ENERGY EFFICIENCY IN BUILDINGS: THE AUROVILLE EXPERIENCE

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1. **Abstract**

As India is beginning to feel the crunch of dwindling conventional energy sources, it is just only beginning to explore alternative sources. It is also poised to manage existing energy sources judiciously. As India's economy continues to grow, the demand for energy increases exponentially, leaving exorbitant prices for commodities in its wake. Infrastructure and development has come of age in India in the past 10 years and the effect is visible in the form of townships, malls, multi-storied apartments. However, a less visible but nonetheless a more negative impact is felt by the surrounding environment and its individual entities. Energy conservation in buildings is an issue that needs to be addressed now. This has been addressed in western countries that have a different climate. The ECBC (India), TERI Griha, and the NBC (India) have indeed provided guidelines on how green buildings should be rated in India. Ideally, buildings should be both energy efficient and kind to the environment – this implies a minimal contribution to GHG. Energy calculations should therefore be presented in terms of CO2 emissions. Production of cement which is used in RCC contributes significantly to the atmospheric CO2 loading. These issues are being addressed by green architects, town planners, and other bodies at the decision-making level and green buildings are now being built all over the country. However, the only place where a holistic approach towards green architecture, sustainability, alternative energy utilization, environmental ethos comes together is the Auroville international township. Auroville is a model township experimenting with a new world-order – new architectural designs are being tried out, building forms and fabrics are currently being tested for their environmental friendliness. The 'green' combination of building orientation that facilitates infiltration, ventilation and natural lighting has found its mark in this township. A precursor to green architecture is a kind micro-climate – Auroville's greening and rain water harvesting methods serve as a bench mark model in this regard. This report is being written as part of a taught course on energy efficient buildings (M. Tech in Construction Technology and Management). The report in a sense is a coming-together of time tested building practices with alternative practices adopted in Auroville.

2. **Introduction**

Energy Efficient Buildings are not new to the Indian ethos. Since times immemorial Indian builders have built houses and cities keeping the microclimate in view. They used natural resources and had a deep understanding of wind-flow patterns over an area as well as an understanding of optimal siting practices. In fact the *sthapatya veda* forms part of the *atharva veda* that involves *vaastu shaastra*(architecture and planning), *shilpa shastra*(sculpture and iconography). Buildings in ancient India often involved four pillars (upamits) and were set up on a good site and against them beams were leant at an angle as props (pratimits). The upright pillars were connected by cross beams (parimits) resting upon them. The roof was formed of bamboo canes (vamsa) and the walls were filled up with grass bundles (palada). This is very reminiscent of our eco walls today.

Buddhist Literature also iterates green concepts -
"We nowhere hear of isolated houses. The houses were all together, in a group, separated only by narrow lanes. Immediately adjoining was the sacred grove of trees of primeval forest." At places it appears as if the Buddha were delivering discourses on architecture! As a matter of fact, he enjoined upon his devotees the supervision of building construction as one of the duties of the order. He seems to have said ‘’ I allow you O Bhikkhus, abodes of 5 kinds-Vihara, Ardhayoga, Prasada, Harmya, and Griha.’’

The essence of such literature not only transcends but etches itself in the form of Auroville. This world's first international township harnesses the flow of its energies to their highest possible potential. Auroville was founded on 28th February 1968, a day that saw an inauguration ceremony which was attended by representatives from 124 nations, including all states of India. It was given its 4-point charter by its founder, French-born Mira Alfassa also known as the Mother. An excerpt from the charter:

"Auroville wants to be a bridge between the past and the future. Taking advantage of all discoveries from without and from within, Auroville will boldly spring towards future realizations."

It is a township driven by a population of 50,000 people from all over the world which sets an exemplary example in the field of "environmentally appropriate" architecture. "Consciousness" is acquired rather than understood at such a place which delivers more than what it promises – a sustainable community that thrives on the unity of collective forces.

As far as efficiency of buildings in terms of energy consumption is concerned, Auroville cuts an indomitable figure in the world of construction. Optimal utilization of renewable sources, low energy designs for heating/cooling, construction materials with lowest of embodied energies and a futuristic design puts Auroville on the map.

