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COMPARATIVE STUDY OF CONVENTIONAL AND GREEN RESIDENTIAL BUILDING

Project Report 2017

Submitted by,

AMJAD NASSER

ASMIN ASHRAF

DILNA K. SALIM

GAYATHRI P.

VISHNU N.

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Thrissur, Kerala, India- 680 551

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ABSTRACT

A green building uses less energy, water and natural resources, creates less waste and is healthier for the people living inside compared to a standard building. There is a rapidly expanding market for green building materials. Green building provide suitable environment by controlling solar radiation temperature, energy efficiency, water conservation using domestic treatment plant and indoor air quality. The main aim of green buildings is to reduce the environmental impact of new buildings. The sustainability in the environment can be well achieved by reducing the energy emission and consumption by the buildings. Sustainability means using the energy efficiently. Green Building refers to a structure that is environmentally responsible and resource-efficient throughout a building's life-cycle. The aim of this project is to conduct a comparative study on conventional and green residential building. Data regarding temperature details are represented in energy simulation software – Energy 2D. A study on various green building rating system is to be conducted. Rate of water consumption and electricity consumption, waste generated in the selected building were collected for grading the building using LEED certification. A model showing all elements of green building such as rainwater harvesting plant, biogas plant, grey water filter, cooling tunnel, etc. were made.

CHAPTER 1
INTRODUCTION

1.1 GENERAL

India is a fast growing country. Rapid industrialization, increasing population, infrastructure development and destruction of natural resources lead to construction of green building. Green building is a structure that is environmentally responsible and resource efficient throughout its life cycle. Green building is also known for its sustainability and high performance.

Thermal comfort studies on traditional residential buildings of Kerala that is known for its use of natural and passive methods for a comfortable indoor environment, are under progress. Passive methods of achieving thermal comfort inside the buildings are the best solution to provide a healthy and energy efficient indoor environment. This is of supreme importance for buildings in the tropics where mechanical systems with high energy consumption are used to condition the indoor environment for thermal comfort. The people are forced to depend on such systems because, majority of the buildings are designed without giving adequate importance to passive methods for controlling the indoor environment. In many cases, failure to provide the required thermal conditions has resulted in discomfort, ill health and productivity loss. Presently, there is a constant need to evaluate the thermal conditions of the indoor environments to learn further and proceed with the research in passive design.

Water is a critical and finite resource. It covers over 71% of the Earth's surface and is essential for life, playing a key role in the production of food, human health and sustaining the natural environment.

However, water, particularly of drinking water quality, is becoming increasingly scarce in most of the populated regions of the planet. The pressure is on to reduce water demand by reducing wastage, to reuse or recycle as much as possible, and to look at other means of minimising our impact on the water environment. Overall we must be more efficient with our water utilization.

Disposing of waste has huge environmental impacts and can cause serious problems. Some waste will eventually rot, but not all, and in the process it may smell or generate methane gas, which is explosive and contributes to the greenhouse effect. Waste that is not properly managed, especially excreta and other liquid and solid waste from households and the community, are a serious health hazard and lead to the spread of infectious diseases. Unattended waste lying around attracts flies, rats, and other creatures that in turn spread disease. Normally it is the wet waste that decomposes and releases a bad odour. This leads to unhygienic conditions and thereby to a rise in the health problems. Plastic waste is another cause for ill health. Thus excessive solid waste that is generated should be controlled by taking certain preventive measures.

Hence green building have high importance and relevance than ordinary residential building.

Some of the top green buildings in India are,

- Solar Air Conditioning: Turbo Energy Limited, Chennai

  The solar air conditioning in Turbo Energy systems in Chennai uses solar power to condition or control the air in the building by passive solar, solar thermal energy conversion and photovoltaic conversion in which sunlight is converted to electricity.
- Earth Air Tunnels and Passive Cooling: Aquamall water solutions, Dehradun and Police Bhavan, IGP office, Gulbarga

  Earth tunnel Air conditioning system also known as passive air conditioning installed in Aqualmall water solutions in Dehradun, is a wonderful utilization of nature. The system sucks in air from the outside and with the help of geothermal cooling the air is sent to interiors.

  The IGP office in Gulbarga uses Passive downdraught evaporative cooling (PDEC) system where air passes through a layer of water in the wind tower. This cools down the water and that water is sent to the interiors of the building which is similar to the Earth tunnel air conditioning system.
- Thermal Storage: TCS Techno-park and Grundfos Pumps, Chennai

  This is achieved with the thermal energy systems which collect energy and store it for later use, even months later. This also works inter-seasonally where during winters it uses the solar heat collected in the solar collectors and during summer it uses the cold air conditioning obtained from the winter air.
- High Performance Envelope: ITC Royal Gardenia, Bangalore

  ITC Gardenia in Bangalore has reduced heat gain to large extent by their design and have experienced serious energy savings.

1.2 SCOPE

The increased demand of living and working places due to population explosion, construction industry grows rapidly. It causes severe impact like different types of pollution, leads to global warming and ozone depletion. It adversely affects the human welfare as well as natural habitats.

The concept of sustainable development can be traced to the energy crisis and environmental pollution. The green building movement in the U.S originated from the need and desire for more energy efficient and environment friendly construction practices. Green building brings together a vast array of practices, techniques and skills to reduce and ultimately eliminates the impacts of buildings on the environment and human health. The green concept and techniques are aimed to achieve energy efficiency, effective waste management and consideration of natural resources and minimum use of fossil fuels. Construction methodology based on these concepts promotes to the health and well-being of the individual and the society at large. These buildings consume minimum energy, water and other resources during the entire life cycle.

1.3 OBJECTIVE

The project aims at the following,

- To select and study the energy consumption of an existing residential building.
- Assessment of the selected building using green building assessing tools.
- To adopt techniques to convert the selected building into green building.
- To prepare a 3D model structure showing the green concept to be adopted
- To compare the conventional and green residential building in terms of passive design, material, energy, water use and energy simulation.
- To conserve the natural resources, reducing the soil waste or zero discharge of waste, improved air and water quality, protection of ecosystem and biodiversity thus mitigating the adverse impact of the built environment on human health
- By employing waste management strategies these buildings aim to minimize the burden on municipal waste management facilities.

- Limiting all kinds of pollution during and after construction is also aimed at to ensure reduced impact on surrounding environment. These buildings ensure proper safety health and sanitation facilities for occupants.

Purpose of project is to convert the selected residential building into green which uses less water, optimizes energy efficiency, conserves natural resources, generates less waste, and provides healthier spaces for occupants.

1.4 METHODOLOGY

1. Site selection and investigation.
2. Conducting an audit on thermal variation, waste production and energy and water consumption in the selected building.
3. Designing of rain water harvesting plant.
4. Designing of biogas plant.
5. Designing and construction of greywater filter.
    - Study on characteristics of greywater.
    - Preparation of synthetic grey water.
    - Filtration
    - Conduct tests on the filtered water.
6. Passive designing
7. Application of green materials
8. Representation of the thermal variation of the selected building before and after conversion to green building using a simulation software – Energy 2D
9. Rating of the building using LEED Certification.
10. Comparison of conventional and green residential building and model preparation.

CHAPTER 2
LITERATURE REVIEW

- **Avinash Shivajirao Pawar**. **"**Green buildings". Journal of Engineering Research and Studies aimed to design green building in order to minimize the demand on non-renewable resources, maximize the reuse, recycle and optimize the use of onsite resources. Green building is define as the one which focuses on increasing the efficiency of resources and thereby reducing building impact on human health and environment. Paper outlines that the green building experiences in India have been exciting and challenging as well and serves to assist the country to conserve energy and natural resources by spurring increased recovery and recycling of building materials.
- **Sunita Bansal, S.K. Singh, Srijit Biswas.** "Green quotient evaluation of existing buildings." International Journal of Advanced Research (2013), Volume-3, Issue-5.A Case Study at Delhi regarding an organisation's methods to improve a building's performance. Issues were evaluated regarding:-

  Water audit to establish the areas of the building consuming large amounts of water and targeted for improvement.

  Waste audit to find out total amount of solid waste generated and how much of it being recycled and sent to incineration and landfill.

  Condition audit to determine the current condition and expected remaining economic life of building's components.

  Thermal audit encompasses thermal comfort, air quality, lighting levels and noise levels.

  These were audited to find how they currently perform & where improvements can be made.
- **Jignesh Kumar R. Chaudhari, Professor Keyur D. Tandel, Professor Vijay .K. Pate** "Energy saving of green building using solar photovoltaic systems". International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 5, May 2013. Paper outline the solutions for the energy efficient futuristic buildings. The implementation of latest technology in construction will lead to better building with green rating. Buildings are the greatest consumers of water,

energy and materials. The idea of green buildings promotes use of renewable energy, recyclable & recycled products. Green building has to save water 36-40%, save energy 30-40% and save material 25-40% compared to conventional building. Green building is which one high thermal insulations, rain water harvesting, terrace gardening, ventilation and energy efficient appliances.

2.1 CONVENTIONAL BUILDING

Conventional Building construction refers to the traditional method of construction where the construction knowledge is passed from one generation to the other Associated to the wet construction (in-situ) using reinforced concrete.

2.1.1 Energy

Efficient energy use, sometimes simply called energy efficiency, is the goal to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature .Installing fluorescent lights, LED lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production process or by application of commonly accepted methods to reduce energy losses.

There are many motivation to improve energy efficiency .Reducing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Reducing energy use is also seen as a solution to the problem of reducing greenhouse gas emissions. Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy. Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily increasing energy consumption. Thus a balanced approach to energy efficiency in buildings should be more comprehensive than simply trying to minimize energy consumed. Issues such as quality of indoor environment and efficiency of space use should be factored in. Thus the measures used to improve energy efficiency can take many different forms. Often they include passive measures that inherently reduce the need to use energy, such as better insulation. Many serve various functions improving the indoor conditions as well as reducing energy use, such as increased use of natural light.

Proper placement of windows and skylights as well as the use of architectural features that reflect light into a building can reduce the need for artificial lighting. Increased use of natural and task lighting has been shown by one study to increase productivity in schools and offices. Compact fluorescent lights use two-thirds less energy and may last 6 to 10 times longer than incandescent light bulbs. Newer fluorescent lights produce a natural light, and in most applications they are cost effective, despite their higher initial cost, with payback periods as low as a few months.

Building Information Modeling efforts, focused on green building design and operation. With the development of modern computer technology, a large number of building energy simulation tools are available on the market. When choosing which simulation tool to use in a project, the user must consider the tool's accuracy and reliability, considering the building information they have at hand, which will serve as input for the tool. It is an artificial intelligence approach towards assessing building performance simulation results and found that more detailed simulation tools have the best simulation performance in terms of heating and cooling electricity consumption within 3% of mean absolute error.

- **Importance of Energy Conservation**

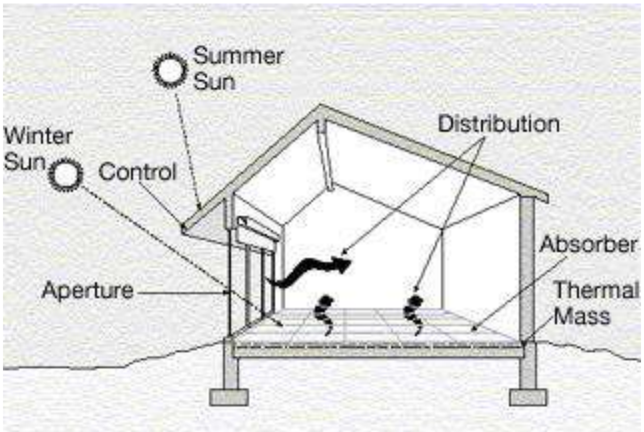

Fig 1: Passive Design

Energy conservation refers to reducing energy consumption through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service. Energy conservation and efficiency are both energy reduction techniques. Energy conservation is a part of the concept of sufficiency. Even though energy conservation reduces energy services, it can result increased environmental quality, national security, personal financial security and higher savings. It also lowers energy costs by preventing future resource depletion.

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2.1.2 Temperature

Temperature is a measure of how hot or cold something is; specifically, a measure of the average kinetic energy of the particles in an object, which is a type of energy associated with motion. The terms hot and cold are not very scientific terms

Temperature is different from heat, though the two concepts are linked. Temperature is a measure of the internal energy of the system, while heat is a measure of how energy is transferred from one system (or body) to another.

- **Energy Simulation**

Building energy simulation, also called building energy modeling, is the use of software to predict the energy use of a building. A typical energy model will have inputs for climate; envelope; internal gains from lighting, equipment, and occupants; heating, cooling, and ventilation systems; schedules of occupants, equipment, and lighting. Energy models will output building energy use predictions in typical end-use categories: heating, cooling, lighting, fan, plug, process. In addition to energy units, most software includes utility rates input, and can predict energy costs.

- **Applications**
  - ➢ Building design: Many modern commercial or residential building codes require minimum energy performance. Energy modeling can be used to demonstrate compliance, or predict energy consumption of proposed developments.
  - ➢ Life-cycle cost analysis: Comparing different building design alternatives to determine which is the least cost, including capital costs and (at a minimum) energy costs.
  - ➢ Energy retrofit analysis: In conjunction with an energy audit, or deep energy retrofit an energy model can be used to predict savings associated to proposed energy cost measures (often called ECMs).

