Green and energy efficient buildings – Case Study of Bangalore & Mysore

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Introduction

Green building (also known as sustainable building) refers to a structure and using process that is environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. A building which can function using an optimum amount of energy, consume less water, conserve natural resources, generate less waste and create spaces for healthy and comfortable living, as compared to conventional buildings, is a green building. Energy efficient building is a structure designed for minimal to optimum use of energy. In broad sense it also involves consideration of environmental impact, minimization of required inputs of energy, water and food, and waste output of heat, air pollution and water pollution.

In view of the higher consumption of energy and resources in urban areas, the concept of sustainable development through green buildings and energy efficiency measures in cities is gaining importance in present times.

The Ministry of New and Renewable Energy, Government of India has been set up with an aim to develop and deploy new and renewable energy for supplementing the energy requirements of the country. Government of Karnataka has set up Karnataka Renewable Energy Development Limited (KREDL) to promote non-conventional energy sources in Karnataka. Several agencies have set up rating systems and codes for qualifying a building as green or a city as energy efficient, such as LEED, GRIHA rating systems and ECBC codes.

Aim of the action research: To study the extent of green technology and concepts adopted by buildings in Bangalore and Mysore City.

Objectives:
1. To overview the rating systems and codes
2. To study one of the green and energy efficient technologies – Rain Water Harvesting and assess its cost-benefits in residential buildings
3. To study the energy efficient building materials and techniques in the buildings
4. To conduct case studies of selected buildings in Bangalore and Mysore
5. To analyse the issues in adoption of green building technologies
Methodology:
1. Broad overview of rating systems, codes and building bye-laws
2. Survey of buildings in Bangalore and Mysore- atleast 3 buildings

Outcome
The action research will assess the adoption of green building and energy efficiency concepts with particular reference to Bangalore and Mysore City and identify issues/ limitations, if any in adopting such concepts.

The viability and costs & benefits of these technologies as revealed out of the study are useful for application

Green and Energy Efficient Buildings
Green building is one that is built so as to minimise environmental impact and create healthy indoor environment for occupants. It includes minimising resources consumed by the building both during its construction as well as its lifetime. A green building may consist of one or more features either in its construction techniques or in materials used.

A green building may be a conventional house using best practices and positioning it to take advantage of the sun. Or it could be a structure built from alternative or recycled materials. It could have all of its energy needs met by alternative sources, such as wind turbines and solar panels.

Green buildings emphasize 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 green buildings include a wide range of issues including water conservation and energy efficiency, energy efficient buildings concentrate on adoption of features that minimise use of non-renewable energy. An energy efficient building is one that from design, technologies and building products uses less energy, from any source, than a traditional or average contemporary house. This includes adoption of features such as insulation, energy efficient window design to minimise/ maximise
sunlight, glare and air circulation, solar heating and lighting systems, landscaping and use of energy efficient electrical appliances.

While the practices or technologies employed in green building are constantly evolving and may differ from region to region, fundamental principles involve: Siting and Structure Design Efficiency, Energy Efficiency, Water Efficiency, Materials Efficiency, Indoor Environmental Quality Enhancement, Operations and Maintenance Optimization, and Waste and Toxics Reduction. The essence of green building is an optimization of one or more of these principles.

As per a survey conducted by Indian Green Building Council (IGBC) during 2012, Mumbai has the country's maximum number of environment-friendly buildings under construction. The city has 60% more green building projects compared to Delhi and Bangalore, which are second and third on the list. The list has six cities, including Pune, Hyderabad and Chennai. Mumbai has 319 registered projects that fall in the green building category and are spread over 229 million square feet. Delhi is second on the list with 199 projects, followed by Bangalore with 198 and Pune with 197.

There are a number of motives for building green, including environmental, economic, and social benefits. However, modern sustainability initiatives call for an integrated and synergistic design to both new construction and in the retrofitting of existing structures. This approach integrates the building life-cycle with each green practice employed with a design-purpose to create a synergy among the practices used.

Green Buildings - Need

There is a growing trend for green buildings all over the world including India. The energy crisis and environmental pollution concern in 1970s all over the world was one of the primary reasons for development of green buildings and sustainable development. Buildings account for a large amount of land. The International Energy Agency released a publication that estimated that existing buildings are responsible for more than 40% of the world’s total primary energy consumption and for 24% of global carbon dioxide emissions.

According to the International Energy Agency (IEA), the buildings sector accounted for the largest share of India’s final energy use between 1995 and 2005. In 2005, this sector consumed 47% of the total final energy use. Residential buildings accounted for the 93% of the total building energy use the same year. For sustainable
development, green and energy efficient building concept can prove invaluable for India and need to be addressed with a more collaborative approach.

India’s energy needs are expected to more than double by 2030. In the wake of this growth, energy efficiency becomes more important to reduce the financial burden of non-renewable energy sources. A study by the World Resources Institute calculated that India could reduce its annual electricity usage by 183.5 billion kilowatt hours by investing $10 billion (Rs 59,720 crore) in energy efficiency improvements.

Traditional and regional buildings were mostly GREEN. Contemporary lifestyles, standard of living and economic status, adoption of standard design and materials such as large glass facades have contributed to extensive use of energy in urban areas through use of automobiles, air conditioning systems, lighting and water. Features used in historic buildings of India such as jaalis, courtyards, stepwells and wind towers contributed a great deal towards making buildings energy efficient.

For sustainable urban development, traditional wisdom of using locally available materials and technology, simple designs, adoption of rain water harvesting, use of solar energy, segregation and reuse/recycling of wastes and greening of surfaces surrounding the buildings, help in making buildings green and energy efficient.

**Regulation and Operation – International**

As a result of the increased interest in green building concepts and practices, a number of organizations have developed standards, codes and rating systems for green building certification. In some cases, codes are written so that local governments can adopt them as byelaws to reduce the local environmental impact of buildings.

Green building rating systems such as BREEAM (United Kingdom), LEED (United States and Canada), DGNB (Germany) and CASBEE (Japan) award credits for optional building features that support green design in categories such as location and maintenance of building site, conservation of water, energy, and building materials, and occupant comfort and health. The number of credits generally determines the level of achievement.

Green building codes and standards, such as the International Code Council’s *Draft International Green Construction Code*, are sets of rules created by standards development organizations that establish minimum requirements for elements of green building such as materials or heating and cooling.
**IPD Environment Code:** The IPD Environment Code was launched in February 2008. The Code is intended as a good practice global standard for measuring the environmental performance of corporate buildings. Its aim is to accurately measure and manage the environmental impacts of corporate buildings and enable property executives to generate high quality, comparable performance information about their buildings anywhere in the world. The Code covers a wide range of building types (from offices to airports).

**ISO 21931:** ISO/TS 21931:2006, *Sustainability in building construction—Framework for methods of assessment for environmental performance of construction works—Part 1: Buildings*, intends to provide a general framework for improving the quality and comparability of methods for assessing the environmental performance of buildings. It is not an assessment system in itself but is intended be used in conjunction with, and following the principles set out in, the ISO 14000 series of standards.

**Green and energy efficient buildings – Initiatives in India**

**Energy Conservation Act 2001:** Recognizing that energy use and air pollution are important issues in India’s buildings, Indian Government enacted the Energy Conservation Act (ECA 2001), which promotes energy efficiency and conservation domestically. ECA 2001 mandated the creation of the Bureau of Energy Efficiency (BEE), authorizing BEE to establish an Energy Conservation Building Code (ECBC). Under BEE, National Building Code of India (NBC) was first issued in 2005, but the issues of energy efficiency were marginally addressed.