Energy Efficient Buildings have found their mark but only in such dire circumstances where alternatives are far and few. The prime element of importance is knowledge and awareness. This indeed is the reason why a course in such a field was undertaken by M.Tech Integrated students of VIT University which was taught by Dr.Satyajit Ghosh. As part of an assignment, we took a trip to Auroville to visit the Auroville Earth Institute and to take part in a "Workshop on Sustainable Architecture". Elaborate presentations and discussions, let us delve deeper into Auroville's history, its kind microclimate exemplified by low energy features and its future-driven approach to architecture and planning. A demonstration of compacted-earth bricks not only confirmed theoretical certainties but set a benchmark for practices that are put to full use at Auroville. Although it is not so cut and dry since a lot of hard work has gone into its creation besides the cumulative talent and research of individuals whose goals are shared and cherished by everyone. Therefore,

If there is a society that promises to convert an idea of humanity into hard-lined reality, Auroville is it.

This report explores the "green" statement that Auroville makes in the field of Energy Efficient Buildings.

3. **Siting and Microclimate**

Climatological processes arising from variations in energy deposition on the earth by the sun dictate patterns of weather we encounter. Auroville is close to the tropical belt ensuring roughly equal hours of day and night. The variation in solar energy deposition repeats annually. As a consequence the climatic variables, including temperature and wind speed and direction, solar intensity and humidity can be anticipated each year, on a national scale within a reasonable degree of accuracy. The physical processes that dictate macroclimates can be modified on a local scale by variations in topography. For example the presence of coasts, valleys, dense woodland or hills interacts with the general climate of the region and cause local variations. Buildings and other discrete features can further modify the local climate by wind channeling, solar trapping and overshadowing. Four areas of knowledge would allow us to minimize the effect of climate on buildings:

1. How climate varies with location: site knowledge through local monitoring or meteorological office data will enable the more extreme climatic variables affecting the site to be identified.
2. How climate affects heat loss. Wind, rain, solar intensity and external temperature all have a direct effect on a building's heat loss or gain rate. An understanding of climate related heat loss processes is a necessary precursor for suggesting methods for preventing such losses.
3. How the landscape can be designed to minimize the effects of climate.
4. How the building fabric and form can be reinforced so that its acts as a climate moderator.

While adapting buildings to the macroclimates is difficult – we have little choice on offer, a kind microclimate is more easily achievable. Since Auroville is located within the tropical belt, the overarching emphasis is on maintaining the building coolth. This is achieved by adding water features, trees and shrubs around the building as shown in the picture below.

Passive Cooling

Just as we try to raise external temperatures to reduce space heating energy consumption, depression of external temperatures will reduce cooling energy consumption. The two strands of this strategy have been adopted in Auroville which involve shading external spaces from the influence of the sun and the introduction of evaporative cooling. Both of these functions can be provided by trees. Fountain and water features can also reduce ambient temperatures.

Fig.1 An aesthetically pleasing and a kind microclimate for the Afsaana's Guest house in Auroville

4. **Building Form**

Auroville has experimented with building forms right from its inception. Starting from the basic A huts in the early 70's, Auroville architecture has come a long way – Auroville architectural styles now famous the world over – combine unique forms built with sustainable building fabrics and the resulting buildings are perfectly adapted to the local microclimate. There are many factors that have an influence on the form of a building. Cost is a major factor here and simple cubical buildings are less expensive than complex forms. Functional requirements and aesthetics also have an important role in deciding the form.

Fig 2. Savitri Bhavan:
Ranch type design with added features to optimize daylight gains

As buildings become more complex, rules of thumb on aspects such as effective distance of cross and single sided ventilation become less reliable. Large buildings are very expensive and house many occupants, so it is important that the theoretical airflows considered at the design stage are achieved in practice when the building is constructed.

