Program for Responsible Energy Management (PREM)

A Guideline for Municipal Energy Managers 2013

Commissionerate of Municipal Administration, Tamil Nadu

Acknowledgements

This publication forms part of Program for Responsible Energy Management (PREM) initiated by the Commissionerate of Municipal Administration, Tamil Nadu, in 2013. A Guideline for Municipal Energy Managers serves as a handbook for Municipal Energy Managers to inform them during implementing energy demand and supply side interventions in their respective corporations and municipalities. The work involved in preparing this publication was coordinated by Auroville Consulting. Contributors are Alexander Broersma, Aurosree Biswas, Debabrata Sahoo, Henrick Bauer-Caunaille, Joerg Zimmerman, Martin Scherfler, Vikram Devatha and Vimal Bhojraj.

The Program for Responsible Energy Management (PREM) attempts to make Tamil Nadu’s municipalities and corporations more efficient and more sustainable in terms of their energy consumption and production. In order to confront the challenges of energy security and rapid climate change, it is important to design and implement efficient energy management solutions on a large scale. This publication has been created with the aim of supporting Municipal Energy Managers in their task of implementing responsible demand and supply side management initiatives. I hope it will serve to enhance the capacity of Municipal Energy Managers in creating a more sustainable energy future in Tamil Nadu and beyond.

Foreword

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List of Acronyms

Bureau of Energy Efficiency	BEE
Compact Fluorescent Lamp	CFL
Coefficient of Performance	COP
Cathode Ray Tube	CRT
Energy Conservation Building Code	ECBC
Energy Efficiency	EE
Energy Efficiency Ratio	EER
Energy Performance Index	EPI
Heating, Ventilation, Air-Conditioning	HVAC
Liquid Crystal Display	LCD
Light Emitting Diodes	LED

Unit Prefixes

Unit Abbreviations		
kilo	(103)	k
mega	(106)	M
giga	(109)	G
Kilo Watts		kW
Kilo Watts Hour		KWh
Cubic Feet		Cu. ft
Tons of Refrigeration		TR
Ministry for New and Renewable Energy		MNRE
Reference Energy System		RES
Renewable Energy Technology		RET
Solar Photovoltaic		Solar PV
Tamil Nadu Energy Development Agency		TNEDA
Uninterrupted Power Supply		UPS
British Thermal Unit		Btu

Conversions

1 British thermal unit (Btu) = 0.252 kcal = 1.055 kJ

1 kilowatt-hour (kWh) = 860 kcal = 3600 kJ = 3412 Btu

INTRODUCTION

Program for Responsible Energy Management (PREM)

Today the building sector accounts for more than 30 percent of Tamil Nadu's electricity consumption. With the projected population growth, economic growth and increased urbanization, energy consumption is expected to rise steeply in the coming years. In order to achieve long-term energy security and sufficiency that enables sustainable and equitable economic growth, Tamil Nadu will have to find smart and effective strategies for introducing energy conservation and energy efficiency programs while simultaneously increasing its share of renewable energy sources.

INTRODUCTION

Program for Responsible Energy Management (PREM) was initiated by the Commissionerate of Municipal Administration, Tamil Nadu. It aims at introducing a responsible demand and supply side management for all buildings and facilities (approximately 8,600 in number) under its administration. The demand side management addresses energy conservation and efficiency while the supply side management aims at installing grid-tied solar photovoltaic systems to maximize the availability of renewable energy.

Objectives of PREM

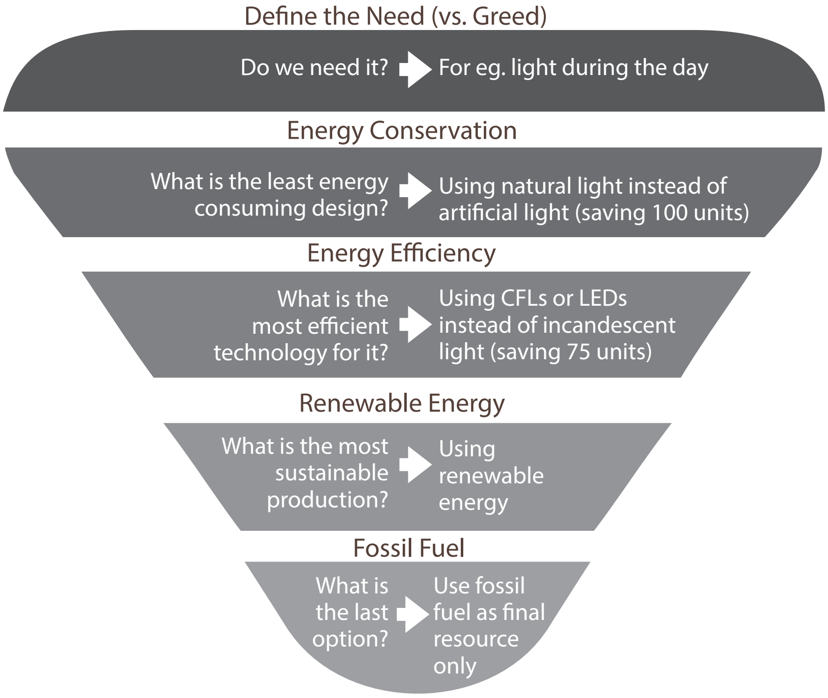
- To train 160 Municipal Energy Managers all over Tamil Nadu in the implementation of energy conservation and efficiency programs as well as Solar PV installations.
- To reduce energy consumption of Municipalities by thirty (30) per cent within two years.
- To install a max. capacity of grid-interactive solar photovoltaic systems in municipal buildings.

What are the objectives of this guideline document?

This publication is made for the Energy Managers under PREM and hopes to provide:

- A simple and practical introduction to the fields of energy conservation, energy efficiency and solar PV installations.
- A step by step manual to guide Energy Managers in their day to day work.
- A document that provides references for further readings.

Figure 1. Energy Pyramid



Adapted from: UN-Habitat 2012

The Energy Pyramid

This publication draws its inspiration from the Energy Pyramid which provides a simple framework for establishing a comprehensive energy management program. The Energy Pyramid addresses energy management from a system's perspective by including demand side management (energy conservation, energy efficiency) and supply side management (renewable energy). Energy conservation asks the question, "Do we need to consume a given good/service?". Energy efficiency asks, "What would be the best possible way to consume the same good/service?", while renewable energy asks, "Could there be sustainable renewable energy alternatives for fossil fuels?".

Figure 1 illustrates the steps towards responsible energy management by taking light as an example. The first question the energy manager will ask is whether artificial light is needed at all or if the natural light present during the day suffices. If better light quality is needed, then one could perhaps move into a better-lit room or even open the curtains to let in more light. If an artificial light source is required, then could one use energy efficient fixtures such as Light Emitting Diodes (LEDs) instead of incandescent lamps? And finally what is the source of energy we are drawing from? Can the energy to power this light come from a renewable source?

Contents of this Guideline Document for Municipal Energy Managers

This publication is divided into three Chapters and attempts to address responsible energy management from a system's perspective by including demand side management (energy conservation, energy efficiency) and supply side management (renewable energy).

Chapter 1 provides an introduction and an implementation manual for energy demand side management practices. Such practices include inducing behaviour change in favor of energy conservation and energy efficiency initiatives for simple appliances such as lighting and cooling appliances. The focus on lighting and cooling (fans and air conditioning) is based on the fact that close to 60% of a commercial building's electricity consumption accounts for these two categories (refer to figure 2) and that a demand side intervention focusing on lighting and cooling promises high energy savings and attractive payback periods.

Demand side management considers the following three steps:

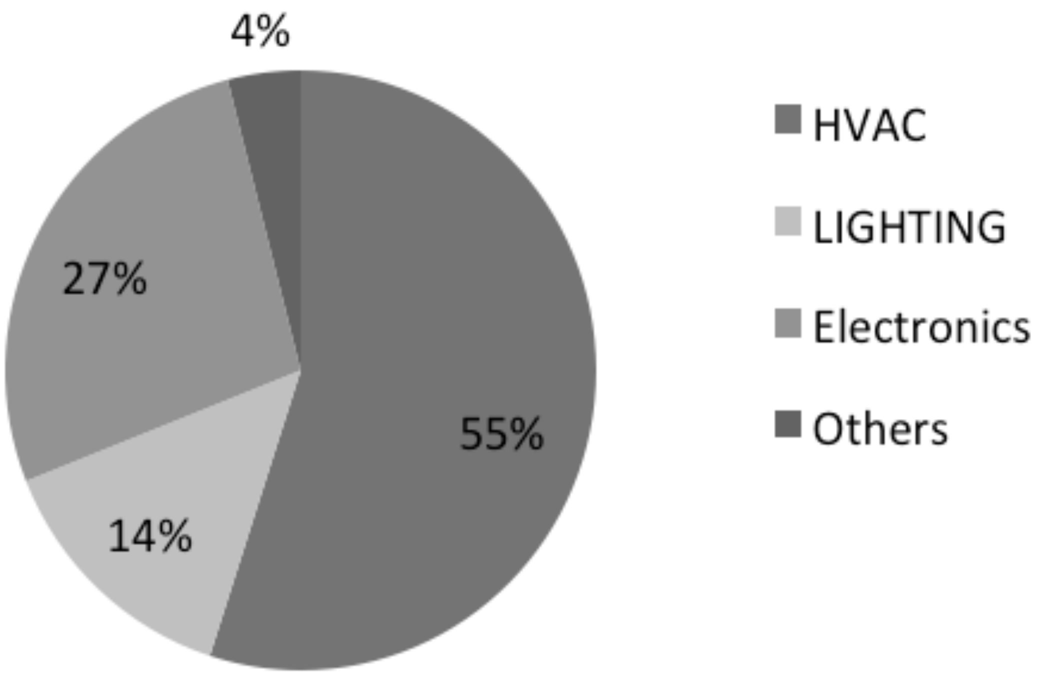
1. Determine the needs of the energy consumer
2. Find and implement energy conservation measures
3. Improve Energy Efficiency of appliances

The three sections will be introduced and then separately applied to lighting, ventilation, air conditioning and other appliances.

Chapter 2 offers an introduction to grid-connected solar photovoltaic systems and aims at equipping the Energy Manager with tools and knowledge required in choosing the appropriate Solar PV systems for the various buildings and facilities under his management.

Chapter 3 provides tools and additional information that the Energy Manager can use on a daily basis in his responsible demand and supply side management.

Figure 2 Average Energy Consumption for Commercial Buildings in India

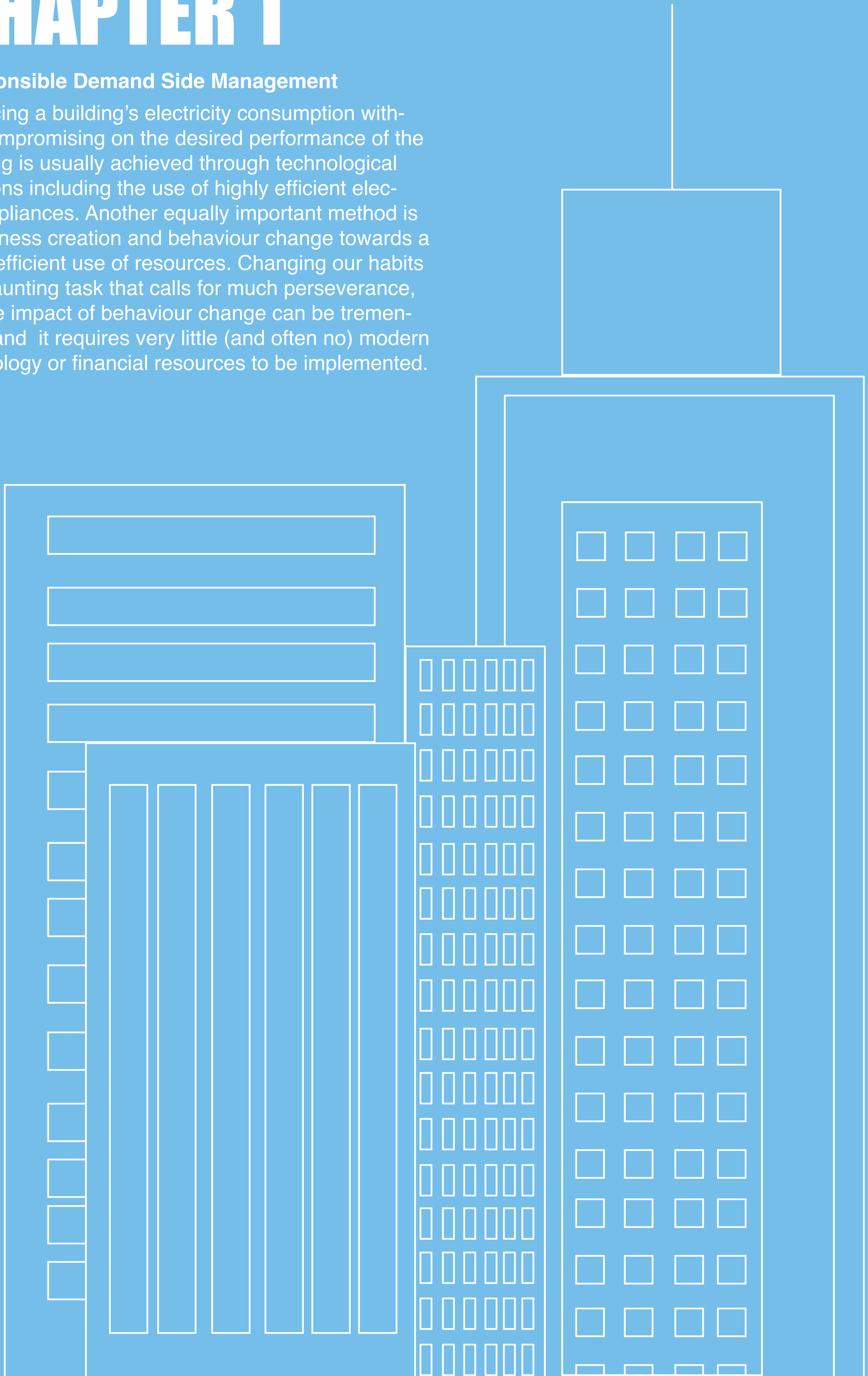


Adapted from: UNDPO 2009

CHAPTER 1

Responsible Demand Side Management

Reducing a building's electricity consumption without compromising on the desired performance of the building is usually achieved through technological solutions including the use of highly efficient electric appliances. Another equally important method is awareness creation and behaviour change towards a more efficient use of resources. Changing our habits is a daunting task that calls for much perseverance, but the impact of behaviour change can be tremendous and it requires very little (and often no) modern technology or financial resources to be implemented.



