Reference Manuals and Checklists for the Hospitality Sector

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Executive Summary

India is rapidly becoming a preferred destination for tourism, both international as well as domestic, with an annual growth of about 15%. The hospitality sector is a major consumer of energy in different forms for various end-uses. There is significant scope for direct energy saving as well as complementing its energy supply through the installation of Solar Water Heating Systems and other Renewable Energy Technologies (RETs). Towards this, the Ministry of New and Renewable Energy (MNRE) has launched a unique initiative, titled "Campaign on Solar Water Heating and other Renewable Energy Technologies in the Hospitality Sector" under UNDP-GEF's National programme on Solar Water Heating Systems (SWHS). The main objective of the project is to promote and accelerate the application of Solar Water Heating and other RETs by developing and implementing a nationwide campaign for the hospitality sector covering the hotel and catering industry. The project focuses on following renewable energy technologies

1. Solar water heating
2. Concentrating solar thermal generation systems
3. Solar photovoltaic system
4. Biogas technologies
5. Energy conservation measures

As a part of this initiative, reference manuals have been developed to introduce the various renewable options available. They touch upon various aspects of the technology including the features, working and operation of the technologies. A series of checklists have also been developed in order to help the hoteliers carry out prefeasibility of the selected technology. These checklists will also help in getting detailed bids from the suppliers. Together with the online tools, reference manuals and checklists will help the hoteliers to access the feasibility of adopting renewable energy options at their site. This report has been arranged under five sections as detailed below.

The section on solar water heater acts as a guide for hoteliers to comprehend application of solar water heater in hospitality sector to meet their hot water requirement. It briefs about basics of solar water heating system, their mechanism of functioning, etc. Various important considerations that should be taken into account while installation of technology have also been discussed. This touches upon factors like climate conditions, water quality, temperature requirement that play an important role for ensuring the maximum output and life of technology. It also discusses about financial incentives offered by government for adoption of this renewable energy technology to carry out cost-benefit analysis of technology at their end. For better estimation of size of technology, post understanding of the basics, checklist can be referred to do a self-assessment of feasibility of technology before consulting any expert. The basic aim is to assist the hotelier in understanding this non-conventional system and selection of right type of technology for generating hot water.

Solar PV section is to guide hoteliers to understand the basic functioning of photovoltaic systems. It briefs about various types of installation techniques and various end-use applications of PV. For example, it can be in form of stand-alone or grid connected. It can also be hybridised with wind technology to generate maximum power through non-conventional mode. System components have also been briefed to give a fair idea of role of each component. Mounting options has also been discussed. This is important as there several hotels which have no freely available space on ground or roof, thus, referring to this can give knowledge of other ways of installation. Proper installation guidelines have been mentioned to ensure maximum efficiency of the system and avert other technical issues. Finally, to give a fair idea of the system cost and the available incentives, a table has been mentioned in the end. This could help in carrying out a cost-benefit analysis before investing in this technology. For better estimation of size and selection of technology, post understanding of the basics, “Checklist for Solar Photovoltaic System in hospitality sector” can be referred to do a self-assessment of feasibility of technology before consulting any expert.

The third section touches upon various aspects of solar concentrating systems in hospitality sector. It discusses about the available type of concentrators, namely, solar dishes and parabolic trough collectors (PTC). Their features and mechanism of functioning have been mentioned and some other technical parameters. Financial incentives available through government have also been mentioned to understand the economics of the technology. Also, installation guidelines have been mentioned to ensure minimum technical issues that may arise during functioning or installation phase. For better estimation of size of the technology, post understanding of the basics, “Checklist for Solar Thermal Concentrators in hospitality sector”, can be referred to do a self-assessment of feasibility of technology before consulting any expert.

Fourth section of the reference manual aims to inform about basics of various biogas technologies that are commercially available to help the hotelier to select suitable biogas technology based on the amount and type of waste produced in their facility. It discusses TEAM process and Mailhem technology elaborately, covering its basic features and mechanism of functioning. Further, advantages and cost benefit analysis have been discussed of TEAM process. Various other indigenous technologies have been tabulated summarising about their processes, biogas production, biogas content, cost and remarks. For better estimation of size of technology, post understanding of the basics, “Checklist for biogas application in hospitality sector” can be referred to do a self-assessment of feasibility of technology before consulting any expert.

The final section of the manual discusses about various energy conservation measures that can be taken up by the hoteliers either at designing stage of an upcoming building or be retro-fitted to reduce the conventional energy consumption. Starting with a briefing of current energy scenario in various hotels across star categories, the manual will take through various ways and areas through which energy could be conserved. They include Solar passive building design, building envelope material, lighting system & Heating, Ventilation and Air Conditioning System (HVAC). All these have been discussed in detail to make the user sound about various areas where energy could be easily conserved. Examples have been cited in several places for better understanding. After developing a basic understanding of measures that can be adopted, checklist can be referred for self-assessment of measures.

CONTENTS

SOLAR WATER HEATING SYSTEMS

1A. Reference Manual for Solar Water Heating Systems

Types of solar water heating systems

A solar water heater consists of a solar collector to collect solar energy, an insulated storage tank to store the hot water, and piping. Broadly, the solar water heating systems are of two types, namely, closed loop system and open loop system. In the first one, heat exchangers are installed to protect the system from hard water obtained from borewells or from freezing temperatures in the cold regions. In the other type - either thermosyphon or forced circulation system- the water in the system is open to the atmosphere at one point or other. The thermosyphon systems are simple and relatively inexpensive. Thermosyphon system relies on the natural circulation of water between the collector and the storage tank. They are more suitable for domestic and small institutional systems, provided the water is treated and potable in quality. The forced circulation systems employ electrical pumps to circulate the water through collectors and storage tanks. The choice of system depends on heat requirement, weather conditions, heat transfer fluid quality, space availability, and annual solar radiation, etc. The schematic of hot water systems are shown in figures 1.1 and 1.2, respectively.

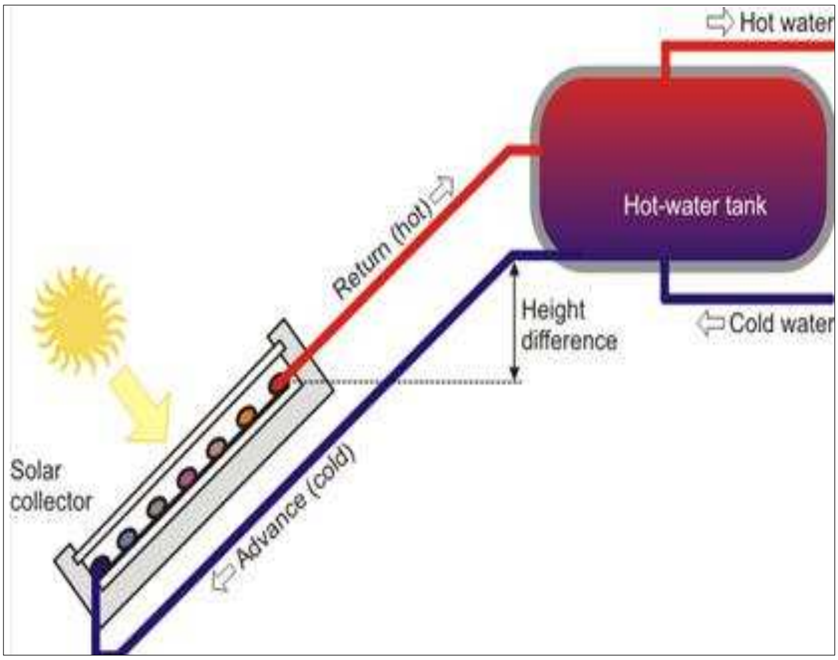


Figure 1.1: Schematic of thermosyphon type solar water heating system

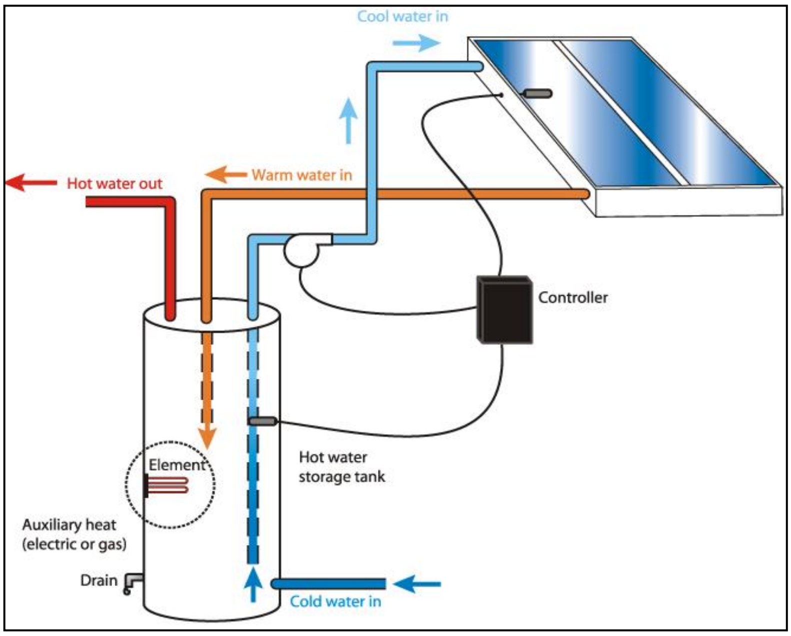


Figure 1.2: Schematic of indirect active open loop solar water heating system

Types of solar collectors

Flat plate collectors

A liquid Flat-plate Solar Collector (FPC) is a widely used solar energy collection device for applications that require heat at temperatures below 80ºC. A typical liquid FPC consists of a selectively black coated absorber plate of high thermal conductivity (such as copper or aluminium), one or more transparent covers, thermal insulation, heat removal system and outer casing. The transparent cover reduces the convective and radiative heat losses from the absorber plate to the surrounding. To achieve operating temperatures higher than 80ºC, two glass covers may also be used. The heat collected by the absorber plate is extracted by circulating a working fluid through the riser tubes attached to the absorber plate, which are further connected to a larger pipe called header at both ends as shown in figure 1.3. The working fluid, usually water or an anti-freeze mixture flows through these tubes to carry away the heat. An outer casing houses all the components; which is finally placed on a stand so that the collector properly inclined to receive maximum solar radiation.

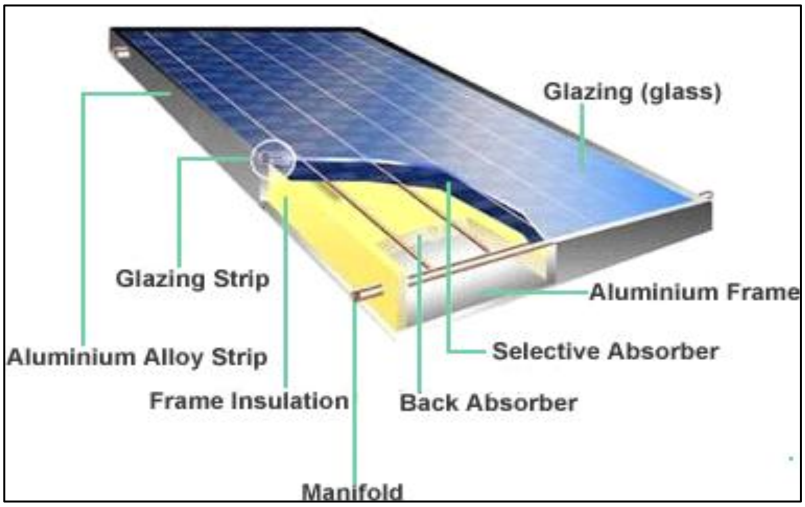


Figure 1.3: Schematic of flat plate collectors

Evacuated tube collectors

Evacuated tube collector (refer to figure 1.4 and 1.5) uses solar energy to heat the fluid inside the glass tube through absorption of radiation, but reduce the loss of heat to atmosphere due to vacuum inside the tube. Evacuated tube has different sub categories based on material used and application requirement. Life of the evacuated tube varies from 5 years to 15 years.

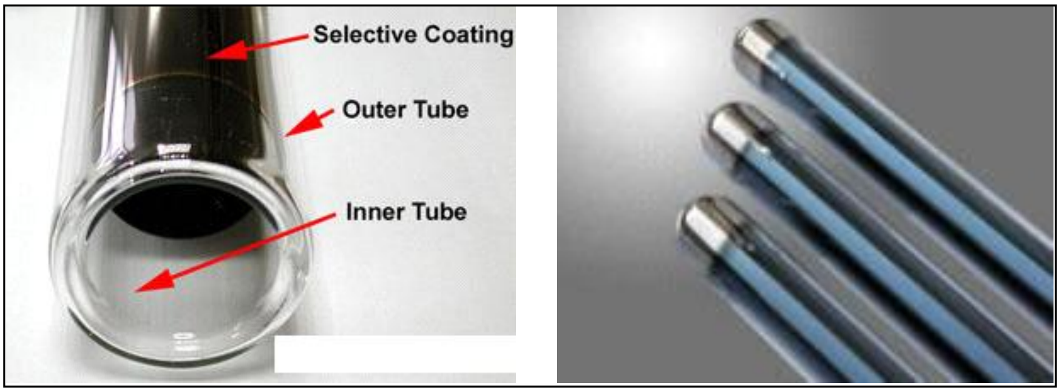


Figure 1.4: Various components of (ETC) collectors based water heating system

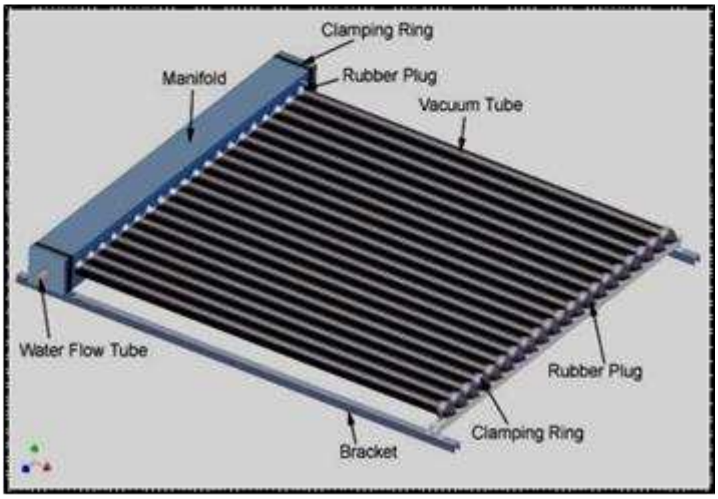


Figure 1.5: Cross sectional view of evacuated glass tube

The technical and economic feasibility of solar water heating systems has been demonstrated and established in India. Depending on the site, technology, utilization and fuel being replaced the payback period varies from 2-6 years.

Selection of right technology

It is necessary to have solar water heating system with the right technology, features and capacity to ensure a long term reliable and smooth operation of the system. Installation of the solar water heater in the right manner, suitable for the specific site conditions is very important for optimal performance of the system. Following additional system-technology features may help in selection of the solar water heating system with appropriate technology, suitable for the size and site conditions.

Active solar water-heating systems

For systems of size larger than 3000 litres per day, customer may choose active (forced) circulation system. These systems may also be used for smaller than 3000 litres/day capacity also where thermosyphon system cannot be used due to limitation of height of the cold water tank. Active solar water heaters rely on electric pumps, valves, and controllers to circulate water, or other heat-transfer fluids (usually a propylene-glycol mixture) through the collectors. There are the three types of active solar water-heating systems:

1. Direct-circulation systems (or open systems) use pumps to circulate water through the collectors. These systems are appropriate in areas that do not freeze for long periods and do not have hard or acidic water.
2. Indirect-circulation systems (or closed systems) pump heat-transfer fluids, such as a mixture of glycol and water antifreeze, through collectors. Heat exchangers transfer the heat from the fluid to the potable water stored in the tanks.
3. Drain back systems, a type of indirect system, use pumps to circulate water through the collectors. The water in the collector loop drains into a reservoir tank when the pumps stop. This makes drain back systems a good choice in colder climates.

Passive solar water-heating systems

Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. For small application, up to 3000 litres capacity, they are preferred for their simplicity and ease of operation. In such cases, the source of the cold water must be placed at least 7 feet above the terrace level for size up to 500 litres,(for larger tank sizes, the height requirement may go up to 10 feet or higher),where solar water heater system will be installed. Passive solar water heaters rely on gravity and natural convection for water to naturally circulate as it is heated. Because they contain no electrical components, passive systems are generally more reliable, easier to maintain, and possibly have a longer work life than active systems.

1. Integral-collector storage systems consist of one or more storage tanks placed in an insulated box with a glazed side facing the sun. These solar collectors may be best suited for areas where temperatures rarely go below freezing. They are also good in households with significant daytime and evening hot-water needs; but they do not work well in households with predominantly morning draws because they lose most of the collected energy overnight.
2. Thermosyphon systems are an economical and reliable choice, especially in new homes. These systems rely on the natural convection of warm water rising to circulate water through the collectors and to the tank (located above the collector).

Solar water-heating systems almost always require a backup system for cloudy days and times of increased demand. Conventional storage water heaters usually provide backup and may already be part of the solar system package. A backup system may also be part of the solar collector, such as rooftop tanks with thermosiphon systems. Since an integral-collector storage system already stores hot water in addition to collecting solar heat, it may be packaged with a demand (tankless or instantaneous) water heater for backup.

Salient features of solar water heating system

- Around 60 deg. – 80 deg. C temperature can be attained depending on solar radiation, weather conditions and solar collector system efficiency
- It can be installed on roof-tops, building terrace and open ground where there is no shading, south orientation of collectors and over-head tank above SWH system
- Solar water heating system generates hot water on clear sunny days (maximum), partially clouded (moderate) but not in rainy or heavy overcast day
- Only soft and potable water can be used
- Stainless Steel is used for small tanks whereas Mild Steel tanks with anticorrosion coating inside are used for large tanks

Environmental benefits

A 100 lpd system on an average saves up to 1500 units of electricity/yr. To generate that much of electricity from a coal based power plant, 1.5 tone of CO_2 /year is released in atmosphere. One million solar water heating systems installed in homes will, therefore, also result in reduction of 1.5 million tone of CO_2 emission in atmosphere.

Additional considerations

In places where water quality is not suitable for direct use in the solar collector, or in cold regions where water may freeze in the collectors at night, solar water heater system with heat exchanger is required. Users located in low temperature zones (minimum night temperature of 2° C and below) have to use solar water heater with indirect heating with antifreeze. If the water pressure coming from the cold water source is very high (above 3 bars) it will be necessary to use heat exchangers. Performance of ETC and FPC based solar water heater systems varies with location, seasons and many other external factors. In cold climatic conditions where ambient temperature reaches the freezing temperature of water, performance of heat pipe based ETC based system is better as compared to FPC based system. Similarly, direct heating of water is not advisable in such conditions. Heat pipe based ETC system or FPC based system with heat exchanger is recommended if the ambient temperature can go below 2°C.

Flat plate collector (FPC) based systems are of metallic type and have longer life as compared to Evacuated tube collector (ETC) based system as ETCs are made of glass which are of fragile in nature.

Desired temperature of hot water

Required temperature of hot water shall vary depending on application and accordingly suitable technology must be selected. Following table 1provides general guideline for selection of a suitable technology for various temperature applications.

Table 1.1: Suitable technology based on application

Application	Technology
Low temperature application from 40° C up to 80° C	FPC / ETC
Medium temperature application from 80° C to 120° C	Heat pipe ETC
Low temperature commercial application (swimming pool)	FPC / ETC

Water quality

Water quality plays an important role in selection of the technology as well as heat exchange mechanism. In case water is hard, there are chances of scale formation in the solar collector. Formation of scale is faster in FPC based system than in ETC based system. However, scale formation takes place in ETC based system as well. In such kind of water, indirect heating through heat exchanger is recommended. In case of indirect heating scale formation takes place at the heat exchanger surface, which can be easily cleaned at periodic intervals. However, newer technologies are coming in where inner surface of the collector tubes are treated with special chemical to reduce scale formation

Other environmental factors

ETC is more susceptible to damage due to the structure of its tubes. In areas where hail is common, ETC should not be used as glass tubes are likely to break due to hail storm. Similarly in areas where animals like monkeys or cats frequent the solar water heater installation area, glass tubes of ETC may break leading to system shutdown. Therefore it is advisable not to use ETC based systems in these areas.