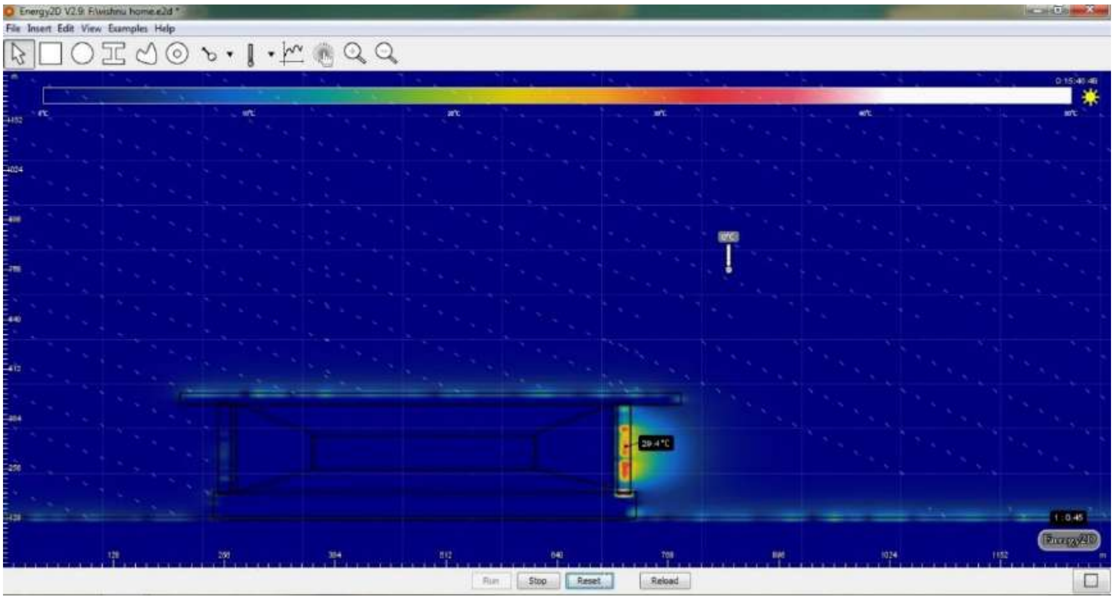

Fig 2: Energy 2D Simulation software

- **Building Materials**
  - Limestone, Steel, Aluminum, Bricks and Tile, Wood etc…

2.1.3 Use of Natural Materials

Natural materials are generally lower in embodied energy and toxicity than man-made materials. They require less processing and are less damaging to the environment. Many, like wood, are theoretically renewable. When natural materials are incorporated into building products, the products become more sustainable.

2.1.4 Reduction of Construction Waste

Minimal construction waste during installation reduces the need for landfill space and also provides cost savings. Concrete, for example, has traditionally been pre-mixed with water and delivered to the site. An excess of material is often ordered, to prevent pouring delays should a new shipment be needed. This excess is usually disposed of in a landfill or on-site. In contrast, concrete mixed on-site, as needed, eliminates waste, and offers better quality control. Designing floor intervals to coincide with the standard lengths of lumber or steel framing members also reduces waste. Taking advantage of the standard sizes of building materials in the design phase reduces waste produced by trimming materials to fit, as well as the labor cost for installation.

2.1.5 Local Materials

Using locally produced building materials shortens transport distances, thus reducing air pollution produced by vehicles. Often, local materials are better suited to climatic conditions, and these purchases support area economies. It is not always possible to use locally available materials, but if materials must be imported they should be used selectively and in as small a volume as possible. For instance, the decorative use of marble quarried halfway around the world is not a sustainable choice. Steel, when required for structural strength and durability, is a justifiable use of a material that is generally manufactured some distance from the building site.

2.1.6 Water

Water is a transparent and nearly colorless chemical substance that is the main constituent of Earth's streams, lakes, and oceans, and the fluids of most living organisms. Its chemical formula is H_2O**.**

Water on the earth moves continually through the water cycle of evaporation and transpiration (evapotranspiration), condensation, precipitation, and runoff, usually reaching the sea. Evaporation and transpiration contribute to the precipitation over land. Safe drinking water is essential to humans and other life forms even though it provides no calories.

Grey water is gently used water from our bathroom sinks, showers, taps and washing machines. It may contain traces of dirt, food, grease, hair, and certain household cleaning products. While grey water may look “dirty”, it is a safe and even beneficial source of irrigation water in a yard. If grey water is released into rivers, lakes or estuaries, its nutrients become pollutants, but to plants, they are valuable fertilizer. Reusing grey water for irrigation reconnects urban residents and our backyard gardens to the natural water cycle.

2.1.7 Waste

Waste, or rubbish, trash, junk, garbage, depending on the type of material or the regional terminology, is an unwanted or undesired material or substance. It may consist of the unwanted materials left over from a manufacturing process (industrial, commercial, mining or agricultural operations,) or from community and household activities. The material may be discarded or accumulated, stored, or treated (physically, chemically, or biologically), prior to being discarded or recycled. It is also used to describe something we use inefficiently or inappropriately.

- **The Problem of Waste**

Waste can be regarded as a human concept as there appears to be no such thing as waste in nature. The waste products created by a natural process or organism quickly become the raw products used by other processes and organisms. Recycling is predominant, therefore production and decomposition are well balanced and nutrient cycles continuously support the next cycles of production. This is the so-called circle of life and is a strategy clearly related to ensuring stability and sustainability in natural systems. On the other hand there are man-made systems which emphasize the economic value of materials and energy, and where production and consumption are the dominant economic activities. Such systems tend to be highly destructive of the environment as they require massive consumption of natural capital and energy, return the end product (waste) to the environment in a form that damages the environment and require more natural capital be consumed in order to feed the system (where resources and space are finite) this is ultimately not suitable. The presence of waste is an indication of overconsumption and that materials and are not being used efficiently. This is carelessly reducing the Earths capacity to supply new raw materials in the future. The capacity of the natural environment to absorb and process these materials is also under stress. Valuable resources in the form of matter and energy are lost during waste disposal, requiring that a greater burden be placed on ecosystems to provide these. The main problem is the sheer volume of waste being produced and how we deal with it.

- **Waste Management**

Waste management is the precise name for the collection, transportation, disposal or recycling and monitoring of waste. This term is assigned to the material, waste material that is produced through human being activity. This material is managed to avoid its adverse effect over human health and environment. Waste management is something that each and every household and business owner in the world needs. Waste management disposes of the products and substances that you have use in a safe and efficient manner.

“Waste management is the generation, prevention, characterization, monitoring, treatment, handling, reuse and residual disposition of solid wastes”. There are various
types of solid waste including municipal (residential, institutional, commercial), agricultural, and special (health care, household hazardous wastes, sewage sludge).”

To be sustainable we need to move the emphasis toward a system that is local, community based, makes use of low tech/low energy systems and is focused on waste minimisation. Other methods of managing waste include:

- Waste minimization is an approach that aims to reduce the production of waste through education and the adoption of improved production processes and less wasteful practices.
- Recycling by separating certain materials within the waste stream and reprocessing them. The recycling of many materials is currently not financially viable.
- Waste processing is treatment and recovery (use) of materials or energy from waste through thermal, chemical, or biological means.

We believe that the ultimate goal of waste management efforts should be waste minimization, however, waste processing and waste recycling play an important role in improving production processes and in dealing with 'waste' in a manner that is more environmentally and economically beneficial. Flows of materials and energy from producers and consumers to processers / recyclers must be encouraged as happens in natural ecosystems, and the elements of the system should be located in close proximity to one another.

This approach has actually been implemented on a very large scale.
As individuals we can start practically at a household level through recycling, energy efficiency and environmentally beneficial technologies such as vermicomposting, grey water systems, biogas generation, solar power and heating systems and so forth.

Organic waste is easily processed at domestic and medium to industrial scale by means of vermicomposting and composting. Vermicomposting, vermitea and compost greatly improve the fertility and health of our soil, and will become increasingly important resources to ensure our food security, as we reduce our dependence on inorganic fertilisers produced from fossil fuels.

2.2 GREEN BUILDING

Green building refers to both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. In other words, green building design involves finding the balance between homebuilding and the sustainable environment. This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages. The Green Building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

Leadership in Energy and Environmental Design (LEED) is a set of rating systems for the design, construction, operation, and maintenance of green buildings which was Developed by the U.S. Green Building Council. Other certificates system that confirms the sustainability of buildings is the British BREEAM (Building Research Establishment Environmental Assessment Method) for buildings and large scale developments. Currently, World Green Building Council is conducting research on the effects of green buildings on the health and productivity of their users and is working with World Bank to promote Green Buildings in Emerging Markets through EDGE Excellence in Design for Greater Efficiencies Market Transformation Program and certification.

Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective of green buildings is to reduce the overall impact of the built environment on human health and the natural environment by:

Efficiently using energy, water, and other resources

- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation

2.2.1 Reducing Environmental Impact

Globally buildings are responsible for a huge share of energy, electricity, and water and materials consumption. Buildings account for 18% of global emissions today or the equivalent of 9 billion tonnes of CO^2 annually. If new technologies in construction are not adopted during this time of rapid growth, emissions could double by 2050, according to the United Nations Environment Program. Green building practices aim to reduce the environmental impact of building. Since construction almost always degrades a building site, not building at all is preferable to green building, in terms of reducing environmental impact. The second rule is that every building should be as small as possible. The third rule is not to contribute to sprawl, even if the most energy-efficient, environmentally sound methods are used in design and construction.

2.2.2 Goals of Green Building

The concept of sustainable development can be traced to the energy (especially fossil oil) crisis and environmental pollution concerns of the 1960s and 1970s. The green building movement in the U.S. originated from the need and desire for more energy efficient and environmentally friendly construction practices. There are a number of motives for building green, including environmental, economic, and social benefits.

Green building brings together a vast array of practices, techniques, and skills to reduce and ultimately eliminate the impacts of buildings on the environment and human health. It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic equipment, and using plants and trees through green roofs, rain gardens, and reduction of rainwater run-off. Many other techniques are used, such as using low-impact building materials or using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water.

While the practices or technologies employed in green building are constantly evolving and may differ from region to region, fundamental principles persist from which the method is derived: siting and structure design efficiency, energy efficiency, water efficiency, materials efficiency, indoor environmental quality enhancement, operations and maintenance optimization and waste and toxics reduction.

On the aesthetic side of green architecture or sustainable design is the philosophy of designing a building that is in harmony with the natural features and resources surrounding the site.

2.2.3 Life Cycle Assessment

A life cycle assessment (LCA) can help avoid a narrow outlook on environmental, social and economic concerns by assessing a full range of impacts associated with all cradle-to-grave stages of a process: from extraction of raw materials through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. Impacts taken into account include (among others) embodied energy, global warming potential, resource use, air pollution, water pollution, and waste.

Although LCA is widely recognized as the best way to evaluate the environmental impacts of buildings (ISO 14040 provides a recognized LCA methodology), it is not yet a consistent requirement of green building rating systems and codes, despite the fact that embodied energy and other life cycle impacts are critical to the design of environmentally responsible buildings.

2.2.4 Energy Efficiency

Green buildings often include measures to reduce energy consumption – both the embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment.

To reduce operating energy use, designers use details that reduce air leakage through the building envelope (the barrier between conditioned and unconditioned space). They also specify high-performance windows and extra insulation in walls, ceilings, and floors. Another strategy, passive solar building design, is often implemented in low-energy homes. Designers orient windows and walls and place awnings, porches, and trees to shade windows and roofs during the summer while maximizing solar gain in the winter. In addition, effective window placement (day lighting) can provide more natural light and lessen the need for electric lighting during the day. Solar water heating further reduces energy costs.

Onsite generation of renewable energy through solar power, wind power, hydro power, or biomass can significantly reduce the environmental impact of the building. Power generation is generally the most expensive feature to add to a building.

2.2.5 Water Efficiency

Reducing water consumption and protecting water quality are key objectives in sustainable building. One critical issue of water consumption is that in many areas, the demands on the supplying aquifer exceed its ability to replenish itself. To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified, and reused on-site. The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing or by using water for washing of the cars. Waste-water may be minimized by utilizing water conserving fixtures such as ultra-low flush toilets and low-flow shower heads. Bidets help eliminate the use of toilet paper, reducing sewer traffic and increasing possibilities of re-using water on-site. Point of use water treatment and heating improves both water quality and energy efficiency while reducing the amount of water in circulation.

2.2.6 Materials Efficiency

Building materials typically considered to be 'green' include lumber from forests that have been certified to a third-party forest standard, rapidly renewable plant materials like bamboo and straw, recycled stone, recycled metal, and other products that are nontoxic, reusable, renewable, and/or recyclable. For concrete a high performance or Roman self-healing concrete is available. The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects.

2.2.7 Waste Reduction

Green architecture also seeks to reduce waste of energy, water and materials used during construction. Well-designed buildings also help reduce the amount of waste generated by the occupants as well, by providing on-site solutions such as compost bins to reduce matter going to landfills.

Deconstruction is a method of harvesting what is commonly considered "waste" and reclaiming it into useful building material. Extending the useful life of a structure also reduces waste – building materials such as wood that are light and easy to work with make renovations easier.

To reduce the impact on wells or water treatment plants, several options exist. "Grey water", wastewater from sources such as dishwashing or washing machines, can be used for subsurface irrigation, or if treated, for non-potable purposes, e.g., to flush toilets and wash cars. Rainwater collectors are used for similar purposes.

Centralized wastewater treatment systems can be costly and use a lot of energy. An alternative to this process is converting waste and wastewater into fertilizer, which avoids these costs and shows other benefits. By collecting human waste at the source and running it to a semi-centralized biogas plant with other biological waste, liquid fertilizer can be produced. Practices like these provide soil with organic nutrients and create carbon sinks that remove carbon dioxide from the atmosphere, offsetting greenhouse gas emission. Producing artificial fertilizer is also more costly in energy than this process.

2.2.8 Cost and Payoff

The most criticized issue about constructing environmentally friendly buildings is the price. Photo-voltaic, new appliances, and modern technologies tend to cost more money. Most green buildings cost a premium of <2%, but yield 10 times as much over the entire life of the building. In regards to the financial benefits of green building, over 20 years, the financial payback typically exceeds the additional cost of greening by a factor of 4-6 times. And broader benefits, such as reductions in greenhouse gases and other pollutants have large positive impacts on surrounding communities and on the planet. The savings in money come from more efficient use of utilities which result in decreased energy bills.

2.3 THREE PRIMARY RATING SYSTEMS FOR GREEN BUILDINGS IN INDIA

The word 'Green Buildings' is continuously hogging limelight in the media. Some of us might have seen the Confederation of Indian Industry (CII) – Green Business Centre building in Hyderabad which is one of the green buildings in India.

We can define Green Buildings as structures that ensure efficient use of natural resources like building materials, water, energy and other resources with minimal generation of non-degradable waste. Technologies like efficient cooling systems have sensors that can sense the heat generated from human body and automatically adjust the room temperature, saving energy. It applies to lighting systems too. Green buildings have a smarter lighting system that automatically switches off when no one is present inside the rooms. Simple technologies like air based flushing system in toilets that avoids water use by 100%, Use of energy efficient LED's and CFL's instead of conventional incandescent lamp, new generation appliances that consume less energy, and many other options help in making the buildings green and make them different from conventional ones.

