \text{Capital stock per person (A)} \times \text{Environmental damage done by particular technologies (T)}
\]

Equation 10: Total Environmental Impact (Stamm, 2008)

Considering the earth’s limited capacity to support environmental impacts sustainably, it is important that negative environment impacts are less or equal to, the earth’s capacity. Therefore it might be necessary to reduce environmental impacts of products and services to such a degree that global ecological sustainability can be achieved. (Stamm, 2008)

Figure 9 shows domestic waste produced in kilograms per head per year and with this information the environmental impact becomes clear.

Figure 9: Domestic Waste Produced per Head per Year (kg) (Stamm, 2008)
3.1 ATMOSPHERIC POLLUTIOM

Fossil fuel combustion, in addition to producing carbon dioxide, results in the emission of numerous undesirable and biologically harmful compounds. Incomplete combustion of petroleum fuels result in carbon monoxide emissions as well as the emission of a variety of complex hydrocarbon compounds, while the incomplete combustion of gas, liquids and coal results in excessive amounts of carbon monoxide being released. (Krenz, 1984)

\[
\text{Carbon Monoxide: } 2C + O_2 = 2CO
\]

Equation 11: Carbon Monoxide (Devins, 1988)

Fuel impurities such as sulphur, in petroleum and coal, contribute to undesirable emissions such as sulphur dioxide.

\[
\text{Sulphur Dioxide: } S + O = SO_2
\]

Equation 12: Sulphur Dioxide (Devins, 1988)

Natural air contains 79 percent (%) nitrogen and serves as oxygen source for all combustion. Subsequently emissions such as nitrogen oxide, especially at elevated temperatures, are emitted.

\[
\text{Nitrogen Dioxide: } N_2 + 2O_2 = 2NO_2
\]

Equation 13: Nitrogen Dioxide (Devins, 1988)

Technological advances such as the internal combustion engine are dominant sources in the production of nitrogen oxides.

3.2 EMBODIED ENERGY

Historically, the construction industry and clients associated with the industry has paid far more attention to the price of building materials than to the amount of energy needed to produce it. (Diana Lopez Barnett, 1995) This “natural energy” used to produce building materials can be named as embodied energy. Wood is normally low in embodied energy because it is produced through photosynthesis and not with high energy fossil fuels. Products such as steel, plastic and aluminium have greater environmental impacts due to their production requiring increased levels of energy. These environmental impacts can be measured through pollution and Greenhouse gas production.
The energy content or embodied energy of a material seems to be connected to its "relative closeness" to the earth; the more a product is processed and refined the more energy it contains.(Vale, 1991) Building material transportation is a major contributor to a materials embodied energy.

Table 5 gives an indication of the embodied energy contained within some building materials.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENERGY CONTENT: kWh/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Energy Materials</strong></td>
<td></td>
</tr>
<tr>
<td>Sand, Gravel</td>
<td>0.01</td>
</tr>
<tr>
<td>Wood</td>
<td>0.1</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.2</td>
</tr>
<tr>
<td>Sand-Lime Brickwork</td>
<td>0.4</td>
</tr>
<tr>
<td>Lightweight Concrete</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Medium Energy Materials</strong></td>
<td></td>
</tr>
<tr>
<td>Plasterboard</td>
<td>1.0</td>
</tr>
<tr>
<td>Brickwork</td>
<td>1.2</td>
</tr>
<tr>
<td>Lime</td>
<td>1.5</td>
</tr>
<tr>
<td>Cement</td>
<td>2.2</td>
</tr>
<tr>
<td>Mineral Fibre Insulation</td>
<td>3.9</td>
</tr>
<tr>
<td>Glass</td>
<td>6.0</td>
</tr>
<tr>
<td>Porcelain (Sanitary Ware)</td>
<td>6.1</td>
</tr>
<tr>
<td><strong>High Energy Materials</strong></td>
<td></td>
</tr>
<tr>
<td>Plastics</td>
<td>10</td>
</tr>
<tr>
<td>Steel</td>
<td>10</td>
</tr>
<tr>
<td>Lead</td>
<td>14</td>
</tr>
<tr>
<td>Zinc</td>
<td>15</td>
</tr>
<tr>
<td>Copper</td>
<td>16</td>
</tr>
<tr>
<td>Aluminium</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 5: Embodied Energy(Vale, 1991)
3.3 PRODUCT LIFE CYCLE

The embodied energy of any material is only one measure of its environmental impact. Environmental impact can also be measured by means of a product's life cycle analysis, underwriting a product's life-span, durability, and structural efficiency. Life cycle analysis argues for maximizing the entire building's longevity and therefore decreasing the impact that the building's construction will have on the environment. (Diana Lopez Barnett, 1995)

3.4 NATURAL CLIMATIC FACTORS

3.4.1 Climatic and Atmospheric Changes

“According to the Intergovernmental Panel on Climate Change (IPCC) in 2007, the atmospheric concentration of CO₂ in 2005 was 379 ppm, compared with preindustrial levels of 280 ppm.” (Yudelson, 2008)

Climate change refers to the variation in global and regional climates (average temperature, amount of precipitation, days of sunlight and other variables) and describes variability in the average state of the atmosphere over specific periods. These changes are caused by internal processes in the earth such as glaciations, oceanic temperature variability etc. or by external forces such as variations in sunlight intensity and human activity. (Gevorkian, 2009) Current research indicates that both natural and anthropogenic factors are primary contributors to global warming.

3.4.2 Orbital Variations

Solar energy absorption variability is in part caused by orbital variation patterns of the earth’s movement around the sun and leads to considerable changes in the distribution and abundance of sunlight reaching the earth’s surface. (Gevorkian, 2009) Variations such as these are considered to be the driving factor underlying the glacial and interglacial cycles of the last ice age as well as some of the most notable climatic variations observed such as the repeated advance and retreat of deserts.

3.4.3 Volcanism

Volcanic activities contribute to extended atmospheric pollutants due to the release of carbon dioxide from the earth’s interior, counteracting the uptake by sedimentary rocks and other geologic carbon sinks over millennia of geologic time periods. (Gevorkian, 2009)
3.4.4 Glaciation

Glaciers are dynamic in nature, growing in winter and collapsing in summer, in so doing contributing to natural climatic variability and acting as sensitive indicators to climate change. (Gevorkian, 2009)

3.4.5 Ocean Variability

Many climatic fluctuations result from the interaction between the atmosphere and oceans due to heat accumulation and storage in the oceans that cause water currents to move between two different heat reservoirs. The movement process of oceanic water, also known as thermo line circulation, plays a major role in redistributing and balancing heat throughout the globe. (Gevorkian, 2009)

3.5 ANTHROPOGENIC CLIMATE FACTORS

3.5.1 Wood Burning

Wood burning was used as the primary source of energy up to the mid eighteenth century. Owing to a smaller global population, the CO₂ gas generated did not saturate the absorption capacity of plants and oceans and consequently did not have a significant effect on the environment. (Gevorkian, 2009)

3.5.2 Coal Burning

Population growth accelerated in an unprecedented manner, due to the invention of the steam engine in 1750, which led to the deployment of steam driven farm equipment and the availability of large amounts of food stock. Increased population growth led to greater energy demand while the use of coal created significant atmospheric and environmental pollution causing major human health problems in industrial centres. (Gevorkian, 2009)

3.5.3 Crude Oil and Natural Gasses

The advent of the internal combustion engine along with the discovery of vast crude oil reservoirs in Texas and the proliferation of electrical energy generation and distribution, brought the industrial revolution into a new era at the beginning of the 20th century

The rapid expansion of urban dwellings and technology created an ever increasing demand for electrical energy and necessitated the construction of massive coal and crude oil fired steam turbines, which have contributed significantly to atmospheric pollution and deterioration of the global environment. (Gevorkian, 2009) Fossil fuel dependency not only shaped our way of life over the last
few centuries, but also had a significant effect on the deterioration of the global habitat for all living species.

3.6 GLOBAL WARMING

“...saving one unit of electricity inside a building saves having to burn three or four units of fuel, often coal, at the power plant. Reducing the average house’s energy use by 80 percent (%) will reduce its CO\textsubscript{2} emissions by about 90 000 pounds over its 30 year lifetime. Reducing water use by 30 percent (%) would avoid the creation of over 4 million gallons of wastewater during the same period.” (Diana Lopez Barnett, 1995)

Climate change is likely to be one of the most detrimental forces of the next century and therefore global warming discussions are vital. Carbon dioxide is the leading Greenhouse gas. It is therefore critical to our ability to combat global warming that carbon dioxide emissions be reduced as much as possible from the building sector and all other sectors. Energy efficient designed and operated buildings, along with onsite renewable energy production have a strong part to play in reducing a buildings “carbon footprint”.

![Figure 10: U.S. Total Greenhouse gas Emissions by Sector for 2005](Sam Kubba, 2010)
3.6.1 Ozone Layer Depletion

Most of the damage to the ozone layer has been caused by chlorofluorocarbons (CFC’s) used in connection with air conditioning units especially associated with high-energy buildings. Although the Montreal protocol (1990) and further European Union directives have started to phase out the production of CFC’s it is still being used in some applications. (Edwards, 2003)

3.6.2 Biodiversity

Buildings being home to a number of species have the potential to influence biodiversities in very distinct ways.

The construction of buildings has an impact on the destruction of endangered global habitats and the creation of others. Bio-diversities are further impacted by the extraction of aggregates, such as chalk and limestone, which alter the face of the land causing valuable land to be lost for agriculture purposes.

3.7 Section Conclusion

Green Design places more focus on the energy used to produce building material than the actual cost of building material used. The energy referred to is known as Embodied Energy. No single analysis such as embodied energy or life cycle analysis can give a definite answer about specifying

Figure 11: Anthropogenic Greenhouse gas Emissions for the year 2000(Sam Kubba, 2010)
a certain material or not. For example, fluorescent lights consume much less energy than incandescent lamps therefore less energy consumption throughout the buildings life cycle. However, fluorescent lights contain mercury and are therefore detrimental to the environment if disposed of inappropriately.

CO$_2$ productions can greatly be reduced by using materials such as home-grown softwood while buildings can be designed as part of self sufficient carbon communities, where buildings and forests exchange CO$_2$ and oxygen.