Financial incentives

To promote solar hot water systems, Ministry of New and Renewable Energy (MNRE) provides subsidies to the tune of 30% of the system capital costs (based on benchmark costs) as shown in the following table 1.2.

Table 1.2: Capital subsidies offered by government for various solar thermal technologies

S. No.	Solar collector type	Capital subsidy/ collector area (Rs. /sq.m.)
1.	Evacuated tube collectors (ETCs	3000
2.	Flat plate collectors (FPC) with liquid as the working fluid	3300
3.	Flat plate collectors with air as the working fluid	2400
4.	Solar collector system for direct heating applications	3600
5.	Concentrator with manual tracking	2100
6.	Non-imaging concentrators	3600
7.	Concentrator with single axis tracking	5400
8.	Concentrator with double axis tracking	6000

Indicative prices of solar water heating systems of different capacities are as in table 1.3.

Table 1.3: Cost of SWHS vs capacity

Capacity (Litres Per Day)	F.P.C. Type (in Rs.)	E.T.C. Type (in Rs.)
100	22,000	20,000
200	38,500	32,400
500	85,500	64,800
1000	1,67,000	1,25,900
1500	2,50,000	1,77,000
2000	3,21,000	2,68,000
3000	4,09,200	3,80,500
4000	6,83,000	4,76,000

Capacity (Litres Per Day)	F.P.C. Type (in Rs.)	E.T.C. Type (in Rs.)
5000	8,49,700	5,58,300

Payback period

Though the initial investment for a solar water heater is high compared to available conventional alternatives, the return on investment has become increasingly attractive with the increase in prices of conventional energy. The payback period depends on the site of installation, utilization pattern and fuel replaced. Typical payback periods are as follows:

- 3-4 years when electricity is replaced
- 4-5 years when furnace oil is replaced
- 5-6 years when coal is replaced

Installing a solar water heating system

1. The orientation of the solar collectors is very important for their functioning. In most of the cases the installer will install the solar collectors at an angle of latitude with the horizontal, facing southwards.
2. Proper insulation of the pipes and of the storage tank is a must.
3. Leakages in the aluminium cladding can lead to water logging in the insulation, thereby defeating the purpose of insulation as well as reducing its life.
4. Just like a boiler or a water heater, the solar hot water should be accurately sized to your needs. An undersized system will not be able to supply your requirements because of lower hot water/steam generation, at the same time an oversized system will be too costly.
5. Just like any other system a maintenance schedule is important to ensure smooth working of the system and for its long life. The maintenance schedule is mostly dependent on the type of water available at your location.

Ensuring these issues are taken care of will go a long way in ensuring that you are able to meet your needs in an economically and environmentally sustainable manner.

For further details, including those of manufacturers, please visit the website:

http://mnre.gov.in/faq-swh.htm

1B. Checklist for Solar Water Heating Systems

Solar Water Heating Systems, consisting of solar collector (either flat plate or evacuated tube), storage tank, piping, and controls can be used to meet the hot water requirement in the hotels. The solar water heating system could be installed to fully or partially cater to hotel's hot water demand, depending upon the availability of shadow-free area. The objective of this checklist is to get the preliminary idea of feasibility of solar water heating system in a particular hotel. The checklist will also help in getting detailed bids from the suppliers for installation of solar water heating system.

A. Hotel Details

1. Type of Hotel (Please tick √ the right option)

☐ 5 Star Deluxe	☐ 5 Star	☐ 4 Star	☐ 3 Star
☐ 2 Star	☐ 1 Star	☐ Heritage	☐ Heritage Classic
☐ Heritage Grand	☐ Government approved non-star category		☐ Unapproved

2. Total number of rooms_________________

3. The number of swimming pools and water capacity of each swimming pool.

Total Number of Swimming Pools	______________________
Water Capacity of each swimming pool	1.________________ cubic metre 2.________________ cubic metre 3.________________ cubic metre

4. Fuel expenditure

Type of Fuel	Average Annual Consumption	Cost per Unit Consumption
	Units	Rs./Unit
Electricity	………...……………………kWh	……………………..(Rs./kWh)
LPG	………………………………..kg	……………………....(Rs./kg)
Diesel	……………………………..Litres	……………………...(Rs./litre)
Other fuel_________	…………………………………	…………………………………
Other fuel_________	…………………………………	…………………………………

5. Hot water requirement in your establishment?

☐ Yes

☐ No

6. The average quantity of hot water requirement. Where available, application wise breakup (guest rooms, laundry, kitchen, pool heating etc.) of hot water requirement would be more helpful to the system supplier.

   ____________________________________ in Litres per Day (LPD)

7. The sources of hot water and steam for the hotel.

Source →	**Boiler (Specify the fuel______________ _______________)**	**Electrical (Grid supply)**	**LPG**	**Other Gas**	**Any other fuel (please specify ______________ ______________)**
For Hot Water					

8. The total available shadow free area within the establishment.

Available Shadow Free Area	**Area (in square metres)**
Available Shadow free roof area	
Available Shadow free open space (other than roof area)	
Total Available Shadow free area	

(N*ote: Available shadow free area is the one presently not occupied by any object or for any activity, is shadow free and can be made available for solar water heating system*)

9. Quality of water available at site ___________________________________

   Is a water softener installed? If yes, provide the respective details.

B. Proposed system

This section of the checklist lists the details of the solar water heating system that can be installed at the hotel. The system supplier/installer will work out these values at the design stage, thus if these values are not readily available they may be consulted for the same. For hotels interested in doing a quick thumb rule based self-estimation go to Section C.

10. Type and capacity of the solar water heating system to be installed

    <u>Type</u>

    ☐ Flat plate Collectors (FPC)

    ☐ Evacuated Tube Collector (ETC)

    Capacity _____________ LPD

11. Details of flow in the system required

    <u>Fluid circulation</u>

    ☐ Forced (pump required)

    ☐ Thermo siphon

Heat Exchanger required

- ☐ Yes
- ☐ No

Whether system will be pressurized

- ☐ Yes
- ☐ No

12. In existing centralized water heating systems, the solar water heaters can be integrated with the boiler etc. If not, a distribution system may be required. Whether integration with existing boiler/geysers will be undertaken?

    - ☐ Yes
    - ☐ No

13. For structural safety of the building (if the system is to be installed on terrace), it is important to do load bearing analysis. Whether this has been completed

    - ☐ Yes
    - ☐ No

    Anticipated total weight of the system when filled with water/fluid (including piping and other accessories) ________________________________

14. Total cost of the system and component wise cost breakup (use a separate sheet)
15. Expected annual fuel savings _______________
16. Expected payback of the system ________________ Year(s)

C. Self-estimation of the size/cost of solar water heating system that can be installed

From question no. 8, you already have an idea of the total available shadow free area within your establishment. Depending upon the available shadow free area, the solar water heating system may be installed on roof top and/or in any other open space within the premises.

Area Requirement for Solar Water Heating System Installation

Approximately 3 sq. meter shadow free space is required for every 100 LPD system having one collector. For higher capacity system, the area required increases proportionately. For every 100 LPD solar water heating system, 2 sq. meter of collector area is required and the remaining space is required for balance of system.

Cost of Solar Water Heating System

Indicative prices of solar water heating systems of different capacities are as follows:

Capacity (Litres Per Day)	F.P.C. Type (in Rs.)	E.T.C. Type (in Rs.)
100	22,000	20,000
200	38,500	32,400
500	85,500	64,800
1000	1,67,000	1,25,900
1500	2,50,000	1,77,000
2000	3,21,000	2,68,000
3000	4,09,200	3,80,500
4000	6,83,000	4,76,000
5000	8,49,700	5,58,300

Capital Subsidy Available on Solar Water Heating Systems

For all MNRE approved SWH systems, as on 01.11.2010 subsidies are available at the following rates:

S. No.	Solar Collector Type	Capital Subsidy/ Collector area (Rs. / sq. m.)
1.	ETC	3000
2.	FPC with liquid as the working fluid	3300
3.	Flat Plate Collectors with air as the working fluid	2400

Apart from the above mentioned subsidies, soft loan @ 5% interest is available for balance cost, which may comprise installation charges, cost of civil work, costs of accessories (viz. insulating pipeline, electric pump, controllers and valves, and additional water tanks)

SOLAR PHOTOVOLTAIC SYSTEMS

2A. Reference Manual for Solar Photovoltaic Systems

Introduction

A solar photovoltaic (SPV) system converts incident solar radiation to electricity using semi-conductor devices. Solar photovoltaic is a commercially available technology in India and solar PV systems have been successfully installed in many buildings. Adoption of this technology will help in meeting the electricity demands to a greater extent. The best part is that they are modular in nature i.e. the depending on the changing requirement of the hotels; the solar modules can be changed to meet the electricity demand.

Components used in a system depend upon the type of system configuration, which in turn is dependent on the application. For example: Storage batteries are not used in case of grid interactive PV system and inverter is not used for DC load. Usually SPV systems have a fixed orientation which can be set (at an appropriate angle) at the time of installation.[1] Depending upon the availability of shadow free space in the hotel facility and purpose of application, solar PV system of various sizes can be installed accordingly to meet the electricity demand for various applications.

Types of PV installation

SPV system configurations can be of three types as described below:

Stand alone

These systems can generate, store and deliver power without depending on the electricity supply Small stand-alone SPV systems can power systems like:

- Home lighting
- Street lights
- Water pumps
- Garden lights
- Illuminated hoardings

Depending on the nature of the load, stand-alone SPV systems are designed with or without storage battery:

a. Stand-alone SPV systems without storage battery

These systems are the simplest and least expensive as compared to other types of photovoltaic systems. They are designed for usage only during the day time. The appliances use the electricity as it is generated. Depending on the magnitude of the incident solar radiation the electricity output of these types of systems varies during the day. These types systems are mostly used for water pumping application as well as garden sprinklers (see figure 2.1 below).

[1] However, there are sophisticated SPV systems available that use sun tracking devices (single or double axis) to achieve high radiation all year round and thus have higher efficiency.

Figure 2.1: Stand-alone PV for water pumping in field

b. Stand- alone SPV systems with storage battery

These systems have batteries for storing electrical energy to operate during night or during periods with cloudy weather conditions. Batteries store the electrical energy generated by the SPV modules and power can be drawn from the batteries as and when required (figure 2.2).

Figure 2.2: Stand-alone PV with battery bank for street lighting

Grid interactive

These systems are connected to the electricity grid. DC electricity generated by the PV system is converted to AC electricity at the grid voltage through a specially designed inverter. Grid-interactive systems can be designed with or without battery storage. The main advantage of this system is that the power can be fed into the grid or can be drawn from the grid as required (Figure 2.3)

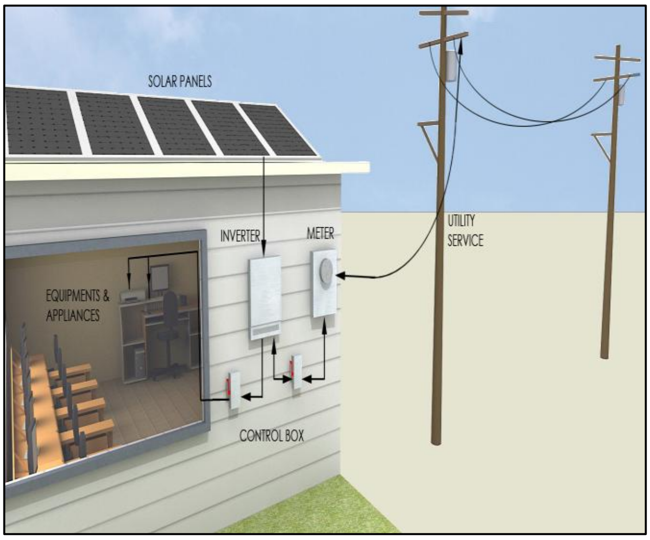


Figure 2.3: Grid connected photovoltaic

Hybrid systems

When SPV systems are combined with any other power generating systems like wind turbines or diesel generators, they are called hybrid systems (figure 2.4).

Figure 2.4: A wind-PV hybrid

Components of typical SPV system

A typical SPV system consists of an array of photovoltaic modules and a balance of system (BoS) which comprises of support structure, cabling, battery, charge controller, inverter, mounting structure, etc. Figure 2.5 shows various BOS components of a PV system.

There are various options for mounting PV panels and it is dependent on the area of the PV panels to be installed. Area of the PV panels to be installed is determined based on the load requirement, electricity usage pattern, technology and overall efficiency of the PV system. The total area required includes the area of the panels as well as the area required for accessing the panels.

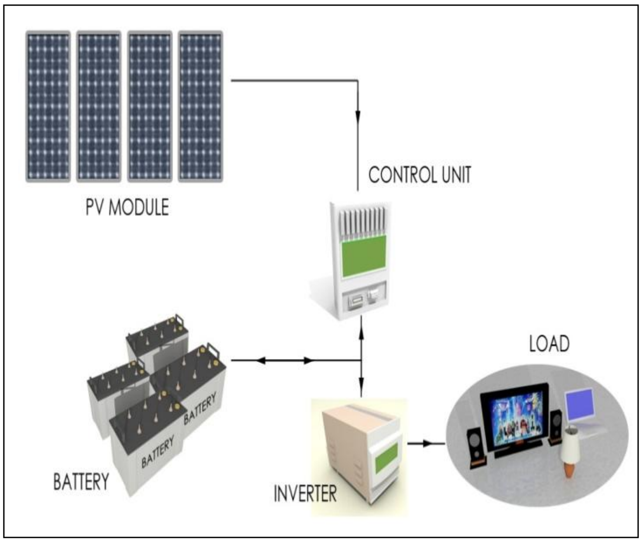


Figure 2.5: Balance of System (BOS) in a Photovoltaic system

- Mounting on Roof: As shown in figure 2.6, this is the most convenient place for installing solar PV panels as it provides an unobstructed area for solar access. In case of flat roofs, PV panels are mounted at such an angle that exposes the panels to maximum incident solar radiation throughout the year for achieving maximum efficiency. During mounting, it should be ensured that any roof penetrations are properly weatherproofed. Another important issue to be considered while installing PV system on roof is the structure of roof and load that the existing roof can take without causing any structural damage.
- Shade Structure: Beside the roof, the PVs can also be mounted on structures like patio. These could even become the complete patio cover as well, eliminating the need for a shade structure for the patio.
- Building Integrated Photovoltaic (BIPV): With the help of new technologies in the field of PV, photovoltaic can be integrated into the building envelope itself making them an integral part of the building roof or facade structure. BIPVs are PV panels integrated into the building structure during construction. They can be used in areas like skylights, glass atrium roofs, curtain and structural glazing systems on the façade. BIPVs help in cutting the heat gain while allowing light to pass through.

Figure 2.6: Roof top PV

Some important non-technical factors that influence the output from a PV system are:

- **Solar radiation:** Power generated by a solar cell is dependent on the incident solar radiation which varies according to the geographical location (latitude and longitude), season and tilt and orientation of the solar panel.
- **Temperature:** The power generated by solar cells decreases with increase in the solar cell temperature. It decreases at a rate of about 0.45% per degree rise in temperature. Each solar cell has its defined nominal operating cell temperature (NOCT).
- **Shading:** Shading has a detrimental impact on the performance on SPV systems. Even partial shading can drastically reduce the solar panel output and if it persists, may even damage the whole system.
- **Other effects:** Dirt and dust accumulating on the surface of the panels results in reduction in the amount of incident solar radiation. This can lead to reduction in power generation. Mismatching of modules in a string, resistance of wires and cables, etc., also have a significant impact on the performance of SPV systems.
- **Life of the battery:** The higher the frequency of charging/discharging for a battery, the shorter its life is. Similarly, the deeper the battery is discharged, the shorter its life.

Installation guidelines

1. Determine the total area requirement for installation of PV power system and identify a suitable building location where the PV can be mounted or integrated into the building envelope.
2. The average solar PV modules and framing will add a load of about 7-8 kilograms per square foot. So, ensure that the roof or any other structure below the PV installation is designed to handle such loads.
3. Ensure that the PV installation is done in a manner such that it will not cause any hindrance to any future construction/extension work.
4. In the northern hemisphere, solar panels should be installed such that they are facing south. For maximum annual energy collection, the tilt of the solar panel should be equal to that of the latitude of the area. Latitude $+15^0$ tilt provides maximum collection during winters and latitude -15^0 tilt provides maximum collection during summers.
5. Ensure that the solar panels are located in a shadow free area.
6. Wiring and electrical load distribution should be planned to have optimum utilization of solar energy.
7. To speed up the installation process and limit errors in wiring connections, devices that simplify connections like plug connectors, polarized caps and push tabs, should be used.
8. The control room where batteries are placed should be well ventilated and other components like the power conditioning equipment can be installed in the same room or in a separate room adjacent to the battery bank.
9. To minimize wiring losses, all the PV components should be placed close to each other and as close as possible to the modules.

In addition to solar photovoltaic there are few other renewable energy technologies that can be used for generating power on site for meeting some portion of the buildings energy requirement.

Subsidy

To promote solar PV systems, Ministry of New and Renewable Energy provides subsidies to the tune of 30% of the system capital costs (based on benchmark costs). The subsidies provided by MNRE are listed in table 1 and 2 below.

Table 2.1: Summary of various subsidies offered by MNRE, GoI

1.	**Individuals**		
A.	All applications except 1B	1 kWp	Capital subsidy and interest subsidy
B.	Pumps for irrigation and community drinking water	5 kWp	
2.	**Non-commercial entities**		
A.	All applications except 2B	100 kWp per site	Capital subsidy and interest subsidy
B.	Mini-grids for rural electrification	250 kWp per site	
3.	**Industrial/commercial entities**		
A.	All applications except 3B	100 kWp per site	Capital subsidy or interest subsidy
B.	Mini-grid for rural electrification	250 kWp per site	

Table 2.2: Summary of scale of various subsidies offered by MNRE, GoI

Scale of capital subsidy		
Based on Benchmarking annually	Rs.81/Wp	With battery storage
	Rs.57/Wp	Without battery storage
Scale of interest subsidy		
	Soft loan@ 5% p.a.	On the amount of project cost
		Less promoter's contribution
		Less capital subsidy amount

2B. Checklist for Solar Photovoltaic Systems

Solar photovoltaic system converts the incident solar radiation into electricity using semiconductor devices. A typical PV system consists of an array of photovoltaic modules and a balance of system (BoS) which comprises of support structure, cabling, battery, charge controller, inverter, mounting structure, etc. These components used in a system depend upon the type of system configuration, which in turn is dependent on the application. For example: Storage batteries are not used in case of grid interactive PV system and inverter is not used for DC load. Small sized systems can help in meeting street and garden lighting demands, water pumps, home lighting etc. You may consider installing Solar PV system to meet a part of your current energy loads and to reduce your carbon footprint.

The objective of this checklist is to give a preliminary idea of estimating the application of solar PV in your campus.