There are three primary Rating systems in India

1. GRIHA
2. IGBC
3. BEE

2.3.1 Green Rating for Integrated Habitat Assessment (GRIHA)

Green Rating for Integrated Habitat Assessment (GRIHA) is India's own rating system jointly developed by TERI and the Ministry of New and Renewable Energy, Government of India. It is a green building design evaluation system where buildings are rated in a three-tier process. The process initiates with the online submission of documents as per the prescribed criteria followed by on site visit and evaluation of the building by a team of professionals and experts from GRIHA Secretariat. GRIHA rating system consists of 34 criteria categorized in four different sections. Some of them are:

1. Site selection and site planning,
2. Conservation and efficient utilization of resources,
3. Building operation and maintenance, and
4. Innovation.

Commonwealth Games Village, New Delhi, Fortis Hospital, New Delhi, CESE (Centre for Environmental Sciences & Engineering) Building, IIT Kanpur, Suzlon One Earth, Pune and many other buildings has received GRIHA rating.

2.3.2 Indian Green Building Council (IGBC)

The Leadership in Energy & Environmental Design (LEED) is the rating system developed for certifying Green Buildings. LEED is developed by the U.S. Green Building Council (USGBC), the organization promoting sustainability through Green Buildings. LEED is a framework for assessing building performance against set criteria and standard points of references. The benchmarks for the LEED Green Building Rating System were developed in year 2000 and are currently available for new and existing constructions. Confederation of Indian Industry (CII) formed the Indian Green Building Council (IGBC) in year 2001.

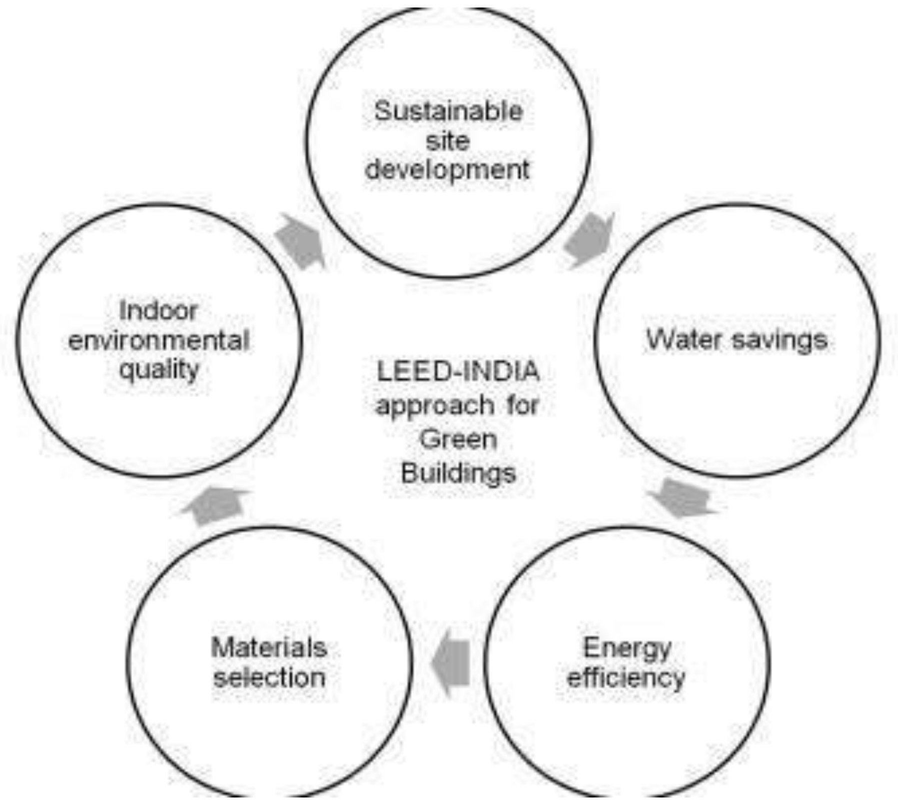

Fig 3: LEED-INDIA Approach for Green Building

IGBC is the non-profit research institution having its offices in CII-Sohrabji Godrej Green Business Centre, which is itself a LEED certified Green building. Indian Green Building

Council (IGBC) has licensed the LEED Green Building Standard from the USGBC. IGBC facilitates Indian green structures to become one of the green buildings.

IGBC has developed the following green building rating systems for different types of building in line and conformity with US Green Building Council. Till date, following Green Building rating systems are available under IGBC

1. LEED India for New Construction
2. LEED India for Core and Shell
3. IGBC Green Homes
4. IGBC Green Factory Building
5. IGBC Green SEZ
6. IGBC Green Townships

Table 1: Some Examples of LEED Rated Buildings in India

Sl. No	Green Buildings	Rating received
1	ABN Amro Bank N.V., Ahmedabad	LEED 'Platinum' rated
2	American Embassy School, Delhi	LEED 'Gold' rated
3	Anna Centenary Library Building, Chennai	LEED 'Gold' rated

2.3.3 Bureau of Energy Efficiency (BEE)

BEE developed its own rating system for the buildings based on a 1 to 5 star scale. More stars mean more energy efficiency. BEE has developed the Energy Performance Index (EPI). The unit of Kilo watt hours per square meter per year is considered for rating the building and especially targets air conditioned and non-air conditioned office buildings. The Reserve Bank of India's buildings in Delhi and Bhubaneshwar, the CII Sohrabji Godrej Green Business Centre and many other buildings have received BEE 5 star ratings.

Indians were aware of Green Building concepts from the beginning. Conventional homes with baked red colour roof tiles and clay made walls is a really good example of energy efficient structures that are used to keep cool during summers and warm during the winters.

Most of rural India is still attached to this building technology with naturally available materials like clay, wood, jute ropes, etc. Today we have advanced technologies that create smarter systems to control inside temperature, lighting systems, power and water supply and waste generation. Green buildings might be a bit heavy on the purse but are good for the environment. In this rapidly changing world, we should adopt the technology that helps us to save precious natural resources. This would lead us to true sustainable development.

Table 2: LEED Certification Rating

Certification Level	Rating Point
LEED Certified	26 - 32
LEED Certified Silver Level	33 - 38
LEED Certified Gold Level	39 - 51

CHAPTER 3

SELECTED RESIDENTIAL BUILDING

3.1 DETAILS OF SELECTED SITE

- Amballur in Thrissur district of Kerala.
- City Thrissur is situated in the southwest of the South Indian state of Kerala of Thrissur district.
- Thrissur district borders with Palakkad district in east, Malappuram district in the south and Arabian Sea in the west.

3.2 GEOGRAPHY

- City lies at 10.52 °N and 76.21 °E.
- Average altitude of 2.83 m.
- It is situated in hillock, which allows rain water to automatically drain out the city.
- Ponds and small rivers acts as natural drainage system for the city.

3.3 CLIMATE [source: Meteorological Department]

- City features a Tropical monsoon climate with only minor differences in temperatures between day and night, as well as over the year.
- Maximum average temperature in summer season is 33 °C.
- Minimum average temperature in summer season is 22.5 °C.
- Maximum average temperature in winter season is 29 °C.
- Minimum average temperature in winter season is 20 °C.

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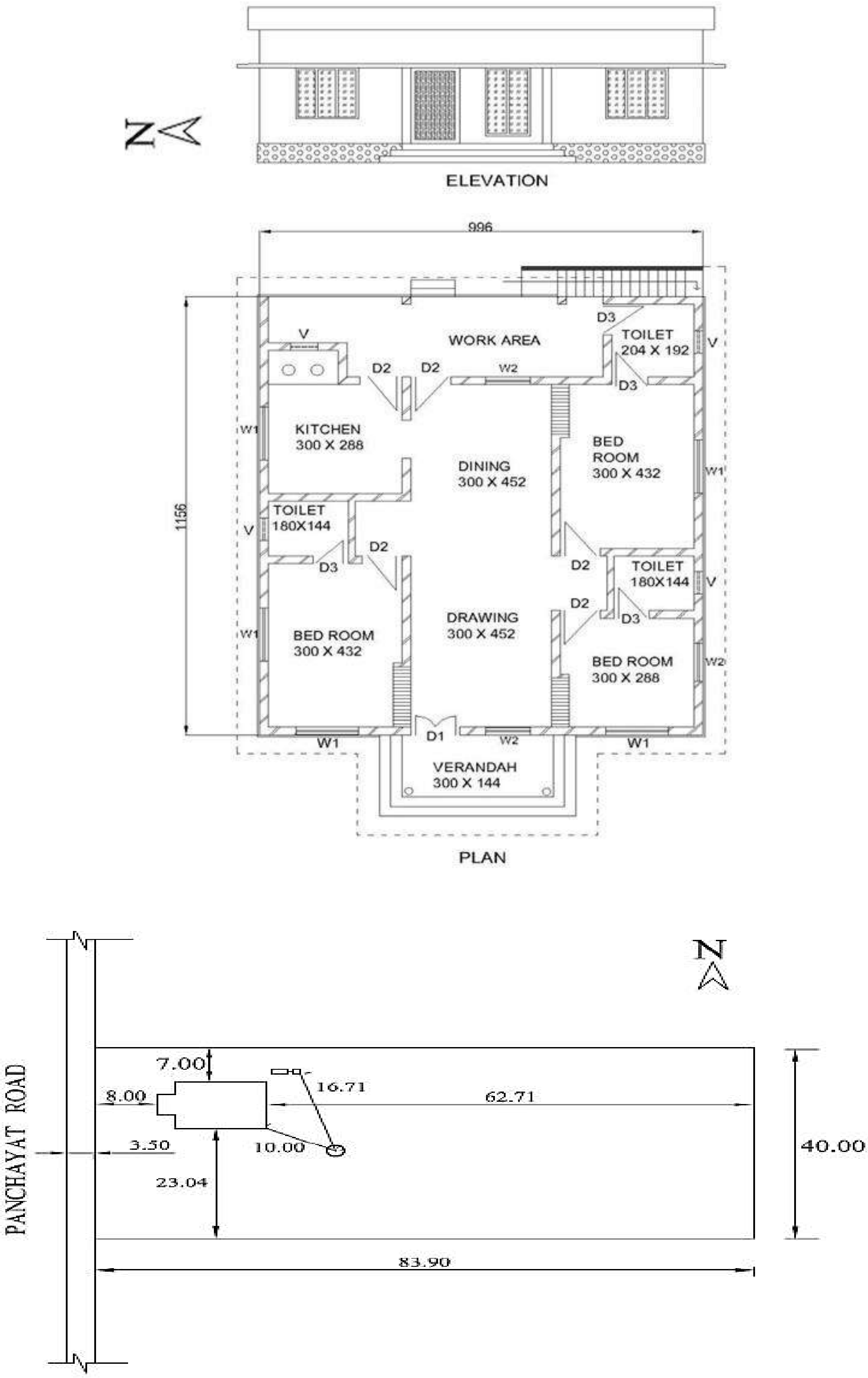

Fig 4: Plan, Elevation and Site Plan of and Selected Building

3.4 ENERGY CONSUMPTION

Energy consumption of each equipment of selected residential building is shown in Table 3.

Table 3: Energy Consumption in Selected Building

Sl. No	Equipment	Power (P) (Watt)	Number (n)	Approximate working hours per day (t) (hr.)	Total energy consumption per day (P*n*t/1000) (KWh)
1.	CFL	20	14	2	0.8
2.	TUBE	40	7	3	0.840
3.	CEILING FAN	75	5	7	2.625
4.	TELEVISION	100	1	5	0.5
5.	LAPTOP	65	1	2	0.130
6.	SCANNER	70	1	0.167	0.012
7.	MOTOR	370	1	0.25	0.0925
8.	IRON BOX	750	1	0.25	0.1875
9.	CELL PHONE CHARGER	2	3	1.5	0.009
10.	SETTOP BOX	8	1	5	0.04
11.	MIXER	750	1	0.167	0.125
	TOTAL				**5.361**

3.5 TEMPERATURE

Temperature readings are taken during morning, noon and evening using alcohol thermometer and are listed below in Table 4.The temperature readings are taken in order to represent the thermal variation of selected residential building before and after converting it in to green building using the software Energy 2D.

Table 4: Daily Temperature Variation in Selected Building

Date	Temperature (°C)		
	Morning	Noon	Evening
11/10/2016	26	28	27
12/10/2016	26	28	27
13/10/2016	26	28.5	27
14/10/2016	26	28.5	27
15/10/2016	26	29	27.5
16/10/2016	25.5	28.5	27.5
17/10/2016	26	28.5	27
18/10/2016	26	28.5	27.5
19/10/2016	25.5	28.5	27
20/10/2016	25.5	28.5	27
21/10/2016	26	29	27
22/10/2016	26	28.5	27
23/10/2016	26	28.5	27.5
24/10/2016	26	28.5	27.5
25/10/2016	25	27	26
26/10/2016	25.5	26.5	26
27/10/2016	25	26.5	26
28/10/2016	24.5	26	25.5
29/10/2016	24.5	25.5	25
30/10/2016	24.5	25	25

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Fig 5: Alcohol Thermometer

3.6 WATER COSUMPTION

Capacity of water tank: 1000 litres

Time taken complete consumption of water in the tank: 1 and ½ day

3.7 QUANTITY OF WASTE

Daily biological waste production (mainly kitchen waste) in the selected residential building	= 2 kg
Monthly biological waste production in the selected residential building	= 2 * 30
	= 60 kg
Monthly plastic waste production in the selected residential building	= 3 kg

CHAPTER 4
CONVERSION TO GREEN BUILDING

4.1 RAIN WATER HARVESTING

It is the collection and distribution of rainwater for using in daily life, rather than allowing it to run off. Rainwater is generally accumulated from roof tops. Then it is deposited in a reservoir with percolation. It is used for gardening, cultivation and domestic uses. The harvested water can also be used as ground water recharge.

Water shortage is caused by climate change, lack of planning of water uses, rapidly increasing water pollution and increasing population.

So, under such conditions some serious steps towards conservation of water must be taken. Rain is a natural source of water. So, if it can be collected and treated, it can be used as potable water. It is a cheap and simple technology, so it can be easily installed in normal households and a lot of water can be saved.

