ALMIPL SOLAR

Powering The New Age (Energy)

INTEGRATION OF EMERGENCY TECHNOLOGY

Mohammed Mubarak
Solar Energy

CHAPTER - 6

CHAPTER 6

INTEGRATION OF EMERGING TECHNOLOGIES

Contents:

A large number of technologies are now available which when integrated into buildings would result in substantial reductions in their demand for conventional energy. These pertain to renewable energy sources and energy conservation measures. Energy used in buildings for cooking, lighting, pumping of water and providing hot water (to bath rooms and kitchens) can be saved substantially by using appropriate renewable systems. Besides, proper energy conservation and management practices would lead to additional energy savings. To promote extensive use of renewable energy technology, the Ministry of Non-conventional Energy Sources, Government of India has been operating an interest subsidy scheme through the Indian Renewable Energy Development Agency (IREDA), and a few designated banks.

Co-operative housing societies and developers of real estates are eligible to seek soft loans from these institutions for installing renewable systems.

In this chapter, we will examine the various ways in which renewable energy technology and energy conservation features can be adopted. The basic principle of each option has been explained. We have described a few case studies to help the reader appreciate the overall integration of these features in building design. More information is available in the references listed at the end of this chapter.

6.1 RENEWABLE ENERGY TECHNOLOGIES

Systems based on renewable energy sources that are being used in the building sector include solar hot water systems, solar hot air systems, solar cookers, solar photovoltaic units, gasifiers and biogas plants. These are commercially available and can easily be integrated into a building for reducing its dependence on conventional power. Some of them can become elements of the architectural design; examples have been presented to demonstrate how this is done.

6.1.1 Solar Water Heating

Solar water heating is one of the most economically attractive applications of solar energy and is widely used throughout the world. There are broadly two types of

4th Floor 4B, Mandira Apartments,
North Boag Road, T-Nagar Chennai- 600 017
Email: Solarbazaarpl@gmail.com
Web: www.almipl.com
Mobile: 94452 30332 /9383132332

water heating systems: (i) Forced and (ii) Thermosyphon. Also known as active systems, the former are suitable for large capacity systems and find applications in hotels, hostels, hospitals, multistoreyed buildings, industries, etc. The latter are usually meant for small capacity systems, and are commonly used in low-rise buildings or bungalow-type buildings. They are also called natural-circulation or passive systems.

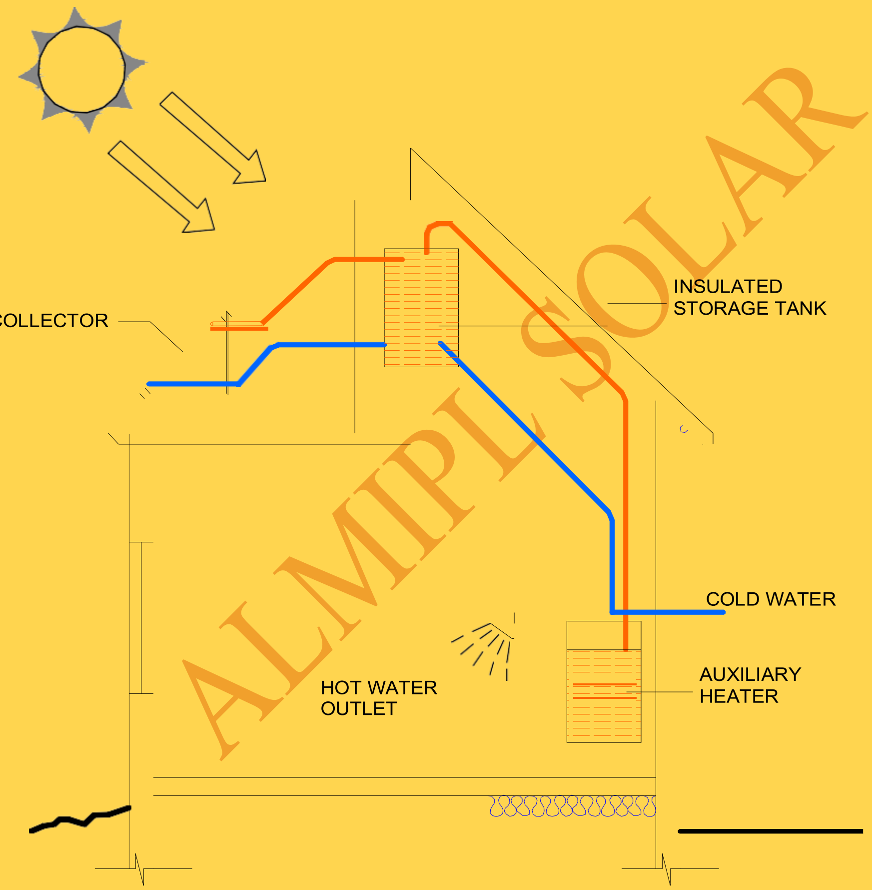

Fig. 6.1 Thermosyphon solar water heating system

4th Floor 4B, Mandira Apartments,
North Boag Road, T-Nagar Chennai- 600 017
Email: Solarbazaarpl@gmail.com
Web: www.almipl.com
Mobile: 94452 30332 /9383132332

(A) Thermosyphon water heating system

The thermosyphon water heating system consists of a solar liquid flat-plate collector and a storage tank (Fig. 6.1). Water in the collector gets heated up by solar energy, becomes lighter and rises to the top of the storage tank. The cooler water from the tank moves to the collector, setting up a natural circulation loop. For such a loop to work, the storage tank must necessarily be located at a higher level than the collector. Hot water is withdrawn from the top of the tank and cold water enters into the bottom of the tank.

The typical temperature variation of hot water in the thermosyphon system over a day (with no hot water withdrawals) is shown in Fig. 6.2. As solar radiation incident on the collector plane increases with the time of the day, the temperature of hot water increases. If water is withdrawn, the temperature would be lower than the values shown in the figure. The nature of variation would strongly depend on the water withdrawal pattern.

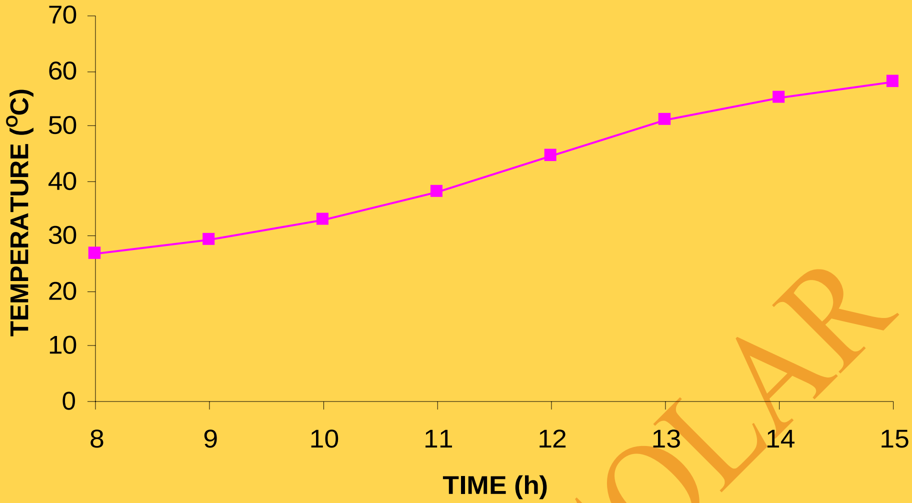

Fig. 6.2 Typical variation of storage water temperature over a few hours in a day

The system is quite simple to install and operate. Most of these systems have capacities of 100 or 150 litres per day, and use one flat plate collector having a face area of 2 m^2. The installed cost is about Rs.110 per litre per day, and the temperature of the hot water ranges from 50 to 80°C. A provision for auxiliary heating may be required for use on cloudy or rainy days. An electrical back-up heating is available with many systems.