The Kyoto protocol endeavoured to reduce carbon dioxide emissions levels by 2012 to the same level as was present in 1990. Green Buildings are an important component in obtaining stability of these levels.
CHAPTER 4. ENERGY CONSUMPTION AND PRODUCT DISCUSSION

From Figure 12 below it can be seen that climate control systems and electrical lighting are major contributing factors to energy consumption in buildings. By applying appropriate insulation and weatherization methods heating systems can be better managed and heat losses reduced. (Smith, 1979)

![Figure 12: Commercial Building Energy Uses Aggregated over All Building Types (Jan F. Kreider, 2001)](image)

For possible question to assist with this topic, please refer to Annexure G.

4.1 ENERGY USAGE PATTERNS

Buildings are currently responsible for approximately one third of global CO$_2$ emissions and 40 percent (%) of the world’s primary energy consumption. As much as 12 to 25 percent (%) of building-related CO$_2$ emissions can be reduced in industrialised countries and 13 to 52 percent (%) in developing countries mainly through heat-related measures. Energy consumption reached 12 x 10$^9$ MWh per year in 2005, as published in the Green Paper on energy efficiency by the European Commission. (Eicker, 2009)
To determine critical areas of power consumption an analysis of electrical energy usage must be performed throughout a building or operation. (Gevorkian, 2009). Generally, it will be necessary to obtain some billing history, before a meaningful energy reduction can be implemented. Each bill should contain information such as kilowatts consumed per hour (kWh) during a certain period of time, the power factor, the billing period and the number of days in each billing period. Climatic changes, temperatures, among others should also be documented and super imposed onto energy consumption graphs to obtain a relationship between climatic conditions per month and monthly energy consumption in terms of production.

In managing heat, unwanted heat gain has to be identified, minimized and the comfort envelope expanded, the remaining load can then be mechanically managed. Different climates warrant different cooling approaches such as a hot dry climate, where evaporative coolers are most effective. In humid climates a desiccant dehumidifier coupled with an efficient absorption, evaporative or refrigerated air conditioner might be a better choice than a conventional air conditioning system.

Reference (Albert Thumann, 1984) states that most energy audits fall into three categories or types:

- **Walk-Through** - This type of audit is the least costly and identifies preliminary energy savings. A visual inspection of the facility with the collection of information but without any tests or measurements are made to determine maintenance and operational energy saving opportunities.

- **Mini-Audit** - This type of audit requires tests and measurements to quantify energy uses, energy losses and to determine the economics of changes.

- **Maxi-Audit** - This type of audit contains an evaluation of how much energy is used for each function within a building including, lighting and process. It also employs a simulation to determine energy use patterns and predictions on a year-round basis, taking into account such variables as weather data.

### 4.2 INTERNAL ENERGY CONSUMPTION

Efficient energy systems and efficiency measures normally include better insulation, high quality glazing, better solar control measures and the use of more energy efficient appliances such as copiers, computer monitors and printers. It also includes building orientation and massing to utilize passive solar heating and cooling design, the deployment of high efficiency lighting through
occupancy sensors as well as carbon dioxide monitors that monitor room occupancy and adjust ventilation accordingly. (Gevorkian, 2009)

A 25 to 50 percent (%) reduction in conventional building energy consumption can be obtained by incorporating high-efficiency systems and conservation measures throughout the basic building envelope such as the HVAC plant and lighting systems. A high efficiency HVAC system, variable speed fans and motor drives will contribute considerably to energy savings.

By outfitting a Green Building with energy-efficient equipment, a spherical logic will be followed that saves money, reduces urban air pollution and improves the indoor environment of the Green Building. For example, burning less natural gas, wood or coal to warm a building, will lead to corresponding reduced emissions of smoke, fog and CO$_2$, the primary Greenhouse gas. Since a coal-fired power plant is only about 33 percent (%) efficient, saving a unit of electricity relates to saving three units of fuel being burned.

### 4.3 SPACE COOLING

Conventional air conditioning units consume large amounts of energy. Through adequate insulation and plugging of air leaks and drafts, a reduction in air conditioning loading can be achieved.

Another option is to use an evaporative cooling system. Evaporative cooling systems can be deployed as energy efficient alternatives using an evaporative process to cool the air by passing it through a wet medium without the use of compressors, chiller coils or cooling towers. Because of the simplicity of the system, the cost of acquiring and operating an evaporative cooling unit is considerably less than for a conventional air conditioning unit. Maintenance costs are also lower owing to the units requiring simpler procedures and lower skilled maintenance workers. Evaporative cooling is eco friendly in the sense that it does not release harmful chlorofluorocarbons (CFC’s) into the atmosphere.

### 4.4 SPACE HEATING

The basic strategy for space heating is firstly to minimize heating losses through the building shell, secondly to capture as much of the sun’s heat as possible and thirdly to meet the remaining heating load with an efficient furnace, boiler, heat pump, wooden stove or other type of heating system. As an added advantage many of the design measures employed to manage a Green Buildings cooling load also reduces the buildings heating loads.
The method of best practice used to heat a building is through a combination of super insulation and passive solar design aimed at increasing the building shell temperature through better insulation, weatherization and appropriate landscaping.

4.4.1 Mechanical solar space-heating systems

Mechanical systems, sometimes called active systems, use pumps and fans to move energy from one point in the system to another. This is in contradiction to passive systems which use as little as possible mechanical energy in carrying out their heating function.

4.4.1.1 Heat Pump

Heat pumps allow for thermal energy to be transferred from a low-temperature reservoir to a high-temperature reservoir. Energy (heat), \( Q_L \), is absorbed by a working fluid from a low temperature reservoir (normally a geothermal resource or solar collectors). The energy content, consisting of temperature and pressure of the working fluid is increased by work input, \( w \). The \( Q_H \) energy of the working fluid is then released to a high-temperature reservoir.

The efficiency of a heat pump can be defined as:

\[
\eta_{heat\, pump} = \frac{\text{desired output energy}}{\text{desired input energy}} = \frac{Q_H}{w} = \frac{Q_H}{Q_H - Q_L}
\]

_Equation 14: Heat Pump Efficiency_ (Jan F. Kreider, 2001)

Where:

- \( Q_H \) = high-temperature thermal reservoir energy
- \( Q_L \) = low temperature thermal reservoir energy

The efficiency of a heat pump is often expressed as coefficient of performance (COP) where the COP of a Carnot heat pump can be expressed as:

\[
COP = \frac{T_H}{T_H - T_L}
\]

_Equation 15: Carnot Heat Pump Efficiency_ (Jan F. Kreider, 2001)
Where:

- $T_H$ = high-temperature thermal reservoir temperature
- $T_L$ = low temperature thermal reservoir temperature

(Jan F. Kreider, 2001)

### 4.5 ELECTRIC LIGHTING

Lighting in a conventional building accounts for up to 30 percent (%) of energy consumption. Therefore, reducing energy consumption through the use of compact fluorescent lights, as opposed to traditional incandescent lights should be readily achievable.

A 15W compact fluorescent globe will supply the same amount of light as a 60W incandescent light, while using only 25 percent (%) of the energy of the 60W incandescent light. Compact fluorescent lights have better lamp lumen depreciation (LLD) factors and with an expected lifetime of 10 000 hours will outlast incandescent lights. These lights have a bigger initial cost per unit, but the investment can be recovered over time through lower expenditures on energy consumption and maintenance. (Gevorkian, 2009)

However, fluorescent lights contain mercury, which is harmful to the environment making the disposal and treatment of these lights of the utmost importance in minimizing the negative environmental effects of the disposal process. It should be noted that fluorescent lights lifespan are greatly reduced with excessive switching on and off operations.

#### 4.5.1 Lighting Design

Lighting should be designed according to the specific needs of a given space by firstly using glare free, well distributed day lighting to minimize the need for electric light. Secondly, deploying high quality, efficient and properly controlled electric lighting. Thirdly, the designer is to consider the different illumination levels and colour contrasts required in different rooms, buildings and building types. Luminous flux should be considered here and is a form of radiant power evaluated by its effect on the human eye. Fourthly, it’s more important to reduce “veiling glare” (stray light that washes out contrast) than it is to add more light.

In general a good design will offer ambient lighting for background and space definition along with task lighting for individual detailed work and accent lighting for the added special touch. It is advised not to light an entire room if light is only needed at one specific desk or workbench. Adjustable task
lamps should be placed in areas where reading, writing or other meticulous work is to be performed, with compact fluorescent lamps being deployed as ambient lighting.

4.5.2 Measurement and Verifications

SANS 50010:2011 provides a methodology for the determination of energy savings. It provides a detailed discussion of information factors such as, but not limited to, the Calculation of a Baseline, Boundaries for Measurement, Measurement Periods and Energy Quantities. (SANS, 2011)

For more information please refer to SANS 50010:2011

4.6 WATER

South-Africa is increasingly becoming a water scarce country, which is why the installation of water efficient showerheads and faucets aerators are important in reducing water consumption and should be standard practice on Green Buildings along with the proper insulation and layout of pipes.

Geysers supporting a reduced load are cheaper to operate than conventional configuration units such as a tank type geyser. Consider using an alternative system such as:

- On demand water geysers;
- Solar water heaters; and
- “Desuperheaters”

All have attractive advantages in water savings and cost reductions.

4.6.1 On Demand Water Heaters

On demand heaters differ from conventional geysers in the sense that they do not have storage tanks, heat water on demand and do not require excessive electricity to keep a tank of water hot. These systems also save on water consumption since water will not have to run until an acceptable temperature has been reached, in effect wasting the water already in the pipe.

4.6.2 Solar Water Heaters

Solar water heating offers a number of very attractive, reliable and frost proof models. Although solar water geysers normally have a higher initial cost and therefore a longer payback period than conventional geysers, the savings in energy cost and pollution will be beneficial in the long run.
4.6.3 Desuperheaters

Two other water heating alternatives to consider are “desuperheaters” and for larger buildings, cogeneration. A “desuperheater” preheats water for commercial and other applications by extracting wasted heat energy from the condensers of air conditioners or refrigeration systems while cogeneration acts as a double purpose system.