1.1 Introduction to Demand Side Management

Reducing Energy Consumption Through Behavioural Change

During the 20th century our energy consumption habits were shaped by the seemingly unending reserves of fossil fuels. The availability of cheap fossil fuel created wasteful behaviour patterns. As we are now facing a national and global energy crisis and the need for a more efficient use of our energy resources, we are asked to examine behaviour in regard to resource management at our workplaces as well as at our homes. The unsustainable use of energy constitutes a huge potential for energy savings.

The top two phases of the Energy Pyramid very clearly demonstrate the steps to be taken by the Energy Manager to bring along behavioural change for energy savings. First of all define the need and second, identify the energy conservation measures.

Define the Need and Conserve Energy

To ‘define the need’ one must actively and consciously think about requirements to create a comfortable working/living environment. Decide on your needs without considering the available options that technology has to offer (e.g. the maximum setting on your AC, fan or lights). These are subjective choices, but we are all similar human beings and you will likely find that we all have similar needs. For example most people agree that a quiet, bright room at 26˚C with an adjustable office chair and desk make a comfortable office environment.

For lighting, AC and ventilation there are many guidelines and even regulations that help to translate needs into objective data and figures. To conserve energy is to reduce the consumption of artificially generated energy, be it thermal, electrical or any other. Use natural flows and systems (i.e. natural light, shading and natural ventilation) to meet your earlier defined needs as much as possible. This is where habits play an important role. Many habitual changes, small and large, that can significantly reduce our consumption are known and available. For lighting, air conditioning and ventilation specifically they will be introduced in their specific subchapters. Now we will focus on tools (based on behavioural science) that increase the effect and improve the chances of success of behavioural interventions.

What Can the Municipal Energy Manager Do?

Motivating the users of the buildings you manage to conserve energy can significantly reduce the energy demand and is an extra tool you can use to meet energy reduction targets. We have set up a list of techniques you can implement to achieve greater energy savings.

- **Energy Reports are Similar to Energy Bills.**

  They state the energy consumption and other information. Energy reports can be designed in a way that they have an impact on consumer behavior. The energy report tool in Chapter 3 is an example that uses social proof as a motivator to reduce energy consumption. This is done by comparing one’s energy use with that of others (preferably within one’s neighborhood) with similar energy consumption characteristics.

- **Periodic Energy Monitoring**

  Put up a notice board with daily energy usage, associated costs and daily interventions. Daily interventions can be in the form of lights off on Wednesdays, half power fans on Tuesdays, etc. This can make people aware of energy savings.

- **Local Press Reports**
  Send out periodic local press reports as an award for municipal sites praising the employees who implemented the best/funniest/most original energy conservation method.

- **Temperature Monitoring**
  Standardize temperature settings of all ACs to 26 degrees Celsius.

- **Competitions, Awards and Prizes**
  Create incentives for the best performing facilities in terms of energy conservation.

- **Check List**
  A simple checklist stating energy conservation methods can be used first of all to make people aware of energy conservation, and second - as a reminder. The sample checklist in table 1 (ref: Energy Conservation Checklist) can be printed and displayed in municipality buildings for these purposes.

Table 1 Energy Conservation Check List

Energy Conservation Check List	
Be aware that simple energy conservation methods are available.	
Turn off the lights in rooms that are not in use.	
Open windows in non-AC rooms for ventilation.	
Turn up the AC temperature to 25˚C, or turn it off and use ceiling fans.	
Close/seal air-conditioned rooms.	
Turn off office equipment when not in use.	
Turn the fan down from maximum setting.	
Open the curtains and replace artificial light with natural light.	

Energy Efficiency
Energy efficiency has been introduced in many sectors over the recent years. Of importance to this guideline is energy efficiency in buildings and appliances. The energy efficiency of a building depends on the appliances used in the building.

Energy Efficiency in the Building Sector
The energy efficiency of a building is the extent to which the energy consumption per square meter of floor area of the building measures up to the established energy consumption benchmarks for the particular type of building under defined climatic conditions. These energy consumption benchmarks are representative values for common building types against which a building's actual performance can be measured. The Bureau of Energy Efficiency is providing star rating of office buildings based on their Energy Performance Index (EPI). The EPI is the energy consumption per square meter (kWh/m²).

Table 2 Energy Performance Index in kWh/m2/year

Star	EPI (kWh/m²/YEAR)	
Label	More than 50 % air conditioned built–up area.	Less than 50 % air conditioned built–up area.
1 Star	200-175	85-75
2 Star	175-150	75-65
3 Star	150-125	65-55
4 Star	125-100	55-45
5 Star	below 100	below-45

Adapted from: BEE 2013

Most of the modern commercial buildings have an EPI of 200 to 400 kWh/m² per year. Energy conscious building design has shown to bring this down to 100-150 kWh/m² per year (including full AC).

Energy Efficiency for Appliances

In May 2006, the Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, launched the Standard and Labeling Program of electrical home appliances including air conditioners. Labeling of appliances in terms of energy efficiency is done by star rating. The higher the number of stars, the more efficient the appliance. There are two kinds of labels – a big label and a smaller label. For ceiling fans, tube lights, computers/laptops and television sets the smaller labels are used, while for refrigerators, air conditioners, geysers and washing machines the big label is used.

Figure 3 BEE Star Labeling

Image 1 BEE Star Labeling

BEE Star label - Small label
For TVs, Computers/laptops, fans and tube-lights
This is a label for 1 Star tubelight – least efficient among the rates appliances

BEE Star Label – Big label
For refrigerators, air-conditioners, geysers and washing machine
This is a label for 4-star refrigerator. It consumes 700 kWh in a year. A 5 star refrigerator will consume lower units for same capacity and cooling

Source : BEE 2013

BEE labels are mandatory for the appliances under the category Mandatory Scheme and are not mandatory for the appliances under the Voluntary Scheme. Table 3 below lists the devices under the Mandatory Scheme:

Table 3 Mandatory and Voluntary Scheme for BEE labels

Mandatory Scheme	Updated every year
1. Frost Free (No-Frost) Refrigerator	Yes
2. Tubal Fluorescent Lamp	Not yet
3. Room Air Conditioner	Yes
4. Distribution Transformer	Not yet

Adapted from: BEE 2013

An additional characteristic of the labeling program is that it is updated every year. The star rating plan is different for products manufactured/imported or assembled in different years. For example a refrigerator of gross volume 250 Liters manufactured in the year 2010 consuming 385 units is rated five stars. A refrigerator of the same volume manufactured in the year 2012 consuming the same number of units is rated four stars. This is so because in 2010 the refrigerator was among the devices consuming least energy. With technology innovation, there are now refrigerators manufactured in 2012 which consume less energy than the most energy efficient ones in 2010.

Box: 1 Energy Report

Energy reports should be clear and simple and include:

- A graph with consumers' usage, the average usage of the consumers they are compared with and the average of the best 20%. The more local, the stronger the result.
- A happy green or a frowning red smiley depending on whether they are above or below average.
- Notes on what the energy manager is installing for them and details of the timeline.
- A series of hints, tips and statements on behaviour that help reduce energy use. Hints and tips may be most powerful in the form of statements, e.g. 'The majority of similar municipal buildings in the area have saved on lighting by opening their curtains and switching off lights'. These statements should be targeted specifically and appropriately to each municipal site.
- Energy reports need proper distribution so that they become most visible to the employees. Some of the possibilities are:
  - Notice boards with large A2/A3 size printouts
  - Leaflet size or A4 size distribution
  - Electronic version emailed to each employee

1.2 Lighting

In 2012 lighting accounted for about 15% of the total energy consumption in India. The lighting sector offers many energy efficiency opportunities in almost any building facility, existing or new. When considering both aspects of the cost benefits – energy savings and saved investments – the transition to energy efficient lighting technologies is financially one of the most attractive interventions worldwide, and the "lowest hanging fruit" when it comes to energy efficiency initiatives. Table 4 below illustrates that by simple replacement of incandescent lamps with LED lamps an energy saving of up to 80 percent can be achieved.

Table 4 Achieving 78% Energy Savings with LED

	Incandescent	**Halogen**	**LED**
Price (INR)	10	100	1300
Wattage	60	42	13
Lumen	700	600	806
Annual electricity consumption (kWh)	96	67.2	20.8
Annual electricity cost (INR)	672	470.4	145.6
Electricity Savings per year (kWh)	-	28.8	75.2
Financial Savings per year (INR)	-	201.6	526.4
Savings in percent	-	30	78
Simple Payback Period (year)	-	0.50	2.5

Assumptions: 1) Usage of 8 hours a day for 200 days, 2) Electricity cost of Rs. 7 per unit, 3) Prices as available in October 2013, 4) Electricity consumption of fan at top

Box: 2 Basic Glossary for the Lighting Sector

Lumen is a unit that measures the total amount of visible light emitted by a source.

Lux is the metric unit of measurement indicating the amount of light present on one square meter of surface or work plane.

Illuminance is the concentration of light falling on a surface. Defined as the luminous flux that is incident from all directions onto a square meter. Illuminance is usually measured in lux.

Power of a light is the Wattage used by the light source.

Efficacy of a light is lumen divided by power. The higher the efficacy of a light the more efficient it is at producing light for a certain input of energy.

Lifespan of a lamp is given in hours and represents the average 'age' that a lamp reaches.

Table 5 Typical Luminous Efficacy and Lifecycle Cost of Tube Lights

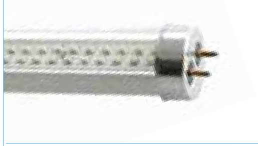
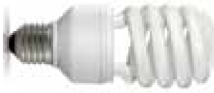
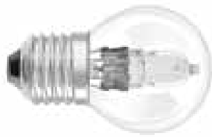
Type	Life cycle cost (Rs / hr)	Efficacy (lm / W)
 LED Tube	0.23	110
 T5	0.24	110
 T8	0.26	85.4
 T12	0.29	76.4

Table 6 Typical Luminous Efficacy and Lifecycle Cost of Bulb Lights

Type	Life cycle cost (Rs / hr)	Efficacy (lm / W)
 LED generic	0.08	100
 CFL	0.09	60
 Tungsten Hallogen	0.23	24
 Tungsten Fillament	0.45	12

Assumption: Cost per unit of electricity used for the calculation is Rs 7 .

Table 5 and Table 6 show that the luminous efficacy of linear fluorescent and LED lamps is the highest among the typical lamps available on the market. It is important to be noted by the Municipal Energy Manager that among the linear fluorescent lamps, there are those that have low efficacy (T12 and T 8) compared to others (T5).

Life Cycle Costing is a method of calculating the costs of an appliance over its entire lifetime. It is the period during which something remains functional.

Energy Savings for tube lights can also be achieved by replacing the standard magnetic ballasts with electronic ballasts. This can increase the overall lamp-ballast system efficacy by about 15% to 20%. Table 7 shows how the actual power consumption of a lamp changes when used with different ballast types.

Table 7 Effect of Power Consumption for Different Ballast Types.

Type of Lamp	With Conventional Electro-Magnetic Ballast	With Electronic Ballast	Power Savings (W)
40W Tube Light	51	35	16
35W Low Pressure	48	32	16
Sodium 70W High Pressure Sodium	81	75	6

Adapted from: BEE 2013

There is another factor that affects the choice of a lamp, which is the lifespan of a lamp. The figure below shows the lifespan of different lamps. An example has been given in figure 4 as to how the lifespan of a lamp affects the saving potential in terms of cost.