Fig 3. A Building in Auromodele demonstrating the nuances of a superior Building Form

Note the sweeping curves and open spaces encouraging the free flow of air. The form is such that it receives optimum daylight without heating the building excessively which minimizes the use of artificial lighting and cooling.

A Summary of Areas of Building Elements for Various Plan Shapes

There is a difference in energy usage between housing and commercial buildings – Auroville continues to explore both these areas. It is well known that as the building size increases the surface area to volume ratio decreases. The above building has experimented with these ideas in such a way that the internal space in that building although in contact with the outside world minimizes the entry of hot air from the outside but takes advantage of solar gains, natural light and ventilation. Auroville has consistently avoided the use of deep plan buildings for residential purposes for this reason. By optimizing the above natural energy flows, Auroville architects have sought to obtain a net improvement in the energy consumption of the buildings. They have aimed to achieve the following balance:

Solar gains + reduction in artificial lighting + reduction in mechanical ventilation >
Increase in fabric cooling losses

Infiltration and Ventilation

A source of fresh air is a vital requirement for all buildings. It provides oxygen for breathing, dilutes and displaces pollutants, avoids condensation by removing moisture and keeps buildings cool.

Natural movement of air through cracks, gaps, and porous elements of the building envelope is known as infiltration. The air movement is driven by pressure difference created by the wind and buoyancy of warm air.

Ventilation can be either natural when it is the movement of air through purpose built openings in the fabric by naturally occurring pressure differences or mechanical when driven by fans through ducted openings.

Most Auroville buildings ensure efficient ventilation and passive cooling techniques.

Fig 4. An Auroville classroom using natural ventilation and lighting

Daylighting

Daylight is the preferred form of illumination in buildings. It gives building occupants contact with the outside world. Weather variations and the passage of the day are revealed in the changing patterns of day light. Of most important to low energy design is the fact that, unlike electric lighting, day light does not require electricity to create it. However, daylight is not entirely free. It is provided through glazing systems which are thermally poor and so there is a cost in terms of additional space heating energy consumption. This energy consumption is not solely due to provision of daylighting but is also shared by the other functions of windows which are the provision of views and ventilation. Day light can only reduce the building’s energy consumption if electric lighting is turned down or switched off in response to daylight entry.

Effective daylight strategy therefore requires:

1. Fenestration, plan shape, internal finishing and partition layout for optimum daylight entry and distribution.
2. Avoidance of unwanted solar gains.

Both these features have been brilliantly achieved in the Savitri Bhavan.

Fig 5. Efficient use of daylighting at Savitri Bhavan

The potential from energy savings from daylight are large. The greatest savings in energy occur when in spaces where illumination in daylight is preferable to artificial illumination.

Fig 6. Efficient daylighting in an Auroville school interior

Side Lit Rooms

The majority of rooms are daylit using vertical side windows. There is a problem in illuminating rooms this way as daylight is mostly available near the window but finds difficulty in spreading to the points furthest from it. Auroville has experimented various methods to improve the spread of daylight by using side lit rooms. The philosophy is to change the direction of light flow so that instead of pooling near the window, it is projected up to the ceiling and reflected to the rear of the room.