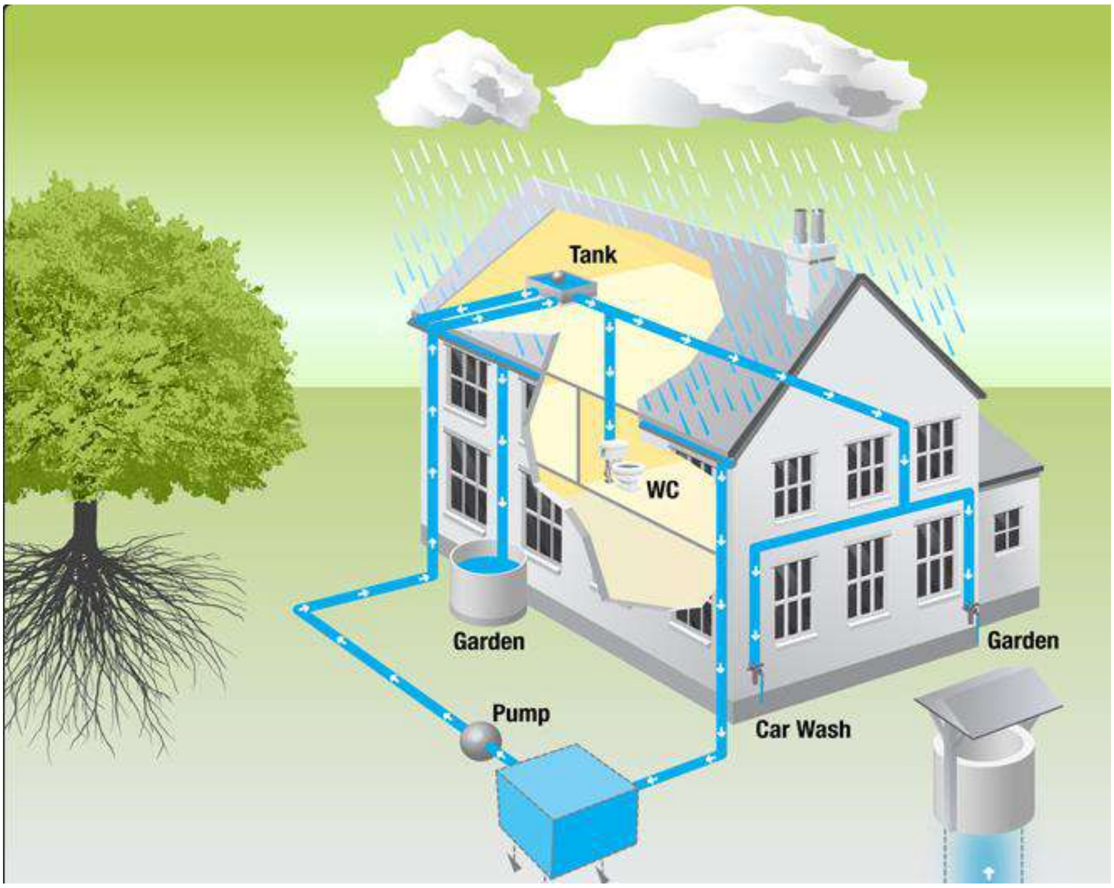

Fig 6: Rain Water Harvesting

4.1.1 Collecting Rain Water for Lawn Irrigation Systems

Green building is a concept that includes a collection of practices meant to reduce whole-building costs and environmental impact through better site selection, design, construction, operation and maintenance. Over the past few years, these practices have significantly expanded, complementing the classical concerns regarding building utility, economy, durability and comfort.

Although most technologies focus on creating greener constructions, new advancements are constantly being developed to help both organizations and homeowners reduce waste, environmental degradation and pollution so that impressive economic, social and environmental benefits can be achieved. One of the best examples of green building practices is rainwater harvesting.

4.1.2 Stages in Rainwater Harvesting

A basic system for the harvesting of rainwater consists of three stages:

- Collection Stage: It is the first step of Rainwater harvesting. At first while it's raining in a catchment area, rainwater is collected in a container on roofs, pavement or the soil surface. Channels all around the edge of a sloping roof to collect and transport rainwater to the storage tank.
- Distribution Stage: Pipelines are the backbone of the distribution system in Rain Water Harvesting (RWH). They carry rainwater from the catchment or rooftop area to the harvesting system. They can be semi-circular or rectangular and are made using galvanized iron sheet (20 to 22 gauge), PVC, Bamboo.
- Storage Stage: After collection and distribution, next comes the most important step, the storage system. For simple RWH storage tank is used. The capacity of the storage tank is based upon several design criteria:

1. Rainfall
2. Length of dry season
3. Estimated need

The increasing requirement of water is resulting in lowering of ground water table. The rainwater recharges the ground water. This water is available in lakes, rivers, ponds, aquifers, etc. but these are fickle sources. Treated rainwater can solve the demand of household water needs. Generally the water sources are located far from community. If rainwater can be collected and used, it will reduce the cost of distribution.

4.1.3 Rainwater Harvesting Methods

Rainwater harvesting systems are divided into two main categories: passive and active. Passive systems are actually small barrels placed at the end of downspouts. Active systems often include pumps, which supply water to distribution systems. Although rainwater is non-potable, it can be safely used for lawn irrigation and washing cars. Some active systems incorporate water treatment technologies, which make rainwater safe for washing, toilet flushing and evaporative cooling.

Rainwater harvesting systems can be connected to different distribution systems for lawn irrigation, such as direct systems, which pump rainwater directly to draw-off points, and gravity systems, which can switch to drinking water when the rainwater supply is depleted.

In conclusion, green building is not only about sustainable design and construction; it is also about integrating the latest technologies in building design to ensure rational use of natural resources.

4.1.4 Components of Rainwater Harvesting Plant

1. Catchment: the surface from which rainwater is collected for storage. This could be a rooftop, a paved flooring surface or a landscaped area. Catchment area is the area of that surface, usually calculated in square meters.
2. Gutters and Down take pipes: lead the water from the catchment surface to the storage tank
3. Filters and first flush devices: remove grit, leaves and dirt that the rainwater may transport from the catchment, before the water enters the storage tank. When it rains after a long gap, the rooftops are usually very dirty and the rainwater also carries with it a lot of dissolved air pollutants. A first flush device diverts the water from the first rain so that it does not enter the storage tank.
4. Storage tanks: These can be above the ground or below the ground.
5. Delivery systems: Piping systems that convey the stored rainwater till the point of end-use.

Fig 7: Rain Water Collection in Asbestos Roofs

Fig 8: Rain Water Collection in Flat Roofs

4.1.5 Design of Rain Water Harvesting Plant

Average rainfall in the area = 2806.7 mm = 2.806 m

Area of catchment or roof top = 8.8*9.44 = 83.072 m^2

Total rainfall = area * average rainfall
= 83.072 * 2.8
= 259.588 m^3
= 233100.03 litres

Runoff Coefficient = 0.7

Coefficient of evaporation, spillage & first flush = 0.8

Total amount of rainfall = 259588.67 * 0.8 * 0.7
= 145.369 m^3
= 130536.01 litres

Tank capacity has to be designed for dry period i.e., the period between 2 consecutive rainy seasons with monsoon extending for 4 months, the dry season is of 245 days.

Drinking water requirement of a person per day = 10 litres

Drinking water requirement for 3 persons = 3 * 10
= 30 litres/day

Amount of water required for 245 days = 30 * 245
= 7350 litres

Safety factor = 20%

Water required = 7350+20% of 7350
= 8820 litres

Storage tank: Length = 3 m
Width = 3 m
Depth = 1 m

Recharge Pit

Generally

Width = 1m to 2m

Depth = 2m to 3m

Pit filled with pebbles and boulders

Cleaning is done annually

Cost of construction = Rs.3000/-

Purification Filters

- Mesh filter (100,500,1000 grades)
- Water purifier

4.2 SOLAR PANEL SYSTEM

Power consumed monthly = 5.36 x 30
= 160 kWh

Power consumed annually = 160 * 12
= 1920 kWh

Specifications of system:

- Solar system size = 3.5 kW
- Approximate roof space = 25.5 m²
- Typical cost = Rs.4,00,000 /-
- Typical annual output = 3,000 kWh

4.3 BIOGAS PLANT

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source and in many cases exerts a very small carbon footprint. Biogas can also be produced by anaerobic digestion with anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials.

Biogas is primarily methane and carbon dioxide and may have small amounts of hydrogen sulfide, moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.

4.3.1 Advantages of Biogas as a Fuel

- High calorific value
- Clean fuel
- No residue produced
- No smoke produced
- Non polluting
- Economical
- Can be supplied through pipe lines
- Burns readily - has a convenient ignition temperature

4.3.2 Uses of Biogas

- Domestic fuel
- For street lighting
- Generation of electricity

4.3.3 Advantages of Biogas Plants

- Reduces burden on forests and fossil fuels
- Produces a clean fuel - helps in controlling air pollution
- Provides nutrient rich (N & P) manure for plants
- Controls water pollution by decomposing sewage, animal dung and human excreta.

4.3.4 Limitations of Biogas Plants

- Initial cost of installation of the plant is high.
- Number of cattle owned by an average family of farmers is inadequate.

4.3.5 Components of Biogas Plant

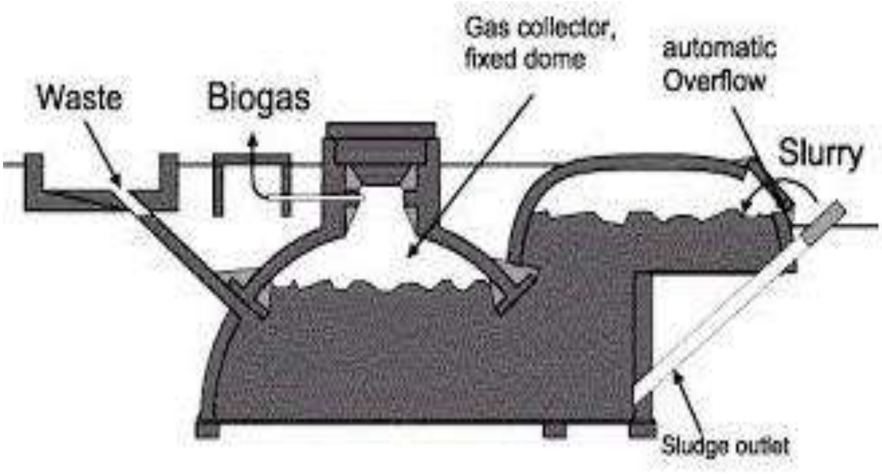

Fig 9: Components of Biogas Plant

1. Digester tank
2. Inlet for feeding the kitchen waste.
3. Outlet for the digested slurry.
4. Gas collection and storage system.

4.3.6 Design of Biogas Plant

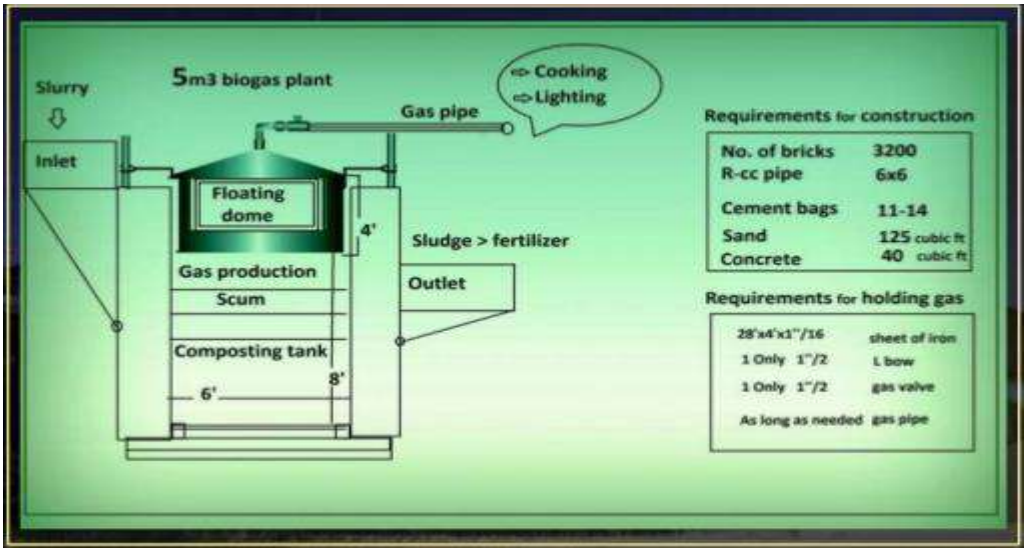

Fig 10: Requirements for 5 m³ Biogas Plant

4.3.6.1 Energy Calculation for Cooking

For cooking

For cattle dung maximum gas production per kg = 0.05 m^3

Total gas = Total dung in kg * 0.05

Medium stove uses 9 MJ of energy per hour.

For 3 animals each producing 8 kg dung,

Amount of fuel to run the stove = 8 * 3

= 24 kg dung

= 1.2 m^3

Duration to run the stove of 1.2 m^3 dung = 1.2 * 19 MJ (1m^3 = 19 Mega Joules)

= 22.8/9

= 2.5 hours

Manure of 3 animals (24kg manure) is used as fuel to run the stove for 2.5 hours.

Fig 11: Biogas Plant

4.4 GREY WATER

It can be defined as any organic waste water produced, excluding sewage. The main difference between grey water and sewage is the organic loading. Sewage has a much larger organic loading compared to grey water.

Two major benefits for grey water use are:

- Reducing the need for fresh water. Saving on freshwater use can reduce household water bills, but also has a broader community benefit in reducing demands on public water supply.
- Reducing the amount of water entering sewers or onsite treatment systems. Again this can benefit the individual household, but also the broader community.

4.4.1 Grey Water Recycling and Reuse

Grey water refers to the domestic waste water which is drained out excluding the waste water from kitchen sink and the water closet as they have high concentration of organic matters. In order to conserve water this water cannot be just drained out but should be recycled and reused. The benefit of using recycled grey water is that it is a large source with low concentration of organic matter.The bathroom grey water consists of waste water from showers, bathtubs and wash basins. It has a very low concentration of organic matter. The other sources of grey water are from washing of clothes, car washing, etc.

According to various studies, an average household produces 140 liter of grey water per day. The various sources and their contribution is categorized in Table 5.