4.6.4 Cogeneration

Cogeneration is the production of electricity, heat and hot water from the same power source. It can be very cost effective for small manufacturers, laundromats, health clubs, hospitals, car washes and other commercial buildings that use a lot of electricity and hot water. Payback timeline for cogeneration units can be as little as three years depending on the system deployed.

4.6.5 Geysers Efficiency

Consider the following as suggestions to increasing the efficiency of geysers:

- Thermostats could be turned down to temperatures of 50–55 °C;
- Locate and fix any leaky faucets or pipes;
- Geysers could be better insulated by covering it with a protective layer;
- The geyser should be turned off when the demand for hot water is limited; and
- A timer should be employed to turn off the geyser during inactive hours of the day.

4.6.6 Water Recirculation Systems

Recirculation systems in commercial buildings are normally controlled by clocks or temperature sensors. Clocks are used to operate the system during known water use cycles while temperature sensors located at the most distant point in the circulation loop can be used to operate the system as demanded. It is important to note that the return line of the circulation loop should be insulated as to reduce standby losses. (Diana Lopez Barnett, 1995)

4.7 INTERNAL APPLIANCES

All appliances in a Green Building should ideally be as efficient and effective as possible. Small initial cost differences that might arise in purchasing energy efficient appliances will be rapidly repaid through energy savings. Manufacturing and disposing of appliances has a high impact on the environment, so sturdy well built appliances will have longer and more economical life cycles.
Most new refrigerators do not use ozone damaging chlorofluorocarbons (CFC’s) as a refrigerant or as a blowing agent, however all equipment should be certified as CFC’s free.

### 4.8 OFFICE EQUIPMENT

“Since efficient office equipment produces less waste heat, a decrease of just 1 watt per square foot in the plug load can decrease the capital cost for the cooling system of a large commercial building by approximately $ 1 per square foot. Adding up the nameplate wattage on all office equipment and then dividing by the square footage will typically result in 3 to 5 watts per square foot. This however is not the cooling load but the device’s spike load at start-up and is used for configuring wire. Sizing cooling system to actual loads as opposed to nameplate loads will result in smaller and more efficient systems.” (Diana Lopez Barnett, 1995)

Intensive electricity usage by office equipment increases peak power demand, utility bills, pollution and the buildings’ cooling loads through dissipated energy. Current research suggests that in some American buildings, there is a direct link between the efficiency of office equipment and the capital costs of the cooling system.

#### 4.8.1 Washing Machines

Washing machines are large consumers of electricity and water. Horizontal axis washing machines, also known as front end loaders have a more efficient spin cycle than top loaders, therefore causing clothes to require less time in the dryer and leading to savings in energy consumption.

#### 4.8.2 Refrigeration Equipment

Conventional refrigerators are major energy consumers, but can be made more effective and efficient by keeping it fully stocked. By increasing the mass of the contents, the cold retention of the refrigeration can be improved.

Having the refrigerant, water, air and oil of a refrigerator out of balance will have major effects on the operating and maintenance costs during a refrigeration cycle. The proper refrigerant for a specific machine will take into account considerations such as the boiling point of the refrigerant and the operating pressures of the system.
4.9 INSULATION AND WEATHERIZATION

Inadequate insulation and air leakage around windows and doors can be leading causes of energy wastage in buildings. By providing adequate insulation, walls, ceilings and floors can be warmer in winter and cooler in summer. Insulation can, as a secondary function, act as a sound absorber or barrier.

4.10 ENERGY SAVING TIPS

Energy Saving Tips (EST) should be viewed as resources assisting building owners or developers to better understand and locate energy-saving opportunities and should be used to perform a comprehensive facility survey, investigating ways employees can save energy mainly on existing buildings and systems.

4.10.1 Shutdown of Air Handling Systems

Shutting down of air-handling systems can have savings associated in the following ways:

- The cost of heating and cooling outside air will be reduced since no outside air will be imported; and
- Stopping the fans will save the cost of electricity for operating fan motors.

With thorough analysis, shutdowns can be made without negatively effecting comfort or maintenance costs.

The following are a few guidelines that must be considered as shutdown criteria:

- All areas served by the air handling system to be shutdown, must be unoccupied for the shutdown period;
- All emergency air supply and exhaust systems for hazardous chemicals and materials must continue to operate; and
- Existing pressure differentials or air paths in the building should not be altered.

A thorough understanding of the system, including details of operating schedules and procedures, existing controls and space usage are required to determine the best methods for controlling and scheduling night time shutdowns.

For a more comprehensive list of possible Energy Saving Tips, please refer to Annexure H.
4.11 PRODUCT DISCUSSION

A large array of technologically advanced products are available to assist in the reduction of a building's energy consumption and ultimately a building's carbon footprint.

4.11.1 Photovoltaic Solar cells

Solar or photovoltaic (PV) cells are electronic devices that convert the solar energy of sunlight into electrical energy or electricity. These cells store energy to batteries, are only operational during sunlight hours and are dormant during night time. Solar cells can convert sunlight into electricity without moving parts or components and without producing any adverse forms of pollution that negatively affect the ecosystem. (Thomas, 1976)

4.11.1.1 Solar Cell Physics

“Most solar cells are constructed from semiconductor material, such as silicon. This is due to the following:

Metals have loosely bound electrons in the outer shell or orbit of their atomic configuration, which can be detached when subjected to an electric voltage or current. Isolators on the other hand have very strongly bonded electrons in the atomic configuration and do not allow the flow of electrons even under the severest application of voltage or current. Semiconductor materials therefore bind electrons midway between that of metals and insulators.” (Edwards, 2003)

Semiconductor elements are constructed by fusing two adjacently doped silicon wafer elements together. Doping implies impregnation of silicon by positive and negative agents such as phosphor and boron. Phosphor creates a free electron that produces so called N-type material while Boron creates a “hole” or a shortage of an electron that produces so-called P-type material. Impregnation is accomplished by depositing the previously referenced dopants on the surface of silicon using a certain heating or chemical process. The N-type material has a propensity to lose electrons and gain holes, so it acquires a positive charge while the P-type material has a propensity to lose holes and gain electrons so it acquires a negative charge. (Thomas, 1976)

When N and P-type doped silicon wafers are fused together, they form a PN-junction. The negative charge on the P-type material prevents electrons from crossing the junction and the positive charge on the N type material prevents holes from crossing the junction. A space created by PN wafers creates a potential barrier across the junction. In solar cells, when a PN-junction is exposed to...
sunlight, the device converts the stream of protons that form the visible light into electrons. This makes the device behave like a miniature battery with a unique characteristic voltage and current depending on the material, dopants and PN-junction physics.

The bundles of photons that penetrate the PN-junction randomly strike silicon atoms and give energy to the outer electrons. The acquired energy allows the outer electrons to break free from the atom. Thus, in the process, the photons are converted into electron movement or electrical energy.

4.11.2 Fuel Cell Technology

Fuel cells are energy-conversion devices that produce electricity through the chemical oxidation of a reactant or fuel and an oxidant. This oxidation reaction takes place in the presence of electrolytes which act as catalysts and strip electrons from atoms in the fuel promoting the circulation of electrons or electric current through an external conduction path. (Krenz, 1984)

Fuel cells can use numerous types of reactants and oxidants, such as listed below, and can operate virtually continuously.

- Hydrogen and Oxygen
- A Hydrocarbon and an Alcohol
- Air and Chlorine
- many more.

4.11.2.1 Fuel cell design

As mentioned, fuel cells operate through a catalytic process that involves the separation of the component electrons and protons from the reactant fuel, resulting in a flow of electrons that circulates through an electric circuit that gives rise to electric power.

In a typical hydrogen-oxygen proton-exchange-membrane fuel cell (PEMFC), a proton-conducting polymer membrane, or electrolyte, separates the anode and the cathode sides and produce water as a waste product. In general, the reactant or fuel, is introduced into a chamber that is exposed to an electrode referred to as the anode. For example, a reactant such as hydrogen, when placed in the intake chamber, diffuses to the anode catalyst, where it later dissociates into protons and electrons. The protons then react with oxidants such as oxygen. In the process, protons are conducted through the membrane to the cathode. However, electrons are forced to travel in an external circuit, supplying power.
On the cathode catalyst, oxygen molecules from air react with the hydrogen molecules that have been reconstructed by the recombination of electrons with protons. The chemical combination of oxygen and hydrogen results in the formation of water molecules in the form of water vapour as the waste product. In addition to hydrogen as a fuel, hydrocarbon fuels such as methanol and many other chemical hydrates are used in various types of fuel cells that produce electricity and different types of waste products. In addition to electric power the chemical reaction also produces a considerable amount of heat energy that can be used for steam cogeneration and many other industrial processes.

4.11.2.2 Water and air control
The membrane in hydrogen- and hydrant-type fuel cells need to be dehydrated by means of precise evaporation at the same rate that water is produced. If the evaporation of water is too rapid the membrane could dry and eventually crack, creating a “gas circuit” where hydrogen and oxygen could combine directly generating excessive heat that might damage the fuel cell. If water evaporation is left to evaporate too slowly, the electrodes could flood, preventing the reactants from reaching catalytic reaction level.

4.11.2.3 Temperature control
The removal of large amounts of heat, resulting from the exothermic reactions, poses another challenge when designing fuel cells. Deconstruction of the fuel cell from thermal loading may occur if the combination of oxygen and hydrogen molecules ($2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O}$) are not controlled.

To prevent excessive thermal loading, the temperatures must be maintained at acceptable levels throughout fuel cell operation.

4.11.2.4 Durability and service life of fuel cells
When the power generated by fuel cells ranges in the hundreds of kilowatts, life expectancies typically exceeding 40 000 hours of reliable operation at temperatures of between -35 and -40ºC.