Fig 6. Interior of an Auroville house optimizing on daylighting

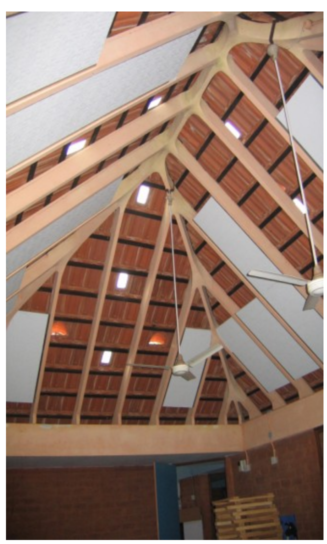


Fig 7. Another example of a sidelit room in Auroville

5. **Building Fabric**

Buildings are constructed so that humans can carry out their various activities in an appropriate environment, efficiently, safely and in thermal comfort. The shell of a building is a barrier between the varying external environment, which can be uncomfortably hot or cold and a stable comfortable internal environment. The building fabric acts as a moderator of climate but it is usual, during seasonal extremes, to use energy to maintain internal conditions. Auroville experiences hot tropical climate and research is underway to minimize the transfer of external heat through the building fabric into the living space. Newer building fabrics are being developed at the Auroville Earth Institute. They have invented a building fabric that not only has a low U-value(Thermal Transmitivity) but also utilizes minimum cement(carbon intensive procedure) content to be as environmentally friendly as possible. Fabric heat losses occur through a combination of heat transfer mechanisms: conduction through masonry, convection across air spaces such as cavities, and radiation across external masonry surface. Ventilation heat losses occur when the warm air inside leaves and is replaced by cool air from outside.

Thermal mass

Thermal mass of a building is a description of its internal fabric in terms of its ability to absorb heat.
SHC: Specific heat capacity is quantity of heat absorbed by 1 kg in order to raise its temperature by 1 deg C. High SHC material is concrete. Low SHC is timber, insulation and plasterboard.

The type of construction used to form vertical elements in the outer shell should vary depending on whether it is a domestic or commercial building. The basic requirements are however the same – the wall must be structurally sound, must have a low u-value and must prevent the ingress of wind and rain. The Auroville Earth Institute has experimented with the use of compressed earth bricks with or without cavities. They are a robust construction that is not easily damaged by prolonged contact with moisture. The cavity offers some insulating value and the width of the cavity is the limiting factor in lowering the U-value. Thermal mass is useful for acting as a passive cooling mechanism in the summer and prevents peaks in temperature. The building below is the Auroville Visitor's Center made out of compressed blocks entirely.

Earth as a Building Material

Compressed Stabilized Earth Block (CSEB) is nowadays the most widely used earth technology worldwide, as well as in Auroville, because it represents a synthesis between traditional practices and modern technology. It benefits from scientific inputs.

The stabilized soil is mixed with a little water to become just humid, and then is compressed into a manual or a motorized press. In cement stabilization, the blocks must be cured for 4 weeks after manufacturing. After this, they can dry freely and be used like common bricks with a stabilized soil cement mortar.

A very high compression of upto 1.83 with 15 tons available force is achieved by the range of presses designed in Auroville

Fig 8. Auroville's Visitor's Centre made out of compressed earth bricks

In addition Auroville is experimenting with ecological walling systems. For example, straw bale buildings utilize normal sized agricultural straw bale which are rendered on the outer skin, to provide protection from the rain and plastered on the inside. This type of wall gives low U-values and is considered as a sustainable material since carbon dioxide is absorbed by the material as it grows and little energy is used to construct the walls.

Fig 9. Casting of Earth blocks

6. **Renewable Energy**

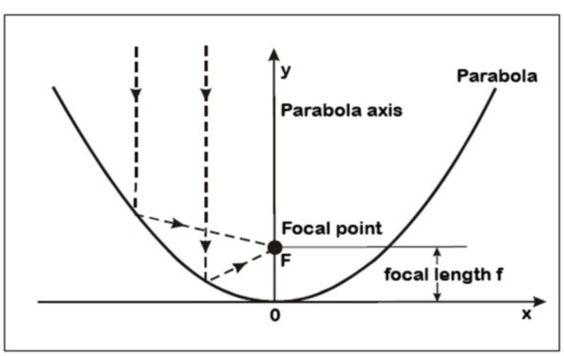
Passive Solar heating is simply the collection of solar energy by a building without using special devices, such as solar panels. However, elements of the building may be modified to optimize solar collection such as increasing the area of south facing glazing. For a passive solar design to be successful the following must be considered:

- Availability of solar energy
- Solar collection methods: windows and conservatories
- Thermal storage: solar energy is unpredictable
- Heat distribution: solar energy is a south side phenomenon in the northern hemisphere.

Siting: allow good solar access to the site but make sure buildings that are collecting solar energy for themselves do not overshadow nearby buildings.
Form: extend south facing façade to increase the area for solar collection.
Fabric: increase the glazed area on the south side and reduce it on the north side.
Cooling: provide shading devices on windows and thermal mass in the interior to avoid summertime overheating.