---

1. Type of Hotel (Please tick √ the right option)

☐ 5 Star Deluxe	☐ 5 Star	☐ 4 Star	☐ 3 Star
☐ 2 Star	☐ 1 Star	☐ Heritage	☐ Heritage Classic
☐ Heritage Grand	☐ Government approved non-star category		☐ Unapproved

2. Please specify the total number of rooms ________________

3. Please specify the number of Street or Pedestrian lights that are there are within your establishment. ______________________________No. of Street/ Pedestrian Light

4. Please specify the source of power for street lighting within your establishment?

   ☐ Only Conventional Source (e.g. Grid Electricity)
   ☐ Solar
   ☐ Both

5. Please specify the total available shadow free area within your establishment

Available Shadow Free Area	**Area (in square metres)**
Available Shadow free roof area	
Available Shadow free open space (other than roof area)	
Total Available Shadow free area (available for installing PV system)	

Please note: *Available shadow free area is the one presently not occupied by any object or for any activity, is shadow free and can be considered as available space for Solar PV system.*

Self-estimation of the size/ capacity of solar PV system that can be installed

From question no. 5, you already have an idea of the total available shadow free area within your establishment. You also know the location of available shadow free space (that is, whether it is on roof top or some other place). Also, question no. 3 tells you the option of going for stand-alone systems to power street lighting. Please find below details on area requirement for Solar PV System installation:

Area requirement for Solar PV System installation

Technology-wise typical area requirement per unit module can be calculated based on the table below:

Solar PV Technology	**Power Output per Unit Area (Wp/ m²)**
Thin Film	65
Monocrystalline	132
Polycrystalline	129

Thin Film based PV modules need almost double the area required by Mono-crystalline or Polycrystalline PV modules for the same power output.

Cost of Solar PV System

Following table gives an indicative idea about the cost economics of off-grid solar PV system:

Cost of the System

The benchmark cost[2] for Solar PV Module has been taken as follows:

Solar PV System	Cost per Watt (Rs.)
Solar PV System with Battery	300
Solar PV System without Battery	210

The above mentioned cost includes cost of PV Panel as well as Balance of System.

Cost of Solar based Street/ Pedestrian Lighting System
Cost of one unit of Solar PV based Street Lighting System is typically Rs. 20000 to Rs. 27000.

Capital Subsidy Available on Solar PV System
For all MNRE approved Solar PV systems, subsidies are available at the following rates:

S. No.	Solar Collector Type	Capital Subsidy (Rs./ Wp.)
1.	Solar PV System with Battery	Rs. 90/ Wp
2.	Solar PV system without Battery	Rs. 70/ Wp

The above subsidy is available for all decentralized systems of 100 kW or below. Apart from the above mentioned subsidies, soft loan @ 5% p.a. interest is available on the amount of project cost *less* promoter's contribution *less* capital subsidy amount.

Average daily output of a solar PV system is typically equivalent to 5 to 6 hours of its peak performance.

[2] Source: MNRE, GoI

Important notes:

1. In case, only conventional source is being used, then you may consider substituting completely or partially the existing conventional street lighting systems with Solar PV systems. If, both Conventional as well as Solar PV systems are being used, then you may further consider substituting the existing conventional Street lighting systems with Solar PV Systems.
2. If, there are any expansion plans within the existing hospitality unit or plans of coming up with new hospitality units, it is recommended to consider installation of solar PV systems in these new units.
3. If you are considering of installing Off-grid Solar PV System within your establishment. Both Decentralized Off-grid as well as Centralized Off-grid Solar PV systems can be installed. Decentralized PV systems can be used for street/ pedestrian lighting, decoration and display boards whereas Centralized PV system may be installed in available shadow free space for power supply within the establishment. Size/ Capacity of Centralized Solar PV System to be installed would depend upon the available shadow free area within the premises of the establishment.

CONCENTRATING SOLAR THERMAL SYSTEMS

3A. Reference Manual for Concentrating Solar Thermal Systems

Introduction

Steam requirement in hotels can be met through concentrating solar thermal systems (CSTS). CSTS are not only environment friendly but also commercially viable. These systems can be installed to fully or partially cater to hotel's steam demand, depending upon the availability of shadow-free area. The amount of steam produced from a concentrating collector critically depends on the design and climatic parameters such as solar radiation and ambient temperature, as well as its operation.

The solar field essentially comprising concentrating collectors, supplies the hot, heat transfer fluid (HTF), which through a heat exchanger generate the high-pressure steam. The cold heat transfer fluid is then returned to the solar field.

Three methods have been employed to generate steam – direct method, flash steam concept and the unfired-boiler concept3. In a steam-flash system, water is pressurized to prevent boiling, is circulated through the collector and then flashed across the throttling valve into a flash vessel to produce steam. In an unfired boiler, hot oil is used to extract the solar thermal energy and then used to heat water in turn produce steam

Types of concentrating solar collectors

It is not possible to generate high temperatures from non-focusing collectors because of the large surface area available for heat loss. The thermal efficiency of flat plate collectors reduces drastically at temperatures above 80°C because of excessive radiative and convective heat losses. Thus to reduce the energy losses at higher temperatures it is necessary to reduce the heat loss surface area as is achieved in concentrating collector technologies discussed in this section and next.

Solar dishes

Solar dish is essentially a concave mirror that concentrates the rays of the sun and produce high temperatures. Solar dishes available in the medium temperature range employ single axis tracking. These might be constructed by continuous or fragmented reflectors, or by Fresnel paraboloid concentrating Solar Collector System. Scheffler dishes, representative of this category have found applications for community cooking, solar cooling and industrial process heat. The Scheffler dishes are also being use for solar kitchen. Figures 3.1 and 3.2 below present the photograph of a typical Scheffler solar dish[4], and Arun dish[5].

[3] Solar Energy Research Institute, *Design Approaches for Solar Industrial Process Heat System'*, Task No. 1007.99, WPA No. 279-81, 1982.

[4] Ministry of New and Renewable Energy, www.mnre.gov.in, Accessed on 15 February 2010.

[5] Courtesy, Clique Development (P) Ltd.

Figure 3.1: A Scheffler solar dish for steam generation

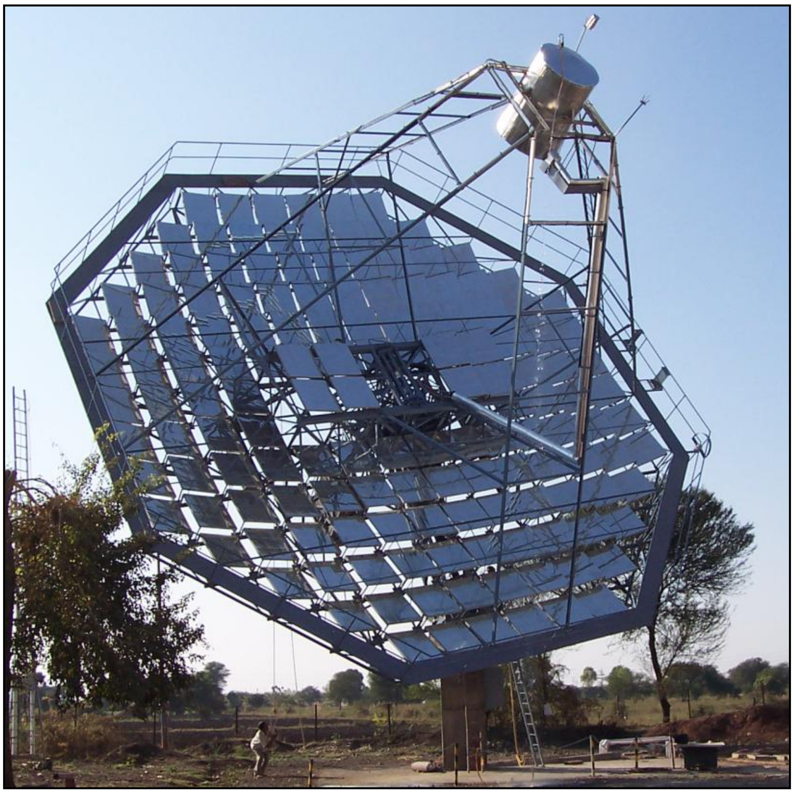


Figure 3.2: Arun 160™ Solar Collector installed at Latur Dairy, Maharashtra, India

Parabolic Trough Collector (PTC)

The schematic diagram and cross sectional view of parabolic trough solar collector is presented in figure 3.3 below. A parabolic trough collector (PTC) essentially has a linear parabolic shaped reflector (usually coated silver or polished aluminum) that focus the incident solar radiation on a linear receiver/ absorber located at the focus of parabola. Parabolic troughs often use single-axis or dual-axis tracking. In order to achieve maximum efficiency of the collector, the trough is usually aligned on a north-south axis which tracks the sun along one axis from east to west during the day to focus maximum incident beam solar radiation along the line. Due to the parabolic shape of the collector, the trough can achieve average temperatures over 400ºC. The heated working fluid may be used for medium temperature space or process heat, or to operate a steam turbine for power or electricity generation.

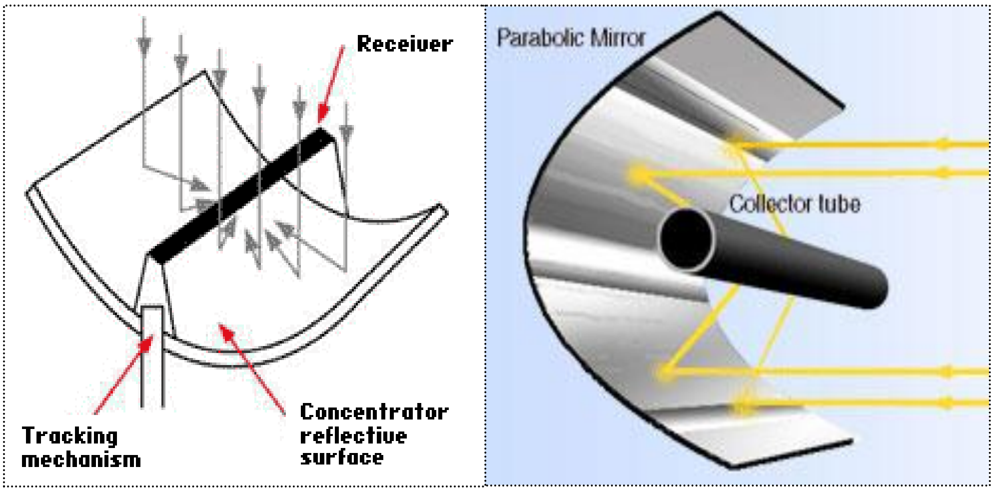


Figure 3.3: Cross sectional view of parabolic trough collector

Water quality

In places where water quality is not suitable for direct use in the solar collector, or in cold regions where water may freeze in the collector at night, solar water heater system with indirect heating is required. Users located in low temperature zones (minimum night temperature of 2º C and below) have to use the collectors with indirect heating with antifreeze. Also in places with hard water, water would need to be treated for use in the solar loop so as to avoid scaling.

Desired temperature of steam

Following table 3.1 provides general guideline for selection of a suitable technology for various temperature applications.

Table 3.1: Summary of suitable technology vs application

Application	Technology
Applications from 100º C up to 140º C	Scheffler/Arun/PTC
Above 140 º C	Arun/PTC

Financial incentives

To promote solar hot water systems, Ministry of New and Renewable Energy (MNRE) provides subsidies to the tune of 30% of the system capital costs (based on benchmark costs) as shown in the following table 3.2.

Table 3.2: Capital subsidy for various solar thermal technologies offered by MNRE, GoI.

S. No.	Solar collector type	Capital subsidy/Collector area (Rs. /sq.m.)
1	Evacuated Tube Collectors (ETCs)	3000
2	Flat Plate Collectors (FPC) with liquid as the working fluid	3300
3	Flat Plate Collectors with air as the working fluid	2400
4	Solar collector system for direct heating applications	3600
5	Concentrator with manual tracking	2100
6	Non-imaging concentrators	3600
7	Concentrator with single axis tracking	5400
8	Concentrator with double axis tracking	6000

Installing a solar concentrating collector system

1. The orientation of the solar collectors is very important for their functioning. Concentrating collectors have a sun tracking mechanism which is very important for their efficient operation.
2. Depending on the level of dust at the location, the mirrors would need to be cleaned on a weekly to once in two days basis.
3. Proper insulation of the pipes and of the storage tank is a must.
4. Leakages in the aluminium cladding can lead to water logging in the insulation, thereby defeating the purpose of insulation as well as reducing its life.
5. Just like a boiler or a water heater, the solar hot water should be accurately sized to your needs. An undersized system will not be able to supply your requirements because of lower hot water/steam generation, at the same time an oversized system will be too costly.
6. Just like any other system a maintenance schedule is important to ensure smooth working of the system and for its long life. The maintenance schedule is mostly dependent on the type of water available at your location.

Ensuring these issues are taken care of will go a long way in ensuring that you are able to meet your needs in an economically and environmentally sustainable manner.

3B. Checklist for Concentrating Solar Thermal Systems

Steam requirement in hotels can be met through concentrating solar thermal systems (CSTS). CSTS are not only environment friendly but also commercially viable. These systems can be installed to fully or partially cater to hotel's steam demand, depending upon the availability of shadow-free area.

The objective of this checklist is to get the preliminary idea of feasibility of CSTS in your hotel.

1. Type of Hotel (Please tick √ the right option)

☐ 5 Star Deluxe	☐ 5 Star	☐ 4 Star	☐ 3 Star
☐ 2 Star	☐ 1 Star	☐ Heritage	☐ Heritage Classic
☐ Heritage Grand	☐ Government approved non-star category		☐ Unapproved

2. Please specify the total number of rooms ___________________

3. Do you have steam requirement in your hotel?

☐ Yes
☐ No

4. Please specify the steam requirement for your establishment.

Consumption Details	Rated Capacity/ Steam Flow Rate (Tonnes per Hour)	Temperature	Pressure	Average Number of Hours of Consumption per Day
Steam Requirement				

5. Please specify the temperature of water in the return line to boiler________________ ^{0}C

6. Fuel expenditure on steam generation

Type of Fuel	Average Annual Consumption Units	Cost per Unit Consumption Rs./Unit
Electricity	……….…………………….kWh	…………………..(Rs./kWh)
LPG	………………………………..kg	……………………......(Rs./kg)
Diesel	……………………………..Litres	…………………….Rs./litre)
Other fuel________	………………………………….	………………………………

Type of Fuel	Average Annual Consumption	Cost per Unit Consumption
	Units	Rs./Unit
Other fuel_________	…………………………………	………………………………

7. Please specify the thermal energy requirement by your hotel

____

For calculating the thermal energy required, please refer to Steam Table in Appendix I (given in the end):

(i) Enthalpy of water in the return line = _______________________kJ/kg ……(A)
(ii) Enthalpy of steam produced in the boiler = ___________________kJ/ kg …..(B)
Steam Flow Rate = _____ (Tones/ Hour) X 1000/ 3600 = __________kg/sec …(C)
Calculate the Total Thermal Power required = C x (B – A) = __________kW_{Th}….(D)

Therefore, Total Thermal Energy required = D X Number of Hours of Consumption per Day

= _____________________________kWh_{Th}

8. Please specify the total available shadow free area within your establishment

Available Shadow Free Area	Area (in square metres)
Available Shadow free roof area	
Available Shadow free open space (other than roof area)	
Total Available Shadow free area	

(***Please note:*** *Available shadow free area is the one presently not occupied by any object or for any activity, is shadow free and can be made available for solar water heating system. Refer to important notes also.*)

Self-estimation of the size/ capacity of solar concentrator system that can be installed:

From question no. 8, you already have an idea of the total available shadow free area within your establishment. Also, question no. 7 gives you your thermal energy requirement for steam production. Based on these, you can develop an idea of size/capacity of concentrator system that can be installed. Please find below details on area requirement for Solar Concentrator System installation:

Area Requirement for Solar Concentrator System Installation

Number of Concentrator Units Required and corresponding Shadow Free Area Requirement can be calculated based on the following data:

Type of technology	Aperture Area	Daily Output[6]
Scheffler[7]	$16m^2$	30 kWh_{Th}/day
Parabolic trough	$13.2m^2$	40 kWh_{Th}/day
Arun	$169m^2$	560 kWh_{Th} / day

Number of Concentrating Units would depend upon the Required Thermal Output.

[6] Values for output as shown are indicative, the actual performance would depend on the solar radiation at the actual site.
[7]Scheffler Dishes are commercially available in aperture sizes of 7.4 m^2, 9.5 m^2 and 12.5 m^2. However, the most common aperture area in case of Scheffler is $16m^2$

Open shadow free area required for a complete system can be taken as 4 to 5 times the total aperture area of concentrator

Cost of Solar Concentrating System

Following table gives an indicative idea about the cost of Solar Concentrating System

Cost Comparison of Different Concentrator Technologies:

Parameter		**Scheffler**	**Parabolic Trough**	**Arun**
Cost	Rs./m^2	9500	12000	14793
Cost	Rs./ kW_{Th}	41626	25963	30010
Cost	Rs./ kWh_{Th}	2.56	1.47	1.32

Capital Subsidy Available on Solar Concentrating Systems:

S. No.	**Solar Collector Type**	**Capital subsidy/ Collector area (Rs. / sq.m.)**
1.	Concentrator with manual tracking	2100
2.	Concentrator with single axis tracking	5400
3.	Concentrator with double axis tracking	6000

The capital subsidy would be computed based on the applicable type of solar collector multiplied by the collector area involved in a given solar thermal application.
A choice also exists to avail soft loan @ 5% p.a. interest for 80% of the system benchmark costs as approved by MNRE and revised time to time.

Important notes:

Available shadow free area is the one presently not occupied by any object or for any activity is shadow free and can be considered as available space for any possible Renewable Energy System installation. In case any Renewable Energy technology based system (such as solar water heater) is already installed in the establishment, please deduct/ subtract the area occupied by this system as well so that only the currently available shadow free area is accounted for)

1. Your premises may need structural strengthening (civil works) to accommodate solar concentrating collectors. This will need to be ascertained by the system installer or a solar systems consultant.
2. You may consider installing CSTS within your establishment. Size of system to be installed would depend upon
    a. The available shadow free area as well as upon
    b. The steam requirement of the establishment.

In case the available shadow free area is not sufficient to cater to the total steam requirement of the establishment, then you may plan to have CSTS along with other fuel sources and systems for steam supply. In other words, even partial substitution of present conventional fuel sources by CSTS may be explored depending upon the cost economics and long term benefits. Please refer to *Appendix II* for primary details with regard to CSTS.

In case, there are any expansion plans of your hotels, provisions for CSTS can be made in the design stage itself.

Appendix I: Steam table

Temperature	Pressure	Enthalpy	
		Sat liq	Sat Vap
T (Deg. Cel.)	P (Bar)	kJ/kg	kJ/kg
40	0.0738	167.5	2574
45	0.0959	188.4	2583
50	0.1235	209.3	2592
55	0.1576	230.2	2601
60	0.1994	251.1	2610
65	0.2503	272	2618
70	0.3119	293	2627
75	0.3858	313.9	2635
80	0.4739	334.9	2644
85	0.5783	355.9	2652
90	0.7013	376.9	2660
95	0.8455	398	2668
100	1.013	419	2676
110	1.433	461.3	2691
120	1.985	503.7	2706
130	2.701	546.3	2720
140	3.613	589.1	2734
150	4.758	632.2	2746
160	6.178	675.5	2758
170	7.916	719.2	2769
180	10.02	763.2	2778
190	12.54	807.6	2786
200	15.54	852.4	2793

Appendix II: Primary details with regard to concentrating solar thermal systems are as follows:

Following CSP technologies can be considered for steam generation in hospitality units:

1. Scheffler Technology
2. Arun Solar Concentrator
3. Parabolic Trough

1. Scheffler Technology

A Scheffler reflector is a parabolic dish that uses single axis tracking to follow the Sun's daily course. These reflectors have a flexible reflective surface that is able to change its curvature to adjust to seasonal variations in the incident angle of sunlight. Scheffler reflectors have the advantage of having a fixed focal point which improves the ease of cooking and are able to reach temperatures of 100-150°C. There are many manufacturers of Scheffler concentrators in India. They are available commercially in four sizes having aperture areas of 7.4, 9.5, 12.5 and 16 m^2.