The technical feasibility and economic viability of solar water heating are beyond doubt. Depending on the site, type of utilisation and electricity or fuel pricing, the payback period varies from 3 to 5 years. A 100 litres capacity system can replace an electric geyser for residential use, saving about 1500 units of electricity annually [1]. The life of such a system is normally 15 to 20 years.

A large number of such systems are successfully being used in the country. Thermosyphon water heating systems can be located on the roof of a building. Such installations exist at the Solar Energy Centre, Gwal Pahari (Gurgaon) and LEDeG Trainees Hostel, Leh among others [2]. The hot water systems may also be easily installed on parapets or the roof of a lift house, and be an integral part of the architecture. Such installations are being used at the residence of Mahendra Patel, Ahmedabad, Tapasya Block, Aurobindo Ashram (New Delhi), and the residence of Sudha and Atam Kumar, New Delhi to name a few [2]. The additional load due to the entire set-up consisting of a storage tank of 125 litres capacity, one collector and associated stands would be approximately 215 kg. Figure 6.3 shows a photograph of Sudha and Atam Kumar’s residence with solar hot water system.

Fig. 6.3 Solar hot water systems in Sudha and Atam Kumar’s residence in New Delhi [2]

4th Floor 4B, Mandira Apartments,
North Boag Road, T-Nagar Chennai- 600 017
Email: Solarbazaarpl@gmail.com
Web: www.almipl.com
Mobile: 94452 30332 /9383132332

Another version of a natural circulation water heating system is shown in Fig. 6.4. This has a simpler design with the functions of the collector and storage tank combined into one unit. It consists of a rectangular box kept in a housing, and is insulated on all sides except the top which has a glass cover.

The box is filled with water in the morning, which gets heated through the day and is withdrawn for use in the evening. It can also have an insulated lid for covering the glazing to reduce overnight loss of heat from the storage.

It may be mentioned that the cost of a collector-cum-storage solar water heater is relatively less. However, it is less efficient and yields water at a lower temperature compared to the thermosyphon-type (Fig 6.1)

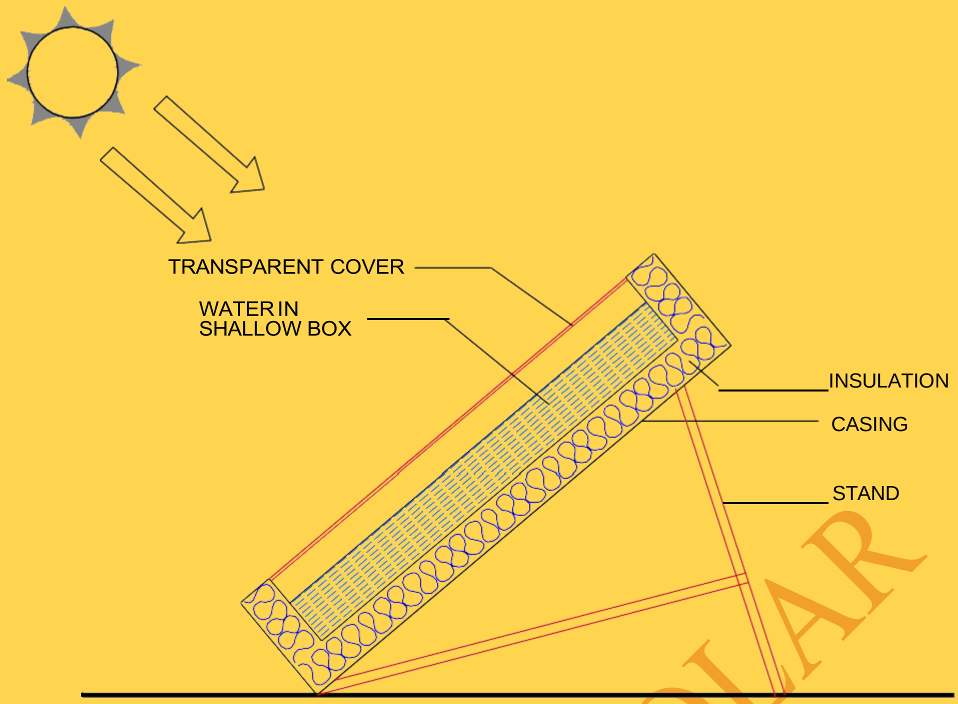

Fig. 6.4 **Collector-cum-storage solar water heating system**

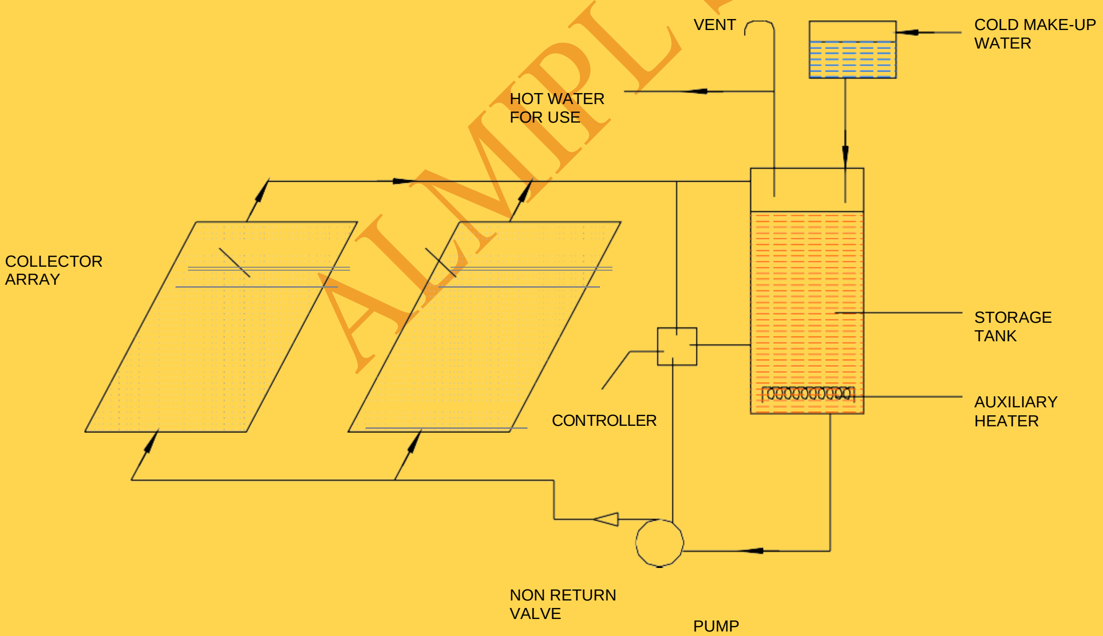

Fig. 6.5 Forced circulation solar water heating system

4th Floor 4B, Mandira Apartments,
North Boag Road, T-Nagar Chennai- 600 017
Email: Solarbazaarpl@gmail.com
Web: www.almipl.com
Mobile: 94452 30332 /9383132332