Flat Plate Collector
The Flat Plate collector is at the heart of solar energy collection systems. It is designed for operation in the low temperature range (60 deg C) or in the medium temperature range (100 deg C). It is used to absorb solar energy, convert it to thermal energy and then transfer that thermal energy to a stream of fluid or gas placed below or above the flat plate. It absorbs both beam and diffuse radiation

Solar Concentrator
Here the solar intensity falling over a large surface is concentrated to a smaller area or receiver. The concentration is achieved by placing a reflector behind the receiver.
Parabolic Trough
This type of collector is generally used in solar power plants. A trough-shaped parabolic reflector is used to concentrate sunlight on an insulated tube (Dewar tube) or heat pipe, placed at the focal point, containing coolant which transfers heat from the collectors to the boilers in the power station.



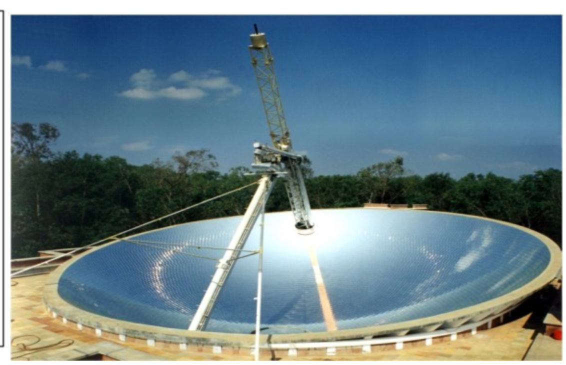


Fig 10. Parabolic Solar Collector used in Solar kitchen in Auroville

Solar water heating systems are generally composed of solar thermal collectors, a fluid system to move the heat from the collector to its point of usage and a reservoir or tank for heat storage and subsequent use. The systems may be used to heat domestic hot water, swimming pool water, or for space heating. The heat can also be used for industrial applications or as an energy input for other uses such as cooling equipment.

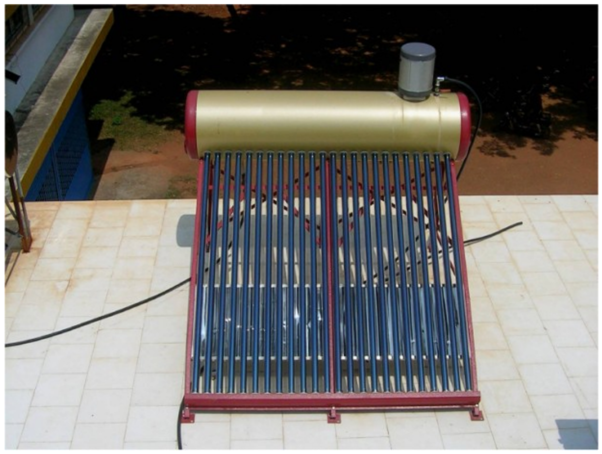


Fig 11. Solar Water Heater used in Auroville

In sunny, warm locations, where freeze protection is not necessary, a batch type solar hot water heater can be extremely cost effective. When calculating the total cost to own and operate, a proper analysis will take into consideration that solar energy is free, thus greatly reducing the operating costs, whereas other energy sources, such as gas and electricity, can be quite expensive over time. Thus, when the initial costs of a solar system are properly financed and compared with energy costs, then, in many cases the total monthly cost of solar heat can be less than other more conventional types of hot water heaters (and also in conjunction with an existing hot water heater). In addition, federal and local incentives can be significant.

Photovoltaic Panels

Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. The complementary positive charges that are also created (like bubbles) are called holes and flow in the direction opposite of the electrons in a silicon solar panel. An array of solar panels converts solar energy into a usable amount of direct current (DC) electricity. Optionally: The DC current enters an inverter and inverter turns DC electricity into 120 or 240-volt AC (alternating current) electricity needed for home appliances. The AC power enters the utility panel in the house. The electricity is then distributed to appliances or lights in the house. The electricity that is not used will be re-routed and used in other facilities.