The Scheffler cooker is useful for institutional kitchens, hotels, etc. A series of such cookers can also be used to generate steam which can be used for cooking and other applications. Such installations have been made at a few places in India.

Till date, the world's largest solar cooker is at Shirdi Sai Baba Temple in Maharashtra that cooks 40,000 meals per day with 73 Scheffler Concentrators of 16 sqmtr each. World's second largest solar cooker is also in India at Tirupati temple that cooks 30,000 meals per day with 106 Scheffler Concentrators of 9.2 sq. mtr

Cost Economics of Solar Concentrator System at Tirupati Temple:

Cost of the System: Rs. 111 lacs

Amount borne by MNRE: Rs. 47.75 lacs

Output from the System: 4000 kg of steam per day at 180^{0}C and 10 bar

Payback Period: 3 – 4 Years

Specifics of a 16m^2Scheffler Concentrator System:

Temperature – 100 to 150^{0}C

Operating Hours – 6 to 7 hours/ day

Daily Output – 30 kWh_{Th}/ day

Cost of System:

- Cost of 16m^2Scheffler Parabolic Dish: Rs.1,25000
- Tracking System: Rs. 42,500
- Cost of Balance of System (Control panel, Receivers with stand, Valves and instruments): 40- 50% of the total system cost

2. Arun Solar Concentrator

Aperture area : 169 m^2

Temperature: 150 to 350°C

Power capacity : 80 to 85 kWth

Operating hours : 7 to 8 hours/day

Daily output : 560 - 680 kWhth / day
Capital cost : Rs.28,50,000
Cost Parameter : Rs. 34,550 /kWth
: Rs. 4191/(kWhth/day)

Back-up heating for monsoon
Annual fuel savings (Furnace Oil or Diesel)* 15 to 20 kL/yr 30 to 40 kL/yr
Aerial unshaded clear space required 18 x 18 x 16 m ht
Foot-print / clear area required on ground / roof 1 x 1 m
System life: 25 to 30 years

Economics of ARUN™
Saves costly fossil fuel for 25 to 30 years with negligible running cost
Subsidy from MNRE and soft loans available as well as 80% accelerated depreciation
Positive cash flow right from the first year of the project
Competitive prices compared to other solar concentrators on energy delivered basis
Reduces CO_2 emissions to the environment. The Carbon Credits (CERs) can be traded internationally

3. Parabolic Trough

Parabolic trough-shaped mirror reflectors are used to concentrate sunlight on to thermally efficient receiver-tubes placed in the trough's focal line. The troughs are usually designed to track the Sun along one axis, predominantly north–south. A thermal transfer fluid, such as synthetic thermal oil, is circulated in these tubes. The fluid is heated to approximately 400°C by the sun's concentrated rays and then pumped through a series of heat exchangers to produce superheated steam.
Minimum Aperture Area : 13.2 m^2
Daily output : About 35700 kcal/hr = 40 kWh_{Th}/day
Number of Hours of operation: 7 – 8 hours (270 days a year)
Cost of the Parabolic Trough System : Rs.12000/ m^2
: Rs. 26000/ kWth
Minimum Area required for Parabolic Trough System: 2.3 × Aperture Area
Maximum Temperature: 400^{0}C
System Life: 25 to 30 years

BIOGAS SYSTEMS

4A. Reference Manual for Biogas Systems

Introduction

With increased emphasis on sustainable tourism and boom in hospitality sector, it becomes imperative for latter to adopt cleaner technologies. Biogas technology, which is based on producing biogas from organic wastes be it kitchen waste, garden waste or animal waste, is so far the most suitable option. It is based on anaerobic digestion, i.e. breaking down of organic waste in absence of oxygen to generate biogas, which is largely methane. The gas generated can be used to meet various energy demand of hotels, for example, in kitchen it can be replaced by conventional fuels (diesel, wood, LPG, etc.) for cooking purpose, it can be used for heating and boiling purposes. Also, the by-product generated out of this process can be used as manure which can either be used in one's own garden or can be marketed. Presently, there are few technologies based on anaerobic digestion which are adapted to Indian conditions. Some of them are described below.

TERI's TEAM process

TERI has developed a high-rate digester called TEAM (TERI Enhanced Acidification and Methanation) process (Patent no. 2655/Del/97) for treatment of organic solid waste/s. The TEAM process is a two stage process comprising of Acidification and Methanation (Figure 4.1: Schematic diagram of TEAM). The process has been designed to overcome the basic hurdles experienced in conventional anaerobic digesters such as scum formation, floating of waste, slurry management, long retention time etc. Also, the separation of the acidification and the methanation phase can solve the problem of control of pH during the methanation phase of digestion. The acidification phase has a retention time of six days; therefore, six such reactors are provided to ensure continuous operation. Anaerobic conditions prevail inside the reactor during the whole process. The phase separation provides suitable environment to the micro-organisms in acidification and methanation stages, thus enhancing the activity. The residue inside the acidification reactor is dried in the sun and then used as manure. Figure 4.2 shows the installation of TEAM plant in National Thermal Power Corporation (NTPC) campus.

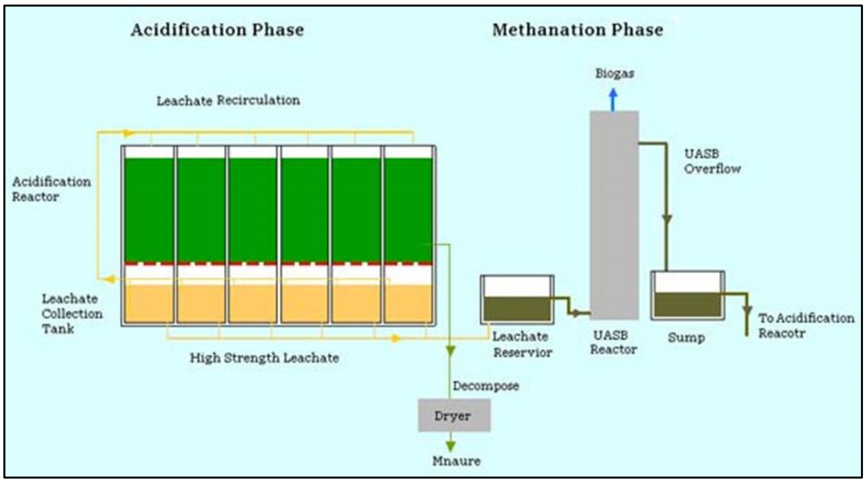


Figure 4.1: Schematic diagram of TEAM process

Figure 4.2: TERI's TEAM process in NTPC Faridabad

Features of TEAM at a glance

1. High rate methane producing reactor.
2. Low HRT of 7 days.
3. Digested waste has high NPK values.
4. High methane content in biogas (75–80%)
5. Elimination of Scum formation - a feature in small size plants.
6. Production of non-flowable/semisolid digested residue.
7. Suitability for small and decentralized application
8. Very low water requirement due to recycling within the process.
9. Aesthetic look with low maintenance cost.
10. No environmental impact.
11. Successfully tested for leafy waste, food waste, press mud, food-processing waste, tea waste, vegetable market waste, township waste etc.

Table 4.1 summarizes the potential of biogas that can be produced from various organic waste and resources required for construction of TEAM, and Table 4.2 briefs about the resource requirement for TEAM construction.

Table 4.1: Product potential from different organic waste

Type of waste	Biogas (m^3/t) (CH_4 >75%)	Manure value (%)		
		N	P	K
Vegetable market	20	2.1	1.6	2.4
Fruit and vegetable processing	20	1.2	0.1	0.6
Pressmud	09	0.6	0.6	0.4
Food waste	50	0.5	0.1	0.3
Coffee pulp	10	1.8	0.1	3.0

Table 4.2: Resource requirement at a glance

Capacity of the plant (kg/day)	Cost (Rs. in lakh)			Land requirement (m²)
	Mild steel with epoxy	FRP	Stainless steel	
50	3.0	4.5	6.0	50
100	4.4	6.63	8.84	70
250	7.3	11.08	14.77	100
500	10.9	16.33	21.78	150
1000	16.05	24.08	32.11	200
2000	23.67	35.5	47.3	250

Cost benefit analysis

Benefits from the plant (Food waste)

1. Plant capacity	1.0 ton/day
2. Annual Biogas generation (@50 m^3/day)	18250 m^3
3. Amount of LPG replaced per annum	9125 kg
4. Savings from replacement of LPG (@Rs 52/kg)	Rs.4.74 Lakh
5. Manure generation	36500 kg/yr
6. Revenue from sale of manure @Rs. 3/kg	Rs. 1.1 lakh
7. Total revenue (Gas and manure) (A)	Rs. 5.84 lakh

Operation cost

1. Electricity (1825 units, @ Rs. 5/uint)	Rs. 9125
2. Cost of chemicals	Rs. 10000
3. Man power cost (2 operator for half days, @ Rs 6000/m)	Rs. 72000
4. Total expenditure (B)	Rs. 91125
5. Net savings (A-B)	Rs. 4.93
6. Simple Payback period (2408000/493000)	4.9 years

Mailhem technology

Mailhem technology, developed by Mailhem Engineers Pvt. Ltd. specializes in high rate biomethanation techniques using Modified Upper Anaerobic Sludge Blanket Process (M-UASB) to treat any biodegradable solid waste. It is a packaged – ready to install Portable Organic Waste Treatment Plant technology used enables the designing of tailor-made projects for all types of needs (figure 4.3).

Mailhem Engineers offers unique integrated municipal solid waste treatment with a combination of biomethanation (wet/green garbage), refuse derived fuel (RDF from combustible waste), and compost (mixed organic waste).

Figure 4.3: Mailhem's packaged technology

Other technologies

Summary of other technologies that are suitable for hospitality sector are summarised in Table 4.3.

Table 4.3: Summary of different biogas models/technologies

Category of technology	Technology	Suitable feed stock	Process	HRT (days)	Biogas production (m^3/tonne of waste)	CH_4 %	Cost for 1TPD (INR)	Remarks
Indigenous	KVIC	Cow dung	-Single phase (Floating drum type)	30-55	40	60	17935	Conventional plant, can use cow dung only
	Deenbandhu	Cow dung	-Single phase (fixed dome)	40-55	40	60	8394	Conventional plant, can use cow dung only
	TEAM Process	MSW, Food waste Industrial waste	Bi-phasic	7	20-60	80-90	10.0 lakh	
	BARC	MSW, Farm Waste, Industrial waste	Biphasic -1st reactor aerobic 50-55^{0}C(thermophilic); -2nd reactor anaerobic mesophilic	17-20	70	55-75	5.5lakhs	Requires solar water heater and 5HP pumps.
	SPRERI	MSW, Farm Waste, Industrial	-Biphasic	10	25			Low biogas yield

Category of technology	Technology	Suitable feed stock	Process	HRT (days)	Biogas production (m^3/tonne of waste)	CH_4 %	Cost for 1TPD (INR)	Remarks
		waste						
Imported	ARTI	Kitchen waste	Single phase - mesophilic	2.5		60		Small scale plant
	BIMA	Vegetable waste	-single phase -mesophilic	25	38-39	55-58		
	DRANCO	MSW	-single phase -thermophilic (50-58⁰C)	15-30	100-200			
	Kompogas Process	Kitchen, yard and paper waste	-single phase plug flow reactor -thermophilic (55-60⁰C)	15-20	100-140			
	Biocomp Process		-Biphasic	30 days	80	60	9 lakhs	Segregation by mechanical means.

Table 4.4 indicates the comparison amongst the most suited indigenous technologies for the digestion of food/kitchen waste. The comparison stated below is based on 1000 kg/day capacity of waste generation.

Table 4.4: Comparison of different indigenous technologies for the digestion of food / kitchen waste

Models	HRT Days	Area required m^2	% of CH_4	Slurry prepara-tion	Manpower required	Mechanical requirements	Power require-ment	Ability to handle mixed waste	Water Recycle-ing
TEAM	< 7	200	80-90	Not required	2 unskilled labor	3 x 100watt magnetic driver pump + one 400 watt dosing pump	Single phase AC	Yes	Yes
BARC	15-20	300	70-75	Yes	2 unskilled labor	5 hp Mixer for slurry preparation	3 phase AC	May work on mixed waste	No
ARTI	2-3	N/A	60	yes	N/A	N/A	N/A	Yes	No

4B. Checklist for Biogas Systems

Biogas technology is a series of processes in which microorganisms break down biodegradable material into the simplest molecules like methane and carbon dioxide in the absence of oxygen. The mixture of methane and carbon produced from decomposition of organic waste is called biogas. Adoption of this technology by hospitality sector is cleaner approach of managing waste that can help in meeting energy demand for various applications like cooking, heating, generation of steam etc. Use of bio – methanation or biogas plants not only makes use of food leftovers and kitchen wastes, including fruit and vegetable wastes and garden waste but also help in disposing them off in an environmentally sound fashion.

The objective of this checklist is to get a preliminary assessment of the feasibility of biogas plant in your hotel.

1. Type of Hotel (Please tick √ the right option)

☐ 5 Star Deluxe	☐ 5 Star	☐ 4 Star	☐ 3 Star
☐ 2 Star	☐ 1 Star	☐ Heritage	☐ Heritage Classic
☐ Heritage Grand	☐ Government approved non-star category		☐ Unapproved

2. Please specify the total number of rooms_________________

3. Fuel expenditure

Type of Fuel	Average Annual Consumption	Cost per Unit Consumption
	Units	Rs./Unit
Electricity	………...……………………kWh	…………………..(Rs./kWh)
LPG	………………………………..kg	……………………...(Rs./kg)
Diesel	……………………………..Litres	…………………...(Rs./litre)
Other fuel___________	…………………………………	………………………………
Other fuel_________	…………………………………	………………………………

4. What is the average quantity of organic kitchen waste generated on daily basis in the hotel?

   ____ (in kg/day)

5. Are there any horticultural wastes from Hotel Garden/ plantation?

   ☐ Yes

   ☐ No

6. If yes, please specify the average quantity of horticultural waste generated per day within the hotel premises?

   ____ (in kg/day)

7. What is being done with the organic waste obtained from kitchen and garden?

   ____ (in kg/day)

8. Does your existing/proposed building comply with the "Solid waste (management and Handling) Rules, 2000"?

   - Yes
   - No

9. Which of the following mechanism has been proposed for waste disposal?

   a) Selling waste as a feed to piggeries.

   b) Resource recovery from waste (Biogas plant/composting unit)

   c) Giving away to Municipality.

   d) Other (Please specify ________________)

10. Please specify the total available free area within your establishment

    ____ (in sq. m.)

Selection of appropriate technology to be installed

Based on above questions, suitable technology can be selected for your facility. Table 1 and 2 list various biogas technologies that are commercially available with their specifications.

Table 1: Summary of different biogas models/technologies.

Category of technology	Technology	Suitable feed stock	Process	HRT (days)	Biogas produc-tion (m^3/tonne of waste)	CH_4%	Cost for 1TPD (INR)	Remarks
Indigenous	KVIC	Cow dung	- Single phase (Floating drum type)	30-55	40	60	17935	Conventional plant, can use cow dung only
	Deenbandhu	Cow dung	-Single phase (fixed dome)	40-55	40	60	8394	Conventional plant, can use cow dung only
	TEAM Process	MSW, Food waste Industrial waste	Bi-phasic	7	20-60	80-90	10.0 lakh	

Category of technology	Technology	Suitable feed stock	Process	HRT (days)	Biogas produc-tion (m^3/tonne of waste)	CH_4%	Cost for 1TPD (INR)	Remarks
	BARC	MSW, Farm Waste, Industrial waste	Biphasic -1st reactor aerobic 50-55^{0}C (thermophilic) ; -2nd reactor anaerobic mesophilic	17-20	70	55-75	5.5lakhs	Requires solar water heater and 5HP pumps.
	SPRERI	MSW, Farm Waste, Industrial waste	-Biphasic	10	25			Low biogas yield
	ARTI	Kitchen waste	Single phase - mesophilic	2.5		60		Small scale plant
Imported	BIMA	Vegetable waste	-single phase -mesophilic	25	38-39	55-58		
	DRANCO	MSW	-single phase -thermophilic (50-58^{0}C)	15-30	100-200			
	Kompogas Process	Kitchen, yard and paper waste	-single phase plug flow reactor -thermophilic (55-60^{0}C)	15-20	100-140			
	Biocomp Process		-Biphasic	30 days	80	60	9 lakhs	Segregation by mechanical means.

Table 2: Comparison amongst the most suited indigenous technologies for the digestion of food/kitchen waste

Models	HRT Days	Area required m^2	% of CH_4	Slurry prepara-tion	Manpower required	Mechanical requirements	Power require-ment	Ability to handle mixed waste	Water recycling
TEAM	<7	200	80-90	Not required	2 unskilled labor	3 x 100watt magnetic driver pump + one 400 watt dosing pump	Single phase AC	Yes	Yes
BARC	15-20	300	70-75	Yes	2 unskilled labor	5 hp Mixer for slurry preparation	3 phase AC	May work on mixed waste	No
ARTI	2-3	N/A	60	yes	N/A	N/A	N/A	Yes	No

Important notes:

There are several recyclable materials in the waste that can generate revenue from the sale of recyclable materials such as paper, plastics, metals, glass etc.

1. Segregation is very essential for both the processes – biogas generation and composting. Thus, it is advisable to keep separate bins in the kitchens and restaurant for biodegradable waste and non-biodegradable waste. Waste from rooms can be segregated at common collection point.
2. A few points to be taken in account while proposing composting as disposal process are as follows
    i. Composting occupies much more space than biogas process as composting has a of retention time of 90-120 days.
    ii. Since there is more spillage of waste and manure in case of composting, the surrounding space will keep stinking.
    iii. There will be a need to search of market for sale of manure.
3. Models like KVIC, Janta, Deenbhandhu etc. are more suited to the animal manure while other models like Arti, BARC and TEAM can suitably be utilized for the mixed waste.

ENERGY CONSERVATION MEASURES

5A. Reference Manual for Energy Conservation Measures

HVAC system

Introduction

The exponential hike in the cost of different forms of energy has led to the growing importance of energy conservation measures in the hospitality sector. Electricity, which has the highest growth rate among all energy sources, is in chronic short supply in many parts of the country. The shortage of peak demand capacity is particularly acute. Huge investments are required to provide fresh generation capacity. Conservation can, therefore, go a long way in alleviating the resources crunch in the energy supply sector ensuring a more productive use of existing resources. Buildings are responsible for about 40% of global energy consumption around the world. With the recent boom in the construction sector, there has been a sudden increase in energy consumption, especially in countries like India and China.

In India, the total energy consumption of all hotels of different category is roundly about 2823 million kWh. Figure 5.1 shows the huge consumptions are 838 million kWh in 5-star deluxe (31% of total energy) and 757 million kWh in licensed hotel (24% of total energy). Energy consumption of an "average hotel" in India (a hotel certified by the Ministry of Tourism is generally of the 4-5 star category and has 200 rooms or more) is approximately 77-112 kWh per room/day. Given the existing sources of energy in India and the average power mix from the various sources, this would amount to a CO_2 emission of approximately 5000 tonnes per annum. The energy consumption in rest of the hotel categories are as follows:

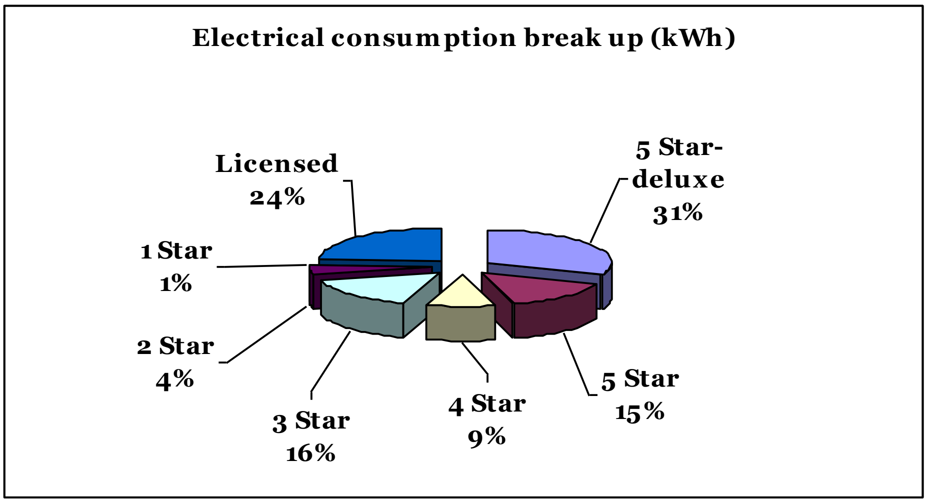


Figure 5.1: Breakup of total energy consumption of different category of hotels

Hotel buildings consume energy for space conditioning, pumping water, lighting, cooking and other hotel equipment. The different energy sources commonly used in hotel buildings are electricity, oil, natural gas and LPG. Electricity which remains the main energy source is used for space conditioning, lighting purposes, pumping, and in kitchen and other equipment, whereas HSD for in-house power generation, LDO or FO for generating hot water and steam and LPG in kitchen.