(B) Forced circulation solar water heating system

Figure 6.5 shows the schematic of a forced circulation system. It consists of an array of collectors (connected appropriately), storage tank, pump, controller and vent. It uses a water pump for maintaining the flow through the collector. The storage tank can

be placed in any position and need not be at a higher level than the collectors. Whenever hot water is withdrawn for use, cold make-up water replaces it. A controller takes care of the schedule of flow circulation in the system. The pump is switched on or off based on the difference between the temperature of the exit water from the collectors, and the temperature of the storage water measured at a suitable location. Auxiliary heating is usually provided for meeting the hot water demand. These systems are suitable for hospitals, hotels, hostels, etc. The rows of collectors are spread out such that one bank of collectors does not shade the other bank.

Forced hot water systems are used in many buildings such as MLA Hostel, Shimla and Solar Passive Hostel, Jodhpur [2]. There are many variations possible in the configuration shown in Fig 6.5. For locations where freezing conditions can occur, antifreeze mixture is used as the working fluid. In such cases, an expansion tank and a pressure relief valve are used in the collector loop to accommodate the thermal expansion of water.

The forced water heating systems are more complex than other types. As mentioned earlier, they are more suitable when a large amount of hot water is required. In addition to providing hot water for the building, these systems can be also used for space heating purposes. Hot water from the storage tank can be used to heat air using a water-to-air heat exchanger and the hot air can be used to heat the desired space. However, the systems, meeting both the requirements, become expensive and are not commonly used in India.

6.1.2 Solar Air Heating

The space heating system using water-to-air heat exchanger has been explained in the previous section. An alternative approach is to heat air directly in the collectors and store the heat in a tank packed with rock, gravel or pebbles. Such a system is shown in Fig 6.6. When hot air is needed for a living space, cool air is pushed through the storage to get heated up before it is circulated in the room. Auxiliary heating may be required to augment the solar heat. Figure 6.7 shows the photograph of an installation of an air heating system in H.P. State Co-operative Bank, Shimla [2].

In principle, one can also obtain hot water for the building through an air to water heat exchanger. Such systems are, however, expensive and are not commonly used in India.

It may be mentioned that in addition to space heating, hot air can also be used for drying purposes. Many types of solar dryers are available to suit different needs.

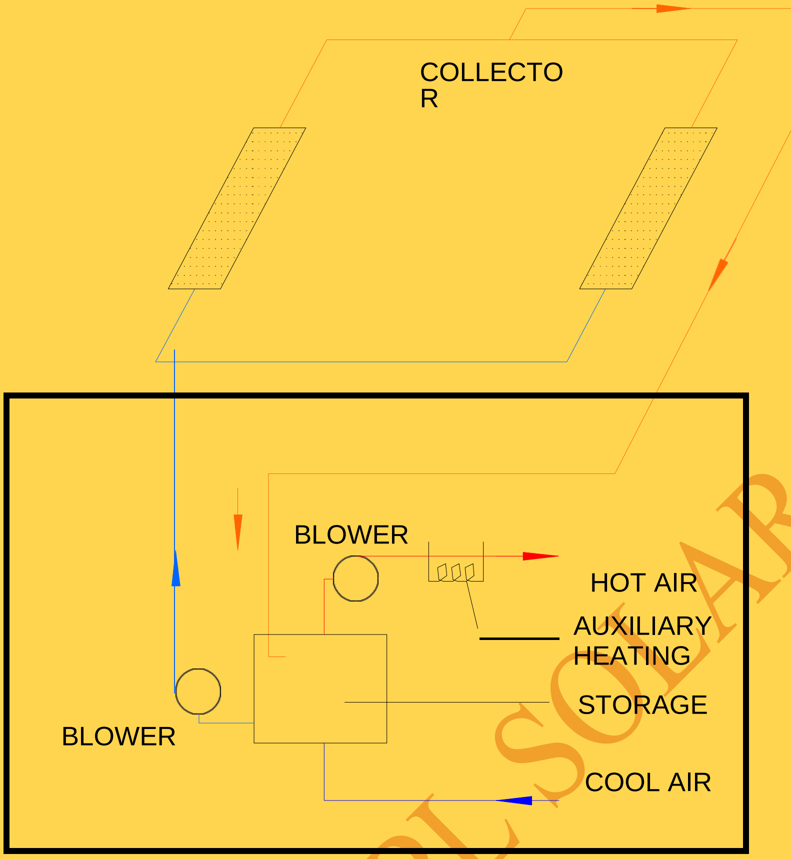

Fig. 6.6 Solar space heating system

Fig. 6.7 Photograph of solar air heating system at the HP State Co-operative Bank, Shimla [2]

6.1.2 Solar Cooking

Cooking is another important and successful domestic thermal application of solar energy. Though a number of designs have been developed, it is the box type cooker that is widely used in India. It consists of a square box insulated on the bottom and sides and having double glazing on the top. Solar radiation gets transmitted through the top and heats up the cooking vessels kept inside the box. A typical size is about 50 cm x 50 cm and 10-15 cm deep. On sunny days, a temperature of about 100° C can be easily achieved inside, and pulses, vegetables, rice etc. can be readily cooked. The time required for cooking varies depending on the level of solar radiation; it may be from half an hour to $2^1/_2$ hours. A solar cooker can cook four dishes at a time and save three to four LPG (liquefied petroleum gas) cylinders a year, if used regularly. Cookers with electrical back up are also available for use during non-sunshine hours.