4.12 ENERGY EFFICIENCY STRATEGY OF THE REPUBLIC OF SOUTH AFRICA

“The Minister signed the Energy Efficiency Accord with over 40 large industrial and commercial consumers and a recent report indicated that 14 of these consumers managed to invest R 9.9 billion
on energy efficiency improvements and saved a significant 1 441 GWh and 5 190 Terrajoules of energy over the 3 year period. This is equal to the entire residential sector consumption for 2 days." (Gazette, 2009)

In 1998 the White Paper on Energy Policy was published within the Republic of South Africa. This led the way for an Energy Efficiency Strategy for South Africa that was first published in March 2005. The Energy Efficiency Strategy is a consolidated Governmental document aimed at the development and implementation of energy efficiency practices in South Africa. It allows for the immediate implementation of low- to no-cost interventions, as well as higher-cost measures with short payback periods and should not be confused with the Governmental Power Conservation Programme. A long term national target for energy efficiency improvements set at 12.5 percent (%) by the year 2015.

The focus of the Strategy will be on the following sectors Industry and Mining, Commercial and Public Buildings, Residential and Transport. Each sector has specific Facts, Core Objectives and Approaches applicable to it as set out in the Energy Efficiency Strategy.

![Figure 13: 2004 Primary Energy Supply (Gazette, 2009)](image-url)
For further information on the South African Energy Efficiency Strategy, please refer to the GOVERNMENT GAZETTE, No. 32342 dated 26 June 2009.

4.13 SECTION CONCLUSION

Green office buildings can save energy with the use of better windows placed more correctly as well as better wall and roof insulation. Building orientation, shape, mass and roof colour play important contributory roles in reducing cooling loads, as does shading and landscaping. In hot climates, a combination of correctly placed porches and shade trees around a building can dramatically reduce air temperatures inside. A building’s thermal mass plays a major role as buffering against outdoor temperature fluctuations.

An often overlooked step in reducing cooling loads is to select efficient lights and appliances that release less waste heat while in operation. These lights and appliances should be equipped with motion sensor activators and timed termination switches.

Whole system engineering aimed at reducing the need for mechanical/artificial cooling should be viewed as the key to cooling a building cheaply and more efficiently. Contributing to this goal is the management of reducing unwanted heat gain, harnessing natural ventilation and cooling
techniques, expanding occupants “comfort envelope” and properly sizing and controlling air conditioners and other cooling equipment.

**Space Heating**
Electric space heaters and geysers require a significant amount of electricity to operate at a time of the year when the least amount of radiation is available and are therefore not viable options to be used in energy efficient systems.

**Electric Lighting**
The modern designer has technologies such as fluorescent lamp tubes the thickness of a pencil, solid state electronic ballast, imaging reflectors, pocket sized compact fluorescent lamps, “smart” light bulbs with built in controls and an array of new lighting fixtures at his or her disposal and should make use of these as best possible when designing a Green Building.

The need for electrical lighting can be reduced through the good use of windows, daylight and higher reflective colours. Since daylight is of such good quality, it would normally take less daylight to perform a task than electric lighting. The lighter the colour of the room finishes and furnishings, the lower the light absorption by these objects and hence fewer watts per square meter will be required to produce the same meter candles.

**Photovoltaic Solar Cells**
It should be noted that the photovoltaic energy-conversion efficiency depends on the wavelength of the impinging light. Red light, which has a low frequency, produces insufficient energy, whereas blue light, which has more energy than needed to break the electrons, is wasted and dissipated as heat.

A typical solar panel used in photovoltaic power generation is constructed from a glass supportive plate that houses solar PV modules, each formed from several hundred interconnected PN devices.

**Fuel Cells**
Fuel cells differ from conventional batteries in the sense that the reactant is consumed and must therefore be replenished continuously, whereas batteries store electrical energy chemically in a closed system. Another difference is that the electrodes within a battery change and become depleted during the charging and discharging cycles, whereas fuel cell electrodes are catalytic and
relatively stable. Water and heat are produced as waste products during the chemical reaction between the reactants and oxidants. Without proper control and regulation of these waste products, the fuel cell operation cannot be sustained for extended periods of time.
5.1 SOLAR ENERGY

“...energy is defined in the classical thermodynamics as the capacity to do work.” (Jan F. Kreider, 1989)

“...each day the sunlit side of the earth receives the energy equivalent of 4000 trillion kilo-Watt hours. By contrast, the whole world uses roughly 80 trillion kilo-Watt hours per year or 0.3 trillion kWh a day.” (Jan F. Kreider, 1989)

The sun is the most important known source of energy. About 47 percent (%) of the energy received is converted to low temperature heat and re-radiated to space, 30 percent (%) is reflected back to space, 23 percent (%) powers the evaporation-precipitation cycle of the biosphere and less than 0.5 percent (%) is represented in the kinetic energy of wind and photosynthetic storage. (Jan F. Kreider, 1989)

5.1.1 Solar Energy Utilization

The three processes by which solar energy can be utilized are:

- Helio-chemical;
- Helio-electrical; and
- Helio-thermal.

The Helio-chemical process maintains life on Earth through photosynthesis, while Helio-electrical energy provides power for all of the communication satellites and some projects on earth by using photovoltaic converters. Helio-thermal energy provides most of the thermal energy needed for space heating and cooling as well as hot water heating. (Gevorkian, 2009)

5.1.2 Solar Design

During the preliminary engineering design phase, a review of available roof mount areas or mounting landscape should be done and should include a survey to ensure that there are no obstructions that can cast a shadow on the solar panels. Only after the solar power area clearances have been established, can the designer model the photovoltaic layout to establish a desirable output of dc power. On finalization of the photovoltaic layout, the designer should arrive at a unit
cost estimate, such as Rand per Watt, which can be used to better approximate the cost of the total project. (Jan F. Kreider, 1989)

5.1.3 Measurement
Solar radiation is measured in langleys (Ly), a unit named after Samuel P. Langley who invented instruments for measuring the phenomenon of solar radiation. Solar radiation flux varies from zero to 1.5 langleys per minute with one langley per minute being a typical value to expect on a clear day.

5.1.4 Solar Energy Economics
Solar energy is normally expensive and the costs and benefits of solar energy systems must be carefully analyzed so that the capital invested can be recalled effectively. Since the primary reason for using solar energy is to save costs over a long term investment, an economic analysis should be carried out to determine whether or not a particular solar energy system is economically advantageous to a particular project. (Gevorkian, 2009)

5.1.4.1 Savings
The saving in energy costs realized from the solar energy system depends on the initial cost of the system as well as the recurring operating and maintenance costs distributed throughout the lifetime of the system. The physics of the interactions between collectors, storage and delivery costs are such that a solar energy system does not produce proportionally more energy savings as the size of the system increases.

5.1.4.2 Costs
The cost of solar energy is defined as the amount invested in the solar energy system, prorated on an annual basis and divided by the annual energy production. The cost should be expressed in units of local currency per kilowatt-hour.

Calculation costs and benefits for different solar energy system sizes are inherently more difficult than specifying a boiler or other fossil fuel powered systems which will be designed to operate at peak heating or cooling load. Therefore a new way of thinking is to size a solar energy system on the basis of engineering economics rather than a specific thermal requirement. The thermal requirement will however still serve as a secondary guideline in determining the size of a solar energy system.
5.1.5 Solar Cooling

“The cooling load of a building is the rate at which heat must be removed from the building to maintain the air in the building at a given temperature.” (Jan F. Kreider, 1989)

Solar energy is more economical for building temperature control in areas where local climates require both heating and air conditioning. The same solar collector and storage system can be used for combined year round heating and cooling operations.

5.1.5.1 Background to Solar Cooling

In 1878 in Paris, steam produced by a solar boiler was used to operate a primitive absorption refrigerator and produced a small quantity of ice. Since then pioneers have explored three main processes by which the sun’s radiant energy can produce cooling effects. (Diana Lopez Barnett, 1995)

The first, a steam jet system, was investigated in 1936 by W.P. Green at the University of Florida. A concentrating solar collector was used to produce steam which was at a high enough pressure to enable a steam jet ejector to function. That in turn caused evaporation and chilling of water in a tank connected to the ejector. The performance of the system proved to be very low and the requirement for a sun following concentrator made the system impractical for commercial applications.

The second system employed the familiar compression refrigeration cycle, driven by a Rankine Cycle engine or turbine and operated by steam generated by using a solar collector. The modern availability of fluorinated hydrocarbons as working fluids, have reawakened solar powered compression refrigeration interests.

Lastly, the University of Florida concentrated its Solar Energy Laboratory on the ammonia water absorption cycle. The university researched the successful operation of a continuous refrigeration system in which the solar absorber is used to drive the ammonia out of the water solution. The Florida system provides cooling at lower collector temperatures and appears well adapted to be used with the modern type of flat plate collectors.
5.1.6 Refrigeration

Cooling, by means of a heat source, works on the principle of latent heat. When a liquid is vaporized it absorbs the latent heat that is required for a change of state from the environment. This principle is utilized during refrigeration. (Rosenberg, 1992)

Refrigeration is accomplished by two distinct processes. The first, referred to as the compression cycle adds heat through compression to a medium such as Freon gas. This transforms the gas into a liquid state. Energy is removed in the subsequent cycle through evaporation or gas expansion that disperses the gas molecules and turns the surrounding chamber into a cold environment. (Swart, 2001)

When circulated within the so-called evaporation chamber, a medium of energy-absorbing liquid such as water or air, surrenders its heat energy to the expanded gas. The cold water or air is then circulated by means of a pump through environments that have higher ambient heat-energy levels. The circulated cold air passes into the ambient space through radiator tubes or fins, lowering the energy and therefore the temperature of the environment as a whole. Temperature control is realized by the opening and closing of cold medium circulating tube valves modulated by a local temperature sensing device such as a thermostat.

5.1.7 Cooling Technologies

There are two main types of refrigeration technologies in use today namely electric vapour compression (Freon gas) and heat-driven absorption cooling. Absorption-cooling chillers are operated by steam, hot water, fossil-fuel burners or any combinations of the above. (Shariff, 2008)

Absorption chillers can be divided into two specific types namely those that use lithium bromide (LiBr) as an energy-conversion medium and water as a refrigerant, and those that use ammonia as the energy conversion medium and a mix of ammonia and water as refrigerant. Both technologies have been around for more than a 100 years. (Krenz, 1984)

The basic principle of absorption chillers is gasification of LiBr or ammonia, which take place when either of the media is exposed to heat. Heat could be derived from energy sources such as fossil-fuel burners, hot water obtained from geothermal energy, passive solar water heaters or micro-turbine generators, which use landfill gases to produce electricity and heat energy.
5.1.8 Solar Water Heating

Solar water heating is one of the least expensive and simplest applications of solar heating in a building.