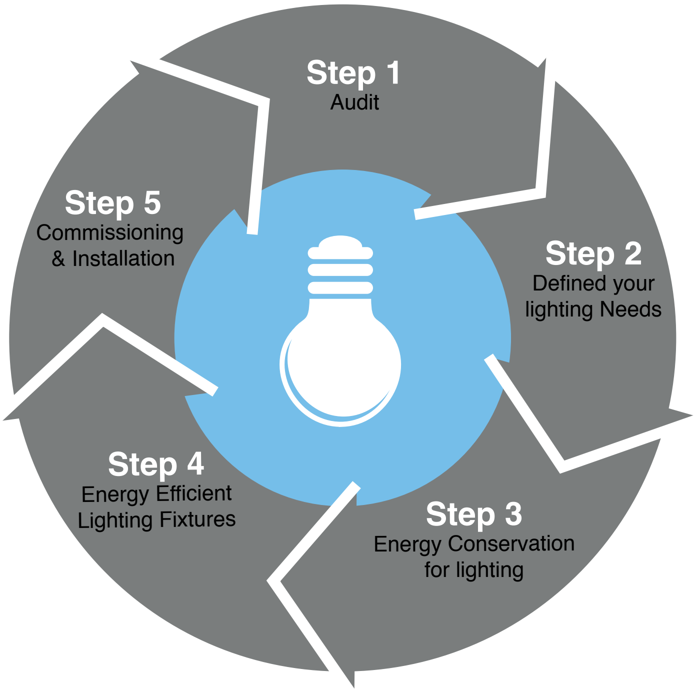
Box: 3 Environmental Problems of CFLs

The only drawback to using compact fluorescent lamps is that each bulb contains about 5 milligrams of mercury, a toxic heavy metal which is harmful for humans and the environment. Proper recycling of CFLs is important. The alternative to CFLs is LEDs (light-emitting diodes). They contain no mercury or other toxic substances and are even more energy efficient than CFLs.

Steps to Implement Energy Savings in the Lighting Sector

For achieving energy savings in the lighting sector the following steps are recommended to the Energy Manager:

Figure 4 Steps for Energy Savings in the Lighting Sector



Step 1 Energy Audit

Capturing the type and number of lighting fixtures currently installed at a facility will give the Energy Managers a basis for future energy saving interventions. Energy audit can be done for all appliances at the same time. It should also be noted that an energy audit is not a one-time undertaking but should be repeated on a regular basis. We recommend that the Energy Managers implement an annual energy audit per building / facility. For the energy audit field sheet please refer to Chapter 3.

Step 2 Define your lighting needs

Various activities such as office work or carpentry require different amount of lighting (luminosity) in order to perform those tasks without straining the human eye. Good lighting is essential to perform visual tasks. Typical book reading for example can be done at 250 to 300 lux, while dining can be done at 100 – 200 lux. To determine the amount of light needed for a certain activity the Energy Manager can refer to minimum and maximum lighting standards. Examples of recommended lighting levels can be found in table 8.

Box: 4 De-Lamping

De-lamping is one fairly simple way to reduce energy. It's done by removing unnecessary light bulbs/ fixtures in areas which produce greater-than-needed illumination. First a lighting assessment must be made, followed by calculations to arrive at the recommended lighting levels.

Table 8 Recommended Lighting Levels

Space	**Lux**	Surface area (m2) per one light fixture	
		T12, T8, T5 or LED Tube*	LED (10W), CFL (17W)
Offices and Other Commercial Buildings+			
General Offices, Computer Work Stations, Conference Rooms, Executive Offices, Computer and Data Preparation Rooms, Drawing Offices, Counters (Office Area)	300	5.4	1.8
Deep Plan General Offices, Drawing Offices, Drawing Boards	500	3.2	1.1
Filing Rooms, General Print Rooms, Public Areas	200	8	2.6
Retail+			
General areas, Small Shops, Super Markets, Checkouts, Showrooms	300	5.4	1.8
Shopping precincts and arcades	100	16	5.3
Hospitals			
General Areas (Anesthetic, Consulting, Cubicles, Observation, Nurses' stations)	200	8	2.6
Examination/Treatment/Inspection (Anesthetic, Consulting, Cubicles, Observation)	750	2.1	0.7
Ward Corridors	100	16	5.3
Schools/Universities			
General lighting for casual reading	300	5.4	1.8
Example levels of Natural Light			
Direct sunlight	100,000+		
Overcast day	500 - 2500		
Clear sunrise or sunset	500		
Full moon overhead at tropical latitudes	1		

*Calculated using A/N=(FxUFxLLF)/E, where A/N is meters squared per fitting, F is flux from one fitting, UF is utilization factor taken at 0.66, LLF the light loss factor taken t 0.8 and E surface flux needed. The fluorescent T12, T8, T5 and the LED tube lights all have very similar luminance levels per light (~3050 lumens). So do the 10W LED and the 17W CFL (1000 lumens).

Adapted from: BEE 2006

Step 3 Energy Conservation for Lighting

After having defined the lighting needs for different activities the Energy Manager focuses on energy conservation by a) harvesting and using the maximum natural light, and by b) avoiding unnecessary energy use for lighting (e.g. light kept on in a storeroom etc.). Most of the work is performed during daytime when the sun provides an abundance of light. In many cases the amount of available natural light can easily cover the amount of light needed for given tasks/areas. Maximizing the use of natural light will substantially help in reducing one's electricity consumption. Often more lights are switched on in one room than is actually needed or lights are left switched on in storerooms all day long contributing unnecessarily to higher energy consumption.

Step 4 Energy Efficient Fixtures

Having identified lighting needs and ways of conserving energy, the Energy Manager proceeds to the next step which is to identify the most efficient lighting fixtures that meet the lighting needs of a room or facility. There are three main categories of electrical lamps: those that emit light by heating (incandescent lamps), those that operate through an electric gas discharge (fluorescent lamps) and light emitting diodes (LEDs). There is a wide range of lamp types available in each of these categories with different levels of performance and for different applications. Table 9 provides a list of recommended energy efficient replacement options for a selection of very common but less energy efficient light fixtures. This data can be used by the Energy Manager in planning his lighting-related energy efficiency program.

Step 5 Installation

Having determined the most appropriate lighting fixtures and lamps, the Energy Manager can proceed with procurement, installation and commissioning of the fixtures and lamps.

Operation and Maintenance

- Keep up with regular system maintenance such as inspections, fixtures cleaning and bulb replacement.
- Install occupancy sensors in low-use areas.
- Check and adjust fixtures so that lights are aimed where needed.
- Clearly label all switching devices to save time and help employees identify which lights should be turned off at specific times.

Box: 4 Reflectors

The most important element in the light system (luminaire), apart from the lamp(s), is the reflector. It determines how much light from the lamp reaches the area to be lit, as well as the lighting distribution pattern.

- For offices a combination of direct and semi-direct type of light systems is recommended so that both work plane illumination and surrounding luminance can be effectively enhanced.
- For corridors and staircases, direct type of light systems with widespread light distribution is recommended.
- In residential buildings, a combination of LED lamps and bare (compact) fluorescent lamps are recommended.

Table 9 Guide for Light Replacement

Existing Lamp	**Efficacy (lm/W)**	**Actual Power (W)**	**Best case replacement**	Efficacy (lm/W)	**Actual Power (W)**	**Savings**
60 W Tugsten Flament (Incandescent)	12	60	LED (Generic)	100	7	88%
60 W Tugsten Halogen	24	60	LED (Generic)	100	8	87%
40 W T12 with Magnetic Ballast	50.5	50	28 W T5 with Electronic Ballast	90.6	33	34%
36 W T8 with Magnetic Ballast	71.7	46	28 W T5 with Electronic Ballast	90.6	33	28%
40 W T12 with Electronic Ballast	76.4	47	28 W T5 with Electronic Ballast	90.6	33	30%
36 W T8 with Electronic Ballast	85.4	42	28 W T5 with Electronic Ballast	90.6	33	21%
28 W T5 with Electronic Ballast	90.6	33	-	-	-	-
14 W T5 with Electronic Ballast	90.6	16.2	-	-	-	-
24 W T5 with Electronic Ballast	90.6	27.6	-	-	-	-
15 W CFL	60	15	-	-	-	-
16 W LED Tube	100	16	-	-	-	-
125 W Mercury Vapor	41	145	30 W LED Street Lamp	100	30	79%
150 W High Pressure Sodium	91	170	70 W LED Street Lamp	100	70	59%
250 W High Pressure Sodium	103	281	130 W LED Street Lamp	100	130	54%
250 W Metal Halide	92.9	281	130 W LED Street Lamp	100	130	54%
400 W Metal Halide	117	440	180 W LED Street Lamp	100	180	59%
400 W High Pressure Sodium	24	440	180 W LED Street Lamp	100	180	59%
1000 W Halogen Flood	90.6	1000	240 W LED Flood	100	240	76%
2 × 14 W T5 Street Light	90.6	31.3	-	-	-	-
2 × 24 W T5 Street Light	90.6	53.5	-	-	-	-
4 × 24 W T5 Street Light	90.6	107	-	-	-	-
30 W LED Street Lamp	100	30	-	-	-	-
70 W LED Street Lamp	100	70	-	-	-	-
130 W LED Street Lamp	100	130	-	-	-	-
180 W LED Street Lamp	100	180	-	-	-	-
240 W LED Flood	100	240	-	-	-	-
Fan	-	70	Super efficient fan	-	35	50%
AC	-	-	AC 5 star	-	-	-

Street Lighting

Street lighting plays an important role in any municipality and constitutes one of the highest constant electric loads and energy costs. Eliminating unnecessary street lighting and converting older lighting technologies to LEDs presents a solid opportunity to reduce electricity bills and consumption for street lighting at the municipal level. In addition, street lighting pole positioning, pole heights and distances between poles can enhance performance.

Most street lights consist of either Metal Halide lamp, High-Pressure Sodium or Mercury Vapor lamp. Each of these lamps can consume between 100W and 400W and can run for up to 12 hours a day. Thus it is important to recognize the LED performance and the appropriate replacement wattage, which can vary widely depending on the specific LED products used and the specific fixture replacement. Table 9 indicates that LED replacements can save between 40 and 80 percent of electricity use depending on the type of lighting being replaced. It is critical that Energy Managers select high quality LED products as replacements.

Control Systems

There are several ways to save energy in the context of street lighting. It makes sense to optimize the operating time of the luminaires and to reduce their output at certain times. Energy saving can be done through conservation measures using automatic control and replacement with energy efficient street lights. Here is a list of possible ways to save energy in street lighting:

- Replacement with high efficiency bulbs and fixtures
- Electronic timer
- Nature switch
- Dimmable ballast or Magic Box
- Voltage regulator
- Centralized control using GSM/SCADA
- Regular maintenance of fixtures
- Power factor improvement techniques

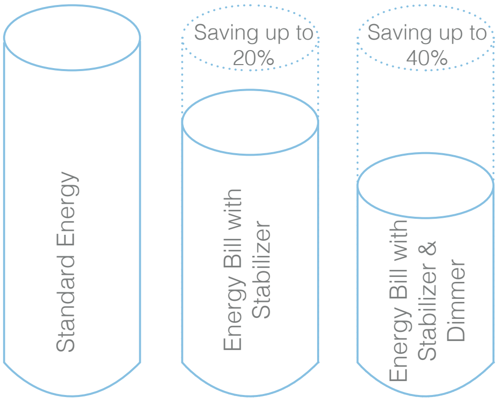
Smart control systems can be used to vary the current passing through selected lights or groups of lights, changing the brightness of the luminaires in real time. This allows, for example, the amount of illumination on the road surface to be precisely matched to the levels required by road conditions and local lighting standards. Some of the common energy saving controllers have dimmable and voltage regulator function with integrated electronic timer switch of the street light.

Box: 5 External Light and Light Pollution

Excessive outdoor scatter of light due to external lighting and advertising display causes light pollution. Excessive light can cause discomfort and distract motorists and negatively impacts the biological cycles of the flora. The behavioural patterns of animals and birds get affected due to artificial lighting. Care should be taken while designing external lighting so that the difference between lit and unlit areas is not very stark. External lighting should be turned off when not required, so as to conserve energy. Sensors for external lighting or corridor lighting are recommended.

Public lighting installations experience considerable voltage fluctuations throughout the night, and the variations can be as high as 10%, increasing energy consumption by about 21%. This can be controlled by the use of a voltage regulator so as to maintain a fixed voltage. Dimming of street lights is done through similar mechanisms. Public lighting installations generally maintain constant lighting levels throughout the night. Dimming the lighting levels after midnight adapted to vehicular and pedestrian traffic on public roads yields substantial saving in energy consumption. Nature Switch on the other hand takes care of automatic switching On and Off of street lights by sensing the ambient light, thus bringing in additional saving of energy from variations in seasonal day length.

Figure 5 Energy Saving for Street Lights Through Voltage and Dimming Control.