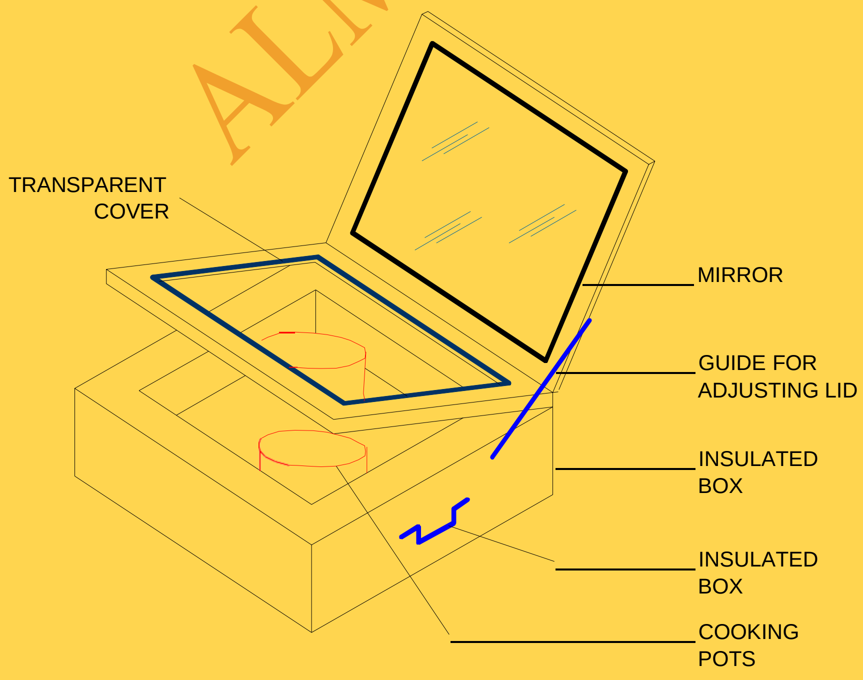

Fig. 6.8 Schematic view of a box type solar cooker

The box is provided with an insulated lid fitted with a mirror in the inner side. The lid can be adjusted to reflect radiation onto the cooking vessels and augment the level of radiation. Figure 6.8 shows a sketch of the box type cooker. Such cookers have been integrated into kitchen walls (Fig. 6.9) [2]. There are many other designs of the solar cooker available in literature [3]. Not all of these can be integrated into the building. A noteworthy model is the community solar cooker (also known as Scheffler cooker), which can be used for indoor cooking. It has a large reflector standing outside the kitchen and is automatically tracked. Solar rays are reflected into the kitchen through an

Fig. 6.9 Box type solar cooker integrated in MLA hostel, Shimla [2]

opening in its north wall (in the northern hemisphere). A secondary reflector further concentrates the radiation onto the bottom of the cooking pot. The community solar cooker can cook all types of food for about 40-50 people, and can save upto 30 LPG cylinders in a year.

6.1.3 Solar Photovoltaic Devices

Photovoltaic conversion is the direct conversion of sunlight into electricity by means of solar cells. The main advantage of solar photovoltaic devices is that they can produce power from microwatts upto kilowatts. Consequently, they are used in many applications such as calculators, watches, water pumps, buildings, communications, satellites, space vehicles, etc.

To obtain desired voltages and currents, individual cells are connected in series and parallel to form a module. A number of modules are interconnected to form an array. Based on the power requirement, arrays of appropriate sizes are used. Currently the cost of solar photovoltaic modules is around Rs.125-130 per peak watt (W_p). The Ministry of Non-conventional Energy Sources, Government of India is promoting five different configurations of solar home systems. They are: 18 W_p PV module (typically 532 mm x 448 mm) with one 9W compact fluorescent lamp (CFL); 40 W_p PV module (typically 828 mm x 433 mm) with two 9W CFLs or one 9 W CFL and a fan; and 75 W_p PV module (typically 1208 mm x 538 mm) with four 9W CFLs or two 9W CFLs and a fan/TV [1]. As far as applications in buildings are concerned, there are various usages such as, domestic lighting, street lighting, water pumping, etc.

The photovoltaic industry is growing rapidly. As a result of technological innovations, the Building Integrated Photovoltaic (BIPV) systems have become a reality [4]. Photovoltaic panels can be made to form components of a building.

Positioned on the façades or roof of a building, PV panels can generate electricity either for internal use or for distribution to an external network. They may become elements of the architectural design. Examples of such buildings including the RETREAT, Gwal Pahari (Gurgaon) and residence of Mahendra Patel, Ahmedabad are discussed by Majumdar [2].

Figures 6.10 – 6.13 show a few configurations of PV integration in buildings. Table 6.1 summarises the advantages and disadvantages of different types of PV modules as far as integration into buildings is concerned. It is desirable to use non-corrosive construction materials because small current leakages invariably occur on PV façades. Secondly, the construction should not shade the PV modules and dust and rainwater should not accumulate on it.