Studies have revealed that incorporation of energy conservation measures in hotel buildings can reduce energy consumption in new buildings by up to 40% of that used in conventional buildings and in existing buildings by up to 20% by suitable retrofit application.

Types of energy conservation measures

The most effective energy conservation measures in hospitality sector include –

1. Solar passive building design
2. Building envelope material
3. Lighting system &
4. HVAC system

All these measures have impact on the overall energy consumption of the hotel/ restaurant building directly or indirectly and are explained one by one in detail as given below.

Solar passive building design

The design of hotel/ restaurant buildings is the most important step in ensuring energy conservation in buildings. The design of an existing building cannot be altered without demolition. Thus it becomes crucial to pay attention to this important aspect. These buildings, by virtue of climate responsive design, can be about 10-15% less energy consuming as compared to conventional buildings, without any incremental cost. Thus climate responsive design of buildings becomes an extremely crucial aspect in the process of adopting energy conservation in buildings.

The current scenario of the hospitality sector consists of buildings which do not respond to macro or micro-climatic parameters, urban context etc. The windows do not have shading devices to cut direct sunlight. Ill-designed openings force building occupants to close the blinds/curtains, even during the day, and turn on the artificial lights. This substantially increases the heat gain inside the building. Such buildings require utilization of energy intensive mechanical systems for providing visual and thermal comfort to the building occupants. Since the buildings have not been designed to reduce their energy requirements, their consumption of energy and imposition on natural resources is massive.

As per the climatic classification of National Building Code-2005, though India has a large variety of climate types, it is a predominantly a tropical climate country. Approximately 90% of the area is covered under hot-dry, warm-humid and composite climate. Therefore the climate responsive buildings, in this context, are designed to avoid the heat gain but at the same time allow adequate daylight inside the living space. Some of the passive design strategies adopted optimize the building design that controls the heat gain and allows maximum natural light are as follows.

1. Optimum orientation;
2. Buffer Spaces or Thermal buffer zone;
3. Allocation of building openings;
4. Sizing of openings;

5. Appropriate shading design (façade shading and fenestration shading);
6. Adequate daylighting etc.

Optimum orientation

The optimum orientation for hotel buildings in India is with the longer façades facing north and south to avoid summer heat gain and allow maximum winter radiation (as shown in figure 5.2). The basic objective is to minimize the building exposure along East & west and reduce the total incident solar radiation on its various surfaces. This forms the first step of climate responsive building design.

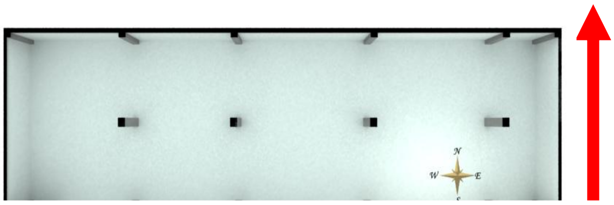


Figure 5.2: Optimum orientation of hotel

Buffer spaces or thermal buffer zone

Spaces like staircases, lifts, corridors, toilets, rest rooms, store rooms, balconies and other service areas can be used as buffer spaces to shield the living spaces from the critical facades. These spaces then act as "thermal buffers" (refer to figure 5.3). Thermal buffer zones cut down the excess solar radiation from penetrating inside the building as well as reduce the cooling load for air conditioned buildings. This concept needs to be incorporated during the conceptual design stage of the building.

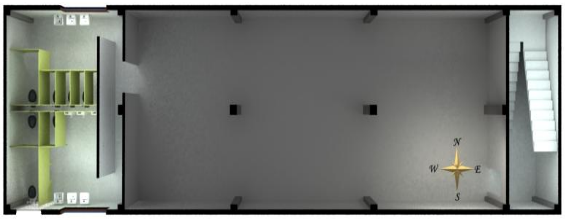


Figure 5.3: Buffer spaces in hotel buildings

Location of building openings

In order to further reduce heat gain in buildings, building openings should be located on the facades with the least amount of insolation (Figure 5.4). Thus, it is always recommended to provide maximum openings along the north and south facades to avail maximum daylight and minimum solar radiation inside building and avoid openings on the eastern and western facades.

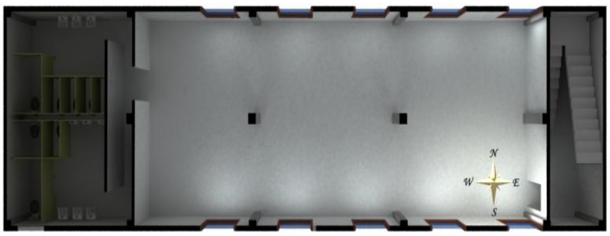


Figure 5.4: Orientation of building openings

Sizing of openings

Glazing allows short wave infra red radiation emitted by the sun to pass through it, but almost opaque to long wave radiation emitted by the objects in the room. The consequence is that once the radiant heat has entered through a window it is trapped inside the building, which is called "greenhouse effect". Hence the heat gain in hotel buildings can be reduced by limiting the glazing area. Windows typically have a higher conductance coefficient than the rest of the building envelope so buildings with high glazing areas will have greater heat gain as compared to similar buildings with lesser glazing area. Therefore ECBC-2007 has limited the glazing area in terms of window to wall ratio (WWR) and skylight to roof ratio (SRR). For example: In ECBC the vertical fenestration area is limited to a maximum of 60% of the gross wall area.

Fenestration shading

The openings/ fenestrations are the prime source of heat gain in the building envelope. Therefore if façade shading is not possible then it becomes important to shade the exposed fenestrations of the building to protect from direct solar exposure. Use of external shading devices is the most effective way to prevent unwanted heat gain during summer. However the shading devices need to be optimized as per the solar angle so that the shading device can keep the summer sun out and let the winter sun in. figure 5.5 shows adoption of external devises for all seasons.

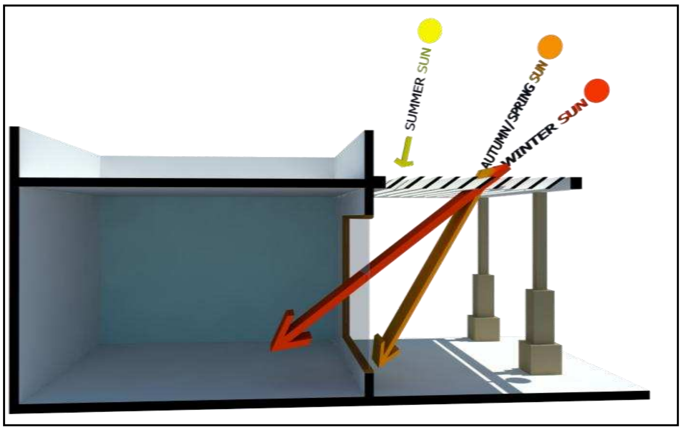


Figure 5.5: Optimised shading device for all

The shading devices can be broadly categorised under three heads, also shown in figure 5.6, such as -

a) Horizontal type (H)

b) Vertical type (V) and

c) Mixed (M) - combination of types H and V.

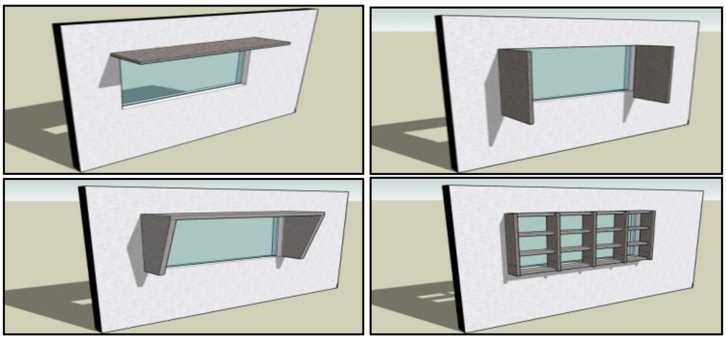


Figure 5.6: Various types of fenestration shading device

Adequate daylighting

Daylight is a natural source of light which meets all the requirements of good lighting and enhances user efficiency and productivity. Therefore though the hotel buildings are mostly dependent on artificial lighting but daylight integration at daytime used spaces and other living spaces can contribute towards energy conservation in hotel/ restaurant buildings. In India plentiful daylight is available outdoors under clear sky conditions which can be used for satisfactory indoor illumination during the day. By proper design of windows in terms of their orientation, size and shape, one can eliminate the use of artificial lighting in most of the buildings during daytime.

Direct sunlight is excluded from the definition of daylight factor, as it is not desirable from the viewpoint of lighting quality. It creates problems of harsh shadows and severe brightness imbalances resulting in glare. Direct sunlight also brings in undesirable heat in summer. Therefore adequate shading devices are recommended not only for thermal comfort but also for visual comfort. The daylight penetration inside the living space depends entirely on the building design i.e. the orientation, internal space arrangement, distribution of openings, size and shape of the openings, shading design and glazing properties etc. An optimum hotel building design allows for maximum penetration of daylight available in the buildings surroundings (see figure 5.7).

Figure 5.7: Daylight integration inside hotel space (Guest room, reception etc.)

Building envelope material

The hotel building envelope and its material are key determinants of the amount of heat gain and loss that enters inside. The primary elements affecting the performance of a building envelope are –

1. Roof
2. Wall and
3. Window

The thermal behaviour (heat gain & loss) of opaque surfaces (roof & wall) is defined by thermal transmittance or U-value or G-value and of transparent surface (window) by solar heat gain co-efficient (radiation or solar gain) & U-value (transmission gain). Lower these values mean lower heat gain and the elements would be of high performance materials.

Roof

The roof receives significant solar radiation and plays and important role in heat gain/ losses. Depending on the climatic needs, proper roof treatment is essential. In a hot region, the roof should have enough insulating properties to minimize the heat gains.

The heat transfers though roof is defined by the heat transfer coefficient of the wall. Higher the U value higher will be the heat transfer through the wall. Higher heat transfer increases the heat load (TR) of the building and hence the energy consumption (kWh) of the building. The two cases shown below in figure 5.8 indicate the U value of roof with no insulation and wall with insulation.

A few roof protection methods are as follows:

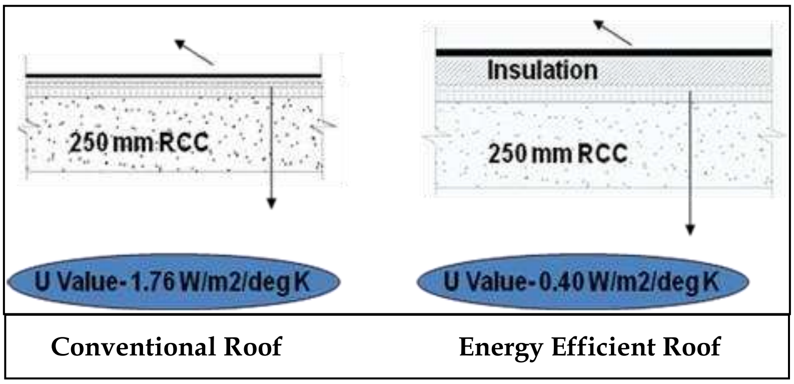


Figure 5.8: U value for roof with and without insulation

Effective roof shading

There are various types of roof shading are applicable for hotel building to make it energy efficient. The entire roof surface can be covered with deciduous plants/ creepers/ pergola/ tensile structure/ solar PV or any other shading device as shown in figure 5.9 below.

Plantation on roof top or terrace

Roof pergola

Tensile structure

Building Integrated Solar PV on Roof

Figure 5.9: Effective roof shading through various means

Effective roof insulation

Energy conservation building code of India, recommends that roof shall comply with either the maximum assembly U-factor or the minimum insulation R-value as shown in the table below (ECBC-2007) in table 5.1 and 5.2.

Table 5.1: Roof assembly U-factor and Insulation R-value Requirements

Climate Zone	Maximum U-factor of the overall assembly (W/m²-°C)	Minimum R-value of insulation alone (m²-°C/W)
Composite	U-0.261	R-3.5
Hot and Dry	U-0.261	R-3.5
Warm and Humid	U-0.261	R-3.5
Moderate	U-0.409	R-2.1
Cold	U-0.261	R-3.5

To achieve the above mentioned U-value/ R-value, the following combination of roof assembly can be adopted in hotel buildings.

Table 5.2: Different combination to achieve the ECBC U-value of roof

S. No	Insulation specification	Roof configuration (inside to outside)
1	Extruded polystyrene (EPS) Density = 28kg/m3 Thermal conductivity =0.029 w/mK	12mm plaster +150 mm RCC +75 mm EPS+12mm plaster
2	Expanded polystyrene (EPU) Density = 45kg/m3 Thermal conductivity =0.023 w/mK	12mm plaster +150 mm RCC +50 mm EPU+12mm plaster
3	Resin bonded Fibre glass Density = 32kg/m3 Thermal conductivity =0.031 w/mK	12mm plaster +150 mm RCC +75 mm fibre glass+12mm plaster
4	Rock wool insulation Density = 250 kg/m3 Thermal conductivity =0.031 w/mK	12mm plaster +150 mm RCC +75 mm Rockwool+12mm plaster

Cool roofs

As per ECBC Cool Roofs (Roofs with high solar reflectance) is also an effective way to achieve the standard U-value/ R-value for different climatic region in India.

Roofs with slopes less than 20 degrees shall have an initial solar reflectance of no less than 0.70 and an initial emittance no less than 0.75. Solar reflectance shall be determined in accordance with ASTM E903-96 and emittance shall be determined in accordance with ASTM E408-71 (RA 1996).

Note: *For details refer section 4.3.1 of ECBC user guide*

Wall

Walls are a major part of the building envelope and receive large amounts of solar radiation. The heat storage capacity and heat conduction property of walls are key to meeting desired thermal comfort conditions. The wall thickness, material & finishes can be chosen based on the heating & cooling needs of the building. Appropriate thermal insulation and air cavities in walls reduce heat transmission in to the building, which is the primary aim in a hot region.

The heats transfer though wall is defined by the heat transfer coefficient of the wall. Higher the U value higher will be the heat transfer through the wall. Higher heat transfer increases the heat load (TR) of the building and hence the energy consumption (kWh) of the building. The two cases have shown in the following figure 5.10 which indicates the U value of a conventional wall and energy efficient wall.

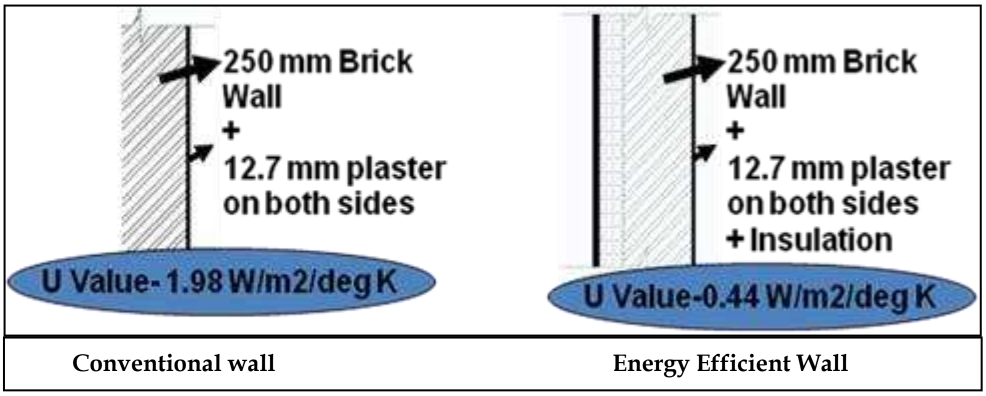


Figure 5.10: Comparison of conventional wall and energy efficient wall

A few wall protection methods are as follows:

1. Effective wall shading

There are various types of wall shading are applicable for hotel building to make it energy efficient. The entire wall surface can be treated with green wall/ wall pergola, false wall/ Jallis, Plantation on E & W or any other shading device as shown below in figure 5.11.

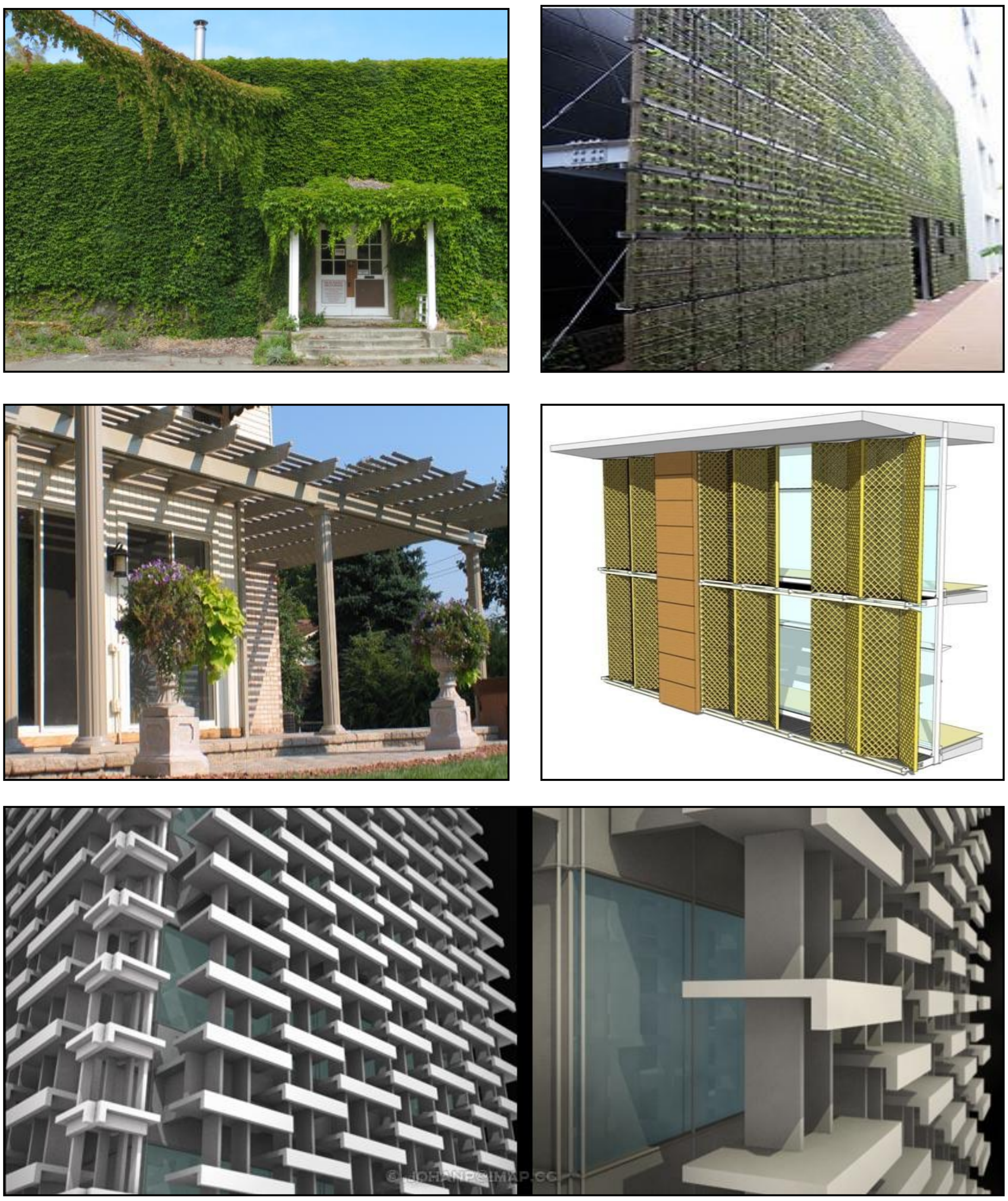


Figure 5.11: Vertical shading through various material treatments over facade

2. Effective wall insulation

Energy conservation building code of India, recommends that the opaque walls shall comply with either the maximum assembly U-factor or the minimum insulation R-value as shown in Table 5.3. R-value is for the insulation alone and does not include building materials or air films.

