RETREAT!

A model sustainable habitat based on new and clean technologies

by Mili Majumdar
Fellow,
Centre for Research on Sustainable Building Science
The Energy Research Institute (TERI), New Delhi

Set amid lush greenery, which was a desolate expanse only a decade ago, TERI's new residential training facility demonstrates effective and efficient utilization of resources. The project won the first prize for Excellence in System Design at the 2nd Bry Air Awards for Excellence held in 2007. Read on...

What Do the Following Have in Common?

- The Sun is a clean, abundant and free source of energy
- Underground cellars are cooler in summer and warmer in winter than the above-ground rooms
- Deciduous trees shed their leaves in winter
- Micro organisms can feed on waste water and thus help purify it.

What these observations have in common is that all of them are natural phenomena that have cut down the electricity requirements of TERI's new executive training facility RETREAT by as much a 60%. Warm in winter and cool in summer, well lit round the year, set amid lush greens and not dependent on grid-fed electricity, the building is intended to be a model of sustainable habitats in the 21st century.

RETREAT, a residential training facility for executives, is designed to be self-sufficient, and independent of any external power supply. It consists of two semicircular blocks arranged one behind the other. The south block comprises the living quarters with 24 single-occupancy rooms and 6 suites and the north block comprises the conference centre with a large hall, a dining room, a lounge, recreational facilities, and a library.

The complex has harnessed both traditional and modern means of tapping renewable sources of energy to offer modern amenities such as lighting, air conditioning, cooking, laundry, etc at substantially reduced costs.

- The complex saves 40%-50% of energy costs over conventionally designed buildings at an additional investment of about 25%.
- Twenty-four solar water-heating panels (inclined at 70 degrees instead of 45 degrees) provide up to 2000 liters of hot water every day.
- Photovoltaic panels capture the Sun's energy and recharge their batteries during the day. The energy generated by the panels is fed into a battery bank, which is the main source of power at night.
- Firewood, dried leaves and twigs, the stubble left in the field after a crop is harvested, and such

About the Author

Mili Majumdar is an M.Tech in civil engineering from IIT Madras with over 13 years experience; all with TERI.

other forms of biomass fuel the 50-kilowatt gasifier that is the source of power for the building during the day.

- Effective insulation, shade provided by trees, and a network of underground earth air tunnels circulating cool subterranean air throughout the residential block ensure that the temperature in the complex remains more or less even all year round at 20°C in winter, 28°C in the dry summer, and 30°C in the monsoon. The system has been augmented by adding chillers for dehumidification and additional cooling during the monsoon.
- Specially designed skylights, energy-efficient lights, and a sophisticated system of monitoring and controlling the consumption of electricity, light up the complex with less than 10 kilowatts; a comparable conventionally designed structure would require nearly 28 kilowatts to provide the same level of lighting.
- A bed of reed plants (phragmytes) clarifies 5 cubic meters of waste water from the toilets and kitchen every day; the recycled water is used for irrigation.
- The estimated CO_2 saving is about 570 tons/year.

The Challenge

Coal, oil, and natural gas are common sources of energy but their supplies, though large at present, are limited. Such sources often pollute the air and moreover, not every country has ample stocks of such fuels. India, for example, imports more than half of all the oil it needs and ends up spending 16% of its foreign exchange paying for it. On the positive side, India enjoys abundant sunshine and can afford to devote some land to growing fuelwood. We decided to exploit this advantage.

Our Approach

The campus is intended to serve as a model sustainable habitat based on new and clean technologies. Therefore, it makes full use of the most abundant source of energy, the Sun, by tapping its energy both directly and indirectly. Some innovative ways of tapping solar energy and using energy more efficiently at the RETREAT are as follows.

- Solar water heaters
- Photovoltaic panels
- Gasifier
- Underground earth tunnels
- Absorption chillers
- Energy-efficient lighting
- Waste-water recycling

Detailed Explanation

Solar water heaters

An array of 24 solar water heaters forms a part of the parapet of the living quarters. The system can deliver up to 2000 litres of hot water (at 65°C) every day. In winter, when the days are short and the sun less intense, a 9 kW electrical heating coil serves as a back-up source of heat.