The ability to remotely monitor and adjust LED output through smart controls allows for three sources of financial savings that can enhance the business case:

1. Maximizing energy savings through dimming light to match the required stand ard, trimming output at sunset and sunrise, and dimming during periods of lower pedestrian-traffic conflict
2. Maximizing LED lifespan through dimming, and through adjusting light output upward as the product depreciates over time
3. Minimizing maintenance costs through remote detection of faults and failures, and through GPS mapping of luminaires

Operation and Maintenance

Energy consumption for street lighting can be reduced by incorporating good maintenance practices such as:

- Replacing defective lamps, accessories and wires
- Early rectification of cable faults
- Making sure that cables are joined properly
- Regular maintenance of service cabinet/fuse box to avoid loose connections
- Regular cleaning of the luminaire cover to keep it free of dust/dirt and increase light output
- A substantial amount of energy savings can also be achieved by installing clock switches in combination with daylight sensors for turning street lights on and off.

1.3 Fans

Fans are an essential requirement for achieving cooling comfort in a built environment on the Indian subcontinent. Ceiling fans consume a significant amount of commercial and residential electricity. At the same time replacement of ceiling fans presents to the Energy Manager a cost-effective option for reducing a building's electricity demand.

The star rating for fans

The Bureau of Energy Efficiency (BEE) has rated the energy consumption of fans according to their service value:

Service value = Minimum air delivery / Power Consumption
Minimum air delivery=210 m^3/min

The table below indicates the star rating

Table 10 Star Rating for Fans

BEE Star Rating for ceilng Fans 1200 mm diameter full speed	
Star Rating	Service Value of ceiling fans
1 Star	> 3.2 to < 3.4
2 Star	< 3.6
3 Star	< 3.6
4 Star	< 4.0
5 Star	> 4.0

Table 11 Typical Ventilation System

Fan	Service value (SV in CMM/Watt) and LCC(INR/hr.)		
	Rating Type	Low limit	High limit
 Regular Fan (75W)	SV	2.65	3.47
	LCC	0.61	0.65
 5 Star rated Fan (50W)	SV	4.00	5.12
	LCC	0.41	0.50
 Super Fan	SV	6.29	6.57
	LCC	0.44	0.46

LCC = Life Cycle Cost
CMM = Cubic meters per minute

Adapted from:BEE 2013

Table 12 Saving Potential: Comparing 5-star-rated and Super Efficient Fans to Regular Fans

	Regular Fan	**BEE 5 Star Rated Fan**	**Super Efficient Fan**
Price	1500	1900	3300
Regulator Cost	200	200	0
Wattage	75	50	35
Air Delivery cum/min	230	220	230
Annual electricity consumption in kWh	180	120	84
Annual electricity consumption in INR	1260	840	588
Electricity Savings pear yearn in kWh		60	96
Financial Savings per year in INR		420	672
Savings in percent		33	53
Payback in years		4.5	4.9

Assumptions: 1) Usage of 12 hours a day for 200 days, 2) Electricity cost of Rs. 7 per unit, 3) Prices as available in October 2013, 4) Electricity consumption of fan at top speed

The table above illustrates the high energy savings achieved by replacing regular fans (75 watt) with 5-star-rated fans or with super efficient fans. In the case of super efficient fans energy savings will be up to 54% and the payback period for the capital investment – approx. 5 years.

If the replacing of fans does not present a viable option due to financial constrains or other reasons, the replacement of conventional regulators with electronic regulators will help reduce electricity demand for fans substantially.

A study showed that power consumption is reduced by:

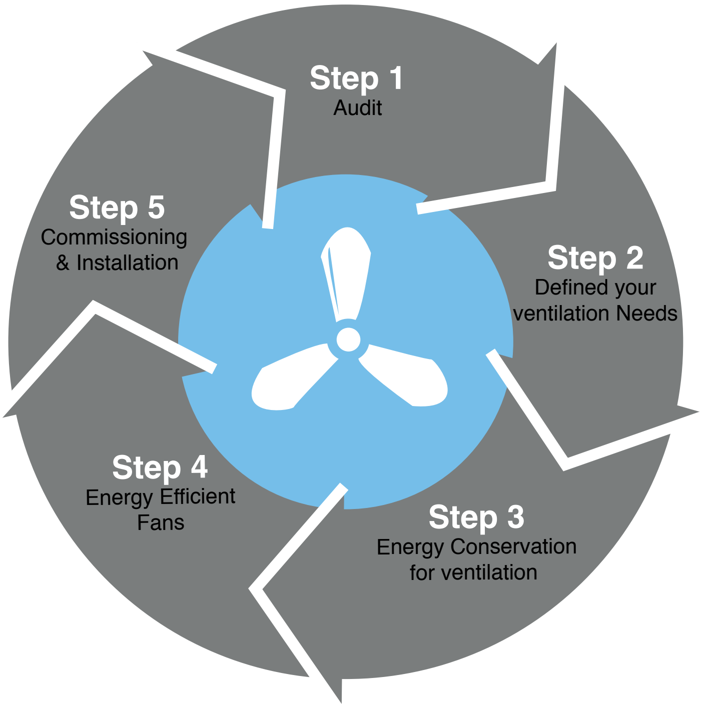
- 61 % at the minimum speed when using an electronic type regulator against a conventional type regulator.
- 27% on average under reduced speed, if the fan is used along with an electronic type regulator against a conventional type regulator (EMC 2007).

Even though the initial cost of an electronic regulator is high, the higher savings will pay back the investor in less than 10 months

Steps to Implement Energy Savings in the Ventilation Sector

For achieving energy savings in cooling through air circulation with fans, the following steps are recommended to the Energy Manager.

Figure 6 Steps to Implement Energy Savings in Cooling Through Air Circulation



Step 1 Energy Audit

Auditing of the type and number of fans at a given facility will give the Energy Managers an overview of the current load related to air circulation cooling and will also show them the future improvement potential in terms of energy efficiency. As mentioned earlier in the lighting section we recommend for the Energy Manager to do a thorough energy audit for all the appliances currently connected to a building's electrical system. A field template for energy auditing is listed in Chapter 3 of this publication

Step 2 Define your ventilation needs

The Energy Conservation Building Code (ECBC) has given a way to evaluate the size and number of fans needed based on the size of the room concerned as per the table below:

Step 3 Energy Conservation for air circulation

Some general tips to consume less energy when using a fan are listed below:

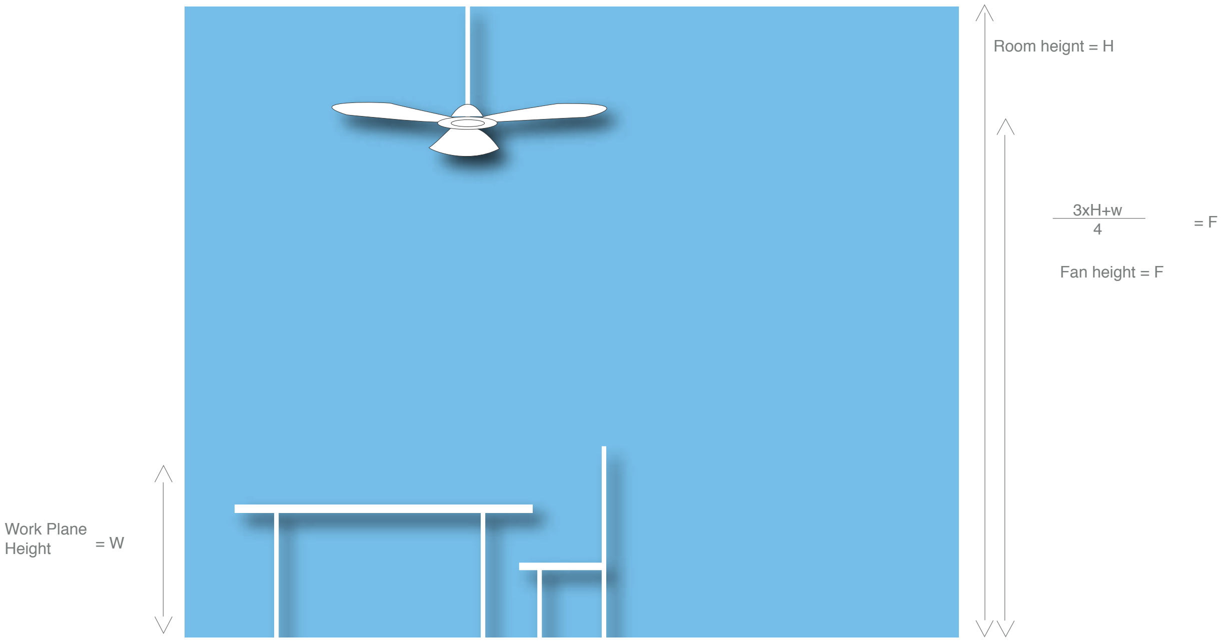
- Keep your windows open to allow natural air circulation. This will en able you to reduce fan usage or to operate the fan at a reduced speed and hence to reduce energy consumption.
- A fan on full speed in a closed room will heat up the air in the room. Always allow indoor warm air to circulate back outside (except if the room is equipped with AC).
- The minimum distance between the fan blades and the ceiling should be 0.3 meters.
- The distance of the fan blades from the floor should be (3xH + W)/4, where H is the height of the fan room, and W is the height of the work plane. Please see figure 7.

Table 12 Number and Size of Fans to Room Size

Room Width	Room Length										
m	4m	5m	6m	7m	8m	9m	10m	11m	12m	14m	16m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
3	1200/1	1400/1	1500/1	1050/2	1200/2	1400/2	1400/2	1400/2	1200/3	1400/3	1400/3
4	1200/1	1400/1	1200/2	1200/2	1200/2	1440/2	1400/2	1500/2	1200/3	1400/3	1500/3
5	1400/1	1400/1	1400/2	1400/2	1400/2	1400/2	1400/2	1500/2	1400/3	1400/3	1500/3
6	1200/2	1400/2	900/4	1050/4	1200/4	1400/4	1400/4	1500/4	1200/6	1400/6	1500/6
7	1200/2	1400/2	1050/4	1050/4	1200/4	1400/4	1400/4	1500/4	1200/6	1400/6	1500/6
8	1200/2	1400/2	1200/4	1200/4	1200/4	1400/4	1400/4	1500/4	1200/6	1400/6	1500/6
9	1400/2	1400/2	1400/4	1400/4	1400/4	1400/4	1400/4	1500/4	1400/6	1400/6	1500/6
10	1400/2	1400/2	1400/4	1400/4	1400/4	1400/4	1400/4	1500/4	1400/6	1400/6	1500/6
11	1500/2	1500/2	1500/4	1500/4	1500/4	1500/4	1500/4	1500/4	1500/6	1500/6	1500/6
12	1200/3	1400/3	1200/6	1200/6	1200/6	1400/6	1400/6	1500/6	1200n	1400/9	1400/9
13	1400/3	1400/3	1200/6	1200/6	1200/6	1400/6	1400/6	1500/6	1400/9	1400/9	1500/9
14	1400/3	1400/3	1400/6	1400/6	1400/6	1400/6	1400/6	1500/6	1400/9	1400/9	1500/9

Source: NBS 2005

Figure 7 Determining Ideal Height for Fan Installation



Step 4 Energy Efficient Fans

Energy efficiency is all about achieving the same results while using less electricity. The older ceiling fans typically consume about 70-80 Watts of electricity. The air delivery of these fan ranges between 230 and 250 m3/min. Nowadays with improved manufacturing technology and a stronger emphasis on energy efficient fans, 5-star-rated fans consume about 45-50 Watts of electricity, which constitutes a reduction in energy consumption of about 35%. The most energy efficient fans on the market are the so-called super efficient fans which consume about 30-35 Watts of electricity. These super efficient fans use a brushless DC (BLDC) motor. This new technology with efficient blade designs makes the super efficient ceiling fans up to 50% more efficient compared to regular fans while providing the same performance. We recommend to the Energy Manager to replace all fans of 70 watt or more which are operated for 6 hours per day and more with super efficient fans of 30 – 35 Watts as this can lead to high energy and financial savings. No regulators are required for the super efficient fans as they come with remote controls.

Table 13 Payback Period for Replacing a 75 Watt Fan with a 35 Watt or a 50 Watt Fan

working hours per day and 300 days/year								
W	4	6	7	8	9	11	12	16
35	🟥 8.0	🟨 5.4	🟨 4.6	🟨 4.0	🟩 3.6	🟩 2.9	🟩 2.7	🟩 2.0
50	🟥 9.0	🟥 6.0	🟨 5.1	🟨 4.5	🟨 4.0	🟨 3.3	🟩 3.0	🟩 2.2

🟥 not attractive payback period

⬛ medium attractive payback period

🟩 attractive payback period

Assumptions: 1) Electricity cost of Rs. 7 per unit, 2) Prices as available in October 2013

Change at least regulators if not fans!

In case the replacement of existing fans with super efficient fans or five-star-rated fans is not a real option, we do recommend changing the regulators from resistor type to electronic type. This can already lead to substantial energy savings.

Quick tips:

- Use energy efficient fans – even though the price is higher, the pay back will be quick.
- Use electronic step-type regulators for controlling the speed of ceiling fans.