**ECBC by BEE:** In 2007, the Ministry of Power and The Indian Bureau of Energy Efficiency issued Energy Conservation Building Code (ECBC) —the first stand alone national building energy code in India. While it is currently voluntary, ECBC establishes minimum energy efficiency requirements for building envelope, lighting, HVAC, electrical system, water heating and pumping systems. To develop ECBC, BEE collaborated with a diverse group of domestic and international technical experts.

The code is set for energy efficiency standards for design and construction with any building of minimum conditioned area of 1000 Sq mts and a connected demand of power of 500 KW or 600 KVA. The energy performance index of the code is set from 90 kWh/sq.m/year to 200 kWh/sq.m/year where any buildings that fall under the index can be termed as "ECBC Compliant Building"
The BEE has launched a 5 star rating scheme for office buildings operated only in the day time in 3 climatic zones, composite, hot & dry, warm & humid on 25 February 2009. IGBC rated green buildings are also able to meet or exceed the ECBC compliance. The Reserve Bank of India's buildings in Delhi, Bhubaneshwar and in Kerala have been star rated. In Tamil Nadu 11 buildings were star rated by BEE, in the year 2010, including RBI buildings.

IGBC and TERI: Nonprofit organizations like The Indian Green Building Council (IGBC) which is a part of Confederation of Indian Industry, The Energy and Resources Institute (TERI) are actively promoting green buildings in India. IGBC has adopted the LEED (The Leadership in Energy & Environmental Design) certification and TERI has developed GRIHA (Green Rating for Integrated Habitat Assessment) rating system. A whole-building approach to sustainability is rated by addressing performance in the following areas:

- Sustainable site development
- Water savings
- Energy efficiency
- Materials selection
- Indoor environmental quality.

GRIHA rating system consists of 34 criteria categorised 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.

LEED-India has adopted several benchmarks for building performance. The rating levels “Platinum,” “Gold,” “Silver,” and “Certified” indicate the extent to which a building excels the requirements of the National Codes.

IGBC has launched different rating programmes to suit variety of building types such as IGBC Green Homes, IGBC Green Factory Building, IGBC Green SEZs, IGBC Green Townships, LEED 2011 for India-New Construction, LEED 2011 for India-Core & Shell.
IGBC has also launched a first-of-its-kind rating system to address sustainability aspects in existing buildings.

**IT/ ITeS companies:** Over last few years, IT/ITeS has been a primary contributor in the acceptance and development of green buildings. The Turbo Energy Limited’s (TEL) R&D and Administration block in Paiyanur, Chennai, has been certified by LEED as the greenest building in India and 2nd greenest in the world. Other prominent green projects include ITC Green Centre (Gurgaon), IGP Office Complex (Bengaluru), Kalpataru Square (Mumbai) and CII-Godrej Green Business Centre (Hyderabad).

**Comparison of LEED and GRIHA:**
LEED is a well established and internationally renowned rating system and is also the most favoured rating system among the private sector. However, it faces criticism for being too American as the United States Green Building Council (USGBC) has not allowed it to be indigenized enough for it to work well in the local context. For example, water is a critical resource in India but LEED offers far fewer points for water conservation in comparison to GRIHA.

GRIHA on the other hand is made in India, and thus is supposed to have many criteria that make more sense in the Indian context, such as compliance criteria for worker safety and well being.

GRIHA is said to be more organized, user-friendly and customized than the LEED India rating system, which is documentation intensive.

**Private buildings:** Both the LEED and GRIHA green building rating systems are voluntary certifications for private sector buildings. Aside from eco-friendly design, construction, and operation processes, the key benefits of both systems are operational energy savings and marketability.

**Public buildings:** GRIHA rating compliance is mandatory for all new CPWD and Govt. of India and PSU projects.

**Cost of ratings:** The cost of obtaining ratings under both LEED and GRIHA are similar and will usually range between Rs.3,50,000 to Rs.5,50,000 depending on the size of the project.

**GRIHA:**
- For projects up to 5,000 sq.m built up area – Rs. 3,14,000 + 12.36% tax
- For built up area more than 5,000 sqm – (Rs. 3,14,000 + 3.75/ sqm) + 12.36% tax
**LEED:**
- INR 25000 for members and INR 30000 for non-members; Certification fee varies by size.

**Financial incentives:** Many State Governments have adopted incentives to promote green buildings. Some of them are

- 10% property tax rebate for occupants of GRIHA-compliant homes in Pimpri, Chinchwad, Maharashtra; 50% rebate for the premium paid by developers in this region is possible
- Registration fee is waived for Government and PSU projects by MNRE
- For building in Kolkata, GRIHA pre-certified buildings can fast-track environmental pre-clearance. Annual awards and incentives to consultants are also available. Depending on the rating level and size, up to 90% of the registration and certification fees can be reimbursed
- The Noida authority awards 1% extra floor area ratio to buildings that commit to LEED Gold certification

**Banks:** A key supportive role is shown by India’s biggest bank, SBI is offering concessions on constructing green developments (lower upfront margin up to 5-10%, and reduction in interest rate by 0.25%) that could start similar trend across industry.

**Green Buildings in India – Scenario:**

Indian green building has grown significantly since 2003, when India only had 20,000 square feet of green building. Now, it has about 461 rated green buildings under LEED and more than 400 rated buildings under GRIHA. India has the second largest market for sustainable construction in the world.

The growth of green building in India is partially due to a decrease in costs. In 2003, building green was 18 percent more expensive than traditional building, and now it is only 5 percent more expensive.
CASE STUDY – MYSORE

Rainfall and climate of Mysore

Mysore district receives an average rainfall of 800 mm with maximum intensity of rainfall being 50mm per hour. There are 53 rainy days in the district and on an average about 50% of annual rainfall occurs during the southwest monsoon period. The rainfall generally decreases from west to east. The coefficient of variation is around 30% in the west to above 35% in the east, indicative of consistent rainfall in the west as compared to the east.

The pre-monsoon rainfall is more consistent than the post-monsoon rainfall. The southwest monsoon had been normal from 1994 onwards till 1999, excessive during 2000 and deficient thereafter. The northwest monsoon is much better comparatively being excessive to normal during the recent past. Over all on an annual basis, there are more normal to excessive rainfall years than deficient ones. While during 1997, 1999, 2000 and 2005, the district received excess rainfall, during 1998, 2001, 2002, 2003 and 2004, it was normal and only during 2006, the district received deficient rainfall.

The average minimum and maximum temperatures vary from 34 to 21.4°C in April to 16.4 to 28.5°C in January. Relative humidity ranges from 21 to 84%. Wind speed ranges from 7.9 in October to 14.1 kmph in July. Annual potential evapotranspiration is 1533.5 mm. The PET is less than the monthly mean rainfall during the months of July, September and October in different taluks, thereby indicating availability of water surplus for recharge to ground water & reuse of rain water.

RAIN WATER HARVESTING

Introduction

Water is essential to all life forms on earth - human, animal and vegetation. It is therefore important that adequate supplies of water be developed to sustain such life. Development of water supplies should, however, be undertaken in such a way as to preserve the hydrological balance and the biological functions of our ecosystems. Consequently, the human Endeavour in the development of water sources must be within the capacity of nature to replenish and to sustain. If this is not done, costly mistakes can occur with serious consequences. The application of innovative technologies and the improvement of indigenous ones should therefore include management of the water sources to ensure sustainability and to safeguard the sources against pollution.
As land pressure rises, cities are growing vertical and in countryside more forest areas are encroached and being used for agriculture. In India the small farmers depend on Monsoon where rainfall is from June to October and much of the precious water is soon lost as surface runoff. While irrigation may be the most obvious response to drought, it has proved costly and can only benefit a fortunate few. There is now increasing interest in the low cost alternative—generally referred to as 'Rain Water Harvesting' (RWH).