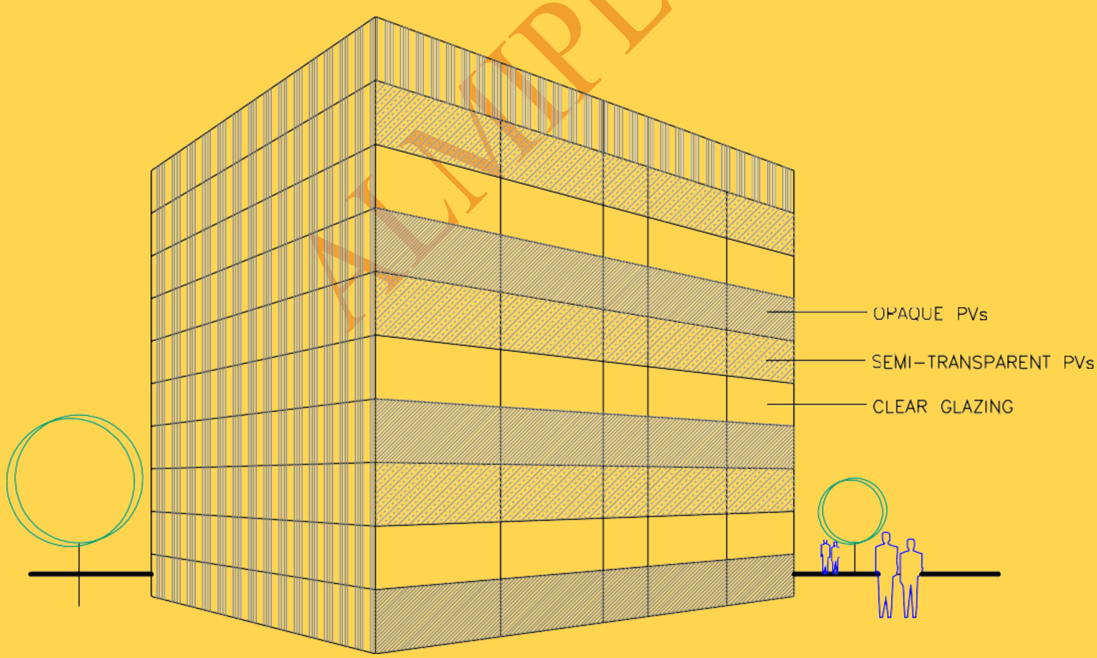

Fig. 6.10 Curtain wall with PV panels

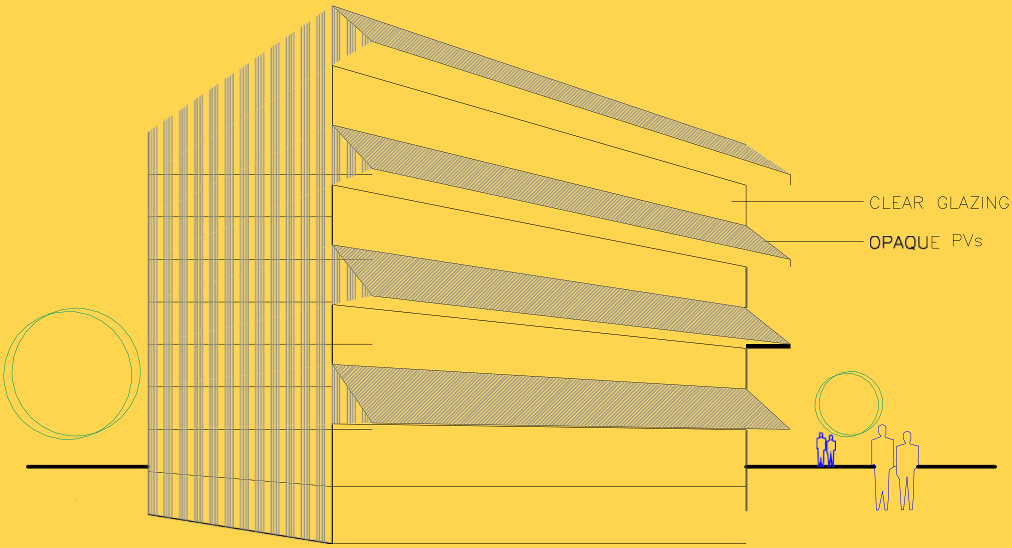

Fig. 6.11 PV panels on shading devices

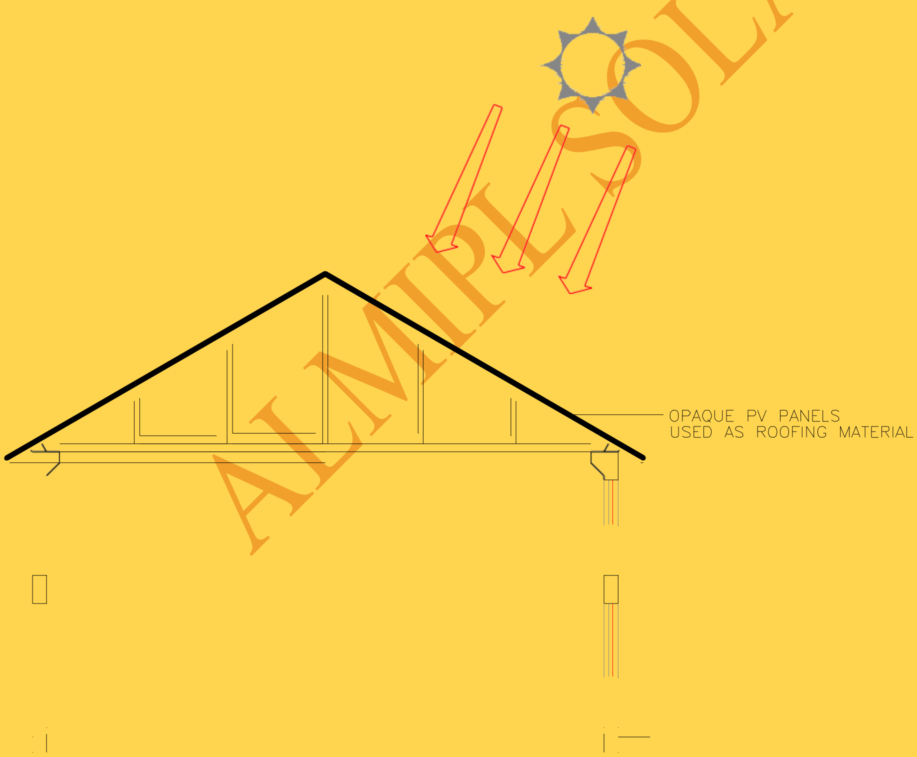

Fig. 6.12 Roof integrated PV panels

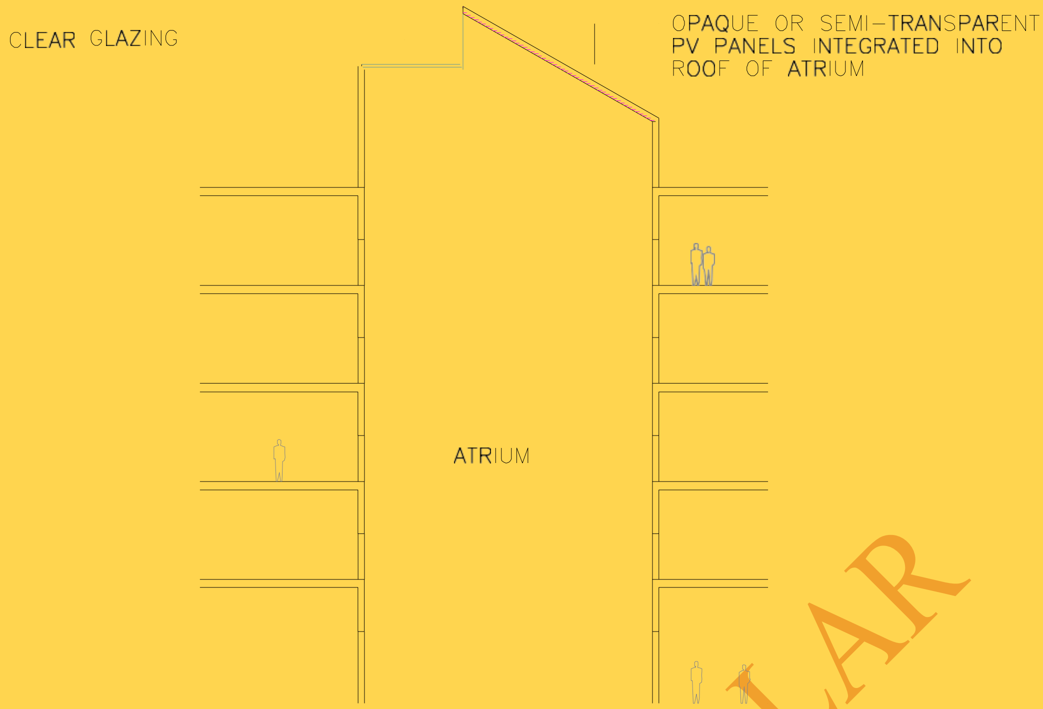

Fig. 6.13 Atrium with PV panel skylight

Table 6.1 Suitability of module types for building integration [4]

Module Type	Application suitability				
	Sloped roof	Flat roof	Wall	Windows	Shading
Standard laminates without frames	+	+	+	-	+
Standard modules with plastic or metal frame (glass multi-layer non-transparent back sheet)	+	0	0	-	0
Roofing modules (tiles/slates)	+	-	-	-	0
Glass-glass modules with predefined transparency	0	0	+	+	+
Glass modules with transparent plastic back sheet (predefined transparency possible)	0	0	+	+	+
Module with metal back sheet and plastic cover	+	+	+	-	+
Custom-designed modules	+	+	+	+	+

+ = high suitability
0 = low suitability
- = not suitable

6.1.4 Biomass

Biomass is a versatile source of energy. It can be burnt directly for heat, fermented for alcohol fuels, anaerobically digested for biogas production, or gasified to get producer gas. It includes all plant life (trees, agricultural plants, bush, grass, algae, etc.), agricultural residues (crop and agro-processing), and wastes (municipal waste, animal and human wastes). The resource is highly decentralized and scattered.

In India, the potential of biomass as an energy resource is very large. The aim of biomass conversion is to convert biomass into more useful forms: gaseous or liquid fuels. Examples of conversion to gaseous fuels include anaerobic fermentation of wet livestock (or human) wastes to produce *biogas*, a mixture of methane (45 to 70%) and carbon dioxide; and high temperature gasification of dry biomass to produce *producer gas*, a mixture of carbon monoxide, hydrogen, methane, carbon dioxide and nitrogen. As far as conversion of biomass to liquid fuel is concerned, one route is the fermentation of sugars to ethanol; another is the thermochemical conversion of biomass to pyrolysis oils or methanol. The processing of vegetable oils to biodiesel is also a method to produce liquid fuel.