.

Step 5 Installation and commissioning

Having determined the most appropriate interventions in terms of energy savings and pay back, the Energy Manager can proceed with the procurement, installation and commissioning of the more efficient ceiling fans and regulators

Box: 6 Benefits of Ceiling Fans

Ceiling fans do not cool space air temperature; instead they move the air around to change the thermal sensation of the occupants of the room. Fans move the air around the human body or the occupants in the room and the air takes off the heat surrounding the human body. This also helps in evaporation of the sweat, which makes a human feel 2 to 4 degrees centigrade cooler. With much lower electricity consumption in comparison with air conditioning, a ceiling fan can give good comfort in warm and humid climates.

Operations and Maintenance of Ceiling Fans

Below is a list of recommended actions to the Energy Manager in order to keep the installed ceiling fans well maintained:

- The motor housing is the body of the fan that encloses the fan motor. Fans that use solid materials for housing, such as metals, tend to vibrate less and last longer.
- The blades should be protected / treated against corrosion.
- The blades are balanced in terms of weight and aerodynamics. For this reason the blades of one fan should not be interchanged with the blades of another fan.

1.4 Air Conditioning

The main purpose of an air conditioning system is to create a cool comfortable indoor environment. An AC accomplishes this by changing the temperature and humidity of the air. According to the National Building Code of 2005, the thermal comfort of a person lies between 25 °C and 30 °C.

While selecting an air conditioner, it is recommended to refer to the BEE Star Rated Label affixed on ACs. The labeling is based on the cooling capacity, power consumption and energy efficiency ratio (EER).

$$\text{EER} \qquad \frac{\text{Cooling Capacity}}{\text{Power Input in Watts}}$$

The cooling capacity is in Btu/hr (but be careful, it is sometimes given in Watts).

The power input is in Watts.

The table below shows the Energy Efficiency Ratio (EER) in Watt/Watt (without any units)

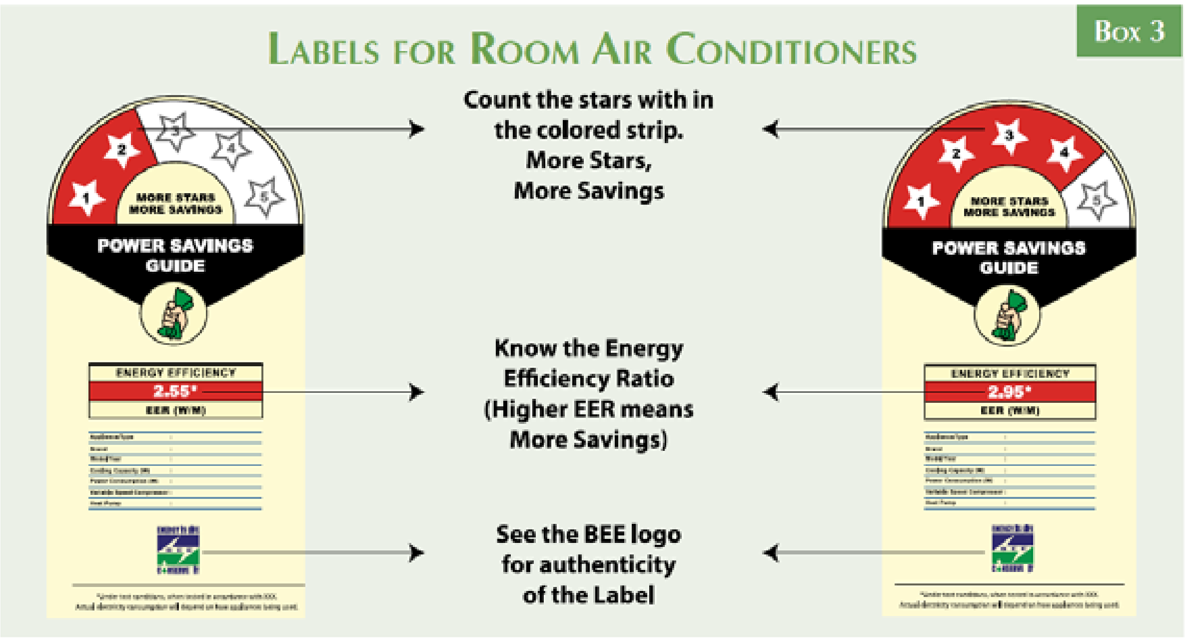
Table 14 Energy Efficiency Ratio for Air Conditioning Systems

EER	Jan 2010	Jan 2012	Jan 2014
ww	Dec 2011	Dec 2013	Dec 2015
1 Star	2.3	2.5	2.7
2 Star	2.5	2.7	2.9
3 Star	2.7	2.9	3.1
4 Star	2.9	3.1	3.3
5 Star	3.1	3.3	3.5

Adapted from: BEE 2013

The image below shows the labels for room air conditioners:

Figure 8 BEE Star Rating Labels for Air Conditioners



Box 3

LABELS FOR ROOM AIR CONDITIONERS

Count the stars with in the colored strip. More Stars, More Savings

Know the Energy Efficiency Ratio (Higher EER means More Savings)

See the BEE logo for authenticity of the Label

Source: BEE 2013

Table 15 Energy & Cost Savings for a 1.5 Ton Window Split Air Conditioner with Different Star Ratings

Start Rating	Cooling capacity(W)	Price (INR)	Rated Power(W)	Annual electricity consumption(kWh)	Electricity Savings per year (kWh/Year)	Financial Savings per year (INR/Year)	Savings in percent	Simple Payback Period (year)
no star	5200	27000	2364	5674	-	-	4%	-
1	5200	28500	2261	5426	248	1730	12%	16.5
2	5200	30750	2080	4992	682	4771	19%	6.4
3	5200	33000	1926	4622	1052	7358	24%	4.5
4	5200	35250	1793	4303	1371	9593	29%	3.7
5	5200	37500	1677	4025	1649	11542		3.2

Assumptions: 1) Usage of 12 hours a day for 200 days, 2) Electricity cost of Rs. 7 per unit, 3) Prices as available in October 2013, 4) Cooling capacity of 5200

The additionnal cost for a 5-star-rated AC will be recovered in a few years due to savings in the electricity bill compared to the bill from using a 1-star-rated AC.

Improvement in Air Conditioner Efficiencies Over the Years:

Due to constant technological progress, the efficiency of air conditioners has improved with time. In fact, the efficient models available today are about 20-40% more efficient than the models that were available 10 years ago and the efficiency will improve much more in the coming years.

Types of AC Systems

Two main types of AC are often observed on site:

- Unitary air conditioners: these are normally used for cooling individual rooms and provide cooling only when needed. Room air conditioners house all the components of an air conditioning system in one casing. Their efficiency is generally lower than that of central plant systems.
- Split-system air conditioning systems: These consist of an outdoor metal cabinet which contains the compressor and condenser, and an indoor cabinet which contains the evaporator and fan.

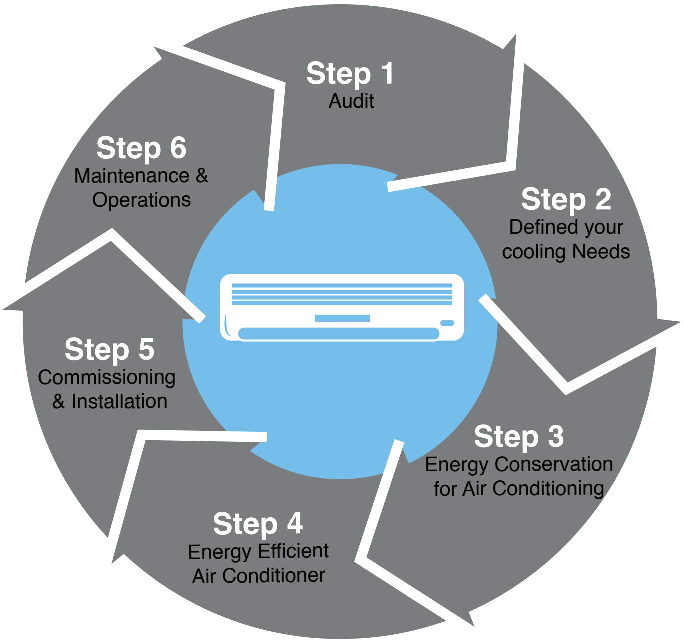
Traditional air conditioners regulate temperature by switching the compressor on and off based on the thermostat setting. Inverter type air conditioners regulate temperature by controlling compressor motor speed. For example, a 1.5 TR-rated inverter AC has a capacity range of 1 – 1.75 TR depending on the compressor speed. Inverter type air conditioners are more energy efficient than air conditioners that work with start-stop cycles. Inverter technology air conditioners have not yet been rated by BEE.

Box: 7 Inverter Air conditioners

An inverter comes into play only if the AC is of a higher capacity than required. This may be the case for rooms which are used rarely at full load but mainly at 50% load. In such cases, power costs are reduced by as much as 30-50%. Therefore, it may seem as an expensive investment while making the purchase, but it definitely reduces the electricity bill by huge margins and results in greater savings in the long run. For usual rooms (office, living room, bedroom, computer room, etc.), right sized ACs don’t require an inverter.

Steps to Implement Energy Savings for Air Conditioning

Figure 9 Steps to Implement Energy Savings for Air Conditioning



Step 1 Do an Energy Audit

During the site visit the Energy Manager should inspect each air conditioning system and make notes on the following:

- Complete insulation of pipes
- No leakage on the pipes or on the device
- Clean condition of the back of the AC

Further notes should be taken down on the following information which can be found on each device:

- The cooling capacity (in Watt or Btu/hr or Ton Refrigerant)
- The nominal power (electrical load)
- The date of manufacture
- The star labeling if any
- The Energy Efficiency Ratio (EER) or COP (see appendix)

Taking pictures of the AC will help for future reference. A field template of energy auditing is given in Chapter 3 of this document.

Step 2 Define Your Air Conditioning Needs

The main purpose of an air conditioning system is to create a cool comfortable indoor environment. Room air conditioners generally available on the market have cooling capacities that range from 0.7 to 2 Tons. The required cooling capacity for a room air conditioner depends mainly on the size of the room being cooled, in addition to several other factors. An air conditioner that is too small may not do a good job of cooling a room at the desired temperature range. An oversized unit costs more and may cool the room quickly but it may lead to poor humidity removal due to excessive on-off cycling. Experience shows that a small unit running for an extended period of time operates more efficiently than a large unit which gets switched on and off too frequently.

Important factors to consider when selecting the size of an air conditioner are:

- room size
- room height
- room location
- number of persons likely to use the room

Our Advice:

- 1-tonne AC (3,5 kW) is appropriate for a 150 sq ft room (14 m²) in area,
- 2-tonne AC (7 kW) is sufficient for a room, which is 300 sq ft (28 m²) in area.

Step 3 Energy Conservation for Air Conditioning

If the use of an air conditioner is necessary the Energy Manager can control and reduce the load by following some or all of the recommendations below:

- Set AC thermostat settings properly: 25-26 °C will provide a comfortable room temperature.
- Keep windows and doors of air-conditioned rooms closed as much as possible.
- Avoid outside air intake. Since outdoor air is warmer and contains more heat and moisture than the conditioned air, outside air intake increases electricity consumption. Keep in mind that natural leakage through windows and doors will generally supply sufficient outdoor air for assuring comfortable conditions and minimizing odor.
- Remove obstructions (e.g., furniture, piled books, etc.) to air passage to the unit. ACs operate most efficiently when intake and discharge air flows are free from nearby obstacles.
- Consider using an interior ceiling fan in conjunction with your AC to spread the cooled air more effectively within the room. Using a fan allows you to set the thermostat temperature higher and thus reduces energy consumption.
- Do not set your thermostat at a colder setting than normally needed when you turn on your air conditioner. This does not cool your room any faster and could result in excessive cooling and unnecessary energy consumption.
- Do not place lamps, television sets or other electronic appliances near the air conditioner as these appliances generate heat and the thermostat senses heat from these appliances causing the air conditioner to run longer than necessary.
- Insulation pipes exposed to weather should be protected by aluminum sheet metal, painted canvas or plastic cover. Cellular foam insulation should be protected as above or painted with water retardant paint.
- For split air conditioners use UV-stabilised thermoplastic casings to protect the pipes and cable that run between the indoor and outdoor units.

Step 4 Energy Efficient Air Conditioners

At this stage the Energy Manager will have to make a decision on whether to replace an existing air conditioner with a more efficient one or not. Table 15 below illustrates the payback period for replacing a non-star-rated air conditioner with various star-rated systems.

Table 15 Payback Period for Replacing Non-star-rated ACs with Star-rated Ones

working hours per day and 200 days/year								
Watt	2	5	8	10	12	14	16	18
5 star	19.8	7.9	5.0	4.0	3.3	2.8	2.5	2.2
3 star	30.0	12.0	7.5	6.0	5.0	4.3	3.7	3.3
1 star	68.2	27.3	17.0	13.6	11.4	9.7	8.5	7.6

Assumptions: 1) Electricity cost of Rs. 7 per unit, 2) Prices as available in October 2013, 3) Star rating as per 2013

Tips to chose an air conditioner:

- Select a five-star-rated air conditioner*.
- Select systems that use inverter technology as they are more energy efficient.
- Select an appliance which uses the less harmful refrigerant (R134 or R410A).
- Select the appliance with the longest warranty period.