Water harvesting is the activity of direct collection of rainwater, which can be stored for direct use or can be recharged into the groundwater. Water harvesting is the collection of runoff for productive purposes. Rain is the first form of water that we know in the hydrological cycle, hence is a primary source of water for us. Rivers, lakes and groundwater are all secondary sources of water. In present times, we depend entirely on such secondary sources of water. In the process, it is forgotten that rain is the ultimate source that feeds all these secondary sources and remain ignorant of its value. Water harvesting is to understand the value of rain, and to make optimum use of rainwater at the place where it falls.

**Need for Rainwater Harvesting**
- As water is becoming scarce, it is the need of the day to attain self-sufficiency to fulfil the water needs.
- As urban water supply system is under tremendous pressure for supplying water to ever increasing population.
- To reduce urban flooding
- Groundwater is getting depleted and polluted.
- Soil erosion resulting from the unchecked runoff.
- Health hazards due to consumption of polluted water.

**Feasibility for Rainwater Harvesting**
The following questions need to be considered in areas where a rainwater cistern system project is being considered, to establish whether or not rainwater catchment warrants further investigation:
- Is there a real need for an improved water supply?
- Are present water supplies either distant or contaminated, or both?
- Do suitable roofs and/or other catchment surfaces exist in the community?
- Does rainfall exceed 400 mm per year?
- Does an improved water supply figure prominently in the community's list of development priorities?
If the answer to these five questions is yes, it is a clear indication that rainwater collection might be a feasible water supply option.

**Benefits of Rainwater Harvesting**
- Environment friendly and easy approach for water requirements
- RWH is the ideal solution for all water requirements.
- Increase in ground water level.
- Mitigates the effects of drought.
- Reduces the runoff, which otherwise flood storm water drains.
- Reduces flooding of roads and low-lying areas.
- Reduced soil erosion.
- Improves the ground water quality.
- Low cost and easy to maintain.
- Reduces water and electricity bills.

**Who can harvest rainwater? And where?**
- People planning construction of House, Modification of house, existing house, etc. from rooftops.
- Govt. Buildings, Institutions, Hospitals, Hotels, Shopping malls etc. from rooftops and open areas.
- Farmlands, Public Parks, Playground, etc.
- Paved and unpaved areas of a layout / city / town / village

**Rainwater Harvesting in Different types of Buildings**

Normally, debris, dirt and dust get deposited on the roof during non-rainy periods. When the first rains arrive, this unwanted material will be washed into the storage tank. This may cause contamination of water collected in the storage tank thereby rendering it unfit for drinking and cooking purposes. Therefore, a first flush system can be incorporated in the Roof top Rainwater Harvesting Systems (RRHS) to dispose of the first flush so that it does not enter the tank. There are two such simple systems. One is based on a simple manually operated arrangement whereby, the down pipe is moved away from the tank inlet and replaced again once the first flush water has been disposed. In another simple and semi automatic system, separate vertical pipe is fixed to the down pipe with a valve provided below the T junction. After the first rain is washed out through the first flush pipe the valve is closed to allow the water to enter the down pipe and reach the storage tank.
**Sloping roofs**

Roofs made of corrugated iron sheet, asbestos sheet or tiles can be utilized for harvesting the rainwater. Gutters and channels can be fixed on the edges of roof all around to collect and transport the rain water from the roof to the storage tank. Gutters can be prepared in semi-circular and rectangular shapes. Locally available material such as plain Galvanized Iron sheets can be easily folded to required shapes to prepare semi-circular and rectangular gutters. Semi-circular gutters of PVC material can be readily prepared by cutting the PVC pipes into two equal semi-circular channels. Bamboo poles can also be used for making gutters if they are locally available in sufficient quantity. Use of such locally available materials reduces the overall cost of the system.

**For Thatched Roofs : Step by step approach**

| If the roof is thatched, polythene sheets can be used for collecting the rainwater | The collected rainwater is filtered through a filter filled with pebbles in the bottom and coarse sand on the top | The filtered water is collected either in storage tank of existing sump and the overflow water may be diverted to percolation pit nearby. |

**For Sloping / Tiled Roofs : Step by step approach:**

| In a slopped/tiled house the rainwater from the roof is collected through the gutter in the roof. | The collected water is filtered through a filter filled with pebbles in the bottom and coarse sand on the top. | The filtered water is collected either in a storage tank or existing sump. Over flow water may be diverted to an existing open well / bore well or percolation pit. |
**For common houses with RCC roof: Step by Step approach**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong></td>
<td>In houses with sloping roofs the rain water may be collected to the half cut PVC pipes fitted along the sloping sides and it may be directed to either sump/open well/bore well or recharge well.</td>
</tr>
<tr>
<td><strong>2.</strong></td>
<td>Check the weather the rain water drain pipes extend up to the bottom of the building.</td>
</tr>
<tr>
<td><strong>3.</strong></td>
<td>Interconnect the rainwater drainpipes if there exist more than one.</td>
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<tr>
<td><strong>4.</strong></td>
<td>To collect rainwater in a sump construct a filter chambers of size 2/1/2’ * 2/1/2’ * 2/1/2’</td>
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<tr>
<td><strong>5.</strong></td>
<td>The bottom half of the filter chamber has to be filled either with broken bricks/bluemental/pebbles and followed by one feet of coarse river sand. A nylon mesh has to be provided in between the two layers. The top portion of the filter chamber should be covered with RCC slab.</td>
</tr>
<tr>
<td><strong>6.</strong></td>
<td>The inlet rainwater drain pipe should be on the top of the filter chamber and the outlet pipe connecting the filter chamber to the sump should be at the bottom.</td>
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**Technical Description**

A rainwater harvesting system consists of three basic elements: A collection area, a conveyance system, and storage facilities.

**The collection area** in most cases is the roof of a house or a building. The effective roof area and the material used in constructing the roof influence the efficiency of collection and the water quality.

**A conveyance system** usually consists of gutters or pipes that deliver rainwater falling on the rooftop to cisterns or other storage vessels. Both drainpipes and roof surfaces should be constructed of chemically inert materials such as wood, plastic, aluminum, or fiberglass, in order to avoid adverse effects on water quality.

**The water ultimately is stored** in a storage tank or cistern, which should also be constructed of an inert material. Reinforced concrete, fiberglass, or stainless steel are suitable materials. Storage tanks may be constructed as part of the building, or may be built as a separate unit located some distance away from the building. Figure 1 shows a schematic of a rooftop catchment system in the Dominican Republic.

**Design Principles**

The roof needs to be designed well for rainwater collection. A flat roof can be gently sloped to drain water towards the storage system. A 'nahani trap' or 'floor trap' can be placed at the time of casting the roof just near the inlets of the down water

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| Surplus spill over water from the sump may be connected with the existing open well/borewell or to the recharge well. | In the absense of sump,filter champer may be connected to the existing open well / borewell. | In the absense of sump,open well and bore well the rain water may be recharged through percolation pits and the bottom of bit should be in the sandy formation. |
pipes Sloping roofs should have a gutter of PVC or zinc sheet to collect water & channel it to the down water pipe system.

Roofs should be uncluttered & should be easy to clean by sweeping & swabbing if necessary. Down water pipes should be preferably with 90mm dia. PVC pipes resistant to UV rays appear to be the best bet as down water pipes. Of course, this depends upon the roof area to be drained. 3 to 4 down water pipes seem sufficient for 1000 to 1200 sft area. Filter the rainwater before storage. Filtering can be as basic as a floor trap placed before the water enters the down water pipe or a piece of sponge placed at the inlet of the down water pipe.