Table 5: Sources of Grey Water and their Contributions

Sl. No.	Source	Quantity/day/person
1	Shower	20-30 lit
2	Washing cloth	15-20 lit

The grey water from all these sources are collected and then treated to make them safe for non- potable use. These treatments include passing the grey water through sand filters or by using natural coagulating agents or by electro-coagulation techniques. Also other biological and chemical treatments. It has been found that using recycled grey water can support the quantity of water required for water closets, car washing and garden watering.

Although it is normally slightly contaminated with a range of chemicals, such as soap or detergent, grease and microbes, it can be successfully reused for a range of purposes which do not require drinking water quality purity, including:

- Watering the garden
- Flushing toilets
- Car-washing

Anything other than the most simple of methods - manually emptying your bath tub with a bucket, for example - will require a separate plumbing system to be installed to collect the grey water, and the detail and extent of this will depend on the intended use and the level of sophistication desired.

4.4.2 Design of Grey Water Filter

As per Manual for Design, Construction Operation and Maintenance.

Following layers are present

I. 25 cm gravel layer at bottom
II. 10 cm gravel layer at top
III. Two 10 cm M sand
IV. Two 10 cm charcoal layer
V. 60 cm sand at middle

Thickness of layer = 10 + 25 + (2 * 10) + (2 * 10) + 16
= 1.35 m
≈ 1.4 m

As per guidelines for greywater reuse in sewered, single household residential premises.

For 3 persons per household approximately 339 litres of grey water produce per house per day. In order to accommodate 339 litres a portion of 0.8 m * 0.7 m *0.7 m is required.

Therefore total depth of the tank = thickness of layers + 0.7
= 1.4 + 0.7

= 2.1 m

Length of tank = 0.8 m

Width of tank = 0.7 m

4.4.3 Treatment for Grey Water

Fig 12: Grey Water Filter

Fig 13 (a): Layers of Filter

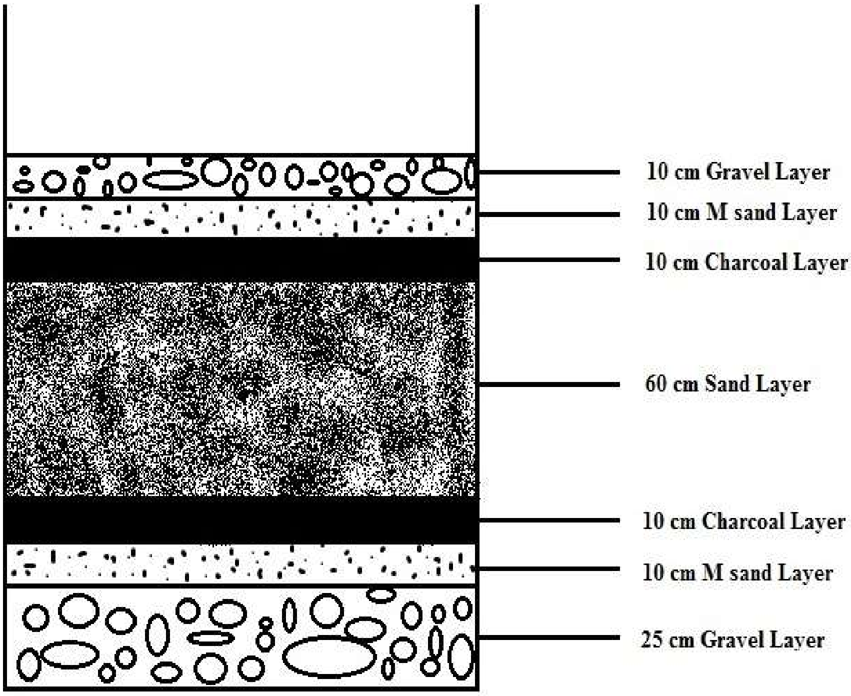

Fig 13 (b): Thickness of each Layers in a Filter

4.4.4 Characteristics of Grey Water

Table 6: Characteristics of Grey Water

Water Source	Characteristics
Laundry	Microbiological: variable thermotolerant coliform loads Chemical: sodium, phosphate, boron, surfactants, ammonia and nitrogen from soap powders and soiled clothes Physical: high in suspended solids, hair and turbidity Biological: lower levels of concentrations of biochemical oxygen demand
Bathroom	Microbiological: lower levels of thermotolerant coliforms Chemical: soap, shampoo, hair dyes, tooth paste and cleaning chemicals Physical: high in suspended solids, hair and turbidity Biological: lower levels of concentrations of biochemical oxygen demand
Kitchen	Microbiological: variable thermotolerant coliform loads Chemical: detergents, cleaning agents Physical: food particles, oils, fats, grease, turbidity Biological: high in biochemical oxygen demand

Preparation of synthetic grey water is shown in Table 7.

Table 7: Preparation of Synthetic Grey Water

Ingredients	Quantity
Tap water (liters)	19.98
Soap (g)	
Multipurpose green bar	14.4
Body care soap bar	4
Hand washing laundry powder	12.8
Fats and greases (g)	
Cooking oil	0.3
Food product (carbohydrates and proteins) (g)	
Cake flour	2
Nutrient broth	2

4.4.5 Experiments Conducted

1. Determination of pH
2. Determination of Alkalinity
3. Determination of Hardness
4. Determination of Sulphates
5. Determination of Chlorides
6. Determination of Dissolved Oxygen

4.4.5.1 Determination of pH

a. Using pH paper

Dip the pH paper in the sample. Compare the colour with that of the colour given on wrapper of the pH paper book. Note down the pH of the sample.

b. Using Universal indicator

10 ml of sample is taken in a cuvette and placed in the position for blank. Another 10 ml sample is taken in another cuvette and 2 drops of universal indicator is added. Compare the obtained colour with colours given in the chart. Note down the corresponding value.

Result

Table 8 (a): pH before filtration

Sample No.	pH paper	Universal indicator
1	8.0	8.5

Table 8 (b): pH after filtration

Sample No.	pH paper	Universal indicator
1 (1 hour)	7	8.0
2 (2 hour)	7	7.5
3 (3 hour)	7	7.5
4 (4 hour)	7	7.5

As per IS 10500 – 2012. The range of pH of drinking water is 6.5 – 8.5. The obtained value of pH is 7.5, which is within the range.

4.4.5.2 Determination of Alkalinity

Pipette 50 ml of sample into a clean Erlenmeyer flask (V). Add 1 drop of sodium thiosulphate solution, if residual chlorine is present. Add 2 drops of phenolphthalein solution, if the pH is above 8.3, colour of solution becomes pink. Titrate against standard sulphuric acid in the burette, till the colour just disappears. Note down the volume (V1). Then add 2 drops of methyl orange indicator, the colour turns yellow. Again titrate against acid until the colour turns to orange yellow. Note down the total volume (V2).

Alkalinity Relationships

The types of alkalinity present in the samples are calculated using the equations given in the following table and results are tabulated in Table 9.

Table 9: Alkalinity Relationships

Results of titration	**Hydroxide alkalinity as $CaCO_3$**	**Carbonate alkalinity as $CaCO_3$**	**Bicarbonate alkalinity as $CaCO_3$**
P = 0	0	0	T
P < ½ T	0	2P	T – 2P
P = ½ T	0	2P	0
P > ½ T	2P-T	2(T-P)	0
P-T	T	0	0

Result

Table 10 (a): Alkalinity before filtration

Description of Sample	Hydroxide alkalinity as $CaCO_3$ (mg/l)	Carbonate alkalinity as $CaCO_3$ (mg/l)	Bicarbonate alkalinity as $CaCO_3$ (mg/l)	Hydroxide carbonate alkalinity as $CaCO_3$ (mg/l)	Carbonate Bicarbonate alkalinity as $CaCO_3$ (mg/l)
1	0	20	184	0	204

Table 10 (b): Alkalinity after filtration

Description of Sample	Hydroxide alkalinity as $CaCO_3$ (mg/l)	Carbonate alkalinity as $CaCO_3$ (mg/l)	Bicarbonate alkalinity as $CaCO_3$ (mg/l)	Hydroxide carbonate alkalinity as $CaCO_3$ (mg/l)	Carbonate Bicarbonate alkalinity as $CaCO_3$ (mg/l)
1 (1 hour)	0	0	192	0	192
2 (2 hour)	0	0	186	0	186
3 (3 hour)	0	0	180	0	180
4 (4 hour)	0	0	180	0	180

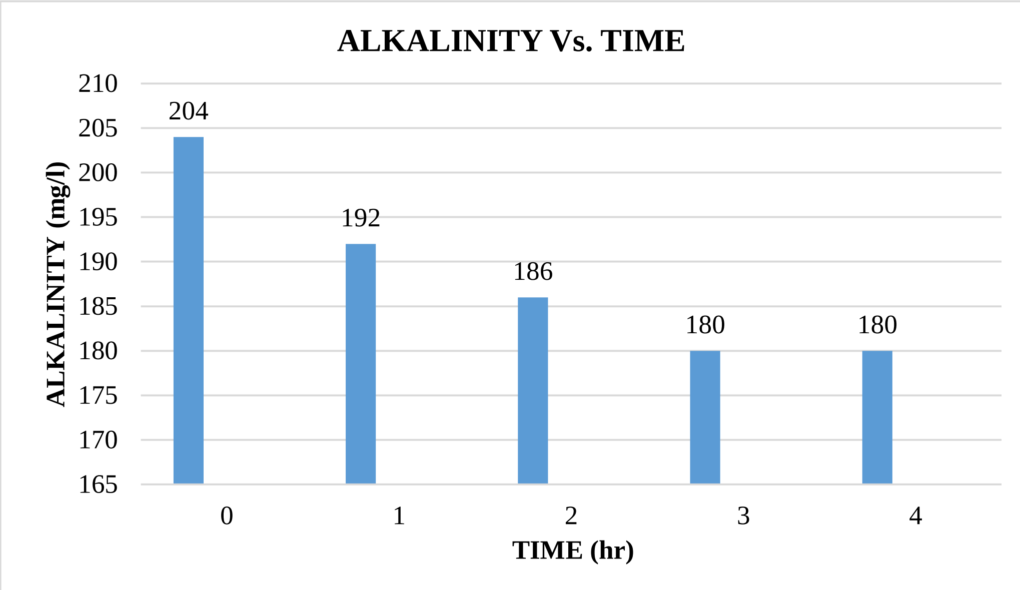

Fig 14: Alkalinity vs. Time

As per Is 10500 – 2012. The desirable limit of alkalinity is 200 mg/l and the maximum permissible limit is 600 mg/l in the absence of any other alternative sources. Here the obtained value is 180 mg/l, which is within the limit.

4.4.5.3 Determination of Hardness

Dilute 25 ml of sample (V) to about 50 ml with distilled water in an Erlenmeyer flask. Add 1 ml of ammonia buffer solution. Add 2 drops of Erichrome Black T indicator. The solution turns wine red in colour. Add the standard EDTA titrant slowly, with continuous stirring until the last reddish tinge disappears from the solution. The colour of the solution at the end point is blue under normal conditions. Note down the volume of EDTA added (V1).

Result

Table 11 (a): Hardness before filtration

Sample No.	Total Hardness an $CaCO_3$ (mg/l)
1	312

Table 11 (b): Hardness after filtration

Sample No./ Description	Total Hardness an $CaCO_3$ (mg/l)
1 (1 hour)	280
2 (2 hour)	272
3 (3 hour)	268
4 (4 hour)	260

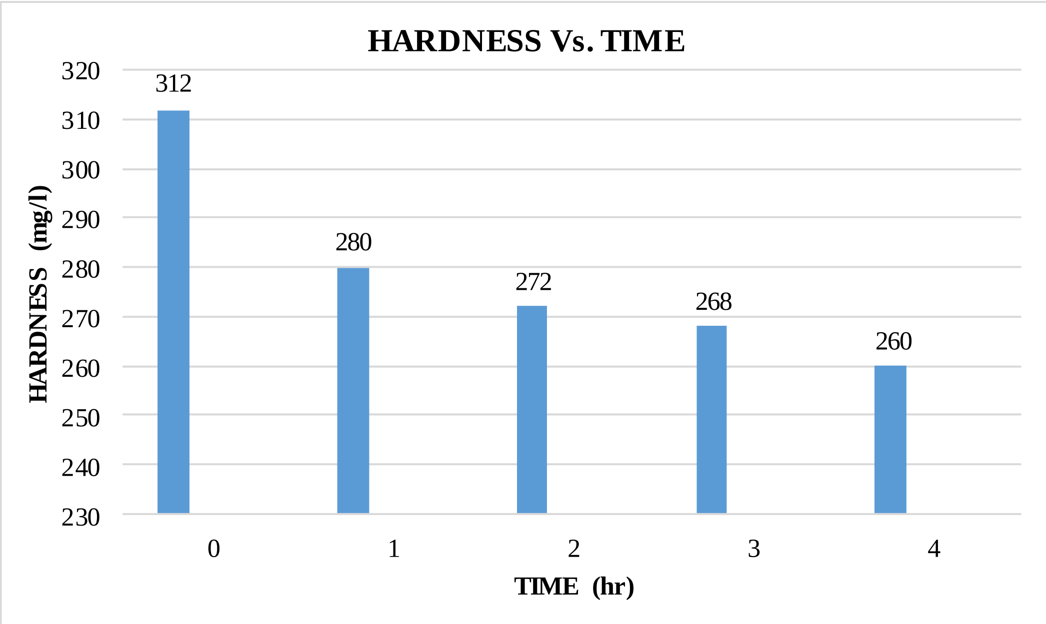

Fig 15: Hardness vs. Time

As per IS 10500 – 2012, drinking water specification the desirable limit of hardness is 200 mg/l and the maximum permissible hardness limit is 600 mg/l in the absence of other substances. The obtained value is 260, which is within the limit.

4.4.5.4 Determination of Sulphate

Measure 100 ml or suitable portion of the sample into a 250 ml Erlenmeyer flask. Add 5 ml of conditioning reagent and mix it. Add a spoonful of barium chloride crystals. Stir at constant speed exactly for 1 minute. After stirring pour some of the solution into the absorption cell of the photometer and measure the turbidity at 30 seconds intervals for 4 minutes. Usually maximum turbidity occurs within 2 minutes and the reading remains constant thereafter for 3 to 10 minutes. So take reading with maximum turbidity occurring in within 4 minutes.