*Even though a 5 star AC is a little bit more expensive at the purchasing phase than a 1 star AC, the operating cost will allow for a lot of financial savings.

Box: 8 Energy Conservation with Temperature Control

An air conditioner uses 3 to 5 percent less energy for each degree set above 22°C, therefore set the thermostat at a temperature as high as is comfortably possible (25 - 26°C). The smaller the difference between the indoor and outdoor temperatures, the lower the electricity consumption will be.

Step 5 Commissioning and Installation

A little planning before installing an air conditioner can save energy and money.

- The unit should be leveled when installed, so that the inside drainage system and other mechanisms operate efficiently.
- The unit should be installed in a shaded spot on the north or east side. Direct sunlight on the unit's outdoor heat exchanger decreases efficiency by as much as 10%. Plant trees and shrubs to shade the air con ditioner, but do not block the airflow.
- Make sure the outdoor unit (or back) is away from heat source such as chimneys.
- Install the oudoor unit where there is an efficient airflow, it would ensure efficient operation of the unit.
- Make sure, upon installation and routine maintenance, that the unit is well-sealed from the outdoors. Air leakage can compromise both comfort and efficiency.
- To uniformly cool a room, it is important to direct cooled air to its center. If the air conditioner cannot be mounted at a position that gives uniform air distribution, adjust the diffuser fins to come closer to the desired air distribution.
- Ensure that the cold air does not hit people directly.

Maintenance and Operations

The average life of an air conditioner is about 10 years. This lifespan can be increased by proper maintenance and operation of the air conditioning system. Also the electricity consumption of badly maintained air conditioners may increase substantially. Hence proper operation and maintenance of air conditioning systems is an essential part of an Energy Managers strategy of reducing and controlling a building's energy consumptiontion.

Box: 9 Structural Interventions for Reducing Air Conditioning Costs

- Providing a false ceiling to limit the height of the room reduces the volume to be cooled.
- Providing curtains/ blinds /sun film on windows reduces heat input into the room.
- Insulating the ceiling which is exposed to the sun with 50 mm thermocol drastically reduces heat input into the room.
- Other “cool” roofing and siding products can reduce your peak cooling demand by 10-15%. There are a number of roofing products that can dramatically cut down on heat gain without blinding the neighbors. Start by looking for ENERGY STAR Reflective Roof Products.
- Consider “cool” exterior finishes: when replacing your roof or painting your house, use light-colored paints.
- Provide shade in the room by planting tree or cover the wall with a creeper.

Below is a General List of Maintenance Tips for the Energy Manager:

- Give the annual maintenance contract of the air conditioner directly to the manufacturer or its authorized distributor which has trained and well-qualified technical staff.
- Clean the air-conditioner filter regularly: A dirty air filter reduces airflow and damage the unit. Clean filters enable the unit to cool down quickly and use less energy. A filter that slides out easily facilitates easier cleaning. Follow the manual’s instructions for removal and cleaning of filter.
- Clean outdoor coils when they become dusty. Efficiency degrades in dusty conditions, especially when layers of dirt and mud are evident.
- Make sure upon installation and routine maintenance that the unit is well sealed from the outdoors.
- If the air conditioner is older and needs major repairs, it is likely to become inefficient after repairs. It may be advisable to replace the old unit with a new and energy efficient one.
- Insulation of cooling systems should respect the ECBC requirements which advice to insulate with a R-value of at least 0.35 $m^2.K/W$.
- Filter cleaning depends on the frequency of usage and the atmospheric conditions. For normal applications, it is recommended to clean the filter once in 15 days.

On Site Observations and Recommendations for Maintenance

On site air conditioners don’t work precisely as they are theoretically planned. This is because the environment that the air conditioner is trying to alter is always changing in terms of temperature and humidity.

Outdoor metal cabinet of a split-system
(front view)

Recommendation:
The outdoor cabinet could be shaded instead of being hit by the sun the whole day

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Zoom on the cooling pipe going down

Recommendation:
Change the insulation of the pipe which is currently damaged

Outdoor metal cabinet of a split-system
(front view)

Recommendation:
Pipes should be completely insulated

Unitary air conditioner
(view from outside)

Recommendation:
Shade the AC, this will reduce its energy consumption

1.5 Other Appliances

It is recommended to the Energy Manager to always select 5-star-rated appliances. Even though the upfront investment may be higher, the savings achieved by more efficient appliances will pay off over the lifespan of the appliance.

Below is a list of all other appliances that have a BEE star rating:

1. Frost Free (No-Frost) Refrigerator
2. Direct Cool Refrigerator
3. Computer
4. Color TV
5. Distribution Transformer
7. Pump Set
8. Electric Geyser
6. Induction Motor

Refrigerator and Freezer

Refrigerators contribute to about 15% of the electricity bill of a household. Refrigerators take the heat from the stored food items (to make them cool) and transfer the heat outside. Thus it is very important that the environment around the refrigerator is cool enough to take the heat. With an increase of every 5-6 degree centigrade ambient temperature, the energy consumption of a refrigerator increases by 40 percent which can significantly impact electricity bills.

Table 16 Energy and Cost Savings for 250l Frost Free Refrigerators with Different Star Ratings

“Start Rating”	““Energy Consumption per year” Units (kWh)	“Electic charges per year” Rs.	Total Savings (w.r.t. No Star) per year Rs.	Refrigurator Costs (approx) Rs.	Cost Difference Rs.	Pay Back Period Years
no star	2364	16,548	-	14,000		
1	2261	15,827	721	15,000	1,000	1.39
2	2080	14,560	1,988	15,500	1,500	0.75
3	1926	13,482	3,066	16,500	2,500	0.82
4	1793	12,551	3,997	17,500	3,500	0.88
5	1677	11,739	4,809	18,500	4,500	0.94

Assumptions: 1) Electricity cost of Rs. 7 per unit 2) Prices as available in October 2013

Life span and payback

The cost of running a refrigerator over its expected life span (15-20 years) will exceed its initial purchase price several times. A BEE 5-star-rated refrigerator with a higher initial upfront cost will have lower electricity consumption because of better construction and insulation, and will pay for itself within a short time.

Tips for saving electricity

1. Do not stuff the refrigerator full as it will hinder the flow of cold air thereby decreasing its efficiency. Adequate space will increase the cooling efficiency of the refrigerator.
2. Set the temperature to medium cool for optimum cooling and a lower electricity bill. Setting it to high cool will increase electricity consumption significantly (by up to 25%).
3. Models with top or bottom mounted freezers use 12% less energy than side-by-side designs.
4. Do not keep any heat sources around the refrigerator. Avoid keeping gas stoves, microwave ovens, etc. close to refrigerators.

Computers & Monitors

The Bureau of Energy Efficiency in India has extended the Energy Star system for computers and laptops available in India and uses the logo below for qualified machines. When this logo is displayed on the computer it means it is going by good efficiency checked by the star rating system.

Achieving high electricity savings is possible by replacing inefficient computer systems with 5-star-rated ones. Laptops typically consume 20-50 Watts of electricity which can be trimmed down by using power saver modes. This may bring up to 50% energy saving compared to using regular desktops.

Tips for savings electricity

- Turn off the monitor when you do not plan to use the computer for more than 20 minutes.
- Turn of both CPU and monitor if you do not plan to use it for more than 2 hours.
- Adjust the brightness of the monitor as the computer uses more electricity when it is brighter.
- Disable wireless, Bluetooth and other connectivity services on your computer when not in use as it can consume about 2-3W of electricity.
- Don’t use screensavers anymore, they are not energy savers. They were designed in initial CRT computers to prevent them from phosphorus ‘burn in’. But the advancements in technology have eliminated the need of screen savers Computers in screensaver mode consume a lot more electricity than computers in standby mode.
- Use power management features in your computer to effectively manage power consumption of your computer.

Typical monitors consume between 60-200 Watts of electricity an account for approx. 50% of the total energy consumption of a computer system. Hence there is good energy saving potential by replacing less energy efficient monitors with energy efficient ones. The type of screen used is essential for the power consumption. A CRT (Cathode Ray Tube) screen consumes more than LCD (Liquid Crystal Display) screens. LCD screens can save up to 75% electricity over a CRT screen. LED a new technology for monitors on the market may consume 20-30% less compared to LCD technology.

Table 17 Replacing a 17” CRT Monitor with a 17” LCD or LED Monitor

Screen Size	LED	LCD	CRT
15 inches	15	18	65
17 inches	18	20	75
19 inches	20	22	80
20 inches	24	26	90
21 inches	26	30	100
22 inches	30	40	110
24 inches	40	50	120

Adapted from: Energy Use Calculator

Assumptions: 1) Usage of 8 hours a day for 200 days 2) Electricity cost of Rs. 7 per unit 3) Prices as available on October 2013, 4) Electricity consumption of monitors in operation 5) Power consumption as of http://www.kilowatts.com.au

Table 18 list some of the most common office equipment, their respective electricity consumption and illustrates potential electricity savings.

	17” CRT Monitor	“17”” LCD Monitor”
Price in INR		6,500
Wattage	150	20
Annual electricity consumption in Watt	240	32
Annual electricity consumption in INR	1,680	224
Electricity Savings pear year in kWh	-	208
Financial Savings per yearin INR		1,456
Savings in percent		87
Payback in years		**4.46**

Distribution transformers

- Select and use energy efficient motors and transformers having less loss, for new installations. Where it is economical, it is worthwhile replacing the existing motors/transformers.
- Locate a substation near the load centers to minimize energy losses in cables and also improve voltage levels.
- Identify under-loaded transformers and redistribute the load to achieve optimum loading conditions.
- Incorporate a warning system in the maximum demand indicator so as to take steps to keep the same within the allowed limit.
- Transfer the operation of high capacity loads to lightly loaded shift hours in order to reduce maxi mum demand and flatten the load curve while maintaining a high load factor.
- Stagger starting and operation of high capacity motors.
- Balance the loads on all three phases within ± 1%, as voltage imbalance results in higher losses.

Table 19 Energy Savings with Office Equipment

EQUIPMENT	WATTAGE	COMMENTS
CRT Monitor	OP 100-120W	CRT monitors consume a lot of power, much of which is wasted as heat, and represent the largest power consumption component in a typical desktop computer. CRT monitors also emit potentially harmful radiation. Fortunately, most CRT monitors these days are legacy equipment as new computers are generally supplied with LCD monitors.
LCD Monitor	OP 30-50W	LCD monitors typically require about 30% of the power required for a CRT monitor with the same screen area. In addition, the amount of heat generated by an LCD monitor is considerably less than a CRT monitor, resulting in a lower load on air conditioning. Building cooling needs may be decreased by up to 20%.
LED Monitor	OP 18 - 25W	LED monitors may consume 20-30% less compared to LCD technology.
Desktop Computer	OP 150W	Power consumption will differ significantly depending on whether a CRT or LCD or LED monitor is used. LED monitors are recommended. Laptop are most energy efficient and should be considered as a replacement for desktop computers wherever possible.
Laptop Computer	OP 15-40W	Laptop computer power consumption is typically 10% to 25% of that of a desktop computer. In situations such as an office or home office, where computers may operate for 8 to 10 hours a day, this difference is significant and could represent an energy saving of up to 1kWh per day.
Fax Machine	“ST 10-30W OP 100W”	Fax machines generally sit idle most of the time, so stand-by power consumption is the biggest factor in their overall energy consumption. Thermal fax machines and inkjet fax machines have a stand-by power consumption of around 10W to 20 W, while laser faxes have a stand-by power consumption of around 30W.
Inkjet Printer	OP 120W	Inkjet printers use relatively little power in comparison to laser printers. From an energy consumption point of view, inkjets are preferable to lasers. Unfortunately, they typically cost more to run on a cost-per-print basis and sometimes produce less than optimum results.
Laser Printer	“ST 25-80W OP 150-1100W”	Laser printers consume significant amounts of power even when in standby mode. Over the course of an 8 - 10 hr working day, a laser printer could consume around 1kWh of energy. On the other hand, laser printers are cheaper to run on a cost-per-page basis and generally produce better results. Both the number of laser printers used, and the number of hours the are operated for, should be minimised. As with printing of any kind, office procedures should be developed which minimise the need for printing to paper.
Photocopier	“SL 7-30W ST 40-300W OP 200-1300W”	Most of the energy used in a photocopier is consumed by the hot rollers, which are usually kept hot on stand-bay, consuming from 40 to 300W. Significant energy savings (40% to 60%) can be made by ensuring that photocopiers are switched off at night and on weekends. Some photocopiers consume up to 30 watts even when switched off, so photocopiers should be switched off at the power outlet to ensure they are really “off”.
A DSL Modem Powerpack	OP 10-20W	In most offices and many households, this represents a relatively small but continuous load as the modem operates 24 hours a day.
SL = Sleep Mode, ST = Standby,	OP = In Operation	

Inverter / UPS

Inverters are a form of UPS that have three units: a charger, a battery and an inverter that converts Direct Current (DC) to Alternating Current (AC)
The charger is connected to the power supply and it charges the battery when the electricity is coming from the utility. The inverter gets activated when electricity from the utility goes off, and as the inverter is connected to the power point, it starts providing electricity to the appliances and electric fixtures connected with it.