- PVC bucket with gravel, sand & charcoal is a good filter before rainwater is stored
- PVC drum with sponge at the inlet & outlet is also a filter
- Small two chamber inspection/ filter tank can also be devised

Storage system should be determined at the planning stage itself. Would it be a:

- Roof level storage tank
- Ground level drum or masonry tank
- Below the ground sump
- Partially below ground and partially above ground tank
- Locate the storage system properly
- Roof level storage tanks may need to be at the rear of the house or on the sides so that it is neither obtrusive nor visually offensive.
- Ground level drums or tanks occupy space and should not hinder movement or appear unsightly.
- Below the ground sump is a good option since most new constructions in Bangalore/Mysore go in for sumps anyway. Sumps are hidden from view, less costly to build and do not obstruct movement.

Note: An outlet for excess collection of water from the storage system should be always provided.

Further treatment of excess rainwater

It is a common perception that water stored for long goes bad. If water does not contain any organic material and if it is stored in a clean container it can stay for a long time. Some small treatment like ‘alum dosing’ or ‘chlorination’ can also be done to stored water to improve its quality. Addition of a small quantity of alum dissolved in half a bucket of water will bring down the suspended solids and clear the stored rainwater.
Similarly adding a small quantity of bleached powder to half a bucket of water and then mixing it with the stored rainwater will kill bacterial contamination. Great care should be exercised while chlorinating and it is not particularly recommended.

It is always recommended that water used for drinking should be boiled and filtered invariably and cooking but only after boiling and filtering the water.

**Tanks**

The size of the tank is dependent on the amount and purpose of the water but also of the annual rainfall and the size of the roof. A normal sized tank for a roof of 20 to 40 square metres is 10 cubic metres.

All rainwater tank designs should include as a minimum requirement:

- A solid secure cover
- A coarse inlet filter
- An overflow pipe
- A manhole, sump, and drain to facilitate cleaning
- An extraction system that does not contaminate the water; e.g., a tap or pump
- A soak away to prevent spilled water from forming puddles near the tank
- Additional features might include:
  - A device to indicate the amount of water in the tank
  - A sediment trap, tipping bucket, or other "foul flush" mechanism
  - A lock on the tap
  - A second sub-surface tank to provide water for livestock, etc

**Plastic tanks:** Available as finished products in various capacities. The cost of these tanks ranges from Rs. 2/litre to about Rs. 3.5/litre. Conduits are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Conduits can be of any material like polyvinyl chloride (PVC) or galvanized iron (GI), materials that are commonly available.

All catchment surfaces must be made of nontoxic material. Painted surfaces should be avoided if possible, or, if the use of paint is unavoidable, only nontoxic paint should be used (e.g., no lead-, chromium-, or zinc-based paints). Overhanging vegetation should also be avoided.
Figure 1: Schematic of a Typical Rainwater Catchment System

**Design of storage tank:**

Design parameters of storage tanks are

1. Average annual rainfall \( R \) in m
2. Size of the catchment \( A \) in sq m.
3. Run-off coefficient \( C \)
4. Water \( D \) in litre = no. of residents x lpcd x 365 days

Annual water harvesting potential = \( A \times R \times C \)

The tank capacity is considered based on amount of rain water harvested and water requirement for household, usually 10% of the annual water potential is considered to decide the capacity of storage tank.

**Flood Mitigation by Rainwater Harvesting**

It is required to mitigate the excess runoff problems at source both in terms of quantity and quality which is the key for controlling flood hazards and should form the basic principle for revamping and designing of drainage system. Municipalities need to implement structural and non-structural mitigation measures to control intense runoff volume and resultant flooding. Following strategies are needed;

1. To conserve storm runoff: Implement technologies and structures that help collection and storage of storm runoff for different domestic and non-domestic uses and infiltration to ground for ground water recharge. Filtration pits will absorb rainfall volume to the extent of 20 to 30%. Rain water harvesting
structure can store water to the extent of 30,000 to 70,000 litres for a house located on 1200 Sq.ft site with an annual rainfall of 800mm

2. **To protect Quality of storm water storage/infiltration:** As runoff from roads is mixed with inorganic and organic wastes/pollutants, it is necessary to adopt appropriate treatment before its use if stored for domestic use.

**Case example of Onsite Technology to prevent Flood: Rain Water Harvesting Structure**

For instance, in Mysore where the average annual rainfall is assumed as 800mm per year and the collection rate of 80%, the rain water yield for a roof area of 150 Square Metre=150x0.80x0.80.00=96 Cubic Metres or 96000 Litres.

**Water Harvestable from a single rain of 50mm/hour intensity**

Tank Volume=150x0.05x0.80 =6.00 cubic metre or 6000 litres

Considering 10% of Water Harvestable per year-0.1x96000=9600 litres

From the above example, it is seen that for a house of 150 Sq. Mts of roof area in Mysore, the owner can collect and store water up to 6000 litres per each rainfall of 50 mm/hour and save water bill to this extent. Or if cost permits to have bigger water tank, the owner can save and store about 90000 Litres per year. More importantly, this much of water from each house of this size will be prevented from entering the roads which ultimately would have caused flash floods. The City Corporation needs to implement this strategy for all types houses starting from 30X40 sft such as gardening, washing, toilets flushing etc.

**Operation and Maintenance**

Rainwater harvesting systems require few skills and little supervision to operate. Major concerns are the prevention of contamination of the tank during construction and while it is being replenished during a rainfall. Contamination of the water supply as a result of contact with certain materials can be avoided by the use of proper materials during construction of the system. Use of alternative roofing materials would have avoided this problem. The main sources of external contamination are pollution from the air, bird and animal droppings, and insects. Bacterial contamination may be minimized by keeping roof surfaces and drains clean but cannot be completely eliminated. If the water is to be used for drinking purposes, filtration and chlorination or disinfection by other means (e.g., boiling) is necessary.
The following maintenance guidelines should be considered in the operation of rainwater harvesting systems:

- A procedure for eliminating the "foul flush" after a long dry spell deserves particular attention. The first part of each rainfall should be diverted from the storage tank since this is most likely to contain undesirable materials which have accumulated on the roof and other surfaces between rainfalls. Generally, water captured during the first 10 minutes of rainfall during an event of average intensity is unfit for drinking purposes. The quantity of water lost by diverting this runoff is usually about 14l/m² of catchment area.

- The storage tank should be checked and cleaned periodically. All tanks need cleaning; their designs should allow for this. Cleaning procedures consist of thorough scrubbing of the inner walls and floors. Use of a chlorine solution is recommended for cleaning, followed by thorough rinsing.

- Care should be taken to keep rainfall collection surfaces covered, to reduce the likelihood of frogs, lizards, mosquitoes, and other pests using the cistern as a breeding ground. Residents may prefer to take care to prevent such problems rather than have to take corrective actions, such as treating or removing water, at a later time.

- Chlorination of the cisterns or storage tanks is necessary if the water is to be used for drinking and domestic uses.

- Gutters and downpipes need to be periodically inspected and cleaned carefully. Periodic maintenance must also be carried out on any pumps used to lift water to selected areas in the house or building. More often than not, maintenance is done only when equipment breaks down.

- Proper ventilation should be provided for storage tank and proper care should be taken to avoid entry of insects to it.

As has been noted, in some cases the rainwater is treated with chlorine tablets. However, in most places it is used without treatment. In such cases, residents are advised to boil the water before drinking. Where cistern users do not treat their water, the quality of the water may be assured through the installation of commercially available in-line charcoal filters or other water treatment devices. Community catchments require additional protections, including:
Fencing of the paved catchment to prevent the entry of animals, primarily livestock such as goats, cows, donkeys, and pigs, that can affect water quality.

Cleaning the paved catchment of leaves and other vegetative matter.

Repairing large cracks in the paved catchment as a result of soil movement, earthquakes, or exposure to the elements.

Maintaining water quality at a level where health risks are minimized. In many systems, this involves chlorination of the supplies at frequent intervals.