Fig 12. Photovoltaic Panel Array

Fig 13. Solar Powered houses designed with Auroville Technology

Biogas

In most cases biomass is made up of large organic polymers. In order for the bacteria in anaerobic digesters to access the energy potential of the material, these chains must first be broken down into their smaller constituent parts. These constituent parts or monomers such as sugars are readily available by other bacteria.

Bio-degradable material at Auroville is digested at Auroville to yield biogas which essentially consists of:

Gases	Percentage(%)
Methane, CH_4	50-75
Carbon dioxide, CO_2	25-50
Nitrogen, N_2	0-10
Hydrogen, H_2	0-1
Hydrogen sulphide, H_2S	0-3
Oxygen, O_2	0-2

Fig 14. A Biogas tank

Buildings are constructed so that humans can carry out their various activities in an appropriate environment, efficiently, safely and in thermal comfort. The shell of a building is a barrier between the varying external environment, which can be uncomfortably hot or cold and stable comfortable internal environment. The building fabric acts as a moderator of climate but it is usual, during seasonal extremes, to use energy to maintain internal conditions.

The energy used to heat or cool a building does not remain in the building but is lost via two routes:
Fabric heat loss arise when heat is transferred from the warm interior to the cold exterior through the external surfaces of the building. This occurs through a combination of heat transfer mechanisms: conduction through masonry, convection across air spaces such as cavities and radiation across external masonry surface.
Ventilation heat losses occur when the warm air inside leaves and is replaced by cool air from outside.

Energy from the Wind

Auroville receives unobstructed wind being on the coast of the Bay of Bengal. The aerodynamic drag induced by the forested canopy in Auroville slows down the wind speed to a certain extent – wind turbine rotor blades are therefore located at a height just above the forested canopy. Research is still underway to extract wind power effectively.

Fig 15. Wind Turbine at Auroville placed above the canopy line

7. **Rainwater Harvesting**

Overuse of fresh ground water has massively depleted the ground water reserves in and around Auroville. This has prompted Aurovillians to find means to replenish the ground water table and rain water harvesting is the most obvious choice.