The resulting liquid and gaseous fuels can be used to produce heat and power. When burnt in silk mantle lamps, biogas serves as a source of lighting. It can also be used in dual-fuel engines to substitute upto 75 per cent diesel oil for motive powers. Besides, biomass can be converted to heat and power by directly burning it – the examples are boilers and steam power plants.

Gasification systems with 5 kW to 1000 kW unit capacity suitable for using a variety of biomass, have been developed in the country. There are various types of gasifiers; the suitability of a particular type depends on the application and type of biomass. For engine applications, a downdraft gasifier is the most suitable. Updraft and crossdraft gasifiers are suitable for thermal applications. Figure 6.14 shows the sketch of a downdraft gasifier.

The Ministry of Non-conventional Energy Sources has been promoting the family type of biogas plants. The models promoted include:

- Floating gas holder type. It is called as “KVIC (Khadi and Village Industries Commission) model”
- Fixed dome type, commonly known as “Deenbandhu model”
- Bag type portable digester made of rubberized nylon fabric

A sketch of a floating dome type biogas plant is shown in Fig. 6.15.

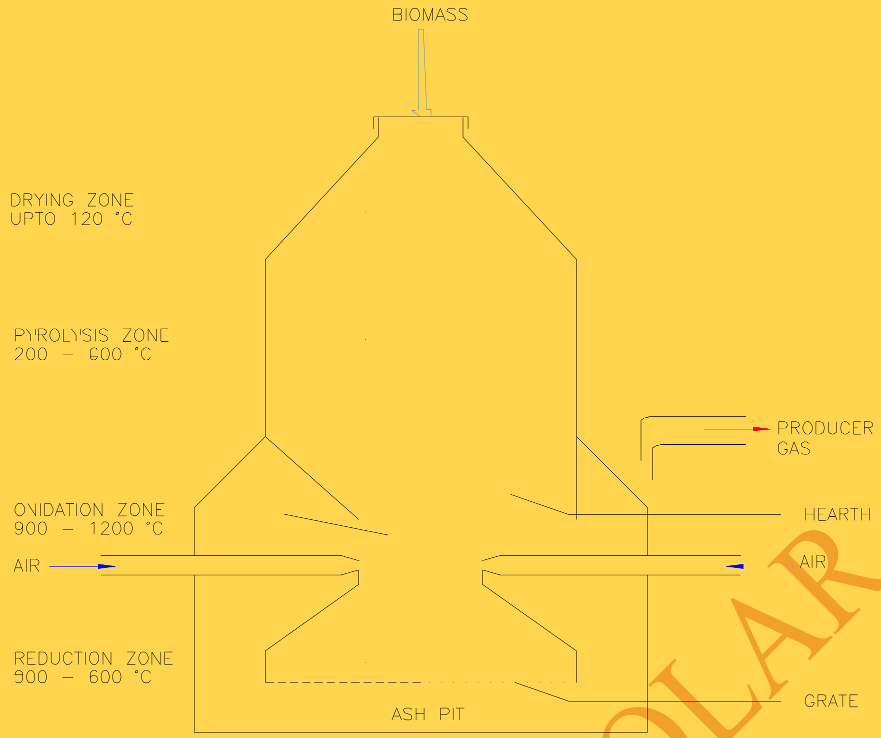

Fig. 6.14 Sketch of a downdraft gasifier

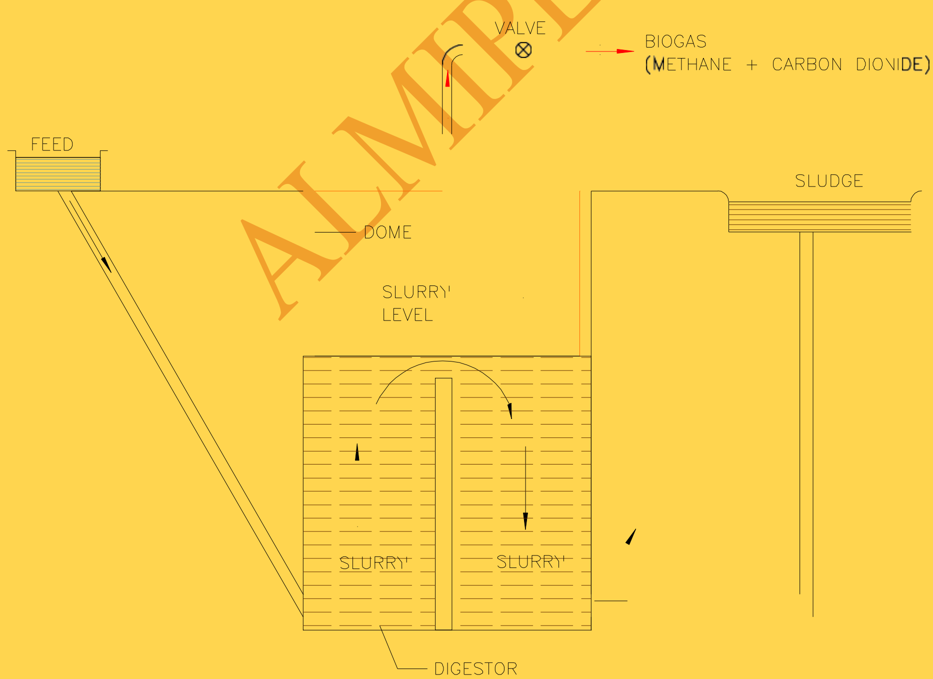

Fig. 6.15 Sketch of a floating dome-type biogas plant

As far as applications in buildings are concerned, the output of a biomass gasifier can be used for a variety of purposes such as cooking, drying, heating water, generating steam, etc. The producer gas can be used as fuel in internal combustion engines to obtain mechanical shaft power or electrical power. Similarly, biogas is an excellent fuel for cooking and lighting. It can also be used as fuel in engines. As cooking accounts for a significant proportion of household energy consumption, integration of the use of the above options with buildings leads to considerable energy savings.

6.2 PROMOTIONAL INCENTIVES

The Ministry of Non-conventional Energy Sources (MNES) as well as various state governments provide many incentives for adoption of renewable energy technologies. The MNES provides partial assistance for preparation of detail project reports (DPR) of buildings based on energy conscious design. According to the current scheme, 50% of the cost of the DPR, subject to a maximum of Rs. 2 lakhs, is paid for preparation of DPRs, including building plan and architectural drawings for public/private institutional buildings.

A maximum of 10 DPRs are supported in each state. Besides, partial funding (currently 10% of the cost of the construction subject to a maximum of Rs. 50 lakhs for each project) is provided towards the construction of demonstration buildings. The support is available for buildings of state nodal agencies and other public/government buildings. Active solar systems installed in such buildings are not covered under the scheme. Two buildings in each state are currently supported through this scheme. The state government of Himachal Pradesh has made it mandatory for all government buildings situated at 2000m above MSL to have passive solar techniques incorporated in them.