Table 5.3: Opaque wall assembly U-factor and insulation R-value requirements

Climate Zone	Hospitals, Hotels, Call Centers (24-Hour)	
	Maximum U-factor of the overall assembly (W/m²-°C)	Minimum R-value of insulation alone (m²-°C/W)
Composite	U-0.440	R-2.10
Hot and Dry	U-0.440	R-2.10
Warm and Humid	U-0.440	R-2.10
Moderate	U-0.431	R-1.80
Cold	U-0.369	R-2.20

To achieve the above mentioned U-value/ R-value, the following table 5.4 combination of roof assembly can be adopted in hotel buildings.

Table 5.4: Different combination to achieve the ECBC U-value of wall

S. No	Insulation specification	Roof configuration (inside to outside)
1	Expanded polystyrene (EPS) Density = 22kg/m3 Thermal conductivity =0.034 w/mK	15mm plaster+230 mm brick+75mm EPS+15mm plaster
2	Extruded polystyrene (EPS) Density = 28kg/m3 Thermal conductivity =0.029 w/mK	15mm plaster + 230+50 mm XPS+15mm plaster.
3	Expanded polystyrene (EPU) Density = 24kg/m3 Thermal conductivity =0.026 w/mK	15mm plaster +230 mm Brick+50 mm EPU +15mm plaster.
4	Resin bonded Fibre glass Density = 32kg/m3 Thermal conductivity =0.035 w/mK	15mm plaster + 230 mm brick+75 mm EPU+15mm plaster.
5	Rock wool insulation Density = 144 kg/m3 Thermal conductivity =0.031 w/mK	15mm plaster +230 mm brick+75 mm Rock wool +15mm plaster.

Note: Note: For details refer section 4.3.3 of ECBC user guide

Glazing system

Windows admit direct solar radiation and hence promote heat gain. This is desirable in cold climates, but is critical in hot climates. Conventional hotels in India use single or double glazing that allows roughly 75% to 85% of solar energy to enter a building. Glasses are partially transparent through out the near ultra violet, visible and near infra-red regions that compose the solar spectrum, but are practically opaque to longer wave thermal radiation. Today advanced glazing with innovative coatings and improved designs are available for energy conservation. These energy efficient glazings minimize unwanted solar gains in summer & heat losses in winter, while maximizing the amount of useful daylight in buildings.

In energy efficient windows, the basic thermal & optical properties are –

a. U-value

b. SHGC

c. VLT

a. U-Value:

The U-value is the standard way to quantify insulating value of windows. The U-factor is the total heat transfer co-efficient of the window system (W/m2K), which includes conductive, convective and radiative heat components. It is therefore represents the heat flow in Jouls per second (watts) through each square meter of window for a 1K (1degC) temperature difference between the indoor & outdoor air temperature. The R-value is the reciprocal of the total U-factor (R=1/U). As opposed to the R-value, the smaller is the U-factor of a material; the lower is the rate of heat flow.

b. SHGC (Solar heat gain co-efficient):

The SHGC is the fraction of incident solar radiation admitted through a window and SHGC measures how well a fenestration blocks heat from the Sun. The lower the SHGC the better the products in blocking unwanted heat gain. SHGC is expressed as a number between 0 and 1. For example if a glazing allows 40% of incident heat to pass through it, then it is represented as SHGC of glass = 0.4.

SHGC accounts for incident solar radiation, it means the heat gain read by the SHGC value is due to all the direct components of sun, which is easily controlled by the provision of external shading devices or any other external obstructions. Therefore SHGC shall be determined for the entire fenestration product (including the sash, frame & external shading) not just for the glass. Therefore besides glazing properties the type of window and shading devices can affect the SHGC calculation of the fenestration. In other words, Effective SHGC is the cumulative solar heat gain coefficient of the fenestration with both the glass and shading devices (overhang and/ or vertical fin).

Note: *for detail calculation of effective SHGC, Refer section-4.3.4 of ECBC-user guide.*

c. VLT (Visible light transmittance):

This is an optical property of a light transmitting material (e.g. window glazing & translucent sheet etc.) that indicates the amount of visible light transmitted of the total incident light. Visible light transmittance is the fraction of the visible portion of the solar spectrum that passes through a glazing material. VLT of glazing ranges from above 90% for water white clear glass to less than 10% for highly reflective coatings on tinted glass. Transmission of visible light through glazing determines the effectiveness of a type of glass in providing daylight and a clear view through the window.

Example:

The heats transfer through glass is defined by the heat transfer coefficient of the glass (U-value) and the solar heat gain coefficient (SHGC). Higher the U-value and SHGC higher will be the heat transfer through the glass. Higher heat transfer increases the heat load (TR) of the building and hence the energy consumption (kWh) of the building.

The two cases shown below in figure 5.12 indicate the U value and SHGC of glass

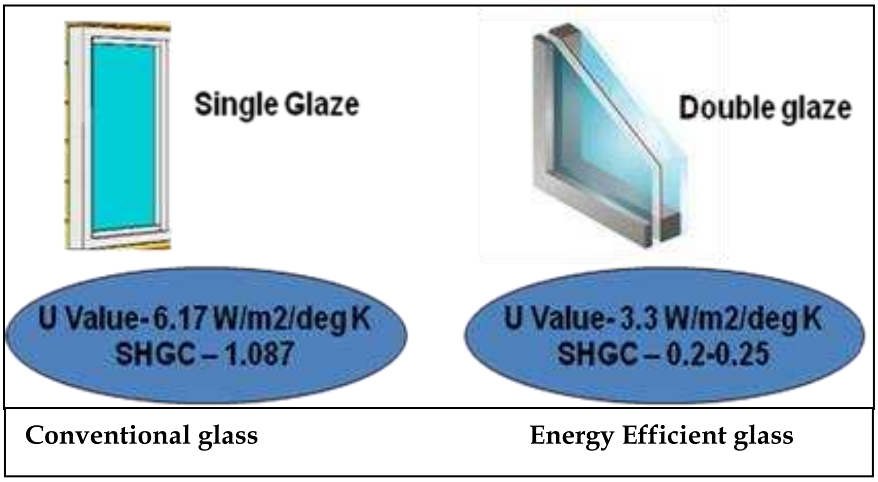


Figure 5.12: Comparative picture of single glaze and double glaze in glasses

Energy conservation building code of India, recommends that the Vertical Fenestration shall comply with the maximum area weighted U-factor and maximum area weighted SHGC requirements as shown in Table 5.5 (ECBC-2007). Vertical fenestration area is limited to a maximum of 60% of the gross wall area for the prescriptive requirement.

Table 5.5: Vertical Fenestration U-factor and SHGC Requirements (U-factor in W/m²-°C)

Climate	WWR≤40%		40% <WWR≤60%
	Maximum U-factor	Maximum SHGC	Maximum SHGC
Composite	3.30	0.25	0.20
Hot and Dry	3.30	0.25	0.20
Warm and Humid	3.30	0.25	0.20
Moderate	6.90	0.40	0.30
Cold	3.30	0.51	0.51

The lower U values of wall, roof, glass and SHGC of glass reduces the heat gain inside the building. Although insulation on wall, roof and high performance glass does increase the initial cost but the increment in this initial cost gets countered by the decrease in the initial capital investment of cooling machines due to the reduction in cooling demand. The energy consumption of the building also gets reduced by applying energy efficient wall, roof and glass on to the building.

Lighting system

Indoor lighting

Lighting account for 15% of total energy consumption in India. Lighting is an area that offers many energy efficiency opportunities in almost any building facilities. While energy efficiency is an attractive goal, the right quantity and quality of light can be provided efficiently by using the right technology and effective integration with daylight.

Lighting controls have the potential to capture significant energy savings in commercial buildings if properly specified, installed, commissioned and maintained. Proper commissioning is often absent in lighting projects and the lack of commissioning can significantly reduce a project's energy savings potential. This guideline focuses on the importance of good commissioning practice for obtaining satisfactory performance from lighting control systems.

Lighting controls allow lighting to be turned down or completely off when it is not needed. Maximising use of control developing a set of strategies that utilises the Energy Conservation Building Code (ECBC) requirements for various devices including on-off controls, dimming controls and both types of equipments.

- Incandescent lamps have been replaced by compact fluorescent lamps not only in service area or toilets but also in guest rooms and guest corridors (figure 5.13).

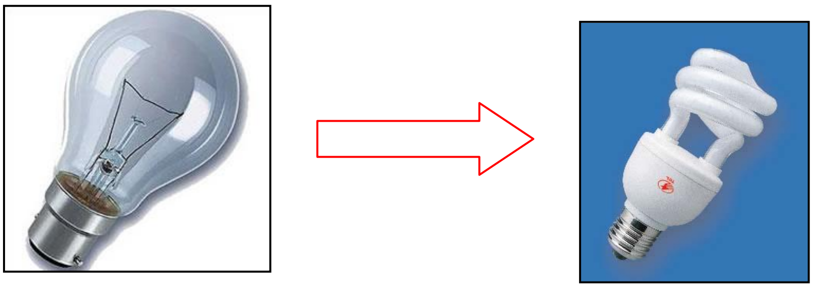


Figure 5.13: Incandescent lamps to Compact Fluorescent Lamps (CFL)

- T-12 fluorescent lamps have been replaced with both T-8 mono phosphor and tri phosphor lamps (figure 5.14).

Figure 5.14: Comparative picture of T-12 lamps, T-8 mono phosphor and tri phosphor lamps

- Copper chokes have been replaced by electronic ballasts in back of the house areas (figure 5.15)

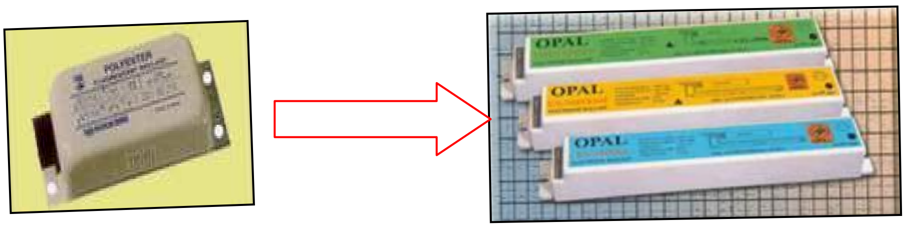


Figure 5.15: Comparative picture of copper chokes and electronic ballasts

- Installation of infrared controlled timers to control remote/outdoor lighting figure 5.16

Figure 5.16: Infrared control timers

- Installation of voltage controller on dedicated lighting circuit to operate at low voltage during daytime or period when occupancy is low
- Installation of lighting dimmers in public areas (figure 5.17)
- Installation of key tag/switch system for guest room automation

Figure 5.17: Lighting dimmers

Lighting controls related guidelines

As per the ECBC code

Interior lighting system in building greater than 500 m^2 shall be equipped with an automatic control device.

Automatic lighting shut-off

Occupancy sensor: Within these buildings, all office areas less than 30 m2 enclosed by wall or ceiling –height partition space shall be equipped with occupancy sensor which shall turn the light off within 30 minutes of an occupant leaving the space.

Schedule controls: For other spaces an automatic lighting control device should be functioned

A schedule basis at specific programmed times. An independent program schedule shall be provided for areas of no more than 2500 m2 and not more than one floor

Space control

Apart from control of individual lights or set of fixtures a master control is required for each space which can shut off all lights within the space.

As per the code

Occupant sensor: The space control device can be switch that is activated manually or automatically by sensing an occupant sensor which can control

- a maximum of 250 m2 for a space less than or equal to 1000 m2
- a maximum of 1000 m2 for a space greater than 1000 m2.
- Be capable of overriding the required shut off control for no more than 2 hours.

Day-lighting controls

As per the code

Luminaire in day lighted areas greater than 25 m2 shall be equipped with either a manual or automatic lighting control device which is

- Capable of reducing lighting output of the luminaries in the day lighted areas by at least 50% .
- Controls only the luminaire located entirely within the day lighted areas.

Outdoor lighting

Outdoor lighting provides safety, security, aesthetics, and economic development opportunities. There are many valid reasons to light the outdoors. However, it is important to understand that outdoor lighting is enough and it balance the need for light while minimizing light pollution and increasing energy efficiency. The method of enhance outdoor lighting efficiency and promote usage of renewable forms of energy to reduce the use of conventional energy resources.

Energy efficiency is an important aspect of optimizing outdoor lighting. Another aspect of reducing the energy consumption is minimize the energy waste hence introduction of automatic control to the outdoor lighting systems. The third aspect to usage of renewable forms of energy to reduce the use of conventional/ fossil –fuel-based energy resources. The electrical consultant should follow the following guidelines to design efficient outdoor lighting

- Luminous efficacy of external light sources used for outdoor lighting shall equal or exceed the specifications in table 5.6 below.

Table 5.6: Minimum luminous efficacy of outdoor lighting

Light source		Minimum allow able luminous efficacy (lm/W)
	Compact fluorescent lamp (CFL)	50
	Fluorescent Lamp (FL)	75
	Metal Hallide (MH)	75
	High pressure sodium vapor (HPSV)	90

Public lighting

This includes lighting other than street lighting such as lighting in parks, shopping complexes etc. The measures here would include.

1. Replacement of existing fluorescent lamps with high pressure sodium lamps (HPSV) in street and security lighting (considered for 12 hour/day operation)
2. Replacement of existing Halogen lamps used for façade lighting with Metal halide lamps

Heating, ventilation and air conditioning system

ECM 1 - Replacing the unitary split AC/window ACs by variable refrigerant volume system

Heating, ventilating, and air-conditioning (HVAC systems) account for 60-80% of the energy used in commercial buildings. Consequently, almost any business or government agency has the potential to realize significant savings by improving its control of HVAC operations and improving the efficiency of the system it uses.

Heating, ventilating, and air conditioning are based on the principles of thermodynamics, fluid mechanics, and heat transfer. The three functions of heating, ventilating, and air-conditioning are closely interrelated. All seek to provide thermal comfort, acceptable indoor air quality, and reasonable installation, operation, and maintenance costs. HVAC systems can provide ventilation, reduce air infiltration, and maintain pressure relationships between spaces. How air is delivered to, and removed from spaces is known as room air distribution.

Window ACs

In window ACs, the compressor, condenser, condenser fan, and evaporator are all enclosed in a single cabinet and the system is installed in a wooden/metal frame, either in a window or in a hole in the wall.

Split ACs

The split AC is split into two basic components: the indoor and the outdoor unit. Refrigeration tubing and electric wires (that can pass through a hole in the wall barely 10 cm in diameter) connect these two units. The outdoor unit houses the compressor, condenser, and the condenser fan. The indoor unit consists of the evaporator (cooling coil) and the evaporator blower

In both Split ACs and Window ACs the compressor gets switched on and off based on the set point temperature which is being maintained inside the room and the cycle of switching on and off varies with the ambient conditions.

VRF System

In a VRF system, the central cooling plant is similar to the outdoor unit of a split AC model, operating as a condensing unit. Also, unlike non-central units – where each unit is driven by separate compressors – all the indoor units are driven by one single compressor in a VRF system. The refrigerant flows through smart valves to different units. The valves are automatically controlled so as to allow only the required volume of the refrigerant to flow in through each indoor unit. Rooms with less heat load at one point in time will require less refrigerant flow and those at high heat load receive more refrigerant. This controlled flow ensures optimum cooling and makes the system quite efficient.

In VRF system the compressor doesn't get switch off or on. In this amount of refrigerant required varies there by reduces the amount of work to be done by the compressor and hence helps in reducing the energy consumption.

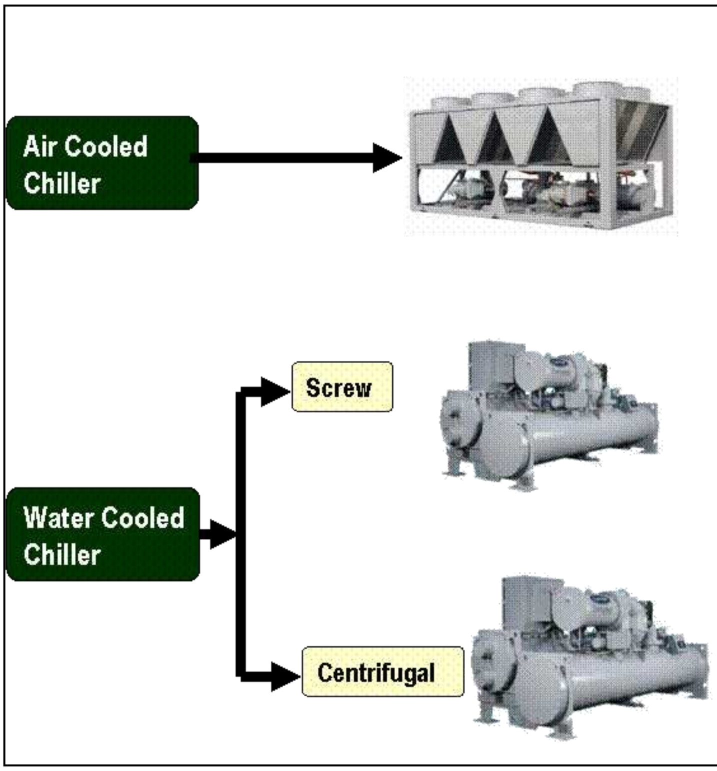
Economics

SAVINGS POTENTIAL: 20-30% percent of annual energy consumption.

PAYBACK PERIOD: Typically less than one year,

ECM 2 - Replacing Inefficient centralised chillers with efficient chillers

The chiller is the major energy consuming part in any HVAC plant. The main function of the chiller is to produce chilled water for cooling the air in air handling units. The efficiency of chiller is of utmost importance. The Energy conservation building code (ECBC-2007) should be followed while selecting any chiller. ECBC has defined the efficiency of different chillers which depends upon the capacity of chiller and the type of chiller i.e., whether the chiller is air cooled or water cooled. Figure 5.18 gives a comparative picture various chillers as suggested by ECBC 2007.



Size of chiller	Min COP	Min IPLV
Less than 150 TR	2.9	3.16
Greater than equal to 150 TR	3.05	3.32

Size of chiller	Min COP	Min IPLV
Less than 150 TR	4.7	5.49
>=150 TR < 300 TR	5.4	6.17
>= 300 TR	5.75	6.43

Size of chiller	Min COP	Min IPLV
Less than 150 TR	5.8	6.09
>=150 TR < 300 TR	5.8	6.17
>= 300 TR	6.3	6.61

Figure 5.18: Comparative picture of various chillers as referred by ECBC 2007

ECM 3 - Keep the chilled water supply temperature as high as possible

This simple procedure applies to virtually all chilled water systems. Raising the chilled water temperature generally does not create any risks to equipment. And, it costs little or nothing to accomplish.