There are 2 cycles in inverters where efficiencies have to be considered:

Charging:

During charging the efficiencies depend on the battery efficiency.
Battery: A lead acid battery that is typically used in inverters has an efficiency of 60% to 90% depending on the type of battery. Unfortunately, manufacturers don't mention this efficiency in their technical specifications as it also depends on the battery model being used.
When the battery is half charged or less the efficiency may be over 90%, which can drop down to 60% when the battery is more than 80% charged (source).

There are 3 types of batteries available on the market:

1) Flat Plate Batteries: cheapest, but the battery life is less and the maintenance required is high.
2) Tubular Batteries: long life, medium maintenance and high cost.
3) Maintenance Free Batteries: medium life span but the maintenance is low and the cost is high.

Do not use car batteries for inverters, as they are not suited to this kind of requirements.
Tips for the charging part:

- Choose Maintenance free batteries (which still have to be maintained) so that the efficiencies are good.
- Maintain the batteries regularly so that the efficiency levels remain good.

Conversion from DC to AC by inverter:

The efficiency of inverters varies from 90% when it is being used at peak load to just over 50% when much less power is used. An inverter draws power from batteries even when no power is being used. Thus the efficiencies are very low when little power is drawn. It is thus very important to size the inverter properly. The Municipal Energy Manager needs to look at the load of a building or facility before buying an inverter. The typical load of inverters is mentioned in VA (Volt-Ampere) which is roughly equal to Watts (W) (assuming the power factor of appliances is 1). To calculate the load required, just sum up the wattage of appliances you want to run on inverter.

There are 2 types of inverters available on the market:

1) Modified Sine Wave

Modified Sine Wave inverters are cheaper but less efficient. They can work with the majority of low-end appliances but they produce a buzzing sound. Electricity is wasted in the form of heat through this kind of inverters. These are also not good for the health of some sensitive electronic appliances.

2) Pure Sine Wave inverters

Pure Sine Wave inverters are expensive but the most efficient type of inverters. This type of inverters are necessary to run high-end appliances like audio systems and video game consoles. They produce the same kind of power as supplied by the utilities and thus are the best in terms of efficiency and usage.The efficiency of the inverter is something that some manufacturers do publish. Ask the manufacturer for this efficiency and buy only if it is above 80%.

Induction motors

- Avoid idle running of motors/machines
- Identify under-loaded motors and examine the possibility of replacing them with the appropriate capacity motor or alternatively fix retrofitting devices that are available to save energy.

Pumps

The efficiency of any appliance is defined in order to rate its capability of converting electricity into some form of energy. Every pump is designed to handle a certain load at which it hasoptimum efficiency (known as BEP or Best Efficiency Point). Most efficient (small) pumps have efficiencies of 50-70% (if operated at BEP). If a pump is oversized it will not give the optimum efficiency even if the most efficient pump is used. If the pumps are not designed properly and also not maintained properly, their efficiency can go down to 10-20%. This means it will use much more electricity to pump the same amount of water to a certain height than it should.

Tips for savings:

- When it is identified that pumps are consuming a lot of electricity, hire a certified engineer who can help identify existing efficiencies of the pump and also suggest the right size for the pump based on load requirement.
- Always buy a BEE certified energy efficient pump as you can get 55-60% efficiency.
- Try using a Variable Speed Drive pump which adjusts its consumption based on the load on it.
- Make sure that the pumps are maintained regularly so that they operate at the right efficiecy.

The BEE Star Labeling System (BEE-SLS) in the case of pump sets covers only 3-phase motor pump sets of up to 15 kW in three categories:

1. open well submersible pump sets
2. submersible pump sets
3. mono block pump sets.

The table 20 shows the star labeling equivalent with energy effefficiency:

Table 20 Star labeling system for pump sets

Bee-SLS star rating	**Overall energy efficiency of pump set (BIS - 1.0)**
1 star	>= 1.0 and <1.05
2 star	>= 1.5 and <1.10
3 star	>= 1.10 and <1.15
4 star	>= 1.15 and <1.20
5 star	>= 1.20

Adapted from: BEE 2013

The BEE Star Labeling System (BEE-SLS) in the case of pump sets covers only 3-phase motor pump sets of up to 15 kW in three categories:

1. open well submersible pump sets
2. submersible pump sets
3. mono block pump sets.

Water Heaters

Water heating can be a big component of electricity and energy expenses for restaurants, hotels, hospital and dispensaries. Types of water heaters that are available are:

- Instant water heaters (electric and gas)
- Storage water heaters (electric, gas and solar).

Instant water heaters come across as the ideal solution as they do not have any storage (so no chance of heating extra water or wasting hot water), but because the instant water heaters have to provide water at the desired temperature, the rate at which they draw electricity at any moment is very high. So while a storage water heater may be rated at 2 kW, an instant water heater is rated at 3 to 4.5 kW. If 15 liters of water is heated in both, although the units consumed may be the same,because instant water heater heats it immediately, it draws more electricity.

Tips to save energy

- Saving water and using less water for all purposes will generate energy savings.
- For the same capacity, choose always the smaller load.
- Choose the right sized water heater
- The amount of electricity used by water heaters depends a lot on the usage of hot water. The less hot water is used, the less electricity is consumed. Also, the less water you heat, the lesselectricity you will consume. Thus it is important to choose the optimum sized water heater that suffices for your needs. The smaller the size the better.
- Switch on the water heater just before use and switch it off immediately after.
- All water heaters have a temperature range of 40 to 75 degree centigrade.

If you keep the thermostat setting to the hottest value, the temperature of the heater would be set to 75 degrees. It is best to keep the temperature knob to the middle or center position.

Solar Water Heaters

A domestic solar water heater of 100 liters can easily replace a 2kW electric geyser, and can save up to 1500 units of electricity a year. This may result in a payback period of about 2 years. (see Table 21).

It is recommended to the Municipal Energy Manager to replace electrical, coal and furnace oil fired water heaters used on a daily basis with Solar Water Heaters.

Table 21 Payback for replacing an electrical geyser of 2 kW by a 100-liter solar water heater

Cost in INR	20,000
Energy Savings per year in kWh	1500
Financial Savings per year in INR	10,500
Payback period in years	1.9

Assumptions: 1) Energy Saving per year as estimated by Teri (2013), Price per kWh Inr 7, 3) Capital investment for 100l Solar Water heater INR 20,000

CHAPTER 2

Responsible Supply Side Management

PREM aims at introducing a responsible supply side management component for all buildings and facilities under the Commissionerate for Municipal Administration. Whereas the demand side management addresses energy conservation and efficiency, the supply side management aims at installing grid-tied Solar photovoltaic systems in order to increase the percentage of renewable energy mixture in the overall energy consumption of municipalities and corporations.

2.1 Introduction to Supply Side Management

One of the tasks of the Municipal Energy Manager under PREM is to identify appropriate Solar PV System capacities and to supervise the quality of workmanship during the installation of grid-connected Solar PV systems on the buildings and facilities under his responsibility. This task comprises of:

- a site survey,
- selection of the appropriate system size,
- initiating the tender process,
- evaluation and selection of prospective bidders based on the technical specifi cations,
- inspection of installation process
- final evaluation of the completed system.

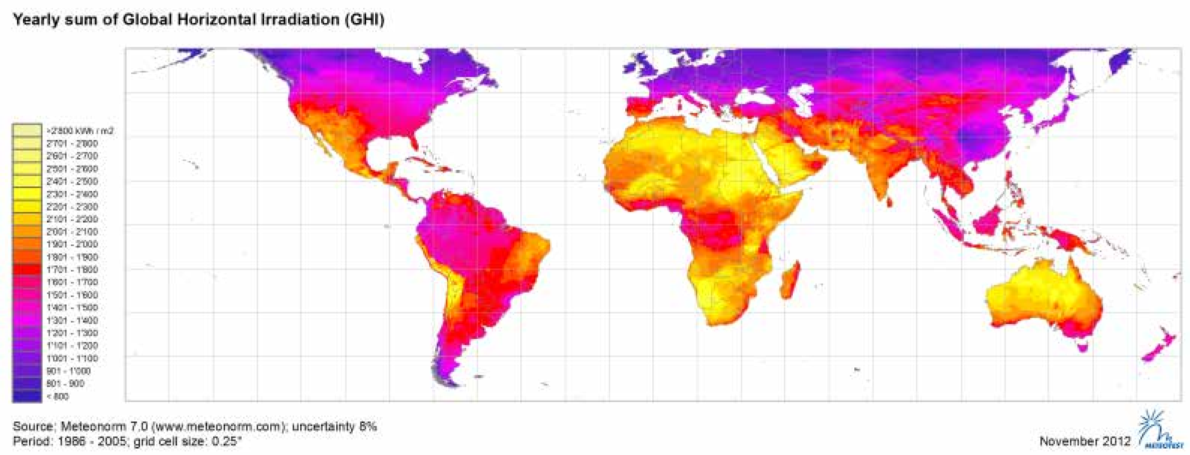
This chapter intends to provide the Municipal Energy Manager with the basic knowledge of Solar PV and to put at disposal tools that will help him in commissioning and managing SPV installations.

2.2 Basics on Solar Energy

Solar Radiation

The sun supplies energy in the form of radiation, which is the basis of all life on Earth. Defacto it is only a tiny part (2ppm) of this energy that reaches the earth's surface. The amount of solar energy reaching the earth's surface is approximately 1000 times the current global energy demand. Thus only 0.01 percent of the global solar energy available would be enough to meet mankind's current entire energy demand.
The radiation level on earth reaches a total of approximately 1000W/m2 during good weather conditions at noon at sea level. The annual global radiation is measured in KWh/m2 and varies significantly according to regional.

Figure 10 Global Distribution of Solar Radiation



Yearly sum of Global Horizontal Irradiation (GHI)

Source: Meteonorm 7.0 (www.meteonorm.com); uncertainty 8%
Period: 1986 - 2005; grid cell size: 0.25°

November 2012

Figure 11 Solar Irradiation of India

Stand-alone vs. Grid-connected Solar PV Systems

Solar PV systems can be divided into two kinds: stand-alone systems and grid-connected systems.

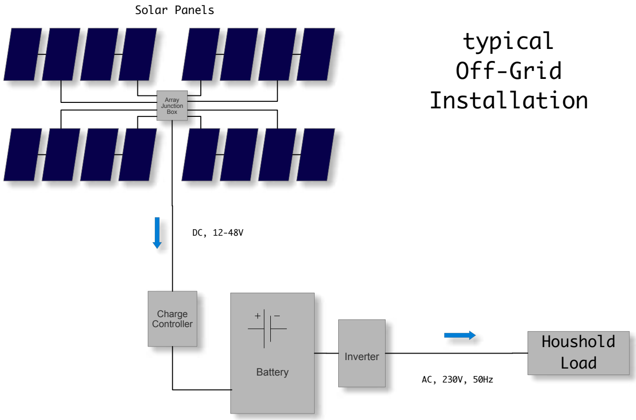
Stand-alone PV Systems

Stand-alone Solar PV systems are not connected to the utility power grid (TNEB in the case of Tamil Nadu). These systems are frequently used in areas where grid supply is not available or not very reliable. Stand-alone systems require energy storage to compensate for the time lapse between the production of energy and the eventual consumption of energy. Rechargeable batteries are suitable for energy storage. In general, the use of storage batteries requires a suitable charging regulator (charge controller) for its protection and to guarantee a high availability and a long life expectancy. Therefore, a typical stand-alone system consists of the following main components:

- Solar PV array (one or several PV modules, mostly in parallel arrangement)
- Charge controller
- Battery
- Stand-alone inverter
- Loads

If the loads in the stand-alone system run on AC current, a Solar Inverter has to be added to the system.

Figure 12 Technical Diagram for AC Off-grid System



Picture 1 Stand-alone Solar system with battery pack

Grid-connected Solar PV Systems

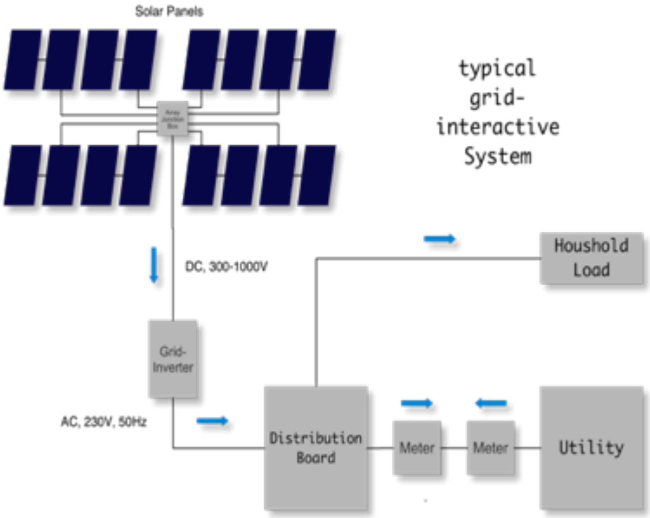
Grid-connected Solar PV systems are interconnected with the existing utility power grid through a service connection. They have the ability to feed solar power into the grid. Unlike the stand-alone solar PV systems, the grid-connected solar PV systems do not have a battery backup. One can distinguish between utility scale grid-connected solar systems, which usually are in the scale of several MW (usually ground-mounted) and small-scale systems in the range of several kW (usually rooftop-mounted).