**General Costing**

The cost of this technology varies considerably depending on location, type of materials used, and degree of implementation. The cost of the system depends on the size of storage tank based on its capacity for its construction and the pipe network for conveyance.

**Suitability**

This technology is suitable for use in all areas as a means of augmenting the amount of water available, thereby reducing the dependence on public water supply.

**Disadvantages**

- The success of rainfall harvesting depends upon the frequency and amount of rainfall; therefore, it is not a dependable water source in times of dry weather or prolonged drought.

- Low storage capacities will limit rainwater harvesting so that the system may not be able to provide water in a low rainfall period. Increased storage capacities add to construction and operating costs and may make the technology economically unfeasible, unless it is subsidized by government.

- Rainfall harvesting systems may reduce revenues to public utilities.

**Methods of rain water harvesting**

- Rainwater stored for direct use in the tanks above ground or underground sumps /overhead tanks and used directly for flushing, gardening, washing etc.
Recharged to ground through recharge pits, dug wells, bore wells, soak pits, recharge trenches, etc. (Ground water recharge)

**Government policies on Rain water harvesting in Karnataka**

The government of Karnataka has introduced the rain water harvesting as one of the mandatory requirements under Nirmal Nagar Scheme.

> “On October 28 2004, the Mysore City Corporation (MCC) made rain water harvesting compulsory for new buildings. Mahanagara Palike byelaws say that rain water harvesting is mandatory in any new building. The byelaw states that “Every building with a plinth area of exceeding 100sq-m should implement rain water harvesting to that building”.”

**CASE STUDY OF BUILDINGS - MYSORE:**

Two buildings have been selected for case study in Mysore – one residential and another non residential.

As per the detailed study of rain water harvesting system, in the residential building, rainwater harvesting system adopted has been studied in detail. Alternate materials and technology adopted has also been studied.

In the non-residential building, a health resort in Mysore – the Village, considered as one of the green buildings has been studied in the overall context of planning and design, materials used, and green technology adopted.

Objectives:

1. To study the rain water harvesting system in Mysore city
2. To assess the Cost Benefits of Rain water harvesting in Residential Houses
3. To study the benefits of alternative and eco-friendly construction materials and techniques adopted in the buildings
4. To understand the issues in adoption of alternate technology and materials
Case study 1:

**Green Technology and Rain Water Harvesting – A Case Study of a Residential Building in Mysore**

- OWNER: SRI. RAVIKUMAR
- LOCATION: BOGADHI 2ND PHASE, MYSORE
- NO. OF FLOORS: GROUND PLUS ONE

The residential building considered for case study is located in Bogadhi IInd phase, Mysore. The owner of this house is Mr Ravi Kumar, former director of CART, NIE Mysore. The building is of ground and first floor in which 103.83sqm is of flat roof and considered for rain water harvesting. The no. of residents are four.
Design consideration:

- Number of residents - 4 no.
- Per capita demand as per standards - 135 lpcd
- Total water requirement per year = 4 \times 135 \times 365 = 197100 \text{ litres/year}
- Amount of rainfall in Mysore city = 800\text{mm/year} (as per statistical dept.)
- Coefficient of runoff = 0.90 for tiled roof.
- Amount of water collected from roof top
  
  \[ = 103.83 \times 0.80 \times 0.90 = 74.76\text{cu.m} \text{ or } 74760 \text{ litres/year} \]

As per the availability of space only 4000 litre capacity storage tank is constructed at first floor.

Note: Usually it is economical to construct the storage tank having capacity of 10\% of the total amount of rain water collected from the roof top per year i.e., it can be taken up to 7476 litres capacity of storage tank.
The above fig shows the Filtering unit and first flush tank.

The conical mesh is used to arrest the leaves and other particles. The first flush unit is used to drain off the first rain water which contains dust and other rooftop impurities and the water thereby enters the filter unit. The filter unit consists of perforated inlet and outlet pipes, a layer of 20-25mm dia pebbles of 100mm thick below sand layer of thickness of 300mm. Fine nylon mesh should be provided in between the coarse and fine filtering media in order to avoid the blockage of the system. This is shown in fig below.
Periodical maintenance

- The roof top should be kept clean well before the rainy season.
- The filter media consisting of sand should be cleaned once a year for better filtering, preferably once before starting of rainy season.
- The sand taken for wash should be dried well in sunlight to get free from microbial activity.
SITE VISIT PHOTOS
Benefits

- Consumption of electricity is reduced due to provision of rain water storage tank in the first floor and making water to flow with the gravity, thereby pumping of water is nullified.

- Minimum use of water from public water source i.e., from MCC. In a year 8 months rain water is being used and rest of the months water is used from public source.

- Rain water can be stored for long period as it doesn’t contain any nutrients which lead to growth of micro organisms but care should be taken to avoid sun light to enter which leads to the growth of algae.

Costing

The cost of this technology varies considerably depending on location, type of materials used, and degree of implementation. The cost of the system depends on the size of storage tank based on its capacity for its construction and the pipe network for conveyance.

In this case study it costs about Rs 6.00 to 7.00 per litre of tank capacity. This is just an initial investment and used for long term. There are no maintenance charges as such in this system, because the same filter media can be used again and again by washing it once in a year which increases its efficiency.

General planning, safety and energy efficiency

The planning stage is crucial in any project and at the stage of planning a house, care has been taken to keep the shape of the plan square, rectangular and symmetric. This would help in reducing the cost and symmetric plan would keep the building resistant against earthquake. Location of openings in the house and materials used for construction provided natural light, ventilation and thermal comfort all the time to the occupants and must satisfied the dweller needs. Interior of a house be given adequate attention rather than Exteriors. Exterior must be kept simple and protected from rain, flood, wind, cyclone and theft. Time, material & labour intensive components in exterior such as ornamental borders, art work on wall and sunshades, putting unsymmetrical and costly elevations in the name of architecture etc., are avoided.
**Eco-friendly construction materials techniques used**

The selection of construction technology and choice of building materials for rural housing/buildings are generally based on the traditional methods of construction, skills and availability of cheaper local building materials. The cost of building materials like cement, bricks, sand, aggregates, steel and wood etc., are increasing every year and the fact that production of these materials has also been the major contributor to climate change as the industries manufacturing these materials produce large scale CFCs.

Moreover, it is to be noted that the Nirmithi Kendras or Building Centres were set up by the GoI and HUDCO with main objective of reaching the poor and the low income groups with affordable, environmental friendly, locally available and appropriate housing solutions. This calls for innovative application of technology and research including up-gradation of traditional skills of the local masons, petty contractors and engineers/architects. But the Building Centre/ Nirmithi Kendra is constructing most of the housing units by beams and columns consuming huge steel and cement in JNNURM projects in Mysore which are Ground plus 2. For simple buildings and houses, we can go for load bearing walls using local stones, bricks or stabilized soil blocks.

In this building, boulder filling is done for foundation in place of regular size stone masonry. This has worked out cheaper as compared to SS masonry. Walls are built with soil cement stabilized blocks with 6 % cement in soil. These blocks are produced on the site using the Block making machine. These blocks are worked out cheaper and about 30 percent cost reduction is achieved in comparison to Bricks.

The walls are load bearing and as can be seen in the photo, these outside wall surfaces are not plastered but painted with Apex paint which is water resistant to some extent. As can be seen in the photo, no erosion of wall surface took place so far.

Inside the building, the wall surfaces are plastered wherever electric conduits, pipes and other such fixtures are laid internally, which need to be plastered. The residents of the building expressed that they enjoy thermal comfort in the house as a result of mud block construction. The roofs are made of filler slab. Below the neutral axis in the slab, the concrete is replaced by split tiles in two layers thereby leaving a void. This system of slab not only helps in reducing the cost by 25% but also makes the ceiling appear beautiful & architecturally aesthetic.