Solar water heating demands can be calculated exactly if the quantity of hot water required is known. The amount of energy needed to heat a specific volume of water is the product of the water's density, specific heat and the required temperature increase. (Gevorkian, 2009)

\[ Q_{hw} = V(\rho c) \times (T_{set} - T_{source}) \]

Equation 16: Solar Water Heating (Gevorkian, 2009)

Where:
- \( Q_{hw} \) = the energy required per day
- \( V \) = is the volume of hot water required
- \( \rho \) = the density
- \( c \) = is the specific heat (4.19kJ/kg °C)
- \( T_{set} \) = the desired delivery temperature
- \( T_{source} \) = the temperature of the inlet water

A second thermal demand, namely the amount of heat lost from the water-heating tank and recirculation system are present for solar water heating systems and can be as high as 25 percent (%) of energy used in a hot water installation. The system losses, namely tank and pipe losses can be calculated through the thermal conductance of the insulation \( U_{hw} \) multiplied by its surface \( A_{hw} \) as well as the temperature difference between the water and the surrounding area.

Simplified it can be expressed as:

\[ Q_{standby} = U_{hw}A_{hw}(T_{set} - T_a)N_h \]

Equation 17: Heatloss (Gevorkian, 2009)

Where:
- \( T_a \) = The ambient temperature in the vicinity of the water-heating and recirculation loop
- \( N_h \) = The number of hours of use per day, normally 24.
The total energy demand for water-heating is the sum of the two mentioned equations.

### 5.1.8.1 Type of Solar Water Heaters

Solar water heaters can be divided into direct and indirect designs. Direct systems are those in which the water is heated directly in the solar collector, while indirect systems make use of a separate heat transfer medium such as a heat exchanger. Furthermore, two distinctive but complementary systems, namely passive and active systems exist.

A passive system can be defined as a system in which the energy and mass flow are by natural means such as conduction, convection, radiation, and evaporation. An active system is one in which all mass flows are by forced means, produced by fans, pumps, etc. A hybrid system exists in which at least one of the significant flows is by natural means and another by forced means.

### 5.1.8.2 Solar Collectors

Solar energy is transmitted through space to the earth by means of electromagnetic radiation. This energy is only useful for heating and cooling systems once it has been converted to heat energy. (Diana Lopez Barnett, 1995)

Non-concentrating or flat plate collectors intercept solar radiation energy on a metal or glass absorber plate from where the energy is converted and transferred. Unrecoverable heat losses occur from the entire surface of the plate collector to the environment. Concentrating collectors reduce energy losses by using an absorber area smaller than the aperture area (the area that intercepts the sun's rays). This performance enhancement is obtained from reflecting the sun's rays off mirrors and reflective surfaces as well as through concentrating lenses.

Only the direct portion of solar radiation is amenable to effective radiation and therefore a concentrating collector must be equipped with a mechanism capable of following the sun's trajectory. Evacuated tube collectors on the other hand have an intermediate position, smaller energy loss factor than flat plate collectors and can be mass produced for large solar markets.

Optimum transfer of heat inside a collector is a delicate balance between the speed of flow within the fluid and the amount of energy transferred. If the fluid inside move slowly it will absorb a lot more heat than normal and reach much higher temperatures causing the collector to dissipate more heat back into the surroundings. If the fluids are permitted to flow at a high flow rate, it will not reach as high temperatures as with the low flow rate, however in this instance a large amount of fluid will be
heated and rapid circulation will result in inefficient heat transfer. The balance is to achieve very little energy loss with the total amount of energy delivered by the collector being greater than the energy needed to circulate.

5.1.8.3 Glazing materials

The purpose of glazing is to admit as much solar radiation or energy as possible and to reduce the upward loss of heat to the lowest attainable value. Glass has been the principal material used to glaze solar collectors as it has the highly desirable property of transmitting as much as 90 percent (%) of the incoming shortwave solar radiation while preventing long wave radiation emitted by the flat plate to escape outward by transmission. (Jan F. Kreider, 1989)

Glass is virtually opaque to the long wave radiation emitted by the collector plate but the absorption of this radiation by the glass, causes the glass temperature to rise and thus to lose energy through heat to the surrounding atmosphere. This type of heat loss can be reduced by applying an infrared-reflective coating on the underside of the glass. For clear glass as used for solar collectors, the 4 percent (%) reflectance from each glass-to-air interface is the most important factor in reducing transmission. This interface can be made more efficient with about a 3 percent (%) gain in transmittance through the use of “water white” glass.

Plastic films and sheets also possess high shortwave transmittance. Plastics are generally limited in the temperatures that it can sustain without undergoing dimensional changes and only a few of the varieties available can withstand the sun’s ultraviolet radiation for prolonged periods of time. Plastics do however possess the advantage of being able to withstand hail and other stones and are very flexible in the form of thin films.

Surfaces with high values of solar radiation absorbance and low values of long wave emittance can be produced using suitable electrolytic or chemical treatments. Essentially such “selective surfaces” consist of a very thin upper layer that is highly absorbent to shortwave solar radiation, but relatively transparent to long wave thermal radiation. These coatings are expensive and reduce the effective transmittance of the glass for solar radiation by as much as 10 percent (%). In addition to serving as a heat trap the glazing also reduces heat loss by convection. The insulating effects of the glazing can be enhanced by using several sheets of glass or glass in combination with plastic.
5.1.9 Solar Energy Factors

In designing a solar energy system, the collector efficiency, \( e \) and the ratio of the output power density, \( P_o \) to the incident power density, \( P_i \), is important. (Jan F. Kreider, 1989)

Therefore

\[
e = \frac{P_o}{P_i}
\]

**Equation 18: Collector Efficiency (Jan F. Kreider, 1989)**

The glass cover on solar collectors reflects as well as absorbs a portion of the incident radiation. If the transmission coefficient of one pane of glass is \( \delta \), the radiation reaching the collector, with the effect of multiple reflections ignored, is \( \delta^n P_i \) for \( n \) is the number of panes of glass. Assuming the collector plate behaves as an ideal black body, the absorbed power, \( P_A \), is equal to that transmitted through the glass.

\[
P_A = \delta^n P_i
\]

**Equation 19: Transmission Coefficient (Jan F. Kreider, 1989)**

5.1.10 Concentrating Solar Power

Concentrating Solar Power (CSP) technologies concentrate solar energy to produce high-temperature heat that is then converted into electricity. Three CSP technologies currently in use are Parabolic Troughs (PT’s), Central Receivers (CR’s) and Dish Engines (DE’s). CSP technologies are considered to be very efficient power plant applications. (Gevorkian, 2009). Concentrating Solar Power (CSP) technology is used at concentrated solar radiation tower-mounted heat exchangers to generate electricity. This system consists of an array of sun-tracking mirrors, commonly referred to as heliostats reflecting the sun’s rays onto the tower.

The receiver contains a fluid that transfers the absorbed heat in the heat exchanger to produce steam that then drives a turbine to produce electricity. DE’s are better suited for distributed power ranging from 10kW to 10MW, where as PT’s and CR’s are suited for larger central power plants as big as 30-200MW and higher. The amount of power generated by a CSP plant depends on the amount of direct sunlight. Like photovoltaic (PV) concentrators these technologies use only direct beams of sunlight to concentrate the thermal energy of the sun.
5.1.10.1 Advantages

Advantages of CSP technologies include not burning any fossil fuels and producing zero Greenhouse gas emissions. Along with cost effective storage or natural gas hybridization CSP’s can deliver power to the electricity grid not only when sunlight is available but whenever power is needed. Because CSP plants use relatively conventional technologies and materials, production can be scaled up to several hundred megawatts per year.

Disadvantages

No studies have been conducted to determine what the effect of a CSP plant would be on the macro as well as microclimates associated with it. Each site is unique and should therefore be evaluated on its own merits.

5.1.11 Section Conclusion

It should be noted that solar energy usage and energy conservation interacts strongly with each other, and that conservation of energy is the first step in reducing the use of fossil fuel energy in buildings while solar technologies could be applied as a further step. Solar power systems normally have a near-zero maintenance requirement, made achievable by solid state technology, lamination techniques and the total absence of mechanical or moving parts. Marginal degradation in output performance can however occur due to dust accumulation.

Solar Energy Utilization

Some of the essential cost components of a solar power system are:

- Solar PV modules capital cost versus output in Rand per Watt;
- Support structure hardware such as tilting or tracking mechanisms; and
- Electrical devices such as inverters, isolation transformers and lightning protection devices as well as hardware such as electric conduits, cables and grounding wire.

The solar energy system is normally sized based on the mean energy demand rather than peak demand as with other non-solar energy sources. The economic optimum is determined by investigating a range of solar energy systems sizes, taking their different costs and benefits into account and then selecting the appropriate size that produces the maximum benefit.
Solar Energy Economics
Fuel price inflation affects the value of solar energy system and should therefore be predicted and incorporated into the present value calculations. The size of a solar energy system that can be economically purchased will increase as the price of fossil fuels increase. Therefore projected inflation in energy prices are an important variable in determining the optimum system size.

Solar Cooling
A great variety of cooling systems are available, mechanical, non-mechanical, absorption air conditioning, desiccant cooling systems etc. Each project might warrant a different application of cooling systems and therefore it is up to the client and design engineer to specify the most appropriate and economical system.

Solar Water Heating
The most widely used energy collectors are flat plate and focusing collectors with the heart of the solar collector consisting of coils filled with a fluid to enable as much heat as possible to be absorbed and transferred. Focused collectors consist of collectors that focus the sun’s rays through lenses and mirrors to ‘concentrate’ the sun’s rays while very closely tracking the sun’s movement.