Photovoltaic panels

The sun is the powering force of RETREAT, where solar panels are used to form a 'solar roof'

While a solar water heater taps the sun's energy directly, a series of photovoltaic panels capture the energy and store it by charging a bank of batteries. A number of panels, each measuring 1.1 by 1.2 metres, are joined and form an integral part of the roof of the building. The panels can generate up to 10.7 kilowatts peak of energy, which is fed into a 900 ampere-hour/240 volt battery bank. Independent panels power most of the lights located outside the building. Each such light has a pair of small photovoltaic panels (roughly a metre wide and half a metre tall) and is thus a self-sufficient 'stand-alone' unit.

Photovoltaic panels cover the entire roof

PV-based water pump

A photovoltaic panel also powers the water pump.

Biomass gasifier

Though fuelwood is the most common fuel in the countryside, it is not a particularly convenient source of power. The biomass gasifier makes fuelwood almost as convenient to use as cooking gas. It also burns such fuel twice as efficiently as the more conventional devices that burn fuelwood directly. TERI's 'energy plantation' provides the complex its supplies of fuelwood.

Apart from fuelwood, the gasifier can also use straw, small twigs and

The biomass gasifier is the main source of power during the day

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branches, and other crop residue. To make such fuel easy to handle, it is chopped into small pieces which are pressed together to form compact cakes or briquettes. The 50-kilowatt gasifier runs a generator, whose diesel requirements have been cut down to 30% after appropriate modifications; the rest of the fuel comes from the gasifier in the form of 'producer gas'. One unit of electricity produced needs 1 kg biomass and 90 ml of diesel.

Any surplus energy generated is used to recharge the battery bank. The battery bank is thus served by two sources of power, the photovoltaic panels and the gasifier. A control device, the 'power manager', constantly works out the most efficient combination, deciding which is the better source at any given time.

The system can function for 25-30 years; the batteries have a life of 6 years.

Underground earth tunnels

The living quarters (the south block) are maintained at comfortable temperatures (approximately between 22°C to 26°C) round the year by circulating naturally cooled air, supplemented, whenever required, by a system of chillers for dehumidification and additional cooling. The concept is based on the observation that underground cellars are usually cooler in summer and warmer in winter. Underground structures are not exposed to the sun and thus do not heat up as much. Secondly, the surrounding earth insulates them, which helps in maintaining a more or less constant temperature. Temperatures recorded at roughly 4 meters below the surface show that they are stable and reflect the average annual temperature of a place (26°C in Delhi). Four tunnels, each 70 meters long and with a diameter of 70 cm, have been laid at a depth of 4 m below the ground.

However, the cooler air underground needs to be circulated in the living space. Each room in the south block has a 'solar chimney'. Warm air rises and escapes through the chimney, creating an air current, and four blowers of 2 hp each force the cooler air from the underground tunnels to rush in and replace the warm air. The same mechanism supplies warm air from the tunnel during winter. However the tunnels cannot remove the excess humidity from the air during the monsoon and hence its efficiency drops in the humid summer and monsoon period. Additional chillers have been installed to be used only during the hot/warm and humid parts of the year to achieve the required comfort levels in the rooms.

Absorption chillers

A set of eco-friendly chillers, which run on LPG and require minimum electricity, provide cooling for the conference facilities. As LPG is a non-renewable source of energy, efforts are under way to run the chillers on producer gas generated by the wood-burning gasifiers.

The conference centre, which accommodates up to 100 participants, requires additional cooling if the temperature is to be maintained at about 25°C. This is achieved by ammonia-based absorption chilling.

Energy-efficient lighting

Sustainable systems do not stop at using such renewable sources of energy as the sun and firewood-the energy so produced must be used efficiently. RETREAT uses energy-efficient compact fluorescent lamps, which give the same quality and amount of light as normal incandescent bulbs but require only one-fourth as much energy. The conference rooms enjoy glare-free daylight through strategically placed skylights. Thirdly, a master control system switches off the lights automatically whenever it senses that daylight alone is enough to maintain the desired level of illumination.

In the living rooms, strategically placed light points and specially designed swivels make it possible to use the light at a study table as well as for bedside reading.

Currently, the photovoltaic panels generate about 55 units of electricity on an average sunny day.