Prepare a calibration curve. The standards are prepared at 5 mg/l increments in the 0 to 40 mg/l sulphate range and their turbidity or absorbance read. Absorbance versus Sulphate concentration is plotted and curve is obtained. Finding the absorbance for a given sample, the concentration of sulphate in the solution is determined with the help of calibration curve.

Result

Table 12 (a): Concentration of Sulphate before filtration

Sample No./ Description	mg/l of Sulphate
1	26

Table 12(b): Concentration of Sulphate after filtration

Sample No./ Description	mg/l of Sulphate
1 (1 hour)	26
2 (2 hour)	25.5
3 (3 hour)	25
4 (4 hour)	25

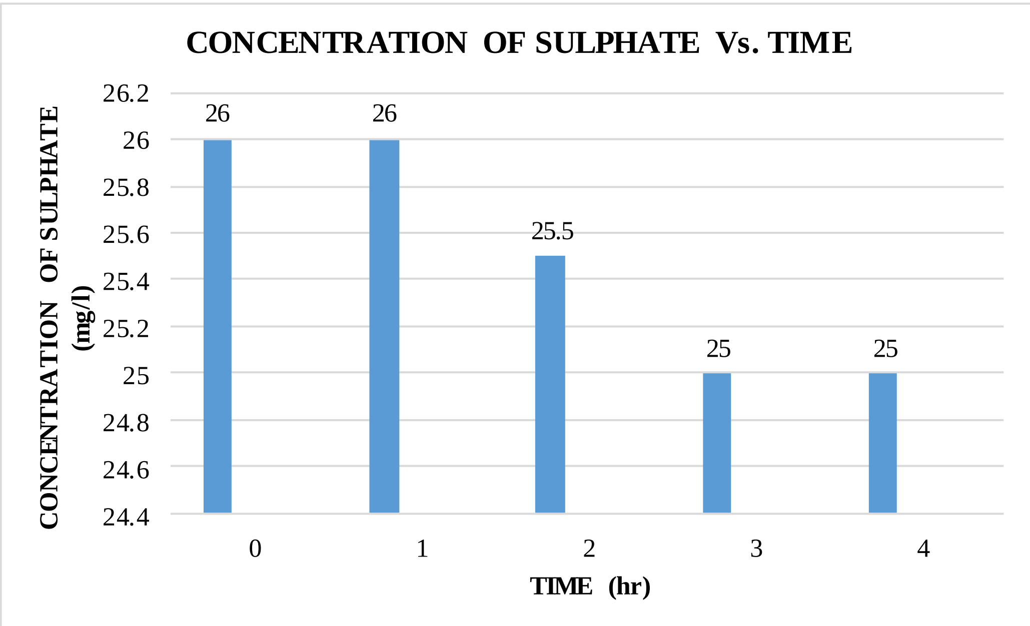

Fig 16: Concentration of Sulphate vs. Time

As per IS 10500 – 2012, the desirable limit of sulphate for drinking water is 200 mg/l and the permissible limit is 400 mg/l, which is within the limit.

4.4.5.5 Determination of Chlorides

Take 10 ml of sample (V) and dilute to 100 ml. If the sample is coloured add 3 ml of aluminium hydroxide, shake well, and allow to settle, filter, wash and collect filtrate. Sample is brought to pH 7-8 by adding acid or alkali as required. Add 1 ml of indicator (Potassium chromate). Titrate the solution against standard silver nitrate solution until a reddish brown precipitate is obtained. Note down the volume (V1). Repeat the procedure for blank and note down the volume (V2).

Result

Table 13 (a): Chloride Concentration before filtration

Sample No.	Chloride Concentration (mg/l)
1	565

Table 13 (b): Chloride Concentration after filtration

Sample No.	Chloride Concentration (mg/l)
1 (1 hour)	485
2 (2 hour)	450
3 (3 hour)	415
4 (4 hour)	405

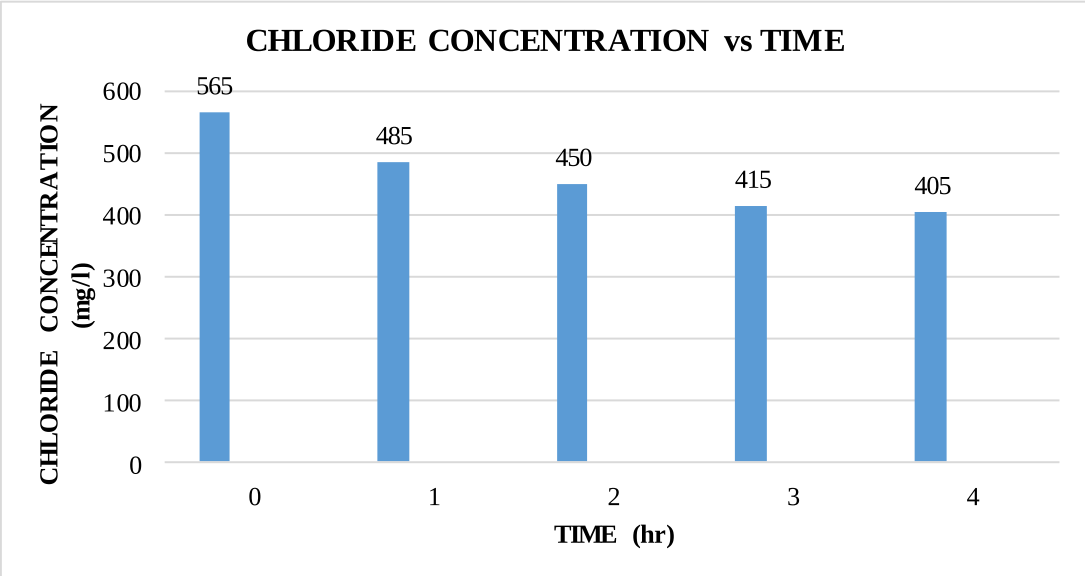

Fig 17: Chloride Concentration vs. Time

As per IS 10500 – 2012, drinking specification of desirable limit of chloride content is 250 mg/l and maximum permissible limit of chloride content is 1000 mg/l. Here the obtained value is 405 mg/l, which is within the limit.

4.4.5.6 Determination of Dissolved Oxygen

Add 2 ml of manganous sulphate solution and 2 ml of alkali-iodide azide reagent to 300 ml sample taken in the bottle, well below the surface of the liquid. Stopper with care to exclude air bubbles and mix by inverting the bottle at least 15 times. When the precipitate settles, leaving a clear supernatant above the manganese hydroxide floc, shake again. After 2 minutes of settling, carefully remove the stopper, immediately add 3 ml concentrated sulphuric acid by allowing the acid to run down the neck of the bottle. Restopper and mix by gentle inversion until dissolution is complete. Measure out 203 ml of the solution from the bottle to an Erlenmeyer flask. Titrate with 0.025 N sodium thiosulphate to a pale straw colour. Add 1-2 ml starch solution and continue the titration to the first disappearance of the blue colour and note down the volume of sodium thiosulphate solution added (V), which gives directly the D.O (Dissolved Oxygen) in mg/l.

Result

Table 14 (a): D.O before filtration

Sample No.	D.O (mg/l)
1	3.3

Table 14 (b): D.O after filtration

Sample No.	D.O (mg/l)
1 (1 hour)	4.4
2 (2 hour)	5.5
3 (3 hour)	5.8
4 (4 hour)	5.8

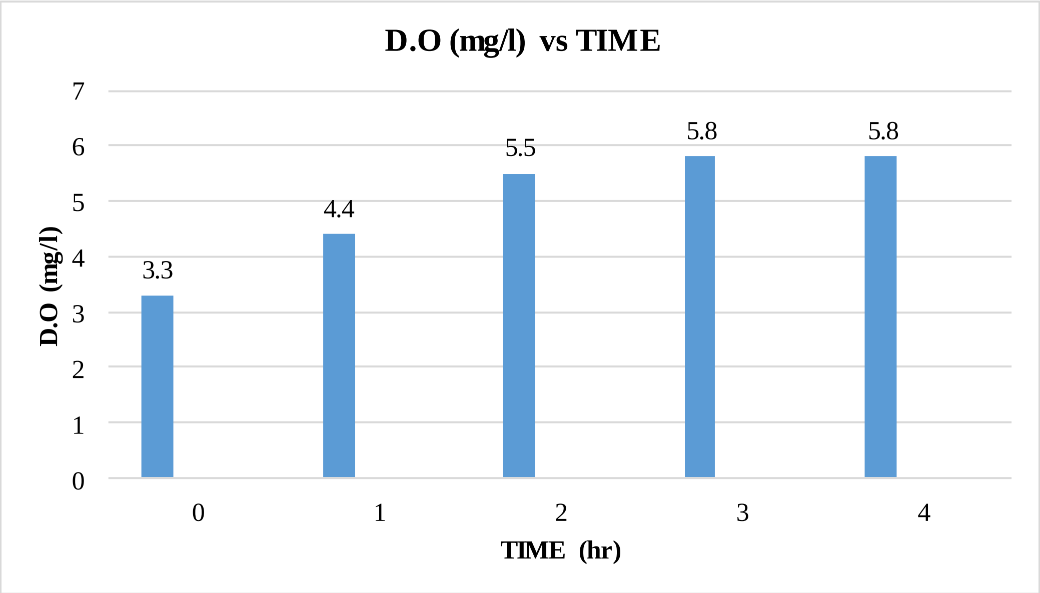

Fig 18: D.O vs. Time

The D.O at 0 °C is 14.4 mg/l and the dissolved oxygen level in natural and waste water at 35 °C is 7 mg/l. Here the obtained D.O level at present (34 °C) is 5.8, which is not within the limit.

4.5 PASSIVE DESIGN

Passive Design regards the particular way to construct a building using the natural movement of heat and air, passive solar gain and cooling in order to maintain a good internal comfort.

Through the use of passive solutions it is possible to eliminate, or at least reduce, the use of mechanical systems and the energy demand by 80% as well as the CO_2 emissions. Building a passive house takes careful planning, which includes the introduction of five basic principles:

- orientation
- overhangs and shadings
- insulation
- thermal mass

The Passive House Concept is defined as follows: “A Passive House is a building in which thermal comfort can be guaranteed by post-heating or post cooling the fresh-air mass flow required for a good indoor air quality”. There has been a drastic increase in the use of air conditioning system for cooling the buildings all around the world. The last two decade has witnessed a severe energy crisis in developing countries especially during summer season primarily due to cooling load requirements of buildings. Increasing consumption of energy has led to environmental pollution resulting in global warming and ozone layer depletion. Passive cooling systems use non-mechanical methods to maintain a comfortable indoor temperature and are a key factor in mitigating the impact of buildings on the environment. Passive cooling techniques can reduce the peak cooling load in buildings, thus reducing the size of the air conditioning equipment and the period for which it is generally required.

4.5.1 Orientation

The first basic principle in a passive house is the orientation, in which the southern façade of the building should be oriented towards the equator in the northern hemisphere (and the northern façade towards the north in the southern hemisphere. By facing the longer axis of the building in the east/west direction, the longer dimension of the home faces will be more likely to gain the maximum solar radiation. For that reason, areas which are most frequently used, such as the kitchen and the living room, must be located into this part of the building. This orientation is also advantageous for summer cooling conditions because it minimizes the east-west façades to morning and afternoon sunlight.

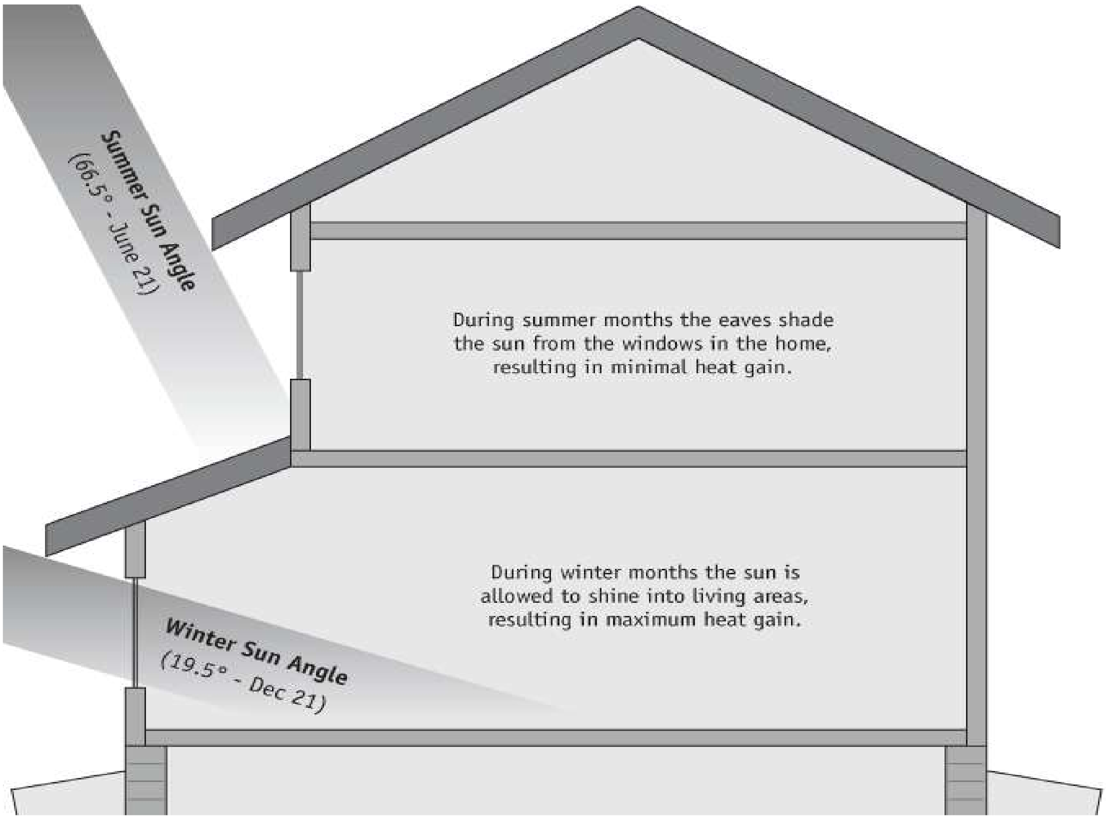

Fig 19: Orientation and Solar Gain

4.5.2 Overhangs and Shading

Overhangs and shadings are important devices in a passive house because they help in reducing overheating during the summer season. Therefore, it is very important that the devices are properly sized. The southern façade through which the sun mostly comes inside must be correctly shaded, or equipped by sized overhangs, in order to prevent overheating and to keep the house cool during summer months. However, a careful design of the device must be made in order to guarantee that the size and sloped can meet the need to let the sun in during the winter and to shade the building during the summer. The type of shade and its degree is always linked with the position of the sun and the geometry of the building. For instance, simple overhangs are very efficient for shading the building in the south façade during the summer when the sun is high in the sky. However, this type of shading device is not efficient for the south-west façade at blocking the sun entering inside during morning and afternoon hours, when the sun is low in the sky. It is very important to understand that in summer the peak sun angles comes in June on the 21st during the solstice, but peak temperature and humidity come mostly in August. Therefore, include a fully shade south façade during the summer will also shade the window in autumn and spring, when actually the passive solar heat is needed for heat up the building and keep the house with a comfort temperature. Having say that, for designing a proper shading device it is necessary to understand how the sun moves along the year and which effect its angles have on the building. The altitude and azimuth angles represent the position of the sun in the sky. Because shading devices can have a huge impact on the building appearance as well as reducing the cooling demand, they must be considered and evaluated at the early stage of the design process, in order to be effective for both technical and visual aspect for being well-integrated in the whole architecture.