Flat plate collectors are best for supplying large amounts of heat at low temperatures and although it does not reach as high temperatures as a focusing collector, it has the advantage of not needing a sun tracking mechanism. The coils of a collector are normally painted black to increase the efficiency of light absorption and energy transformation into heat. Black is however also good at radiating heat and most of this re-radiated heat is lost back into the surrounding atmosphere. This specific property of black as a colour has prompted further development into areas such as selective surfaces that are good at absorbing light but poor at radiating heat. Dirt and dust play a surprisingly small part on the collectors’ effectiveness and the cleansing effect of occasional rain is viewed as adequate to maintain the transmittance within 2 to 4 percent (%) of the maximum value. (Jan F. Kreider, 1989)

5.2 WIND ENERGY
Wind power is arguably the greatest terrestrial medium for harvesting, harnessing and converting solar energy. Air waves circulating around the globe are energy mediums whose captured energy may be used to generate electrical, pneumatic and hydraulic powered systems. (Twidell, 2011)
5.2.1 Wind Power Generation

“At the end of 2007, worldwide capacity for wind powered generators was 94.1 GW. This represented about 1 percent (%) of the world’s electricity.” (Gevorkian, 2009)

Wind circulation or convection results from an uneven distribution of solar heat. This phenomenon is used for power generation resulting in the conversion of kinetic wind energy into electricity through the use of wind turbines. (Kreider, 2011)

Wind energy is one of the most abundant forms of renewable energy and could be harvested throughout the globe, however owing to the intermittent nature of wind, power produced by wind turbines lacks stability and consistency. In order to stabilize, regulate and harmonize electrical power production, wind farms make use of special energy storage devices and supplementary power co-generation through auxiliary gas turbines or other energy production means. (Devins, 1988)

5.2.2 Wind Farm Economics

“A wind power generator converts the kinetic energy of the wind into rotational energy of the propeller and generator shaft and hence to electrical energy. It is easy to show that the maximum rate of energy conversion, the power output to the area is proportional to the area of the intercepting blades and also to the third power of the wind velocity.” (Devins, 1988)

Energy payback time is the term used to measure the net energy value of a wind turbine. In other words, it determines how long a plant has to operate to match the initial amount invested in its manufacturing and construction. Several studies have concluded that wind energy has one of the shortest energy payback times of any energy technology. Critical factors associated with wind power economics are site location, land acquisition costs, land use considerations, environmental-impact consideration and most important the availability of transmission lines. (Twidell, 2011)

5.2.3 Advantages and Disadvantages of Wind Power

Advantages:

- Wind energy is readily available, with mature technology;
- After initial installation capital, wind turbines require relatively minimal maintenance and produce energy without producing any atmospheric pollution;
- Wind turbines have a minimal footprint, allowing the surrounding land to be occupied for agricultural uses and cattle rearing purposes;
- Small wind farm projects offer an economic alternative to grid electricity in rural areas; and
- Energy production is relatively inexpensive.

Disadvantages:
- Wind turbines normally require a minimum wind speed of around 10km/h to produce power. Power produced by wind turbines is therefore irregular and needs to be supplemented with an alternative source of energy;
- There have been objections by animal protection and environmentalist groups who object to wind energy production owing to the possibility of accidental bird collision with wind turbine blades and the disturbance of marine life in offshore installations;
- Landscape disfigurement is a large negative owing to the imposing structure heights of wind turbines; and
- Some pollution is produced during manufacturing and placement of the wind turbines.

5.3 OCEAN ENERGY

5.3.1 Tidal Power

The sun and primarily the moon have an impact in causing twice-daily variations in sea levels which result in tidal movements. These tidal movements can be related to tidal power which has been used for milling grain since the eleventh century in Britain and France. (Diana Lopez Barnett, 1995)

5.3.2 Tidal Power Generation

Tidal power generation is similar to hydroelectric power generation, with the primary exception that water flows in and out of the turbines in both directions. A tidal station, known as an Ebb-generating system, involves the construction of a dam, called a barrage, across an estuary. A number of sluice gates on the barrage allow the tidal basin to fill with the incoming high tides and to exit through the turbine system on the outgoing tide, referred to as the Ebb-tide. (Smith, 1979)

The energy potential contained in a volume of water is determined by the formula

$$E = xmg$$

Equation 20: Water Energy Potential (Smith, 1979)
where:

- \( x \) is the height of the tide
- \( m \) is the mass of water
- \( g \) is the acceleration of gravitational energy.

Tidal energy generators are normally installed in locations where high-amplitude tides occur.

### 5.3.3 Tidal Power Economics

Tidal power generation technology’s main disadvantage is the long payback periods that will be encountered due to the large capital expenditure to construct a barrage. Once the construction of the barrage is complete and the plant operational, there are few associated maintenance and operational costs with the turbines on average only needing replacement every 30 years.

### 5.3.4 Environmental Concerns

Each location’s different environmental and ecologic systems need to be considered when constructing tidal barrages. The change in water level and possible flooding could affect the vegetation around the coast as well as have an impact on the aquatic and shoreline ecosystems. The quality of the water in the basin or estuary might be affected and the sediment levels could change affecting the turbidity of the water and thus the animals that live in and depend on it. Provisions should be made for wildlife such as fish to pass through the barrage and therefore minimize the environmental impact on the area.

Although a close study should be conducted before a barrage is constructed, not all changes adversely affect the environment. Some changes may result in the growth of different species of plants, animals and ecosystems, which may flourish in an area which might previously have been desolate.

### 5.4 HYDROELECTRIC POWER

Ancient civilizations such as the Greeks used hydropower to turn water wheels for grinding wheat into flour around 4000 BC. With the invention of the water turbine in the early 1800s, hydroelectric power technology advanced to produce electricity. (Diana Lopez Barnett, 1995)
5.4.1 Hydroelectric Power Usage

Hydroelectric power is the most desirable renewable-energy resource, among those that have successful and proven track records. Norway, derives up to 98 percent (%) of its electrical energy from hydroelectric power and serves as an example to the rest of the world. (Diana Lopez Barnett, 1995)

5.4.2 Hydroelectric Power Plant Potential

Hydroelectric power plant generation potential is determined by two main parameters, namely, the amount of water flow per unit of time and the vertical height, or head, that water can be made to fall. The power available at a particular hydroelectric plant depends on the amount of drop the water makes between the reservoir surface and the generator. (Devins, 1988)

5.4.3 Environmental Effects of Hydroelectric Power

Hydroelectric power projects have some irreversible ecologic and environmental damage associated with dam construction and operation. This along with some negative factors associated with initial capital investment costs are the main disadvantages of hydro electrical power generation.

Furthermore dams and barriers along with the construction of artificial lakes and reservoirs used in the project, often prevents the migration of downstream fish to upstream habitats and may alter the ecologic conditions of aquatic life. Reference (Devins, 1988) states that many hydroelectric facilities have been built in arid regions. Concern therefore arises that creating large water surfaces in these areas could, over the long term, climatologically change the area.

5.5 GEOTHERMAL ENERGY

The word geothermal is a composition of two Greek words, geo meaning “earth” and thermo, meaning “heat”. Combined geothermal literally means “heat generated from the earth”. The estimated temperature of the earths’ core is about 5000 °C; heat which conducts outward from the centre and heats up the outer layers of rock, referred to as the mantel. Rain water seepage through geologic cracks and faults becomes superheated and emerges as geysers and hot springs.

Geothermal resources include the following:

- Geo-pressurized reservoirs – These consists of underground water that is extremely pressurised and saturated with natural gas, resulting from the weight of the overlying land mass;
• Geothermal gradients – These are drilled shafts that allow access to dry, hot rocks for heat-energy extraction; and
• Molten magma – This is produced as a result of volcanic activity and has a temperature of about 2000 ºC, which is not suitable for heat extraction.

5.6 BIO-FUEL AND BIO-GAS

5.6.1 Biomass
Biomass is the stored energy in plant and animal tissues that can be used as fuel. The chemical composition of biomass depends on the various types of tissues found among plants and animal species, formed when carbon dioxide from the atmosphere and water from the earth are combined in the photosynthetic process to produce carbohydrates or sugars, which are the building blocks of biomass. Solar energy, which promotes photosynthesis in plants through chlorophyll, leads to the sun’s energy being stored in the chemical bonds of the structural components of biomass.

5.6.2 Landfill Gas
Biological degradation of organic waste as well as some industrial processes commonly generate very large volumes of methane gas as a by-product. Landfill gases (LFG), consisting of about 50 percent (%) methane (CH\textsubscript{4}), the primary component of natural gas, about 50 percent (%) carbon dioxide (CO\textsubscript{2}) and a small amount of non-methane organic compounds are created when organic waste decomposes in waste landfills. These LFG’s can be captured, converted and used as an energy source instead of releasing the gasses into the atmosphere and contributing to air pollution.

5.6.3 Biodiesel
Biodiesel is now considered one of the most promising alternatives to petroleum based diesel fuel. Biodiesels chemical composition consists of a combination of long chains of fatty acids known as mono-alkyl esters. The process of producing biodiesel is known as trans-esterification and involves the removal of esters and fatty acids from the base oil producing biodiesel which has a flash point of 150 ºC and is not as readily ignited as petroleum diesel, which has a flash point of 64 ºC.

One advantage of biodiesel is that it gels or solidifies at much lower temperatures than petroleum diesel. This “gelling” characteristic depends on the property of the base feedstock of which the diesel is made and therefore biodiesel, unlike petroleum diesel, is completely biodegradable and non-toxic, resulting in lower toxic gas emissions when burned.
5.6.4 Environmental Effects

The environmental benefits of biodiesel include the reduction of carbon monoxide (CO) emissions by approximately 50 percent (%) and carbon dioxide (CO$_2$) emissions by about 79 percent (%) on a net life cycle basis since the carbon in biodiesel emissions is produced by vegetation and it is reabsorbed by plants. Since biodiesel extracted from animal and vegetable fats does not include sulphur, it eliminates sulphur emissions present in the burning of conventional diesel fuels. (Kreider, 2011)

5.7 SECTION CONCLUSION

Wind Energy

Wind turbines produce power from the sun-generated differentials of heat causing the flow of air. Locations of wind farms must have appropriate atmospheric wind current conditions to ensure a high probability of power production. Owing to the considerably consistent and stronger winds, the cost of energy production by wind farms in offshore locations generally becomes much lower even though the construction of these wind farms in general costs considerably more.