The amount that you can increase the chilled water temperature is limited only by the need to satisfy the cooling load. Most of the work of accomplishing this measure consists of determining the maximum allowable chilled water temperatures over the range of cooling loads. The two subsidiary Measures offer manual and automatic methods, respectively.

The potential for raising chilled water temperature

Chilled water systems are commonly designed to provide full cooling load with a chilled water temperature of about 42°F. Plant operators typically leave the chilled water temperature fixed at this value or some other. This is inefficient for most applications, such as air conditioning, where the load is well below its maximum most of the time. Typically, you can raise the chilled water temperature by 5°F to 10°F for much of the time. Even at full load, the typical over sizing of airside components (air handling units, fan-coil units, etc.) usually allows some increase in chilled water temperature.

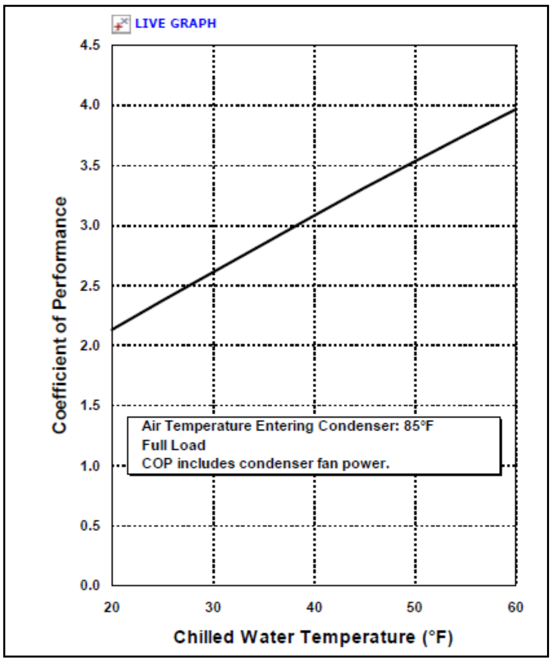


Figure 5.19: Variation of COP with chilled water temperature

A saving of approximately two percent of input energy per degree Fahrenheit (or about four percent per degree Celsius) that the chilled water temperature is raised. This number applies to all types of chillers, with minor variations. Above figure 5.19 shows how COP improves with increasing chilled water temperature, for a typical chiller.

ECM 4 - Reset the chilled water automatically

Reset the chilled water temperature using an automatic control. This is a simple, common control function that can be accomplished with a few standard control components.

The challenge with automatic controls is designing them to maintain the most efficient relationship between the chilled water temperature and the cooling load. Failing to do this accurately wastes some of the savings potential of the Measure, or causes comfort problems. The cooling load relates to several conditions, including the outside air temperature, the humidity, the amount of sunshine, the number of occupants, and the heat emitted by equipment. The most accurate way of responding to the cooling load is to use the signals from the space thermostats. When the signal from any one thermostat indicates that the airside unit is unable to satisfy the load in that space, the chilled water temperature is lowered incrementally.

A cruder method of controlling chilled water is to sense the load at the chiller, for example, by sensing the difference between the supply and return chilled water temperatures. This method is less accurate than sensing space loads directly, but it is simple, cheap, and reliable.

With either method, a single space or piece of equipment should not force the entire chiller system to operate at a much lower chilled water temperature.

Economics

- Saving potential: 5 to 15 percent of annual chiller energy consumption.
- Payback period: Typically less than one year, with larger chiller systems. Up to several years, with small systems.

ECM 5 - Reset the condenser water temperature automatically

The energy consumption of chillers can be reduced by keeping the condensing temperature as low as possible. Typically, compressor power drops by about 1.5 percent per degree Fahrenheit (about 3 percent per degree Celsius) of condensing temperature.

Coefficient of performance (COP) improves with lower condensing temperature (refer to figure 5.20).

The simplest case is maintaining a constant differential between the condensing temperature and the outside air temperature (either dry-bulb or wet-bulb)

Economics

- Savings Potential: 5 to 15 percent of the average annual chiller energy consumption.
- Payback period: One year, to many years.

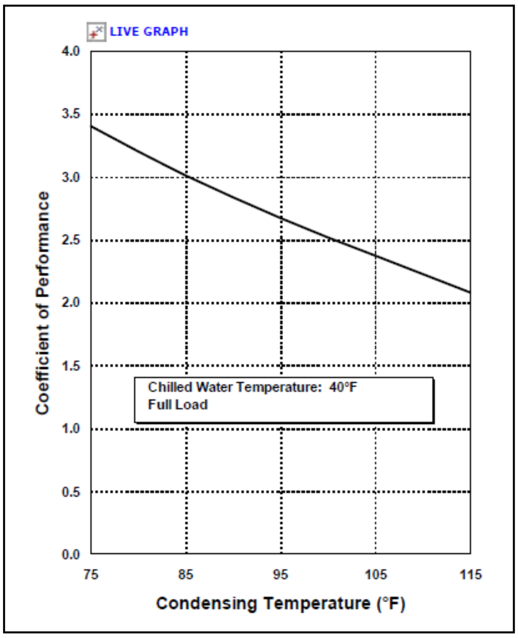


Figure 5.20: COP vs condensing temperature

ECM 6- Variable frequency drives in cooling tower fans

In many cooling systems, especially larger ones, water is cooled by evaporation in a remote cooling tower," and the water is pumped some distance to the condenser for cooling.

The fans in these units are major consumers of energy, accounting for typically 5 to 20 percent of chiller system energy consumption. The least fan energy is used in systems that are aided by evaporation, and the most is used by equipment that is directly air-cooled.

Measure

This Measure eliminates or minimizes energy waste due to the cycling of fan output that occurs in cooling units with single-speed, fixed-pitch fans. Cycling fan output wastes fan power and raises the average condensing temperature. The solution is to install a fan drive that is better able to follow the actual cooling load.

The lowest energy consumption occurs when all the fans serving a particular cooling system are operated at the same speed (assuming that the fans are identical). This arrangement is also simple to control.

Economics

- Savings Potential: 30 to 70 percent of fan energy. 0.5 to 3 percent of chiller energy, because of lower condensing temperature.
- Payback period: One year, to many years.

ECM 7- Installing energy efficient motors

The efficiency of motors has increased in recent decades because of improvements in motor design and manufacturing processes. These improvements were spurred by market pressures and regulations. The percentage increase in efficiency has been modest because all motors, especially larger ones, have always been fairly efficient. However, the total amount of energy that can be saved by using more efficient motors is large.

Motor efficiency in new construction

The best time to optimize motor efficiency is before the facility is built. Doing this is as simple as specifying the motor model or the efficiency rating that you want.

Energy and Cost Saving Potential

Better motor efficiency saves energy, both directly and indirectly. Most of the cost savings result from the energy savings, but some cost saving also results from the way electricity is priced.

Reduced motor energy consumption

Larger electric motors annually consume electricity that costs several times the price of the motor. The energy savings from upgrading motor efficiency depend primarily on the size of the motor, its hours of operation, its load profile, its efficiency, and the efficiencies of potential replacement motors. In addition, the cost saving depends on the unit price of electricity. Most of the economic savings from improving motor efficiency typically results from a reduction in kilowatt-hour consumption.

Economics

- Savings Potential: 2% to 15% of energy consumption, with 3-phase motors. Up to 30% of energy consumption, with small single-phase motors. Larger motors have smaller percentages of savings, but save much more energy in absolute terms.
- Payback period: Usually less than one year, in new construction and for replacing failed motors. Several years or much longer, for upgrading motors that are still working.

ECM 8 - Installing cooling thermal storage

A cooling thermal storage system is like a conventional chiller system, with the addition of a large container that stores cooling in ice, chilled water, or some other material.

Cooling storage has two main advantages over a system without storage. One is that cooling can be available on any desired schedule, independently of the operation of the chillers (within limits). The other is that the cooling storage unit may be able to deliver cooling at a higher rate than the chillers, or to supplement the chillers.

Thermal storage exists primarily for the benefit of the electric utility. It allows the utility to generate more of its electricity with its most efficient generators. It may also allow the utility to generate electricity with fuels that are less scarce or less critical. From the standpoint of the facility owner, thermal storage is a means of purchasing electricity at lower rates. The electric utility rewards the facility owner who uses cooling storage by offering lower electricity rates.

Reduced electricity cost

At the present time, most cooling storage is installed to reduce electricity cost. The price of electricity is related to the time period when the electricity is purchased. Electrically powered chillers typically account for a large fraction of a facility's energy consumption, and cooling storage allows the operation of the chillers to be shifted to time periods when electricity is cheaper.

The key issue in reducing electricity costs is the "demand" charge, which varies with the time of day, the day of the week, and the season. Make sure that you are comfortable with this concept before studying the following examples. In brief, the demand charge is a charge based on the maximum rate of energy consumption (measured in kilowatts), not for the amount of electricity consumption (measured in kilowatt-hours). In the following examples, the objective of cooling storage is the minimize the demand charge.

For example consider a typical office building or a retail store. In this example, cooling is provided by storage, rather than by chiller operation, during the periods of higher demand charges. There are three demand charge periods during the day, and the objective is to operate the chillers only during the period of lowest rates. The cooling load to be avoided during periods of higher demand charges is marked "A." The cooling storage unit can be charged at any time during the off-peak rate period, but preferably during the coolest hours of the night (to maximize chiller efficiency). This cooling load is marked as "B." During off-peak periods the chillers can also serve the cooling load directly, if a cooling load exists then. Direct cooling is more efficient than cooling with storage, as we shall see, so we try to use direct cooling as much as possible during the off-peak

Economics

- Savings Potential: Cooling storage provides cost savings, not energy savings. The savings vary widely with circumstances, depending mostly on the pricing policies of electric utilities and your ability to negotiate with the utility. The cost savings provided over the life of the system are much less predictable than with most energy conservation measures.
- Payback period: Several years, too much longer.

ECM 9 - Controlling of Air Handling Units (AHUs)

Larger buildings use centralized air handling systems to provide cooling, heating, and ventilation. Air handling systems are usually the largest user of energy in buildings that use them as their primary conditioning equipment. Typical modern air handling systems expend much of their energy consumption for overhead functions, especially air delivery and reheat, that provide no useful heating or cooling of the spaces. Much of this energy consumption can be eliminated. As usual, the opportunities are greatest when designing new buildings, but major improvements are usually possible with existing systems that are wasteful. Make this excess energy consumption a prime target of your efforts to conserve energy. Many significant improvements to air handling systems can be made at modest cost.

What air handling systems do

Air handling systems may perform a surprisingly large number of functions, including these:

- Heat and/or cool space air.
- Control the humidity of space air.
- Bring in outside air for cooling.
- Provide cooling by evaporation of water.
- Distribute air within the spaces
- Control the interior pressure of the building with respect to the outside pressure.
- Control pressure relationships between different areas in the building.

An individual air handling system typically does not perform all these functions. Some of the functions may not be needed, or they may be overlooked in the system design. Some of these functions may be accomplished in a manner that wastes energy. As a result, many air handling systems offer opportunities both for improving functional performance and for saving energy. By the same token, when you set out to improve the efficiency of existing air handling systems, keep all these functions in mind, so you do not undermine any of the system's purposes. The Measures discuss these functions where appropriate.

Turn off air handling systems when they are not needed using automatic control.

Turning off air handling equipment whenever possible eliminates or reduces these causes of energy waste which will arise due to unnecessary conditioning.

Where spaces operate on regular schedules, use time clocks to start and stop air handling equipment.

Where a facility operates on a regular schedule, time clocks are usually the best way of automatically starting and stopping equipment, at least as a starting point. Time clocks can be combined effectively with controls that respond to other inputs, such as outdoor temperature, occupancy, etc.

Economics

- Savings Potential: 10 to 70 percent of the air handling system's operating cost.
- Payback Period: Less than one year, to several years.

Install optimum-start controllers to adapt starting times to weather conditions.

Optimum-start control is a supplemental feature of time clocks that automatically adjusts the equipment start time in response to weather conditions. If air handling systems are started using simple time clocks, facility operators typically set the start time to cover the worst weather conditions that may occur. This wastes conditioning energy, and also wastes the energy required to operate fans, pumps, and other equipment.

The time required for a building interior to reach normal temperature after a period of shutdown depends on the building's thermal mass and on its rate of heat loss. Thermal mass soaks up conditioning energy during the start-up interval, increasing the time required to reach normal temperature. Heat loss diverts conditioning energy from the building interior, extending the startup interval. Optimum-start controllers take both of these factors into account. The time required to replenish heat lost from the internal mass of the building depends on the space temperature at start-up. The controller uses an inside thermometer to sense the space temperature. The controller calculates the rate of heat loss to the outside from the difference between the outside temperature and the desired inside temperature. The controller also has an outside thermometer for this purpose.

Economics

- Savings Potential: 1 to 10 percent of the cost of operating the air handling systems, compared to using ordinary time clocks. The greatest savings occur with long shutdown periods and severe climates.
- Payback Period: Several months to several years, the period being shorter with larger systems and more severe climates.

Provide outside air economizer cycle operation of air handling units.

An economizer cycle is a method of providing free cooling during periods when the outside air is cooler than the indoor temperature, typically, when the outside air temperature is below about 60°F. The economizer cycle is a damper control sequence that increases outside air intake just enough to meet the cooling requirements of the air handling system. If outside air cannot provide sufficient cooling, mechanical cooling makes up the difference.

In order for an economizer cycle to work properly, the air handling system must be able to control the amount of outside air intake accurately. Also, the air intake and relief passage must be large enough to allow large volumes of air to be brought into the building. In new construction, these features can be included at modest cost.

In many existing facilities, the outside air intake capacity is ample and the necessary dampers are already installed in the system. In such cases, you can retrofit an economizer cycle without major mechanical modifications, and the additional controls are the only major expense. In other retrofit applications, you may have to make major modifications to the "front end" of the air handling system to handle the large volumes of outside air and relief air.

Economics

- Savings Potential: An economizer cycle can eliminate the need for mechanical cooling during periods when the outside air temperature is below about 60°F. The savings depend on the cooling loads that exist during these periods.
- Payback period: Less than one year, to many years.

ECM 10 - Replace existing inefficient plant (chillers, chilled water pumps, condenser water pumps & cooling towers) with efficient all variable plant with integrated plant controller works on Hartman loop principle

It is just not chiller efficiency what really matters in efficient HVAC system but also the plant efficiency. HVAC plant includes chillers, chilled water pumps, condenser water pumps and cooling towers. It is also understood that the plant is designed for peak load but seldom has it operated at full load. Most of the time HVAC plant operates at part load and therefore it is part load efficiency of plant which matters most. In conventional design only chillers may operate at better efficiency but auxiliary equipment always operate on full load since these are constant speed equipment. This makes overall efficiency of the plant less efficient as compared to only chiller efficiency which may be more efficient at that part load. Keeping this in mind an all variable HVAC plant which will include two variable speed chillers each of 180 TR capacities, three nos. of variable primary chilled water pumps, 3 nos. of variable condenser water pumps and two numbers of cooling towers with variable frequency drive fitted with ARMSTRONG IPC (integrated plant controller) is recommended to replace the existing inefficient plant at French Embassy.

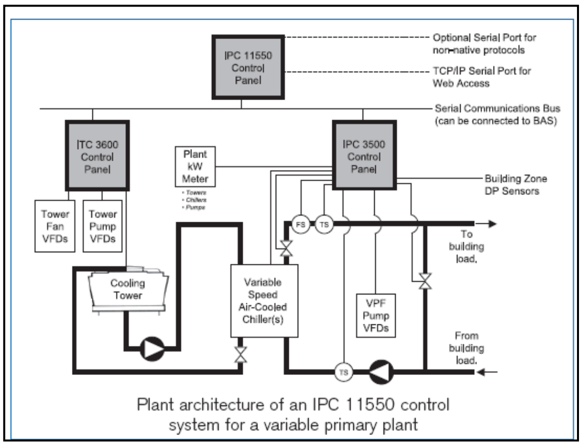


Figure 5.21: IPC control system

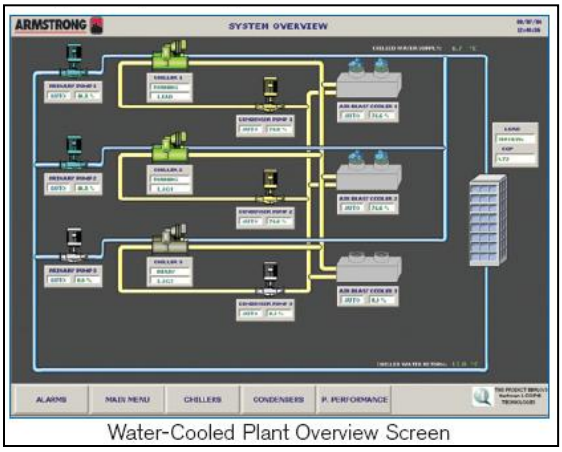


Figure 5.22: Water-cooled plant system

Employing the Hartman LOOP methodology of the IPC control system (figure 5.21), chilled water plant control (figure 5.22) maximizes the benefits of all variable speed plant design and it is different from conventional PID control mechanism. The IPC system architecture is based on high level serial communication between a network of three control panels, master panel, chiller and pump control panel, and the integrated tower control panel. The IPC control system employs the Hartman LOOP Natural Curve sequencing logic to ensure that the variable speed chillers are always operating as close as possible to their maximum efficiency for a given entering condenser water temperature (ECWT). To reach the optimum ECWT, the controller maintains the greatest active surface area on the cooling towers by slowing down the condenser water pump and tower fan, as opposed to staging off cooling towers. Combining this with Hartman LOOP patented demand-based control algorithm results in most of the stable and efficient systems with average operating IKW/TR as low as 0.5.

ECM 11- Precooling of fresh air by Earth air tunnel (EAT) system

Earth air tunnel is nothing but a buried pipe at a depth of 4 meter below the ground level. The tunnel pipes may be metal, plastic or concrete (figure 5.23). At a depth of 4-meter from the earth surface, temperature remains constant throughout the year. Ambient air is sucked from one end passed through the tunnel and depending on the ambient temperature; air gets cooled in summer and heated up in winter. This cooled/heated air then supplied to the various areas for space cooling/heating and provides recommended thermal comfort to the building occupants. The earth air tunnel comprises of mainly four parts. First part is fresh air intake column which is nothing but a masonry structure like manhole. Top of the intake structure is kept 1 m above the ground and hot air is sucked from the top and is taken up to the depth of 4 m. Second part is the tunnel which is a straight tunnel made of hume pipe laid at the depth of 4 m below the ground level. The diameter of the tunnel depending on the quantity of air which is to be cooled could vary from 0.3 m to 0.7 m and length of pipe from 50 m to 100 m. This is part which is responsible for heat transfer or cooling of the air.

At the end of EAT , a fan room is generally provided which could be at 4 m depth or may be at ground level depending on the application and site conditions. A blower fan is provided in the fan room which draws the air from intake column and supplies it through supply ducts or pipes. If fan room is constructed at the 4 m depth a supply column is provided and later it is connected to the distribution network which supplies air to the zone where cooling is to be provided. Otherwise ducts (either masonry or GI) can be directly connected to the discharge side of fan. The earth air tunnel can provide air to the spaces at 28 to 30 0C in summer and 18 to 20 0C in winter.