Waste-water recycling

Every attempt to create a sustainable habitat must include specific strategies to ensure that water is used efficiently and recycled after use. The model habitat in Gual Pahari uses modern methods to 'harvest' and store rainwater and a novel technique to recycle waste-water for irrigation.

The World Health Organization recommends that for healthy living, each person needs 135 litres of water a day. This figure includes water for drinking, cooking, washing, laundry, and so on. RETREAT meets these requirements but ensures that water is used more

Waste water is recycled by the 'root zone' technique, in which the roots of plants with special capabilities are used to clean the water which is used for irrigation purposes

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effectively by using an efficient flushing system, aerated taps that deliver water at pre-set rates, and a centralized laundry.

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Sewage is collected initially in a settling tank (an Imhoff tank) that allows sludge to settle to the bottom. Part of the waste is decomposed at this stage by microbes. Next, the water is passed through a bed of soil, which also supports specially selected reeds well adapted to waterlogged soils. The roots of these plants act as living filters: the plant roots absorb and remove many of the toxic substances from waste water. This combination of microbes and plants can make even very dirty sewage water clean enough to be used for irrigation and even a shower.

Nuances of Building and System Design

It would also be worth the while to list down architectural and mechanical considerations made from the point of energy conservation, right from the beginning.

Orientation, insulation and design of building

- Wall insulation with 40 mm thick expanded polystyrene and roof insulation using vermiculite concrete (vermiculite a porous material, is mixed with concrete to form a homogenous mixture) topped with china mosaic for heat reflection.
- Building is oriented to face south for winter gains, summer gains are offset using deciduous trees and shading
- The south side is partially sunk into the ground to reduce heat gains and losses.
- East and west walls are devoid of openings and are shaded.

System design

As explained earlier, the building consists of two blocks - north and south. The north block consists of conference rooms and hence expected to be occupied mostly during the day. The south block consists of guest rooms and suites, and hence expected to be occupied mostly during the night. The cooling requirement of the north block was estimated higher than the south block, making the south block more favorable for applying passive strategies for energy conservation.

Application/Replication of Concepts

The RETREAT has been operational for more than a year, and the concepts and technologies used are replicable in part or whole. Some of the concepts which could be adopted and applied to reduce energy use in buildings are:

- Proper orientation to take maximum advantage of the sun
- Landscaping to alter wind direction and ambient temperature
- Choice of building insulation/roof gardens/colours and textures
- Properly sized and shaded windows
- Window placement to allow cross ventilation
- Placement of rooms (e.g. buffer spaces like toilets, staircases on west)
- Detail roof innovatively to admit maximum daylight
- Use efficient lamps, fixtures and controls
- Use solar water heating system
- Use a hybrid of an earth air tunnel system and airconditioning to reduce loads

RETREAT is a part of TERI's Gual Pahari campus, about 30 km south of Delhi, in the northern state of Haryana. The beautifully landscaped 36-hectare site, including a garden that features prize-winning roses, is living testimony to TERI's research. Nine years ago, the site was barren. The land was not leveled; the topsoil was badly eroded and not very fertile; water used to collect in some places, making the land swampy, while at others, the land could hardly retain enough water. Today, the site is transformed: green, productive, and sustainable.

The Way Forward

This training center in Gual Pahari is proof that near self-sufficiency in energy is not a utopian ideal but a reality cast in brick and mortar. But it is also an evolving experiment: the information gathered on how well the building really performs under varying ambient conditions - in winter, summer, on bright days, cloudy days, at varying levels of occupancy, and so on - is helping TERI design better systems for buildings and complexes of organizations seeking to attain sustainability in building design and operation. An elaborate, extensive, and sensitive network of sensors linked to a central station monitors the system 24 hours a day, 365 days a year.

The 'data-loggers' keep tabs on virtually every relevant part of the system. At any given instant, you can find out what it is like outside – how warm, how sunny, how humid – and how these conditions have affected the same parameters inside; you can dertermine how much power is being consumed in different parts of the building and how much is being generated; you can check the temperature of the water being delivered through the hot water system. Thus, the facility is also a first-rate source of immense quantities of scientific data that can power more experiments and indeed influence the design of other such facilities the world over. ❖