There are various types of promotional schemes floated by central as well as state government as far as solar water heating, air heating, cooking, biomass gasification, biogas etc are concerned. For example, the States of Andhra Pradesh, Haryana, Himachal Pradesh, Madhya Pradesh, Punjab, Rajasthan & Union Territory of Dadra & Nagar Haveli have made it mandatory to install water heating systems in state government buildings.

4th Floor 4B, Mandira Apartments,
North Boag Road, T-Nagar Chennai- 600 017
Email: Solarbazaarpl@gmail.com
Web: www.almipl.com
Mobile: 94452 30332 /9383132332

A few municipal bodies such as Thane in Maharashtra and Rajkot in Gujarat have modified building bye-laws to enforce solar water heating systems in new buildings. In addition to government incentives, certain companies also offer promotional schemes. For example, the Bangalore Electricity Supply Company Limited currently offers Rs.0.40 rebate on every unit of electricity used subject to a maximum of Rs.40/- per month.

The MNES has been implementing a soft loan programme for various renewable energy systems. Under this, loans at reduced interest rates are currently available to customers from IREDA and seven designated banks (Andhra Bank, Bank of Maharashtra Canara Bank, Punjab National Bank, Punjab & Sind Bank, Union Bank of India and Syndicate Bank). Also, for certain areas and for certain types of renewal energy systems, subsidies are available from the MNES through state nodal agencies.

6.3 CONSERVATION MEASURES

In addition to designing building along bioclimatic principles and using appropriate materials, it is desirable to adopt proper conservation and management practices for a building to remain both economically and environmentally viable. Both designer and user must work together to achieve this objective. While the designer should provide facilities, the user must properly understand, apply and practice the conservation measures. Recycling household wastes (such as bio-waste, kitchen waste, water, etc.), buying energy-efficient home appliances and non-hazardous products, reducing consumption of water and electricity, are some of the measures that should be implemented. Some of these can be achieved through very moderate investments. Using auto flush and auto taps in washrooms for air handling units, and water management systems such as hydro-pneumatic system including sewage pump, transfer pump and water pressurisation pumps, can also result in substantial energy saving. Similarly, vermiculture can be adopted for waste management. Biodegradable kitchen-waste can be decomposed by vermiculture to produce good quality manure, which can be used in lawns, parks etc.

Energy consumption can be reduced by the use of energy efficient home appliances, or building management systems (BMS) in offices and public buildings [5]. These work automatically depending on the building occupation status. But some of these systems may require substantial investment.

Water is a precious commodity and water conservation measures are very essential. Rainwater harvesting and recycling of water are important measures for tackling the growing shortage of pure and safe water.

(A) Rain water harvesting

Rainwater is an ideal source that can be conserved and used by people. Broadly, water harvesting is defined as the direct collection of rainwater. The total amount of rainfall over an area is called as the "Rain Water Endowment" of that area, and the part that can be effectively collected is called as the "Water Harvesting Potential". One can devise any technique to collect and store rain water in an open land. However, for urban and semi urban areas, two most suitable systems are [6]:

- Roof top rain water harvesting
- Artificial ground water recharge

In the first case, water is collected in tanks through roof gutters and down-take pipes (Fig.6.16). There should be a provision for discarding water after the first rainfall so that dust, soot, leaves etc. are drained away. The water tank should be located in an area protected from contamination by any other water. The water should not be allowed to stagnate for a long period, and it must be chlorinated appropriately.

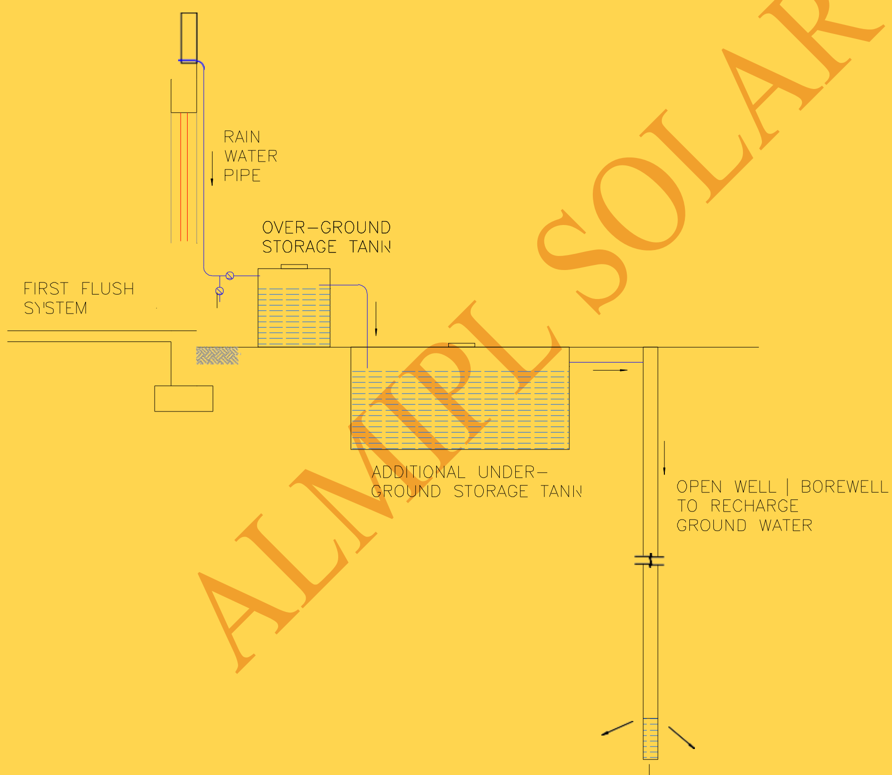

Fig. 6.16 Sketch of a rooftop rain water harvesting system

4th Floor 4B, Mandira Apartments,
North Boag Road, T-Nagar Chennai- 600 017
Email: Solarbazaarpl@gmail.com
Web: www.almipl.com
Mobile: 94452 30332 /9383132332

Alternatively, the rain water may be used to recharge the ground water by artificial means. Figure 6.17 shows a schematic sketch of a recharging structure usable in any urban and semi-urban area. It is important that the well be terminated at least 5 m above any natural source of water so that the rain water flows through naturally, and contamination hazards from ground water is avoided [6]. These wells should not be used for drawing water for any purpose. A publication from Centre for Science and Environment [7] provides detailed information on water harvesting.

Rain water harvesting has been practiced in many parts of the country. In fact, it is mandatory in many cities, facing scarcity of water. In many places, the withdrawal rate of ground water is very high compared to its replenishment. Artificial recharge programmes are already being implemented for increasing the level of ground water in some places [8]. One of the very successful programs is the construction of percolation tanks for holding rain water. This recharges the underground water of the area so that any well dug on the slopes downstream of the embankment will have plenty of water. The most successful example has been the Ralegan Siddhi area of Ahmednagar, Maharashtra [9]. It has resulted in an overall development of that area.