There are several type of shading devices, but it is very difficult to make a generalization of their design. However, some general recommendations have been listed just below:

- to control direct solar radiation in the south façade use fixed overhangs limit the number of east and west windows because they are very difficult to shade
- compared to the south side. Maybe some consideration of the surrounded landscape, such as type of tree that might be used to shade
- north façade can be out of shading as it receives very little direct solar radiation
- interior shading devices, such as Venetian blinds or vertical louvres, might be used in order to control glare, however exterior shadings must be included since the interior ones have already admitted the solar gain in.

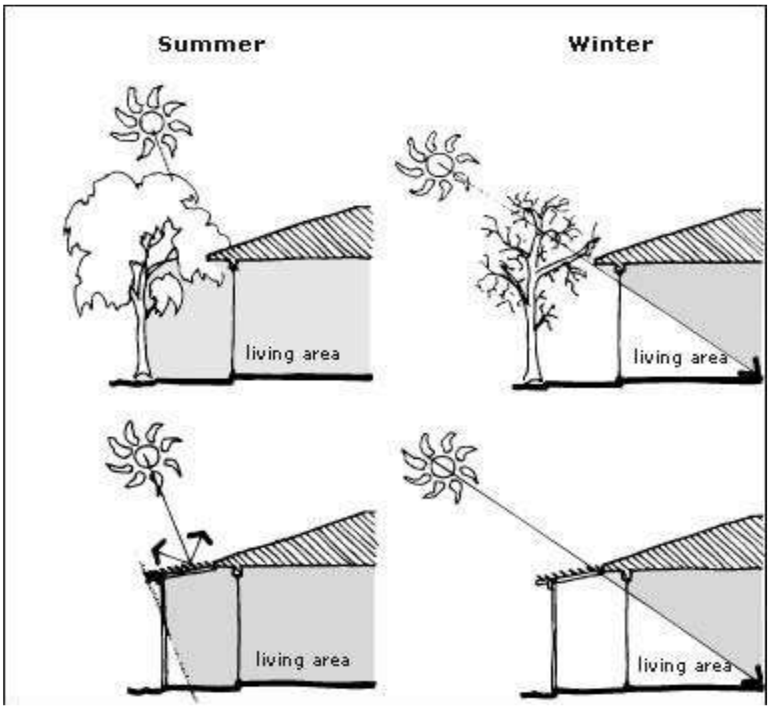

Fig 20: Shading

4.5.3 Insulation

A well-insulated building helps in reducing heat loss during the winter and keeping the house cool during the summer. Insulated materials, so called because they are poor conductors of heat, form a barrier between interior and exterior spaces, by means between warmed interior and cool exterior, and cool interior and hot exterior according to the season. Since insulation is important in warm climate as well as in cold climate, less energy is required to heat houses in cold conditions or cool houses in warm condition which results in a good interior temperature along the whole year. Regarding insulation, the heat loss through the construction (walls, floor, basement, ceiling or the roof) is represented by the thermal heat loss coefficient or U-value, which represents how much heat in Watts is lost per m^2 at a standard temperature difference.

Insulation materials are normally used in walls, floors and roof because they work by resisting heat flow, which is measured by an R-value (the higher the R-value, the greater the insulation).

There are many type of insulation material which might be used in a passive house, such as cellulose, cotton, fiberglass, polyurethane, mineral wool, perlite and sheep's wool.

4.5.4 Thermal Mass

The concept of thermal mass regards a solid or liquid material which absorbs and store warmth and releases it when is needed. By means that, the excess solar heat gain can be stored and used when the sun is not shining or where there is no sun at all, as during the night. It actually works as a battery because during the summer season it absorbs heat keeping the house comfortable, while in winter it stores the heat gained and gives it back at night keeping the house warm. Basically in a passive house a thermal mass can work in two ways: by direct solar gain or by indirect solar gain.

A thermal mass could moderate the temperature of internal spaces, reducing the need for mechanical cooling and winter heating requirements and the most cost effective method normally is to take advantage of thermal mass in the building structure.

4.5.5 Cooling Tunnels

The cooling tunnel enhances indoor air quality. By using a single exhaust fan the hot air entrapped inside the closed room of residence is circulated out and with the help of approximately 14 cooling tunnels (for normal room) it circulates fresh air in to the room, keeps the room cool and increase the comfort level. This system requires a maximum of 2hrs working for effective cooling. This technique is successively implemented in Kerala. There is no need to use mechanical ceiling, hence consumes less energy.

Fig 21: Cooling Tunnel

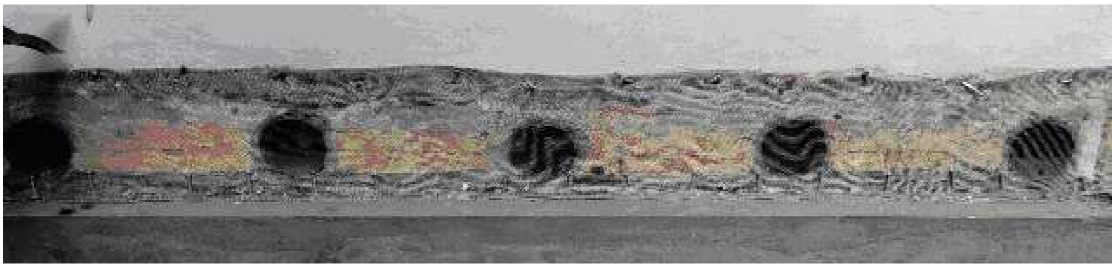

Fig 22: Openings outside the Room

Fig 23: Openings inside the Room

4.6 SIMULATION SOFTWARE

It was developed as a means for students to visualize the underlying concepts necessary to approach and solve heat transfer problems. The author's stated goal is to develop a free interactive computational tool that can run simulations in real time to provide students with a powerful online learning environment for the subject of heat transfer. The sequenced materials include: heat and temperature, conduction, convection, radiation, Stefan-Boltzman Law, fluid dynamics, boundary conditions, and the heat equation.

Figure 24 (a): Tools in Energy 2D

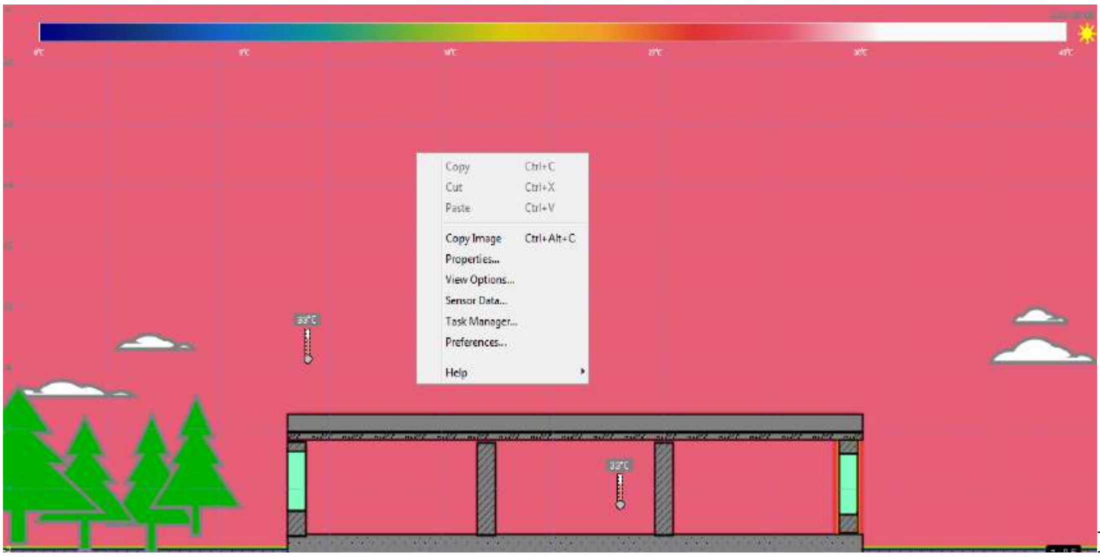

Figure 24 (b): Tools in Energy 2D

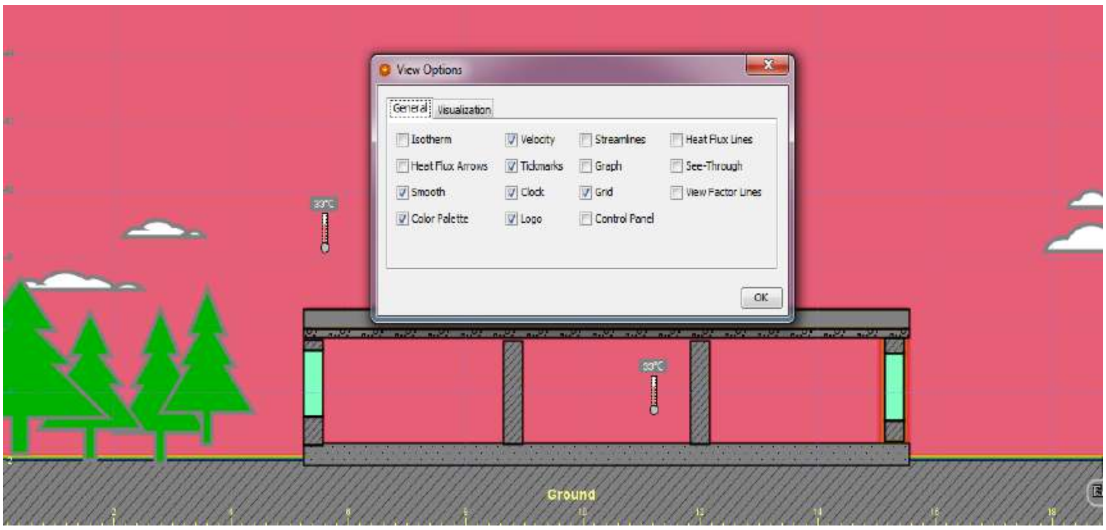

Figure 24 (c): Tools in Energy 2D

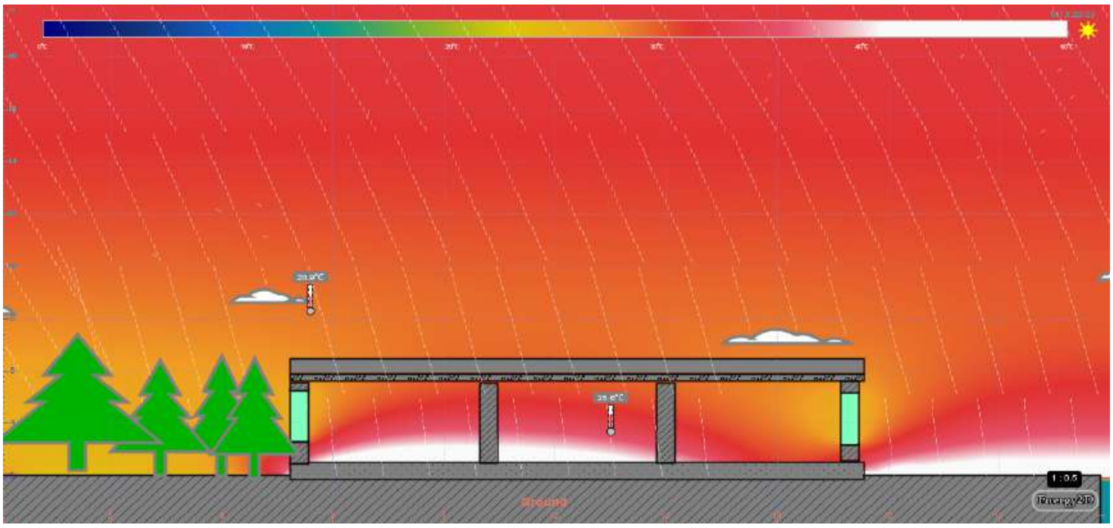

Figure 25: Working of Simulation Software in Section 1

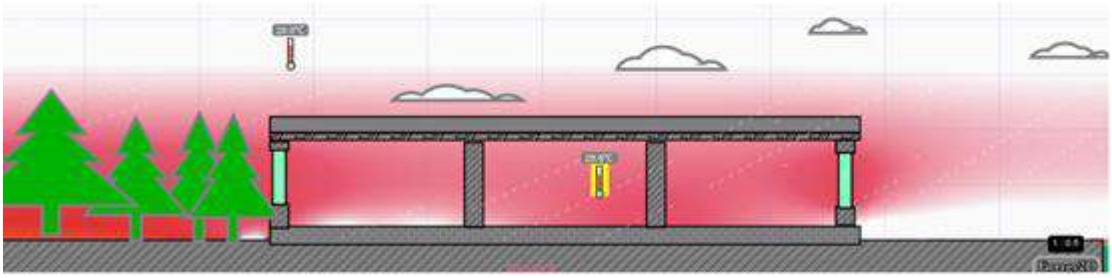

Figure 26: Working of Simulation Software in Section 2

4.7 MODEL REPRESENTATION

A model showing all elements of green building such as rainwater harvesting plant, biogas plant, grey water filter, cooling tunnel, innovative ventilation methods etc. were made.