The filler material provides thermal comfort to the residents. Brick arch lintels in place of RCC are used over the doors and windows thereby saving in the cost of
Steel and concrete. In order to prevent the heat emission from the roof, hollow clay tiles are laid over the roof surface as can be seen from the photo.

**Stabilized Mud Block Walling**

Soil is the versatile material and its strength when used as a building block is improved by mixing one or combination of lime, cement (Pozzolana Cement), Fly ash, gypsum and sand in appropriate proportions so as to get adequate compressive strength as a load bearing unit. For houses of one to two storeys, the plain soil stabilized blocks of compressive strength is 20-30 Kg/Sq.cm will be adequate for load bearing walls as the stress at the plinth level is about 5-6 Kg/Sq.cm. It is an alternative method of construction of walls using soil cement blocks in place of burnt brick masonry. It is an energy efficient method of construction where soil mixed with 5% cement and pressed in hand operated machine and cured well and then used in the masonry. This masonry doesn’t require plastering on both sides of the wall.

The overall economy that could be achieved with the soil cement technology is about 15 to 20% compared to conventional method of construction. These blocks are used by MNK for housing projects wherever soil is good. Red soil and laterite soil are good. The size of the blocks are 305X143X100mm or 230X190X100 mm. These blocks are 2.5 times the normal burnt bricks. Both manually operated and hydraulically operated machines are available.

**Advantages**

1. These are energy efficient and do not require burning. 70% energy saving when compared to burnt bricks
2. 20-40% savings in cost when compared to brick masonry
3. Plastering can be eliminated
4. Better block finish and aesthetically pleasing appearance
5. Soil from the site can be used to make the blocks
6. Only cost of labour

The table below explains the extent of energy saving and consequent reduction in the emission of carbon dioxide for small area of 50 sq.m of construction using rat trap/cavity bond walling, filler slab and brick arch for lintels. It is seen that 2.4 tons of carbon dioxide emission can be prevented with the use of these techniques.
Reduction in CO2 emission for a 50 sq.m building (Source: Auroville BC)

<table>
<thead>
<tr>
<th>Building material required by conventional method</th>
<th>Reduction by using cost-effective construction technology (rat trap bond wall, brick arch and filler slab)</th>
<th>Reduction in carbon dioxide emission (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick- 20,000nos</td>
<td>20%, i.e 4000 nos</td>
<td>1440</td>
</tr>
<tr>
<td>Cement- 60 bags or 3.0 t</td>
<td>20%, i.e. 0.6 t</td>
<td>540</td>
</tr>
<tr>
<td>Steel- 500 kg or 0.5t</td>
<td>25%, i.e. 0.125 t</td>
<td>375</td>
</tr>
<tr>
<td>Total reduction in carbon dioxide emission</td>
<td></td>
<td>2355 (say 2.4 t)</td>
</tr>
</tbody>
</table>

Conclusion

Rain water harvesting has gained momentum through individual efforts to adopt towards water self sufficiency and to meet the ever increasing demands of both urban and rural areas. The use and availability of rain water is a sustainable alternative in places where pollution of water which is the major cause of health problem. With all these issues it is understood that the rain water is the future water because drinking water exhaustion may take place due to ground water depletion and water pollution in rivers and tanks. So, it is necessary to adopt rain water harvesting with cost effective technique to save and conserve the precious natural resources.

The alternative and low cost eco-friendly local materials and techniques such as foundation with boulder filling, Brick arch lintels, soil-cement stabilized blocks for load bearing walls, filler RCC slab for roofing, hollow clay tiles for roofing surface, rain water harvesting have all contributed in making this building an eco-friendly, energy efficient structure.

Implementation of RWH system throughout the city reduces 2/3rd of water dependency on MCC as we came to know from this case study.

It is the better alternate water source in dry areas.

Energy efficient construction and materials not only reduce the cost but also to a great extent contribute towards thermal comfort.
Case study 2: The Village, Mysore

- ARCHITECT: DR. BS BHOOSHAN
- LOCATION: NANJANGUD ROAD, MYSORE
- TYPE: RESORT
- BUILT IN: 1990
- RATING: 30 POINTS (SILVER)

The village is a health resort located in southern part of Mysore city at the foot of the Chamundi hill on the Bangalore-Nilgiri highway which is having wonderful scenic beauty. It is designed by Architect Dr. BS Bhooshan, an Architect based in Mysore who is known for designs and construction that will have the least overall impact on both human health and the environment.

The complex is located on main road and thereby exposed to high noise and pollution. Efforts have been made to reduce these effects through adoption of green concepts. The concept involves creating green structures using a combination of simple home-grown techniques and well established traditional green practices.

The project won the JIIA award for Excellence in Architecture from the Indian Institute of Architects in 1994 and The South Asian Award for Excellence in Architecture in 1999.

The facilities include rooms, dining, Jacuzzi, multigym, outdoor play areas, indoor games, conference hall, board room and amphitheatre.
GREEN CONCEPTS USED:

SITE DESIGN:

Buildings are interspersed with large open spaces which house lawns and plants/trees. Open space and landscape area act as lung space. The windows of rooms and balconies face the landscape. The site has about 80% of green cover, which helps in reduction of temperature and effect on microclimate.

BUILDING DESIGN:

- Major building orientation is north and south and wall exposed to east and west is minimal. The entrance to the building is east facing. The North-South orientation helps in avoiding direct sunlight and glare. All the verandas and balcony face towards north. Entry to the balcony is provided with a glass door which provide good natural lighting and no fans are used for ventilation in toilets and bath room.

- Pergola is used on south side to reduce heat and allow balanced light with diffusion.

- Longer span is achieved by steel truss of minimum steel numbers

- Well balanced natural colours are used for buildings.

- Windows are designed in such a way that chajjas are not required and even in case of rain window design reduces splashing.

- Painting used in minimum.

- In common toilets in restaurant they are no windows; only openings are provided to reduce cost.

BUILDING MATERIALS:

- Bricks are prepared by using locally available mud.
doors and windows are reused from old buildings and scrap materials.

roof with wooden rafters reduce the heat absorption.

exposed brick wall on external as well as interior space reduces the plastering cost and painting cost is minimal.

roof overlaying reduces heat carried by wind.

stone pillar is used for corridor space reducing the amount of steel and concrete used.

clay tile filler slab/infill slab for roof to reduce steel quantity and for better thermal comfort and light weight reduce the load on structure.

coconut tree is used for interior wood work which is low cost and easily available.

redoxide flooring used in major portion of room.

simple stone and brick staircase is used.

**RENEWABLE ENERGY:**

- New technologies for use of alternate and renewable energy such as solar, biogas, wind, LED have not been adopted.

- Rain water harvesting system has not been adopted. Water for purposes is procured through borewell.

**SOLID WASTE MANAGEMENT:**

There is no solid waste management inside the premises all waste materials are taken and thrown to dump yard. There is recycling of water and waste materials inside the premises. Separate bore is there for drinking and other purpose such as cooking gardening washing etc.
GENERAL OBSERVATIONS:

- Good light and ventilation for buildings reduce the overall energy consumption. About 75% of spaces get good daylight and views.
- Locally available materials have been used and materials have also been reused.
- Effective window and ventilation design provides thermal comfort.

CONCLUSION:

The building has been designed and built about 2 decades back when adoption of systems such as Rain Water Harvesting, Recycle and Reuse of waste water, Solar Lighting and Heating systems, Biogas were not in highlight.

The building qualifies as a green building through its design, the incorporation of local sensitivities and traditional materials and design into modern techniques where the fusion augurs well.

There is a scope to adopt systems such as RWH, solar lighting and heating and biogas for achieving better energy efficiency.

With time, the materials used are leading to certain maintenance problems in terms of durability; need more strengthening.