Ocean Energy

Tidal power is considered a renewable resource because the tidal phenomenon is caused by the orbital mechanics of the solar system, which can be viewed as inexhaustible for the foreseeable future.

Hydroelectric Turbine Power

The main advantage of hydroelectric power is that it is renewable and generates no atmospheric pollution during operation. Secondly, it has relatively low operational and maintenance costs. High initial capital costs as well as potential site-specific negative environmental and ecologic impacts are disadvantages associated with hydroelectric power generation.
CHAPTER 6. CONCLUSION

6.1 GENERAL

Green Design Aim

Green Designs’ primary aim is to provide the human population with as much comfort as possible through more effective utilization of resources, decreased energy consumption, better indoor air quality and decreased water usage, without negatively impacting on the environment. Green Design performs optimally when natural resources are firstly employed and only supplemented through technological interventions.

A scenario has been created where current rising fossil fuel and energy costs have stimulated the search for better and more affordable methods of providing in human energy consumption and therefore assists in making Green Design more viable and attractive.

Green Design Benefits

Green Building benefits are measured in financial terms as well as other social measurements such as lower work force absenteeism, which equates to more productivity, decreased carbon footprints etc. Social benefits such as these can only be obtained through the correct application of the Green Design process.

Financially, a Green Building is a logical solution, as it will not only be more cost effective to operate during the life of the building, it will also have a better market value and lower maintenance costs associated with it. Energy savings achieved through integrated design will repay initial capital expenditure.

Green Design Process

The Green Building Design Process starts with an articulation of goals and objectives. The design team receives these goals and set about investigating alternatives methods of reaching these goals. Owners need to define their Triple Bottom Line requirements in terms of Planet, Profit and People enabling the design team to identify and evaluate synergies amongst the different Triple Bottom Line elements.

If the design process is followed and implemented correctly, energy efficiency will be achieved which ultimately determines the success of a project.
Economics

In respect of how cost shifting can be obtained through energy efficient technologies, it is concluded that Green Buildings offer a wide variety of economic benefits. A good understanding of the relationship between capital and running costs is necessary to mitigate as much as possible risk.

Green Building Classifications

A buildings performance can be rated through different classification and rating systems such as LEED™, ENERGY STAR® and BREEAM. Although some of these rating systems are only concerned with the energy consumption of a building, others take into account a myriad of other considerations. Alternative rating systems include systems such as Green Globes and the Japanese CASBEE system.

Green Building Optimization

A building as considered without any mechanical systems, can be optimized through several primary measures. Site selection, the deployment of natural resources as well as services locations relevant to the site will have major influences on the buildings overall carbon footprint while building placement, configuration, shape and shell along with the life cycle costs of building materials and technological advanced windows such as “superwindows”, all play a significant role in a buildings’ energy consumption.

Energy Consumption

It is important to have readily available information pertaining to, among others, the billing history, climatic conditions and units of production when aiming to determine a buildings actual energy consumption rate. This data can be represented in overlaid graphs to produce an accurate representation of energy consumption, which in turn can be used to identify and manage possible problem areas.

6.2 FINAL CONCLUSION

Green Buildings should be energy efficient, water wise and filled with daylight and healthy air. All of these elements combine in creating environments where building users are healthier and more satisfied, driving productivity gains and operational efficiency while lowering absenteeism.
Most existing Green Buildings are connected to an energy supplier, such as Eskom, and receive electricity indirectly from coal-, nuclear-, natural gas- or hydroelectric-power stations. Ideally, a Green Building would get daylight, heat and electricity from the sun or other renewable energy sources. Continuous improvements made in the reduction of costs and increased reliability in photovoltaic’s (PVs), wind power, micro-hydro and other renewable energy technologies, will in the near future enable Green buildings to function even more cost effective and without an energy supplier such as Eskom.

Technological advances and social responsibilities are converging to make renewable energy more cost effective and more attractive than ever. Appliances, lights and other office equipment are becoming more and more energy efficient, decreasing a buildings energy needs and environmental impact.

6.3 FURTHER RESEARCH WORK

6.3.1 SANS 204: Energy Efficiency in Buildings

The SANS 204 code consists of three parts published and the fourth in development. The code is not yet mandatory, but the Department of Minerals and Energy along with the Department of Trade and Industry hope to hold it as a mandatory standard, as soon as possible, for all new buildings in South Africa.

SANS 204-1:

Gives the general requirements for energy efficiency and will eventually form part of the National Building Regulations.

SANS 204-2:

Deals with naturally ventilated buildings and will become part of the SANS 10400 National Building Code along with SANS 204-3.

SANS 204-3:

Covers artificially ventilated buildings, including buildings with a central HVAC system (humidity, ventilation and air conditioning), but excluding buildings with free standing heating and cooling systems.
6.3.2 SAICE Magazine March 2009 Volume 17 No2

“If thermal ceiling insulation and high-performance window systems were introduced today into all new residential and commercial buildings, an estimated 3 500 MW in electricity could be saved by 2020. “ – SAICE magazine

6.3.3 Online Articles and Websites

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<td>U.S. Environmental Protection Agency</td>
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Table 6: Further Reading
BIBLIOGRAPHY


SANS, 5. (2011) 'Measurement and Verification of Energy Savings'.
ANNEXURES
The building under consideration is located at 2 Lake Road Longmeadow Business Park, Johannesburg. It is a modern Green Building, which has energy efficient fixtures as well as economical water fixtures.

**Air Conditioning**

The building is fitted with a central HVAC system, as well as Split Air conditioning Units. Performance Infra Red sensors (PIR) are used to monitor and activate the air conditioning system in specific areas. The central HVAC system consists of four Chillers (all fitted with heat recovery units), two which are used for cooling and two for dual function of cooling and heating. The HVAC system operation is further strengthened by heat recovery off chillers as well as a heat exchange hot water plant and solar panels. There are a total of 68 solar panels, for heating water to up to 70 ºC, installed on the building.
The 21 air-handling units are all run by ABB products, which are powered by ABB F1 high efficiency motors and have variable speed controls. All chillers and air-handling units are on timers and “sleep” at low peak periods. The system as a whole is controlled by a program called Building Energy Management System (BEMS).

Picture 2: Rooftop AC Setup

Picture 3: Indoor AC Controller
Superwindows

Although the building is not fitted with superwindows, all windows are UV tinted. This ensures that there are no glare issues, or damaging UV rays on furniture as well as a reduced heating load in the building. All windows have outside sun shading reducing suns glare into building.
Lighting

The building is orientated so that daylight can be utilised as much as possible. Most of the electrical lighting is activated by motion sensors and programmed to automatically switch off if the area is stagnant. All desk lamps are fitted with motion sensors, can be dimmed or turned off and are area focused. Overhead lighting is only provided in centre corridors, while all lighting has energy efficient lamps. The buildings perimeter lights all have timers installed.

Picture 6 : Desk Lamp

Picture 7 : Workstation Setup
Photocopiers
All photocopiers are user linked through employee cards and can be billed to separate business units within the building.

Rainwater
Rainwater runoff is collected in two attenuation ponds. These ponds in turn provide water to the gardens consisting of indigenous plants only.
Picture 9: Eastern Attenuation Pond Top View

Picture 10: Eastern Attenuation Pond Side View
Picture 11: Western Attenuation Pond Top View

Picture 12: Western Attenuation Pond
**Kitchens**

The kitchens are fitted with an array of modern technology such as Zip taps that provide instant hot or chilled water and energy efficient dishwashers that use two minute cycles.

The main kitchen utilizes both electricity and gas due to the increasing frequency of power outages. It is also equipped with grease hoods that have UV lights build in, therefore making them self cleaning and precautionary to fire hazards.

**Bathrooms**

The male bathrooms are fitted with urinals that have infrared sensors and flush individually while all toilets have two settings for flushing. The handtowels used in the bathrooms are made from recycled material and the lockers provided are made from recycled plastics such as food containers. These lockers can in turn be recycled and made into plastic pallets or truck binders.
Picture 14: Soap Dispenser and Automatic Tap

Picture 15: Bathroom Motion Sensor
Factory Setup

The whole factory is a positive pressure factory, generated by two fans at opposite ends of the factory. The positive pressure is used to reduce dust ingress and is maintained by features such as High Speed Shutter Doors, which eliminates the standing time of forklifts and uses less power to open and close. T5 energy efficient lights are used and all light switches, breakers, DB boards and plug points are ABB products.
ANNEXURE A: A CASE STUDY OF ABB SOUTH AFRICA, GREEN BUILDING

**Picture 18:** Positive Pressure Factory

**Picture 19:** High Speed Shutter Doors
Waste Recycling

Recycling of waste products is mainly done on site, and is assisted by Enviroserve.

Power Generation

The ABB campus can supply its own electricity in case of emergencies, by means of Diesel powered generators.
Graywater
All non-potable water used by basins and showers, among others, is collected, treated and transferred to the attenuation ponds.
Future Expansion

ABB plans to implement a worm farm for kitchen wastes. The wet waste produced by the worm farm can then be converted and dumped into reticulation pond while the solid waste will be used as fertilizer in the garden.
Electrical Consumption: Distribution

The main power feeder is metered, while the HV feeder has been harmonically filtered and the LV Incomer has Power Factor corrections as well as being filtered. The UPS is fitted with harmonic filters. The separate factory Business Units are individually metered and checked for energy consumption. All equipment is ABB energy efficient products and generator backed up. The company has decided to follow a phased approach to lap top usage, eliminating UPS to desks requirements.

Picture 26: High Voltage Distribution Board and Filters

Picture 27: Low Voltage Distribution Board
**Hot and Cold Water**

Solar Panels provide the primary heating for hot water while the chiller heat recovery systems provide secondary heating. Electrical elements are provided as a last resort of heating.

The cold water supply is supplemented with a 50 000 litre bulk tank in parallel with the council’s main supply.