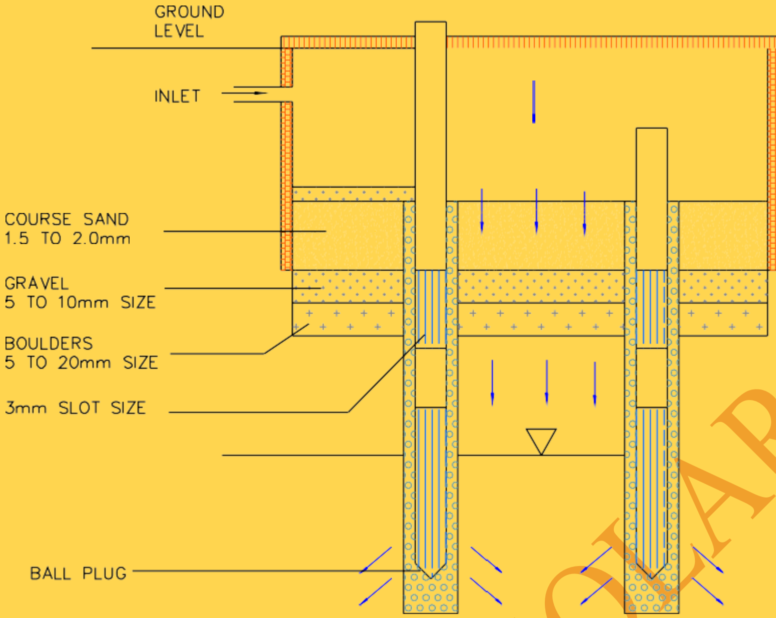

Fig. 6.17 Sketch of a recharging structure

(B) Recycling of water

Recycling of water is another important aspect of water conservation. One way of recycling is by using aquatic plants [10]. Raw sewage is recycled using aquatic plants (such as duckweed, water hyacinth, etc.) to produce clean water suitable for re-use in irrigation and industry. The plants themselves can be harvested and used for producing biogas, thus providing additional benefits.

The technique can also be used for treating animal manure and other farm wastes. The main energy saving in these ecological/biological systems occurs due to the fact that natural processes are fully utilised in the cleaning process.

(C) Energy-efficient lighting

The lighting load in some buildings could be very high and hence energy efficient lighting assumes prime importance. This depends on:

- the illuminance level for an application (Appendix VI.1 provides a list of recommended values of illuminance)
- the efficiency of various components (lamps, ballasts, luminaires)
- control
- maintenance

There are a number of ways through which energy can be conserved by lighting systems. To name a few, one can install automatic voltage stabilizers for the entire lighting circuits.

This increases the bulb life as also its efficiency; it can save upto 20% of the lighting bill. Compact fluorescent lamps (CFL) can be used in areas such as lobbies, corridors, showrooms, etc. These are highly energy efficient lamps. The chokes (magnetic ballasts) of tube lights can be replaced by energy conserving electronic ballasts. Key card systems in hotel rooms and offices, or circuit breakers for lighting and appliances in residential buildings can help reduce energy wastage. Dimmers can also be used to reduce lighting levels when bright light is not required.

6.4 EXAMPLES

There are a number of buildings that use renewable energy and energy conservation measures. Majumdar [2] has reviewed such buildings in great detail . Table 6.2 presents a few of such buildings; it lists the renewable energy features incorporated in these buildings.

Table 6.2 List of buildings using renewable energy and energy conservation measures [2]

S. No.	Name of the building	Location	Features
1.	Himurja Office	Shimla	Water heating, PV for lighting
2.	HP State Co-operative Bank	Shimla	Air heating
3.	Residence of Mohini Mullick	Bhowali Nainital	Integrated solar cooker, water heating
4.	MLA Hostel	Shimla	Integrated solar cooker, water heating
5.	LEDeG Trainees Hostel	Leh	Water heating
6.	Residence of Madhu and Anirudth	Panchkula	Water heating, PV for lighting
7.	PEDA Office Complex	Chandigarh	BIPV, water heating
8.	Tapasya Block, Sri Aurbindo Ashram	New Delhi	Water heating
9.	Residence of Sudha and Atam Kumar	New Delhi	Water heating, integrated solar cooker
10.	RETREAT	Gwal Pahari, Gurgaon	BIPV, gasifier, water heating, water recycling, building management system
11.	Solar Energy Centre	Gwal Pahari, Gurgaon	Water heating
12.	National Media Centre Cooperating Housing Complex	Gurgaon	Rain water harvesting, solid waste recycling, water heating
13.	American Institute of Indian studies	Gurgaon	Water heating
14.	Sangath	Ahmedabad	Rain water harvesting
15.	Residence of Mahendra Patel	Ahmedabad	Roof integrated PV, water heating, building automation system
16.	Solar Passive Hostel	Jodhpur	Water heating
17.	Residence of Mary Mathew	Bangalore	Water heating
18.	TERI office building	Bangalore	Rain water harvesting, PV, water heating
19.	WBREDA	Kolkata	Roof-mounted grid-interactive PV
20.	WB Pollution Control Board Laboratory	Kolkata	Waste water recycling
21.	Silent valley	Kalasa	Water harvesting, waste water and sewage recycling, biomass heater for water heating
22.	Vikas Apartments	Auroville, Pondicherry	Waste water treatment, PV, water heating, solar pumps

References

1. Ministry of Non-conventional Energy Sources, Government of India, New Delhi. website: *http://www.mnes.nic.in*
2. Majumdar M (Ed.), *Energy-efficient buildings in India*, Tata Energy Research Institute, New Delhi, 2001
3. Sukhatme S.P., *Solar energy*, 2nd Edition, Tata McGraw Hill, New Delhi, 1996.
4. Sick F. and Erge T. (Ed.) *Photovoltaic in buildings: a design handbook for architects and engineers*, James and James (Science publishers) Ltd., London, 1996
5. Bradshaw P.E.V., *Building control systems*, John Wiley and Sons, New York, 1985.
6. *SP 7: 2005, National building code of India 2005*, Bureau of Indian Standards, New Delhi, 2005.
7. *Water harvesting manual for urban areas: case study from Delhi*, Centre for Science and Environment, Delhi, 2003
8. Reddy I.V., *Water resources in Pondicherry*, Indian Architect and Builder, 6, pp. 54-55, 1992.
9. Mehta K., *The greening of a village*, Indian Architect and Builder, 6, pp. 62- 66, 1992.

10. Baetens T., *Waste water recycling using aquatic plants*, Indian Architect and Builder, 6, pp. 34-40, 1992.
11. *SP: 41 (S&T) -1987 - Handbook on functional requirements of buildings*, Bureau of Indian Standards, New Delhi, 1987.

APPENDIX VI.1

Recommended values of illumination for a few building types [11]

Buildings and Processes	Recommended Illumination (lux)
A. Offices, Schools and Public Buildings	
Airport buildings	
Reception area (desks)	300
Customs and immigration halls	300
Circulation areas, lounges	150
Assembly and concert buildings	
Foyers, auditoria	100 to 150
Platforms	450
Corridors	70
Stairs	100
Banks	
Counters, typing, accounting book area	300
Public areas	150
Cinemas	
Foyers	150
Auditoria	50
Corridors	70
Stairs	100
Offices	
Entrance halls and reception areas	150
Conference rooms, executive offices	300
General offices	300
Business machine operation	450
Assembly halls of schools and colleges	
General	150
When used for examinations	300
Platforms	300
Class room desks	300
Class room blackboards	200 to 300
B. Homes	
Kitchens	200
Bathrooms	100
Stairs	100
Workshops	200
Garages	70
Reading (Casual)	150
Homework and sustained reading	300