CASE STUDY OF BUILDINGS - BANGALORE:

Two buildings have been selected for case study in Bangalore – one residential and another non residential.

In the residential building, planning and design elements for green technology have been studied.

In the non-residential building, the campus of TERI who have developed GRIHA rating system, has been studied in the overall context of planning and design, materials used, and green technology adopted. It is considered as one of the iconic green buildings in Bangalore.

Objectives:

1. To study the planning and design elements for making building green.
2. To assess the Cost Benefits of green and energy efficient buildings
Case study 1: Residence of Architect Chitra Vishwanath, Bangalore

- **ARCHITECT:** CHITRA VISHWANATH.
- **LOCATION:** VIDYARANYAPURA- BANGALORE.
- **SITE:** 30 ft X 50 ft.
- **BUILT UP AREA:** 1500 sft.
- **BUILT IN:** 1995

The residence was designed and built by Architect Chitra Vishwanath for own use. The building is built of mud. Bangalore is one of the cities which have many mud houses. Chitra Vishwanath is one of the architects who has specialised in mud houses. She works on the philosophy of ecology and sustainability.

According to the Architect, the term green architecture has mega connotations both in terms of money and who it is meant for (bigwigs, corporates and institutions). But green architecture is possible, actually ideal, for low-income groups because one saves a lot on energy use and
building costs. A sustainable project should be socially relevant, technically possible, institutionally responsible, financially viable, legally correct and ecological. So these frameworks go beyond simple rating systems.

Further, a rating system at best acts as a pointer or a guideline which helps to bring a formalised system into the process. It also helps to synergise the design with the actual construction so that the construction too becomes environmentally sound. Moreover, with the new monitoring system in place which supervises the project after the receipt of a rating, there does exist a certain pinning of responsibility to follow the process and design it to its logical conclusion.

Many a times rating help achieve some marketing brownies but if in the process some good is achieved in terms of resource conservation then it is an asset worth considering.

The building has not obtained formal certification as green building.

**GREEN & ENERGY EFFICIENCY COMPONENTS:**

**PLANNING AND DESIGNING:**

The philosophy followed is to employ local resources in an optimised way, to plan considering the natural elements, passively and actively, and to render the social impact of construction positive, improving lifestyle quality of both the doers and users. As a part of the range of resources used, mud is a major component since it is well suited for local conditions, and is relatively labour intensive and locally available.

The building is a earthy construction with stone arches, east light, top lighting and no fans. The basement provided mud for the compressed stabilised earth blocks and mortar used in the construction. The building harvests 90,000 litres of rainwater (20,000 from the neighbours), reuses washing machine water, uses solar energy for cooking, lighting and water heating. This house was built to conserve and enhance biodiversity on site and also make use of all natural resources available on it.
Basement:

The basement is a thermally balanced space with temperatures never going above 23°C and is used as a study and playroom.

The house has “basement windows” opening at the ground level. According to the architect, a basement is a great way to keep the entire house cool.

Three of the basement walls have rows of wire mesh-covered windows above lintel level, all of which open into the garden at the ground level. These basement windows control the temperature of the entire house by letting in cool air. If the weather is cold, simply closing the windows ensures that the whole house becomes warm.

The arches, the open stairwell, and the large number of windows and ventilators let the hot air out, so that the basement windows keep drawing more cool air, preventing indoor temperature from rising.

Arches:

The arches serve two purposes. First, unlike concrete beams, the arches let the weight of the roof come onto the walls, which reduces use of concrete and cement. Second, they help dispense with unnecessary walls and doors and ensure continuity of air flow. For instance, in the living room on the ground floor, two inner walls have been replaced with four arches, two of which open into the kitchen and the other two into the stairwell.

Energy efficient systems:

Earth in the form of compressed stabilized blocks and stabilized rammed earth is used for load bearing structure, arches, vaults and domes. Beside the use of stabilized earth, alternative systems and energies are used which include waste water
treatment system, grey water recycling system, solar and wind energy generating systems, rainwater harvesting.

Surface treatment:

The house inside has no plaster or paint and works with mezzanines to use the volume available to the maximum. One mezzanine area is a sleeping loft and the other is a study room.

Lighting:

From the roof of the first floor rise several chimney-like structures with slanting roofs which are skylights. Apart from letting in light, tiny sections of these structures have been removed and replaced with wire meshes to make ventilators. The ceilings of the bedrooms are high (four metres) which furthers the cooling effect and allows for a partial mezzanine space.

It is, however, not possible to maintain uniform temperature throughout the house. According to the architect, on a hot afternoon, the basement is the coolest place and on a cold night, the mezzanine above the bedroom is the warmest place.

Roof:

The roof is another highlight of the house. A part of it is covered with a vegetable patch. Earlier, rice was grown in a much larger space, after most of the trees surrounding the house have grown tall and shady, part of the plot has been removed.

BUILDING MATERIALS AND CONSTRUCTION TECHNIQUES:

1) Structure: load bearing.
2) Wall: Unplastered, Mud blocks
3) ROOF: Arched panels and R.C.C filler slabs.
RAIN WATER HARVESTING, RENEWABLE SOURCES OF ENERGY AND WASTE MANAGEMENT:

The roof is designed to capture rainwater (water harvesting takes care of more than 70% of water requirements of the house), use solar energy for cooking, water heating and for lighting.

<table>
<thead>
<tr>
<th>Roof Area (square metre)</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (millimetres)</td>
<td>912</td>
</tr>
</tbody>
</table>

The roof is also the seat of many ecological experiments, including a wastewater recycling unit that recycles bathwater for the garden, a model of waterless toilet, a solar cooker and a cement trough with water-plants growing in it.

Innovations:

An "ecosan" toilet (separates the solid and the liquid matter) placed on the terrace provides nutrients to grow rice in a rooftop paddy patch which is irrigated using waste water from the washing machine which is treated using a reed drum system.

Rice and millet grown on the rooftop provide food while vegetables are grown in pots. The mulch layer rests upon silpaulin lining sheets to prevent dampness. The rooftop garden also helps to keep the house cool.

No artificial cooling systems such as fans or AC's have been used in this home.

SHORT TERM AND LONG TERM BENEFITS OF ADOPTING ENERGY EFFICIENT TECHNIQUES:

a. The energy efficient techniques that have been adopted result in saving the electricity, water and food expenses thus reducing the cost of living.
b. The rice grown on the roof top keeps the interiors cool thus reducing the necessity for the usage of electrical appliances like fans, AC’s etc.

c. The use of solar panels not only reduces the incurred electrical expenditures but also helps in saving gas due to the usage of solar cookers for cooking.

COST BENEFIT ANALYSIS:

According to the Architect, saving cost is not the idea with a mud house. Savings come from the simplicity of the finish. Today's walls and roofs take only 40 per cent of the total cost of buildings. Rest of the money goes into modular kitchen, floors and other accessories. There is little scope for the mud wall and roofs to make a significant difference to the cost of the house.

a. In this building, the usage of mud as a major component is beneficial since it is well suited for local conditions, is relatively labour intensive and is economical as the mud is got from the site.

b. The unplastered walls reduce the initial expenses and are easy maintenance.

c. According to the Architect, there are other benefits that go beyond the normal outlook. The house has 32 kinds of birds coming into it. It functions without a fan, and recycles water besides harvesting rainwater. The house has a facility (Eco-san) to turn waste into fertilizer.

d. A regular building using RCC roof and plaster consumes 20 tonnes of coal energy while a mud house of the same size will need only nine tonnes.