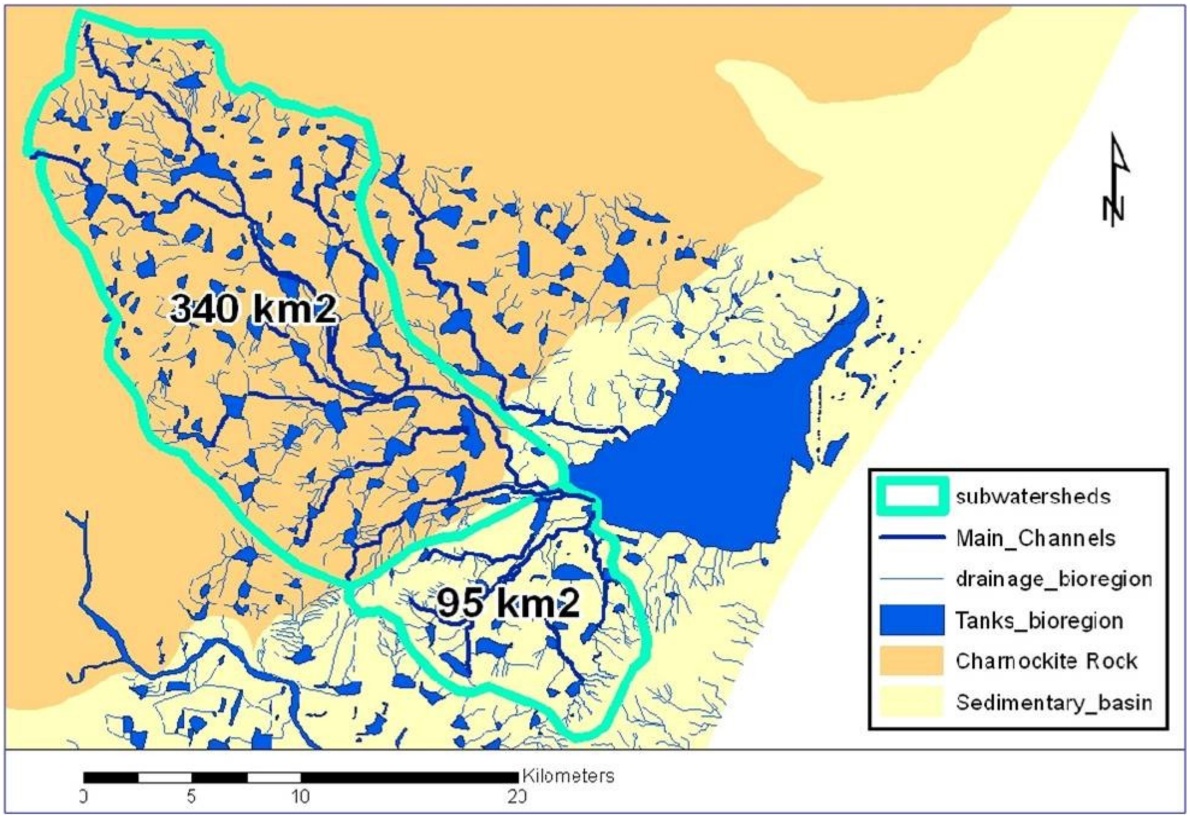


Fig 16. Picture showing the Kaliveli sub-water-shed and other catchment areas which have been in use for above 1500 years

Rainwater harvesting is the process of collecting, filtering and storing water from roof tops, paved and unpaved areas for multiple uses. The harvested water can also be used for potable purposes after testing and treatment. The surplus water after usage can be used for recharging ground water aquifer through artificial recharge techniques.

Methods Adopted in Auroville

Aurovillians adopt the following measures to harvest rainwater:

1. In-site rain water harvesting (Direct Method)
   Terraces
   Under Ground Tanks
   Ponds

2. Macro catchments Harvesting (In Direct Method)
   Pits
   Trenches
   Dug wells
   Recharge wells and etc.

Fig 17. A trench being dug in Auroville for rainwater harvesting

Common adopted methods in Auroville include afforestation of wasteland areas, building recharge structures, repair of the feeding channels to the tanks and awareness activities for farmers.

Fig 18. Afforestation around an artifical basin created to collect rainwater

8**. Concluding Remarks**

Sustainable Architecture has evolved progressively over the last 40 years in Auroville. The project of Auroville was conceived as an urban experiment to undertake the work of 'evolution of consciousness' in a society coming to terms with environmental degradation and irreversible climate change. New cities are being built the world over – rapidly growing cities are clearing forests and vegetated areas and reducing the surface absorption of greenhouse gases. Therefore, cities have responsibilities both to their own citizens and to everyone else to mitigate future climate change, at the same time helping their communities to adapt to the growing seriousness of the consequences for people's health and welfare. Since the planning of such policies is complex as well as politically difficult, decision makers responsible for future of cities require the best expert knowledge available. Hence the importance and timeliness of offering Graduate Level courses on 'Energy Efficient Buildings' in Indian Universities. Not many Indian universities offer this course and those that offer do not have an entire community engaged in developing sustainable technology for the buildings of the future at their door step – our proximity to Auroville and the forward-looking vision of the School of Mechanical and Building Sciences led the two communities to come together on 8th August 2008. On that day all the final year M. Tech students participated in a one day workshop on sustainable architecture in Auroville. The workshop included all aspects of green architecture – siting and micro-climate, building forms, building fabrics, advanced passive cooling and lighting, infiltration and ventilation, use of renewable energy sources and rain water harvesting. In addition, there was a practical demonstration of earth-block making at the Auroville Earth Institute. Such a unique day could not just pass by as another workshop – the outcome of the day's proceedings were far too precious and needed a written record - this is indeed the raison d'etre for this technical report.

Discussion regarding sustainable practices at Auroville

Acknowledgements

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