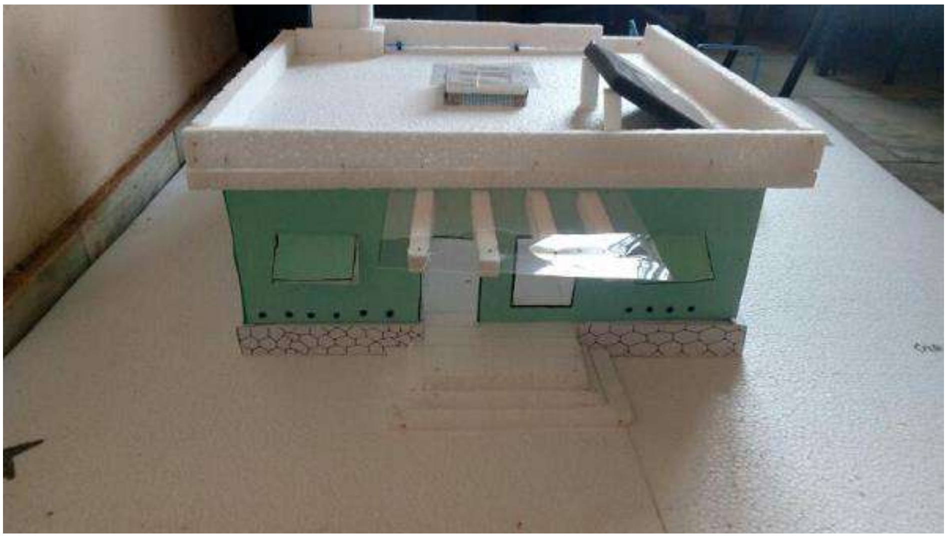

Figure 27: Front view of model

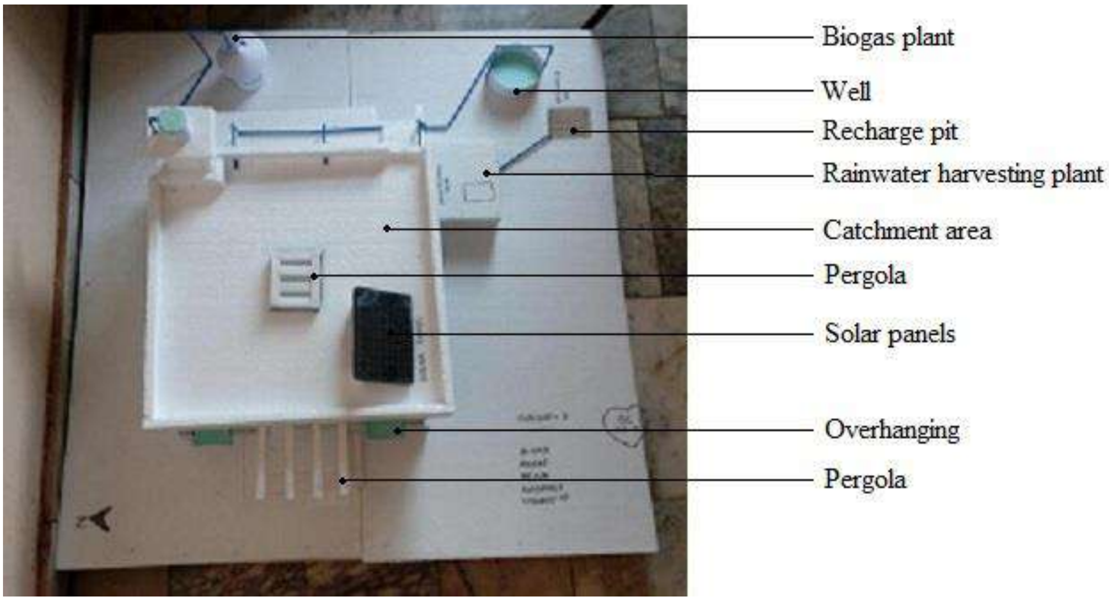

Figure 28: Top view of model

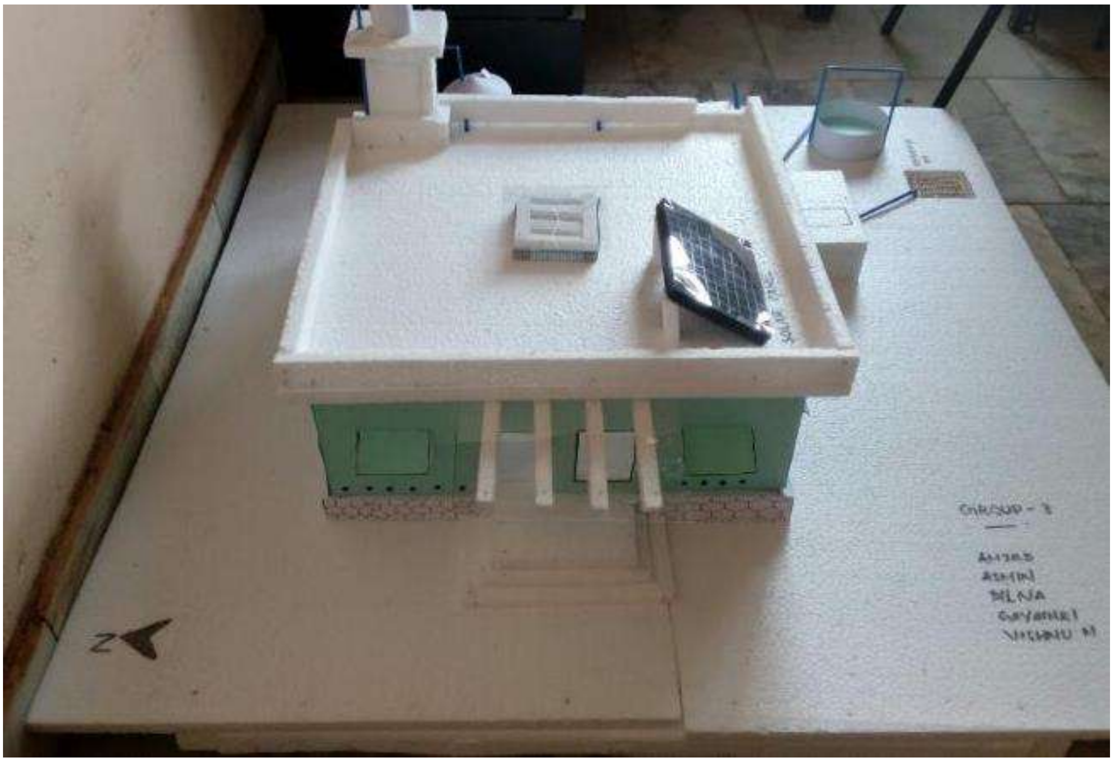

Figure 29: Elements of model (front side)

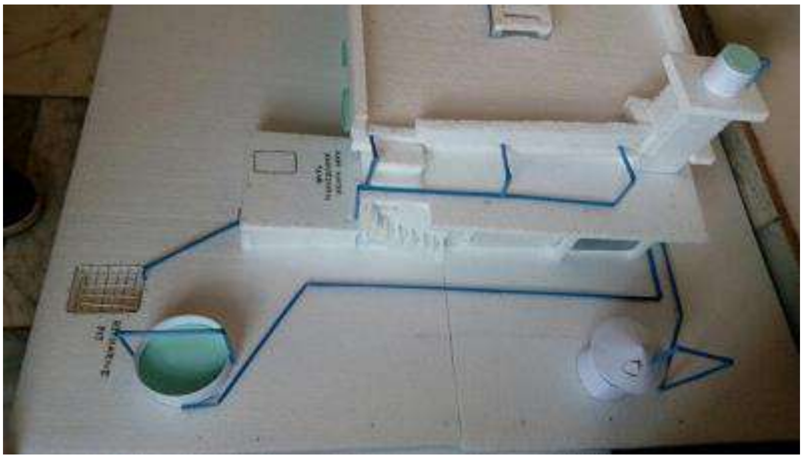

Figure 30: Elements of model (backside)

CHAPTER 5
LEED CERTIFICATION

LEED 2009 FOR EXISTING BUILDINGS: OPERATIONS & MAINTENANCE PROJECT CHECKLIST

Sustainable Sites 26 Possible Points

Credit 1	LEED Certified Design and Construction	4
Credit 2	Building Exterior and Hardscape Management Plan	1
Credit 3	Integrated Pest Management, Erosion Control, and Landscape Management Plan	1
Credit 4	Alternative Commuting Transportation	3-15
Credit 5	Site Development—Protect or Restore Open Habitat	1
Credit 6	Stormwater Quantity Control	1
Credit 7.1	Heat Island Reduction—Nonroof	1
Credit 7.2	Heat Island Reduction—Roof	1
Credit 8	Light Pollution Reduction	1

Water Efficiency 14 Possible Points

Prerequisite 1	Minimum Indoor Plumbing Fixture and Fitting Efficiency Required	
Credit 1	Water Performance Measurement	1-2
Credit 2	Additional Indoor Plumbing Fixture and Fitting Efficiency	1-5
Credit 3	Water Efficient Landscaping	1-5
Credit 4.1	Cooling Tower Water Management—Chemical Management	1
Credit 4.2	Cooling Tower Water Management—Non potable Water Source Use	1

Energy and Atmosphere 35 Possible Points

Prerequisite 1 Energy Efficiency Best Management Practices—Planning, Documentation, and Opportunity Assessment Required

Prerequisite 2 Minimum Energy Efficiency Performance Required

Prerequisite 3 Fundamental Refrigerant Management Required

Credit 1	Optimize Energy Efficiency Performance	1-18
Credit 2.1	Existing Building Commissioning—Investigation and Analysis	2
Credit 2.2	Existing Building Commissioning—Implementation	2

Credit 2.3 Existing Building Commissioning—Ongoing Commissioning 2

Credit 3.1 Performance Measurement—Building Automation System 1

Credit 3.2 Performance Measurement—System Level Metering 1-2

Credit 4 On-site and Off-site Renewable Energy 1-6

Credit 5 Enhanced Refrigerant Management 1

Credit 6 Emissions Reduction Reporting 1

Materials and Resources 10 Possible Points

Prerequisite 1 Sustainable Purchasing Policy Required

Prerequisite 2 Solid Waste Management Policy Required

Credit 1 Sustainable Purchasing—Ongoing Consumables 1

Credit 2.1 Sustainable Purchasing—Electric-Powered Equipment 1

Credit 2.2 Sustainable Purchasing—Furniture 1

Credit 3 Sustainable Purchasing—Facility Alterations and Additions 1

Credit 4 Sustainable Purchasing—Reduced Mercury in Lamps 1

Credit 5 Sustainable Purchasing—Food 1 Credit 6

Solid Waste Management—Waste Stream Audit 1 Credit 7

Solid Waste Management—Ongoing Consumables 1

Credit 8 Solid Waste Management—Durable Goods 1

Credit 9 Solid Waste Management—Facility Alterations and Additions 1

Indoor Environmental Quality 15 Possible Points

Prerequisite 1 Minimum Indoor Air Quality Performance Required

Prerequisite 2 Environmental Tobacco Smoke (ETS) Control Required

Prerequisite 3 Green Cleaning Policy Required

Credit 1.1 Indoor Air Quality Best Management Practices—Indoor Air Quality Management Program 1

Credit 1.2 Indoor Air Quality Best Management Practices—Outdoor Air Delivery Monitoring 1

Credit 1.3 Indoor Air Quality Best Management Practices—Increased Ventilation 1

Credit 1.4 Indoor Air Quality Best Management Practices—Reduce Particulates in Air Distribution 1

Credit 1.5 Indoor Air Quality Best Management Practices—Indoor Air Quality Management for Facility Alterations and Additions 1

Credit 2.1	Occupant Comfort—Occupant Survey	1
Credit 2.2	Controllability of Systems—Lighting	1
Credit 2.3	Occupant Comfort—Thermal Comfort Monitoring	1
Credit 2.4	Daylight and Views	1
Credit 3.1	Green Cleaning—High Performance Cleaning Program	1
Credit 3.2	Green Cleaning—Custodial Effectiveness Assessment	1
Credit 3.3	Green Cleaning—Purchase of Sustainable Cleaning Products and Materials	1
Credit 3.4	Green Cleaning—Sustainable Cleaning Equipment	1 Credit
3.5	Green Cleaning—Indoor Chemical and Pollutant Source Control	1
Credit 3.6	Green Cleaning—Indoor Integrated Pest Management	1

Innovation in Operations 6 Possible Points

Credit 1	Innovation in Operations	1-4
Credit 2	LEED Accredited Professional	1
Credit 3	Documenting Sustainable Building Cost Impacts	1

Regional Priority 4 Possible Points

Credit 1	Regional Priority	1-4

LEED 2009 for Existing Buildings: Operations & Maintenance

100 base points; 6 possible Innovation in Operations and 4 Regional Priority points

Table 15: LEED Certification

Certified	40–49 points
Silver	50–59 points
Gold	60–79 points
Platinum	80 points and above

Points acquired by the converted building, as per LEED Certification = 17 points

Point calculation as per LEED Certification is not completed since LEED Panel does not reveal the LEED Certification process.

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CHAPTER 6
COMPARISION OF SELECTED BUILDING WITH GREEN BUILDING

Table 16: Comparison of Green and Non-green

Item	Non-Green	Green
Rainwater Harvesting Plant	Not Present	Present
Biogas Plant	Not Present	Present
Greywater Treatment Filter	Not Present	Present
Passive Design Overhangs and Shading	Not Present	Present
Cooling Tunnel	Not Present	Present
Pergola	Not Present	Present
LEED points	2 points	17 points

Even though the initial cost of implementation of green buildings is high, it will prove to be cost effective in future. It also guarantees an eco-friendly means of livelihood.

CHAPTER 7
CONCLUSIONS

Coped with production of bio waste which can be converted to bio gas, thus reducing the burning of other fossil fuels. Effective treatment of grey water that can be used for gardening, flushing etc. Harvesting rain water in order to reduce deal with water scarcity in dry period. Effective cooling system that provides air conditioning similar to that provided by an electric air conditioner. Passive design which increases internal air flow and provides sufficient ambient light. Solar panels help to produce necessary amount of electricity for household purposes. Thermal variation is represented using energy-2D simulation software. A model representing all elements of green building were made. LEED point increased after converting the selected residential building into green building.

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