Thus the above mentioned advantages serve beneficial over the long run.
COMPARISON OF ENERGY EFFICIENT TECHNIQUES AS COMPARED TO CONVENTIONAL TECHNIQUES:

a. The provision of rain water harvesting facility helps in taking care of 70% of the water consumption as compared to a conventional technique where in the water consumption is chargeable.

b. The usage of solar panels in turn helps for water heating, lighting and cooking, in turn reducing the expenses incurred by adopting the conventional measures.

c. The recycled water i.e the grey water helps in growing crops thus conserving the ground water level and preventing wastage of water.

CONCLUSION:

a. The house is aesthetically appealing with minimalistic and earthy approach.

b. The main idea of conservation and enhancement of biodiversity is well achieved through the design and the facilities provided

c. The entire expenditure of living is reduced with the energy efficient facilities provided and also with the use of naturally available materials thus making it economical and eco-friendly.

d. Building sustainable houses would not only be economical but also would help conserve energy.

Case study 2: Campus of The Energy and Resources Institute (TERI), Bangalore

- ARCHITECT: SANJAY MOHE
- LOCATION: DOMLUR- BANGALORE.
- TYPE: INSTITUTIONAL (OFFICE CUM GUEST HOUSE)
- NO. OF FLOORS: GROUND + TWO
- BUILT UP AREA: 26,663 sft.
- BUILT IN: 1990

TERI has developed the GRIHA rating system which has been adopted as national rating system by MNRE, Government of India. TERI’s Southern Regional Center in Bangalore has been developed as a green
building and it is one of the first energy efficient and environmentally sustainable campuses in South India. It accommodates spaces for work, conference rooms, library, a laboratory and a guest house, dining and recreational facilities.

**GREEN & ENERGY EFFICIENCY COMPONENTS:**

**PLANNING AND DESIGNING:**

The site is long and narrow with roads on Eastern and Northern sides. On the southern side, there is an open drain of about 9m width.

The buildings are aligned along east-west axis with entrance from northern road.

Generous amounts of lighting and ventilation is received by the clever combination of SOLAR PASSIVE DESIGN, ENERGY-EFFICIENT EQUIPMENT, RENEWABLE SOURCES OF ENERGY and MATERIALS with low embodied energy.

The building opens to the north to take maximum benefit of glare free light. Continuations of skylight and atrium spaces carry natural light into building.

The TERI building has a unique ventilation system that incorporates the use of solar chimneys and vents.

Another important design aspect is the cavity wall construction method adopted for the southern wall to minimize solar heat gain, the material used is black Kadappa stone.

The terrace gardens at various levels also provide good heat insulation. Terrace gardens and earth berms have been introduced as a replacement to the ground disturbed.

They act as a positive design solution to the following problems:
a) Reduction in radiation  
b) Moderation of temperature fluctuations  
c) Insulation  

MATERIALS AND APPLIANCES:  

- Local materials have been used to a large extent.  
- Southern wall is built of kadappa stone.  
- Energy efficient lighting devices such as CFL have been used.  
- The windows used are double glazed and coated so as to reduce the solar heat gain  
- Trombe walls used in the hostel blocks aid in insulation of the interiors during sunlit hours  

RAINWATER HARVESTING:  

Rainwater is collected through DOWNTAKE PIPES at the various levels of terraces. The roof above the amphitheatre is used as a collection point for the run-off rainwater collected from the roof and paved areas, the space below the amphitheatre is used as the collection sump. The concept of reduce, reuse, recycle is put into action in the form of landscaping and flushing toilets.  

SOLAR HEATING AND LIGHTING  

A 5kW peak solar photovoltaic system has been integrated with the roof skylights to provide day light and also generate electricity. A solar water heating system meets the requirements of kitchen and guest rooms.
BENEFITS OF ADOPTING GREEN AND ENERGY EFFICIENT TECHNIQUES

The monthly energy consumption of TERI building is said to be about Rs.30,000. The energy consumption per sq. ft. sums up to Rs.1.12 which is a considerable difference—one-tenth of the conventional building with air conditioning in Bangalore.

Long term benefits include:

1. Greater monetary savings
2. Reduction in carbon footprint
3. Improvement in quality of workspace

The short term benefits of using energy efficient designs are:

1. These methods require very little maintenance
2. Disregards the use of mechanical ventilation and regulates the temperature indoors

CONCLUSION:

The TERI building in Bangalore can be described as an icon for green building techniques. The interiors are designed to near perfection with the implementation of natural methods of lighting and ventilation.

The campus exhibits the elements from planning to post operation stage in the overall building lifecycle that can be adopted to become green and energy efficient.

The building envelope has been used efficiently and it has abundant open spaces and green areas for the students and faculty to use as a recreational space.

The project stays true to the concept used incorporating all natural elements into the usable spaces

ADOPTION OF GREEN BUILDING CONCEPTS – INFERENCES FROM CASE STUDIES:

There is a growing awareness on adoption of green and energy efficient technology in building design and construction.

Professionals such as architects are experimenting with local and traditional materials, traditional and simple technologies to help build green and energy efficient buildings and also reduce overall construction cost.
Measures such as rainwater harvesting, solar heating, energy efficient gadgets/appliances landscaping and overall design to the extent possible within the sital and building area are being adopted.

Though such measures have been adopted, there is no enthusiasm found to get the buildings rated either under GRIHA or LEED, especially residential.

Planning and design of green buildings need the engagement of professionals such as architects and engineers, while majority of residential buildings are still designed and constructed by local masons.

The general perception is that ratings require compliance on a large list of factors which is cumbersome and may not be sometimes possible to follow. Also the charges for rating buildings are perceived to be quite high.

While measures such as rain water harvesting, solar heating and energy efficient electrical gadgets/applications are possible to be adopted in existing old buildings also through minor modifications in waterlines, piping etc., it is not possible to fully adopt all measures suggested under GRIHA in existing buildings.

Cost is not a major criterion for owners to adopt green building technology and concepts. Availability of technology and materials, easy processes are desired.

The subsidy given in electricity bills (Rs.50) is not really of a value to push people to adopt such measures.

**ADOPTION OF GREEN BUILDING CONCEPTS –CONCLUSIONS**

It is well established fact that green building technology and designs are not fanciful but are an essential requirement for sustainable development. In order to encourage and enforce adoption of green building practices, the following areas may be addressed.

Mandatory provision in building bye-laws need to be made for adoption of rain water harvesting solar heating/lighting systems, dual piping systems, planting minimum 2-3 plants/trees within the sital area. The zonal regulations of approved Master Plans include many such provisions. However, since Master Plans have not been prepared for all urban areas, the common building bye-laws in force needs to be suitably amended and updated by the Directorate of Municipal Administration in consultation with Directorate of Town & Country Planning.
There is a general perception that initial cost of green buildings is higher than conventional buildings. Certain banks in India provide loans at subsidized rates to homebuyers who want to purchase a home in an ‘environmentally friendly building’. MNRE also provides subsidies for purchase of solar systems. Financial incentive in electricity bills is also provided. However, such subsidies and financial incentives are not perceived to be significant. Also there is a need to build awareness on the procedure to avail such benefits.

Only buildings planned by architects and such professionals are able to adopt green building concepts. For large-scale adoption, there is a need for continuous research and development in order to bring in low cost technologies and simple procedures to the door step of citizens. Depending upon the diversity of climate, topography, availability of local materials for construction and traditional preferences of living spaces, there is a need for developing building standards that meet local needs.

Adoption of green building concepts is slowly gaining favour among builders and multiple codes and standards will create uncertainty and may eventually hurt the growth of green buildings. Ratings and codes should have minimum parameters and documentation processes in order to encourage more buildings adopting the same. Criteria may be too stringent for some projects to comply.

Implementation of ECBC as a mandatory standard needs to be pursued. It has become mandatory only for buildings that require the clearance from environmental ministry, green buildings and TERI GRIHA rated buildings. This can be done through adoption in building byelaws.