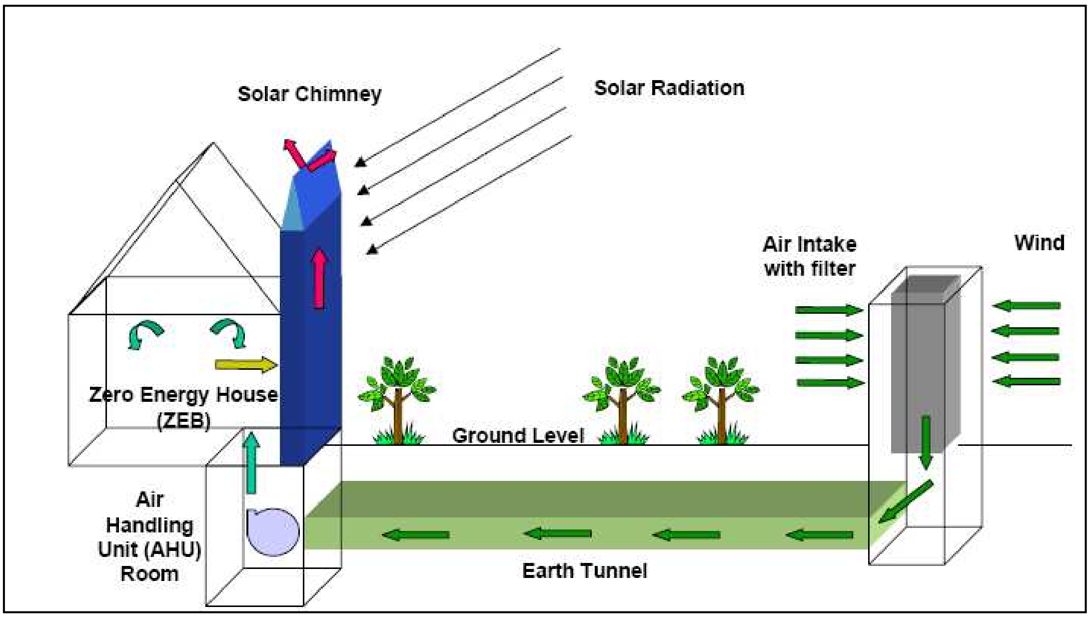


Figure 5.23: Schematic diagram of Earth air tunnel system

ECM 12 - Heat exchange using geothermal heating and cooling

Geothermal heat pumps use the constant temperature of the earth as the exchange medium instead of the outside air temperature. Many parts of the country experience seasonal temperature variation, from scorching heat in the summer to extreme cold in the winter. Below certain depth of earth's surface, the ground temperature remains at a relatively constant. Depending on latitude, ground temperatures range from 45°F (7°C) to 75°F (21°C). The ground temperature is warmer than the air above it during the winter and cooler than the air in the summer. The GHP takes advantage of this by exchanging heat with the earth through a ground heat exchanger. So this contact temperature can be used to provide heating, cooling, and hot water for homes and commercial buildings.

Geothermal heat pumps can be classified as closed looped system and open loop system. The pipes can be installed in three ways, viz. vertically, horizontally and in a pond or lake, depending upon the availability of land area and soil type at the chosen site.

Open loop system

Open loop systems pump ground water from an aquifer through one well, and send through the heat pump's heat exchanger, and is discharged to the same aquifer via another well at a distance from the first, shown in the figure below. Since the temperature of groundwater is nearly constant throughout the year, open loops are a popular option in areas where they are permitted (figure 5.24).

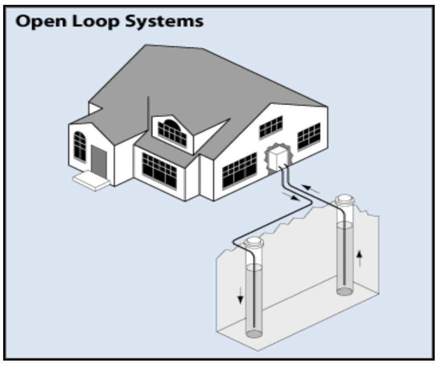


Figure 5.24: schematic diagram of open loop system

Closed loop system

Compared to open loop system, they are economical, efficient, and reliable (figure 5.25). Water is circulated through a continuous buried pipe and it is commonly used system. The closed loop system is environmentally friendly because water in the loop prevents contamination to the external environment. The length of loop piping varies depending on ground temperature, thermal conductivity of the ground, soil moisture, and system design. Closed loop system can be classified as horizontal closed loop, vertical closed loop and Pond Closed Loop.

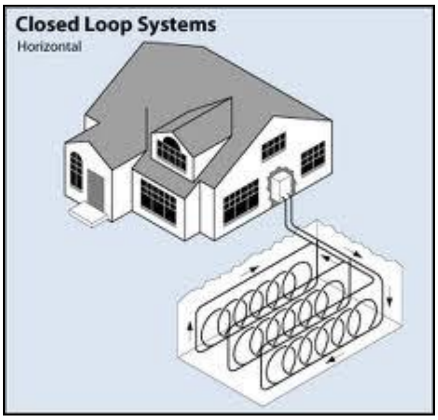


Figure 5.25: Closed loop system

ECM 13 - Pre cooling of fresh air by energy recovery wheel

When a unit is equipped with an optional enthalpy wheel, energy recovery is provided by drawing outside air across half of the enthalpy wheel and drawing exhaust air across the other half. Latent heat and sensible heat are transferred from the hotter and moist exhaust air to the colder and dry outside air during winter conditions. Latent heat and sensible heat are transferred from the hotter and moist outside air to the cooler and dry exhaust air during summer conditions. Figure 5.26 shows the energy recovery wheel

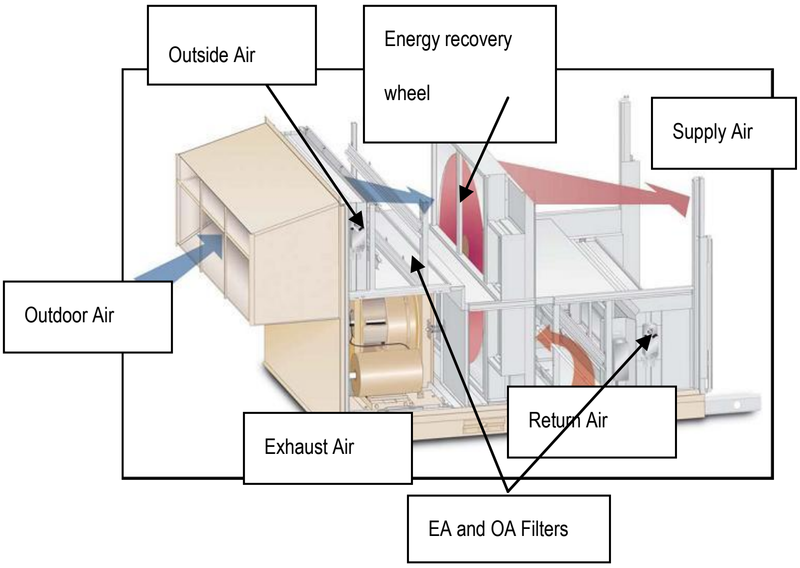


Figure 5.26: Energy recovery wheel for pre-cooling of fresh air

5B. Checklist for Energy Conservation Measures

Hotel buildings consume lot of conventional fuels like electricity, oil, natural gas and LPG to generate energy for space conditioning, pumping water, lighting, cooking and other hotel equipment. Incorporation of energy conservation measures in hotel buildings can reduce energy consumption in new buildings by up to 40% of that used in conventional buildings and in existing buildings by up to 20% by suitable retrofit application.

The objective of this checklist is to assess the potential of adoption of various ECM in your hotel.

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1. Is your building already existing or in an upcoming building?

2. Type of Hotel (Please tick √ the right option)

☐ 5 Star Deluxe	☐ 5 Star	☐ 4 Star	☐ 3 Star
☐ 2 Star	☐ 1 Star	☐ Heritage	☐ Heritage Classic
☐ Heritage Grand	☐ Government approved non-star category		☐ Unapproved

3. Is your building registered or certified under any green building rating system (such as- GRIHA, LEED, Green Globe or Any other)?

☐ Yes

☐ No

If "No"; let's find out the potential of the new hotel building in terms of its Energy Conservation Measures (ECM).

i. What is the orientation of the longer/ major facades of your proposed hotel building?
   a. Longer facades are facing N-S
   b. Longer facades are facing E-W

ii. What is the internal arrangement of the majority living spaces (guest rooms) in the proposed hotel building?
   a. Along the N-S façade
   b. Along the E-W facade

iii. What is the orientation of large openings/ glazed facades/ maximum number of windows?
   a. Along the N-S façade
   b. Along the E-W façade

iv. What is the window to wall ratio (WWR) of the proposed hotel building?
   a. $\leq$ 40%

b. 40% – 60%
c. ≥ 60%

v. Have you proposed any shading for your wall, roof or window those are exposed to direct solar radiation?
a. Yes
b. No

vi. What type of wall shadings is proposed in hotel building?
a. Green wall
b. Wall pergola
c. Vertical screening or Jallies
d. Plantation along E-W façade
e. Any other

vii. What type of roof shadings is proposed in hotel building?
a. Roof pergola
b. Shading with solar PV system
c. Terrace garden
d. Reflective coating on roof
e. Any other

viii. What type of window shading is proposed in the hotel buildings?
a. Horizontal louver or louvers
b. Vertical louver or louvers
c. Combination of horizontal & vertical louver or louvers
d. Any other

ix. Is there any provision for insulation on the proposed wall & roof?
a. Yes
b. No

x. What type of insulation is proposed for the wall?
a. Expanded polystyrene (15mm plaster+115 mm brick+75mm EPS+115 mm brick+15mm plaster)
b. Extruded polystyrene (15mm plaster +115 mm brick+50 mm XPS+115 mm brick+15mm plaster)
c. Expanded polystyrene (15mm plaster +115 mm brick+50 mm EPU+115 mm brick+15mm plaster)
d. Resin bonded Fibre glass (15mm plaster +115 mm brick+75 mm EPU+115 mm brick+15mm plaster)
e. Rock wool insulation (15mm plaster +115 mm brick+75 mm Rock wool +115 mm brick+15mm plaster)
f. Autoclaved aerated concrete (15mm plaster +325mm AACB +115 mm brick+15mm plaster)
g. Any other

xi. What type of insulation is proposed for the roof?
a. Extruded polystyrene (12mm plaster +150 mm RCC +75 mm EPS+12mm plaster)
b. Expanded polystyrene (12mm plaster +150 mm RCC +50 mm EPU+12mm plaster)

c. Rock wool insulation (12mm plaster +150 mm RCC +75 mm fibre glass+12mm plaster)
d. Resin bonded Fibre glass (12mm plaster +150 mm RCC +75 mm Rockwool+12mm plaster)
e. Any other

xii. Is there any provision for providing high performance glazing (Double glazing, Triple glazing, Solar film coated etc.)?

a. Yes
b. No

xiii. Is there any special provision in the proposed hotel building to integrate natural light inside the living spaces (daytime used occupied/ functional spaces if any)?

a. Yes
b. No

xiv. What is the special design intervention in the proposed hotel building to allow maximum natural light inside the daylight required living spaces?

a. Orient these spaces along N-S
b. Shaded windows/ glazed facades along these spaces
c. Top lighting provision (central atrium with glass roof, skylights etc.)
d. Glazing with high visible light transmittance value (VLT$\geq$50%)
e. Any other

xv. What type of lighting source is predominantly used to illuminate in the back of the house (BOH) areas and service area?

a. Incandescent bulb
b. Compact fluorescent lamp (CFL)
c. Tubular fluorescent lamp (TFL) with magnetic ballast
d. Tubular fluorescent lamp (TFL) with electronic ballast
e. LED

xvi. What type of lighting source is predominantly used to illuminate the public area in the hotel building?

a. Incandescent bulb
b. Compact fluorescent lamp (CFL)
c. Tubular fluorescent lamp (TFL) with magnetic ballast
d. Tubular fluorescent lamp (TFL) with electronic ballast
e. LED

xvii. What type of lighting source is predominantly used to illuminate in the guest rooms and corridors in the hotel building?

a. Incandescent bulb
b. Compact fluorescent lamp (CFL)
c. Tubular fluorescent lamp (TFL) with magnetic ballast
d. Tubular fluorescent lamp (TFL) with electronic ballast
e. LED

(*Note*: The lighting systems installed with CFL, TFL with electronic ballasts and LED lighting systems are generally energy efficient.)

xviii. What is the lighting power density (LPD) (W/m^2) in the hotel building?

a. Greater than 10.8 W/m^2
b. Less than 10.8 W/m^2

(*Note*: Lighting power density (LPD) is the ratio of connected lighting load (W) to the built up area (m^2). ECBC recommends that LPD (W/m^2) of a hotel should not exceed 10.8 W/m^2.)

xix. What lighting levels (lux) are maintained in the back of the office area and service area in the hotel building?

a. Greater than 300 lux
b. Less than 300 lux

(*Note*: Lighting levels (lux) are maintained as per the recommendation of NBC 2005- for providing adequate visual comfort)

xx. What kind of lighting controls used in the hotel in different spaces?

a. Occupancy sensor in toilets/offices/meeting rooms etc.
b. Timer based sensor for outdoor lighting
c. Daylight sensor for offices/lobby
d. Others

xxi. What temperature are you going to maintain in Front of house (Receptions area), Back of house spaces (engineers office), Guest rooms and Lobby area?

a. Temp < 23 deg C
b. 23 deg C$\leq$ Temp$\leq$26 deg C

xxii. What is the sqft/TR for the proposed hotel building?

a.Sqft/TR $\leq$ 250
b.Sqft/TR $\geq$ 250

xxiii. What type of air-conditioning system is proposed to cater the cooling load requirement?

a. Distributed system
b. Centralized system

xxiv. What air-conditioning system is proposed in distributed system to cater to the cooling load requirement?

a. Split AC &/ Window AC (lower efficiency)
b. Split AC with Inverter (medium efficiency)
c. Variable refrigerant flow system (higher efficiency)

xxv. What is star rating of window AC / Split AC in distributed system you are going to propose?

a. Two Star (COP -2.9)
b. Three star (COP -3.1)
c. Four star (COP -3.3)
d. Five star (COP -3.5)

xxvi. What air-conditioning system is proposed in centralized system to cater to the cooling load requirement

a. Centralized air conditioning plant.

b. Hybrid system. (Central air conditioning plant integrated with geothermal or solar system)

xxvii. What mode type of machine is proposed under centralized air-conditioning system?

a. Air cooled machine
c. Water cooled machine

xxviii. What controls you will incorporate in the central system?

a. Chilled water Reset
b. Variable frequency drives in chiller, chilled water pumps
c. Pre cooling of Fresh air through Energy recovery wheel
d. Pre cooling of fresh air through Earth air tunnel
e. None of the above
f. None of the above

xxix. What is the motor efficiency of AHU fan, chilled water pumps, condenser water pumps and cooling tower fans?

a. Eff 1 of IS 12615
b. Eff 2 of 12615

Important notes:

1. If the building is not appropriately oriented then following measures can be incorporated in order to increase the energy efficiency; such as-

    a. Provide majority of the living spaces along N-S
    b. Provide minimum openings/ glazing along E-W
    c. Limit the WWR within 40% - 60%
    d. Provide adequate shading on exposed wall, roof & window
    e. Provide appropriate insulation on exposed wall & roof (U-value as per ECBC-2007)
    f. Select high performance glazing (U-value & SHGC as per ECBC-2007)

2. ECBC recommended U-value for Wall & Roof (for 24 hr occupied hotel buildings) as per five climatic zones of India

    - For composite, Warm and humid and hot and dry climate,
        - Wall U value - 0.440 W/m²/deg C
        - Roof U value - 0.409 W/m²/deg C
    - For Moderate climate,
        - Wall U value - 0.397m²/deg C
        - Roof U value - 0.409 W/m²/deg C
    - For cold climate,
        - Wall U value - 0.352m²/deg C

- Roof U value - 0.409 W/m²/deg C

The U value for building Wall, roof and glazing defines the heat gain or loss. The higher the U value the higher will be heat gain or loss which results in inefficiency

3. ECBC recommended U-value & SHGC value for windows for five climatic zones of India.
   - For composite, Warm and humid and hot and dry climate,
     - Glass U value - 3.3
     - Glass SHGC - 0.25 (for Window wall ration <40%)

     0.20(for Window wall ratio b/w 40 to 60%)
   - For Moderate climate,
     - Glass U value - 6.9
     - Glass SHGC - 0.40 (for Window wall ratio <40%)

     0.30 (for Window wall ratio b/w 40 to 60%)
   - For cold climate,
     - Glass U value - 3.3
     - Glass SHGC - 0.51 (for Window wall ration <40%)

     0.46 (for Window wall ration b/w 40 to 60%)

4. ECBC recommended specification for chiller efficiency.

Air cooled chiller chiller

Size of chiller	COP
Less than 150 TR	2.9
Greater than equal to 150 TR	3.05

Water cooled centrifugal chiller

Size of chiller	COP
Less than 150 TR	5.8
>=150 TR < 300 TR	5.8
>= 300 TR	6.3

Water cooled screw

Size of chiller	COP
Less than 150 TR	4.7
>=150 TR < 300 TR	5.4
>= 300 TR	5.75

5. The chilled water and condenser water pump efficiency should be greater than 80 %. Lower pump efficiency will lead to inefficiency in the system

6. ECBC recommended no load losses and load losses of the transformer

Table 8.2.1.1 maximum allowable losses for dry type distribution transformer with highest voltage for equipment 24 kV, at 50% and 100% of the load.		
Transformer Capacity (kVA)	Maximum Allowable losses at 50% kVA or load	Maximum Allowable losses at full load/Rated kVA
100	1.88%	2.44%
160	1.61%	2.07%
200	1.50%	1.90%
250	1.36%	1.73%
400	1.19%	1.51%
500	1.12%	1.45%
630	1.06%	1.40%
1000	0.90%	1.20%
1600	0.79%	1.05%
2000	0.75%	1.00%

Table 8.2.1.2 maximum allowable losses for oil filled distribution transformer with highest voltage for equipment 36 kV, at 50% and 100% of the load.		
Transformer Capacity (kVA)	Maximum Allowable losses at 50% kVA or load	Maximum Allowable losses at full load/Rated kVA
100	1.04%	1.80%
160	0.96%	1.38%
200	0.93%	1.35%
250	0.89%	1.27%
400	0.79%	1.12%
500	0.75%	1.05%
630	0.70%	0.99%
1000	0.70%	0.98%
1600	0.65%	0.98%
2000	0.64%	0.98%

7. The power factor should be maintained 0.95 or above as per ECBC-2007.

8. If the hotel is not installed energy efficient lighting systems then the following measures can be incorporated
   a. Provide equivalent compact fluorescent lamp (CFL) in case of incandescent bulb
   b. Provide high efficiency fixture fitted with electronic ballast in case of electro-magnetic ballast
   c. Provide an appropriate lighting control mechanism to efficient use of light
   d. Lighting Power Density should not exceed 10.8 W/m2 as recommended by ECBC

RENEWABLE ENERGY AT TERI

The Renewable Energy Technology Applications (RETA) area at TERI focuses on a range of services in various fields such as solar photovoltaic, solar thermal, wind, and renewable based hybrid systems. The thrust areas and capabilities of the Group include:

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- *Product development and demonstration*
- *Performance evaluation and field testing*
- *Renewable energy policy and planning*
- *Regulatory interventions for renewables*
- *Project development under clean climate initiatives*
- *Distributed generation and delivery models for electricity in rural areas*
- *Training and capacity building*

Particularly in the field of solar power space, TERI has been working with research institutes, technology suppliers, industry, as well as the governments; especially looking at solar power technology due diligence, resource assessment as well as detailed feasibility studies. Apart from these, TERI focuses on the complete value chain of solar power from the point of view of localization of its component. TERI's experts have extensive experience in developing solar energy related research infrastructure – in TERI as well as outside TERI. Moreover, TERI is in a position to exploit its excellent association with the research institutions of international repute like Solar Institute, Julich, Germany; Fraunhofer Institute for Solar Energy Technologies (ISET), Germany; and Institute of Energy Technologies (IFE), Norway.

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