![Hot/Cold Water Setup](image1)

*Picture 28: Hot/Cold Water Setup*

![Hot/Cold Water Control Panel](image2)

*Picture 29: Hot/Cold Water Control Panel*
Picture 30: Flow Monitoring

Picture 31: Supply Tank
ANNEXURE A: A CASE STUDY OF ABB SOUTH AFRICA, GREEN BUILDING

Picture 32: Hot Water Reservoirs

Picture 33: Plate Heat Exchanger Front View
Disclaimer

Unfortunately the author was unable to secure actual data of savings and impacts accomplished through the implementation of energy saving measures.
ANNEXURE B: GREEN BUILDING BENEFITS

Some Green Building benefits include:

1.) Increased value to the business from higher net operating income (NOI) and increased public relations from “Green” public perceptions surrounding commercial buildings;

2.) Productivity improvements for long term building owners or occupying companies, typically between 3 to 5 percent;

3.) Improved risk management, less risk of employee exposure to irritating or toxic chemicals in building materials, furniture and furnishings;

4.) Typically a 5 percent (%), or higher, reduction in employee absenteeism due to health benefits.

5.) Recruitment and retention of key employees due to higher morale, etc.;

6.) Public relations benefits, especially for developers and occupying companies;

7.) Increased marketing benefits, especially for developers, large corporations and consumer products companies;

8.) Demonstration of commitment to sustainability and environmental stewardship normally holds water with stakeholders and therefore could relate to an increased share price;

9.) In some countries, a tax benefit might apply for specific Green Building investments such as energy conservation and solar power as well as local incentives, depending on location;

10.) Typical cost savings of 30 to 50 percent (%) for electricity and water, along with a reduced “carbon footprint” from energy savings; and

11.) Maintenance cost reductions from commissioning, operator training, performance monitoring and other measures to improve and ensure proper systems integration.
ANNEXURE C: CONCEPTUAL DESIGN QUESTIONS

At the conceptual design stage, it is a good idea to have design team members sit down and discuss questions such as:

1.) Should the building be conspicuously “Green”, with environmental strategies on display or should these operate quietly behind the scenes?

2.) If yes, can the building be educational to others by making the Green features more obvious, such as the use of photovoltaic solar panels, a Green roof, or by opening up the internal workings of the building to show systems such as an “enthalpy wheel” for energy recovery in operation?

3.) Are there marketing benefits of such obvious Green features to the client organization?

4.) Is the building design to be influenced and facilitated by a LEED™-oriented design charter or any other form of publication?

5.) If renovating a new building, how much of the existing shell can be maintained?
ANNEXURE D: INDOOR CLIMATE QUESTIONS

Some major benefits of Green Buildings derive from gains in productivity and health of the occupants. It is vital to consider the following issues early in the design effort.

1.) If the building must have a large floor plan, can an atrium be designed that will enhance daylight penetration and natural ventilation into all occupied areas of the structure?

2.) Will the massing and orientation of the building support passive solar design and/or natural ventilation and day lighting strategies?

3.) Do seasonal winds differ in direction? If so what are the frequency, magnitude and duration as well as impacts that these might have on the building?

4.) How will localized wind directions and air pressures affect the natural ventilation design?

5.) Can internal passages be used as air circulation routes for natural ventilation?

6.) Should the building be “sealed” for climate control, or can operable windows enhance natural ventilation such as “stack effect” ventilators?

7.) Are operable windows compatible with other program needs?

8.) Have under floor air distribution systems been considered for this project, both in terms of cost and technical feasibility?
ANNEXURE E: SITE RELATED QUESTIONS

To better understand the choice of materials, building location on the site and similar issues, it is imperative that the design team answer site related questions such as:

1.) Are there, natural or artificial materials available on site that can be used or reused in the current project?
2.) Can the impact on wildlife habitat on or near the building site be reduced? If so, how?
3.) If unlimited space is available, can earthworks and clearing of vegetation be limited to 10 meters beyond the development perimeter?
4.) Does the design follow the natural “flow” of the site or does it overly alter the site, such as excavations, berms and any other construction features?
5.) If alterations to the site are necessary, can the indigenous vegetation and trees be stored and replanted?
6.) Does the development incorporate and maximize the site’s unique features such as topography, woods, pastures or proximity to water bodies?
7.) Does the development create ecologically useful outdoor spaces and incorporate habitat preservation, for example by having slatted bridges over streams so that sunlight can penetrate below?
8.) How can the design be made unique to the place and/or region, for example, through the use of regional or onsite building materials or design references to local or natural features?
9.) Are there landscape elements such as trees or water-courses that can be extended into the building, to connect indoors to outdoors and thereby enhance the natural feeling of the building?
ANNEXURE F: WATER MANAGEMENT QUESTIONS

Water is emerging as a crucial design concern in many high performance projects, therefore an integrated design team will have to look at water in a much more holistic way, considering the entire “water balance” of the site and surroundings.

The energy used in the supply and treatment of this defining resource for civilization, accounts for more than 10 percent (%) of building energy. Therefore, questions about water such as the following are important to integrated building design:

1.) How can storm water on the site be managed in such a way as to reduce the impact of added impervious areas on storm water sewers and water ways?

2.) Can a storm water management plan be implemented that results in no net increase in the rate or quantity of storm water runoff from existing, Greenfield site, to developed conditions?

3.) Will it be possible to reduce storm water runoff from the site, by adjusting the type of roof, paving and landscaping measures chosen?

4.) Have the slopes and types of soils present on site, been investigated to determine the best management of storm water?

5.) Have investigations been done on in-situ or imported soils to determine the percolation rates and the potential for groundwater to recharge from natural rainfall?

6.) Have the civil engineer and the local public works and planning officials been consulted about anything unique in the management of water resources on this site?

7.) Will the developer be allowed to recover rainwater and reuse it onsite? It should be noted that this practice is currently illegal in the United States of America, more specifically in the states of Washington and Colorado.

8.) Can the storm water management plan help to restore waterways running through, under or adjacent to the site?

9.) Does the water management plan consider how to reduce, reuse or recharge rainwater falling on the building?

10.) Does the construction budget allow for dual plumbing systems, so rain water can be reused in the building?

11.) Will the local municipality allow graywater or rainwater to be reused for landscape irrigation and/or building water uses such as toilet flushing, cooling tower makeup water, parking lot washing and so on?

12.) Will the available roof catchment area be able to supply enough water for the maintenance of gardens and urinals in the building?

13.) Is the rainfall seasonal or more evenly distributed throughout the year?
14.) Is there adequate space within the building or on the site for underground or even surface storage of harvested rainwater?

15.) Does the design take into account explicit water conservation goals for the project?

16.) Are there locally more stringent requirements for water conservation, owing to local climate or current drought conditions?

17.) Are the water consumption and conservation practices of the building going to be measured and evaluated against an established baseline?

18.) Can the use of potable water to flush toilets and urinals be reduced through the use of low-flow fixtures, dual flush toilets, water free urinals and other means?

19.) Has the design team considered the use of indigenous or adapted vegetation for the site landscaping?

20.) Has the landscape architect been instructed to reduce water use for the irrigation of this site?

21.) If this is a high rise building, can the fire sprinkler onsite storage tank also be used for rainwater storage, in this way combining uses and saving money?

It is clear that there is a whole array of infinite questions that should be asked when considering a water management plan. However it must be stressed that each project is unique and the requirements will differ from site to site.
ANNEXURE G: ENERGY RELATED QUESTIONS

The following is a series of questions that can be used to evaluate energy consumption:

1. Can vegetation be placed on different sides of the building to reduce cooling loads, due to hot afternoon sun in summer?
2. Will the new development through the building height or mass or even through landscape plantings affect solar climates or neighbouring properties access to light and air?
3. How should the building be orientated and how will this impact the buildings ability to utilize day lighting and passive solar design strategies?
4. Has potential future vegetation growth around the building, been examined to determine if it might affect the design for day lighting, passive solar heating and cooling requirements?
5. Is existing vegetation deciduous or evergreen, and can our design take advantage of those characteristics through passive solar features?
6. What natural elements such as winds, sunlight and topography should affect the building form, and to what degree?
7. Have higher ceilings, narrower floor plates and larger windows been considered to support day lighting designs?
8. How much central operational control is needed over the buildings environment?
9. What are the buildings planned occupancy schedule and usage patterns?
10. What will be the major energy supply to this building? Is it possible to specify and utilize energy systems that have better future potential cost control, such as geothermal heat pumps?
11. How much cooling will be required?
12. Is it possible to condition the interior space without mechanical cooling?
13. Is there a nearby source of cool water, such as a lake or ocean that can be used for cooling the building in summer and heating it in the winter?
14. Can the choice of structural and glazing systems influence the degree of infiltration from the outside and exfiltration of conditioned air from the inside?
15. Have consideration been given to energy questions such as embodied energy?
16. Have energy saving goals versus relevant standards been set?
17. Will specifying variable frequency or variable speed drives (VFD or VSD) for all fans and variable air volumes (VAV) controls for all mechanical air distribution decrease energy consumption?
ANNEXURE H: ENERGY SAVING TIPS

Energy saving tips:

1.) All possible systems should be shutdown during unoccupied hours of the day ;
2.) Return air should be utilized as much as possible ;
3.) Automatic temperature control should be utilized and set to minimum comfortable temperatures ;
4.) Pre-heater operation and control should be monitored ;
5.) Room air conditioners rather than central HVAC systems should be employed ;
6.) Energy efficient tests should be conducted regularly on chillers ;
7.) Steam energy waste prevention must be implemented as far as possible ;
8.) Piping insulation should be checked regularly ;
9.) Demand control should be done by centralized monitoring and computer systems ;
10.) Lighting must be regulated by motion sensors as far as possible ;
11.) Window and door leakages should be sealed ; and
12.) Window modification can be done by replacing single insulation windows with double insulation or applying glazing to windows.

Maintenance tips:

To ensure proper fan operation and so reduce energy consumption, the following should be taken into account:

1.) Fans should regularly be checked for excessive noise and vibration. Causes determined and rectified as necessary ;
2.) Fan blades should be kept clean ;
3.) Inspect and lubricate bearings regularly ;
4.) Inspect belt drives and tension of belts periodically ; and
5.) Inspect inlet and discharge screens on fans and keep these clear of debris.

Pumps:

1.) Pumps should be checked for packing wear that could cause excessive leakage or shaft erosion ; and
2.) Bearings and drive belts should regularly be inspected for wear and binding, and then adjusted, repaired or be replaced as necessary.