Picture 2 Big Utility Scale Solar Power Plant in Gujarat

Picture 3 10 kW grid-connected Rooftop System at Auroville, Tamil Nadu

The output of the solar grid inverter is connected to the main distribution board of the building. The energy produced in the solar system is used mainly by the loads in the . If the energy requirement of the building is higher than the solar energy produced by the Solar PV system at any point of time, the shortfall will be imported from the grid.
If the energy requirement of the building is lower than the Solar energy produced by the solar PV system at any point of time, the surplus energy is exported to the grid.

Figure 13 Typical Diagram of a Grid-Connected Solar PV System



Picture 4 Solar Grid Inverters and DC/AC distribution boxes

PV System Components for Grid-connected Systems

A grid-connected Solar PV system generally consists of the following main components:

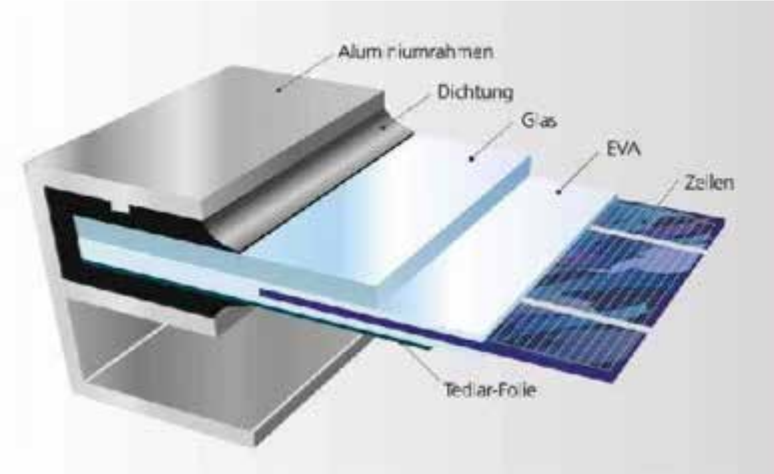
- Solar PV array (comprising of a number of Solar PV modules con nected in series,parallel and grouped in sub-arrays atop a mounting structure)
- Solar panels mounting structure
- DC combiner box with solar array fuses
- DC distribution box with protection devices
- Solar grid-inverter
- AC distribution board with protection devices
- Cabling

These will be described in the following chapters.

Solar PV Modules

The most common solar PV module is manufactures with crystalline cells. Solar PV modules are manufactured with the aim of achieving maximum energy yields per square meter at as low a cost as possible. These are mostly glass-film laminates encapsulated in EVA (Ethylene Vinyl Acetat), which are offered with fixed dimensions and power outputs. The figures below show a cross section of a typical standard module and a full-framed standard module.

Picture 5 Cross Section of a Standard Module



Picture 6 Standard Solar PV Module

Solar PV Modules Mounting Structure

RCC Flat Roof Mounting

Most of the potential sites for Solar PV installations at the municipalities and corporations have a flat concrete roof (office buildings, schools, bus stands, etc.). For flat roofs, mounting of the solar PV system is relatively easy. Two things are important to consider for the installation: a) The mounting structure should not penetrate into the roof surface; b) The stability and wind load bearing capacity should be achieved by removable foundation blocks and / or ballasts.

Picture 7 RCC Flat Roof Mounting with Removable Concrete Foundation Blocks

Corrugated Sheet Roof Mounting

Corrugated sheet roofs are usable for mounting solar PV systems but certain conditions need to be met before safe installation can be done.

There are two ways for mounting solar PV systems on a corrugated sheet roof:

- Fixing the solar structure directly on the sheet metal
- Perforating the sheet metal and anchoring the solar structure on the supporting structure of the roof.

Direct connection to the sheet metal

Under the following conditions, the solar structure can be mounted directly on the sheet metal:

- The sheet metal must have a minimum thickness (usually 0,8mm).
- It must be made out of strong metal (usually galvanized steel).
- The sheet metal has to be appropriately fixed to the substructure to ensure wind load withstanding capacity.
- Only mounting systems especially designed for this type of fixing must be used.
- The shape of the sheet metal must correspond to the mounting struc ture requirements.
  The system has to be well designed to withstand the wind-loads and to carry the weight of the solar system.

The advantages of this type of mounting are the lightweight, the fast implementation and the longevity. These specialized mounting systems are not yet readily available everywhere in India and may have to be imported.

Picture 8 Professional Mounting System Attaching Directly to the Corrugated Roof Sheet

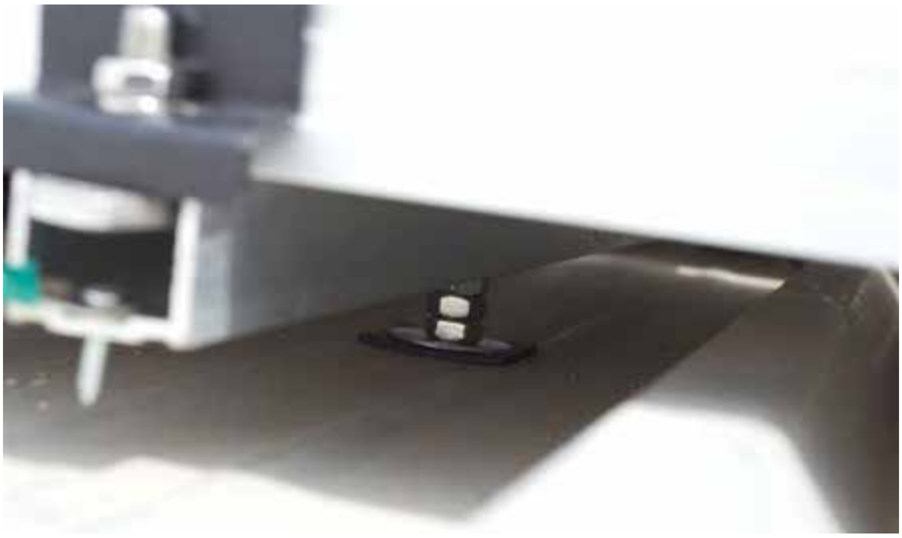
Connection to the supporting structure

As an alternative, the solar structure can perforate the sheet metal and be connected to the supporting structure of the roof sheets. These are the prerequisites for this type of mounting:

- The substructure must be strong enough to support the solar PV arrays.
- The perforation of the sheet must be done very carefully and must be sealed off appropriately to prevent leakage.
- The solar PV mounting structure must be customized to the existing substructure of the roof.

The advantages of this type of mounting are the lower cost and the possibility of local manufacture.

Picture 9 Aluminum Structure on Corrugated Sheet



Elevated Structure Mounting

Elevated solar mounting structures may be used if the space occupied by the solar PV system is needed for other purposes (like roof terraces) or for safety reasons (e.g. damage through animals in ground mounting scenarios).

Elevated structures are especially susceptible to damage through high wind speeds as the solar PV modules are far off the ground. It is therefore important to secure the elevated structure firmly with the supporting surface. In case of a concrete surface (e.g. RCC roof), the elevated structure shall be secured either through anchor bolts into the RCC or through additional concreting or both.

In case of ground mounting the poles of the elevated structure should be rooted in a concrete foundation of appropriate size and weight.

Ground Mounting

Mounting the Solar system on ground level makes sense mainly for bigger systems. There are two main options for ground installations:

- Penetration into the ground
- Removable on-ground mounting with ballast

The first option is used for utility-scale projects where the placement of the structure and the penetration is done by machinery. The second option is suitable for system sizes of 1-100kW. It is easy to install, no machinery is needed on site and it can be moved if necessary.

Picture 10 Utility Scale Ground Mounting Structure

Picture 11 Ground installation with removable concrete foundation blocks

DC Combiner Box with Solar Array Fuses

TThe individual arrays/strings are connected together in the DC combiner box. The string cables, the DC main cable, and, if required, the earthing conductor are connected. The DC combiner box contains the terminals and the array/string fuses. There needs to be adequate clearance between the positive and negative wires and terminals within the box. The DC combiner box must be of the thermoplastic IP65 DIN-rail mounting type.

Picture 12 DC Combiner Box

DC Distribution Box

The DC distribution box is mounted close to the solar grid inverter. It must also be of the thermoplastic IP65 DIN-rail mounting type with transparent cover. It houses the following components and cable terminations:

- Incoming positive and negative DC cables from the DC Combiner Box;
- DC circuit breaker or isolator (see below), 2 pole (the cables from the DC Com biner Box will be connected to this circuit breaker on the incoming side);
- DC surge protection device (SPD), class 2 as per IEC 60364-5-53;
- Outgoing positive and negative DC cables to the solar grid inverter.

As an alternative to the DC circuit breaker a DC isolator may be used inside the DC Distribution Box or in a separate external thermoplastic IP 65 enclosure adjacent to the DC Distribution Box. If a DC isolator is used instead of a DC circuit breaker, a DC fuse must be installed inside the DC Distribution Box to protect the DC cable that runs from the DC Distribution Box to the Solar Grid Inverter.

Grid-connected Inverters

The grid-connected solar inverter is the link between the PV generator and the AC grid or AC load. Its basic task is to convert the solar DC electricity generated by the solar modules into AC electricity at grid frequency and voltage. Using modern power electronics, the conversion into grid-standard alternating current involves only small losses. The efficiency of modern grid-connected inverters is in the range of 92-98%.

In grid-connected solar PV systems, the inverter is linked to the main electricity grid directly or via the buildings grid (distribution board). With a direct connection, the generated electricity is fed only into the main grid. With a coupling to the building's grid (DB), the generated solar power is first consumed in the building, and then any surplus is fed into the mains electricity grid.

Small solar PV systems are typically built as single-phase systems. With larger systems the feed is in three-phase form and is connected to the three-phase supply system. Modern solar grid inverters are able to perform the following functions:

- Converting DC current generated by the PV generator into AC current to comply with the grid requirements.
- Adjusting the operating point of the inverter to the MPP of the PV generator (MPP tracking).
- Recording operational data and signaling (e.g. display, data storage, data transfer).
- Anti-islanding protection whereby the solar grid inverter stops producing energy when there is grid outage or when the grid frequency or voltage are outside a preset range.

Picture 13 Solar Grid Inverter 3.3 kW Capacity

Data Logger

If the Solar grid inverter does not have a data-logging functionality, a separate data logger has to be installed. It collects all relevant data and usually has the ability to transmit the data via internet to a central server from which the data can be viewed via a dedicated website. This allows the owner/user to track the Solar system remotely and in real-time.

Picture 14 External Data Logger

Picture 15 Remote Monitoring via Internet

AC Distribution Box

The AC distribution box is mounted close to the solar grid inverter on the AC side. It is of the thermo plastic IP65 DIN rail mounting type and contains the following components and cable terminations:

- The incoming 3-core / 5-core (single-phase/three-phase) cable from the Solar grid inverter
- An AC circuit breaker, 2-pole / 4-pole
- The AC surge protection device (SPD), class 2 as per IEC 60364-5-53
- The outgoing cable to the building's electrical distribution board.

Picture 16 DC Distribution Box, solar grid inverter; AC distribution box

Cables

For the electrical installation of a solar PV system, cables must meet the requirements of this application in terms of current carrying capacity and voltage rating. The electrical wiring between the individual modules of a solar generator and the DC combiner box is termed module cables or string cables. These cables are generally used outdoors. Single-core cables with double insulation (conductor insulation and an outer sheath) have proven to be a practicable solution and offer high reliability. The cables must be UV- and weather-resistant and suitable for a large temperature range (cables routed behind PV modules must be rated for a minimum of 80°C).

Picture 17 Double Insulated Solar PV Cable

Connection Systems

The connection of the module cables and other DC wiring should be made with extreme care. Poor quality contacts can lead to arcing and, hence an increased fire risk.

Nowadays solar PV modules come with module cables and touch-proof plug connectors.

Picture 18 Solar PV Connectors MC4

DC Main Cable

The DC main cable connects the DC combiner box with the solar grid inverter through the DC distribution box and should be selected so as to minimize the risk of short-circuits and earth faults. This is achieved through single core cables with double insulation (conductor insulation and an outer sheath). To keep cables protected from mechanical impact and to ensure neat installation, the DC Main Cables are installed with the help of UV stabilized PVC conduits.

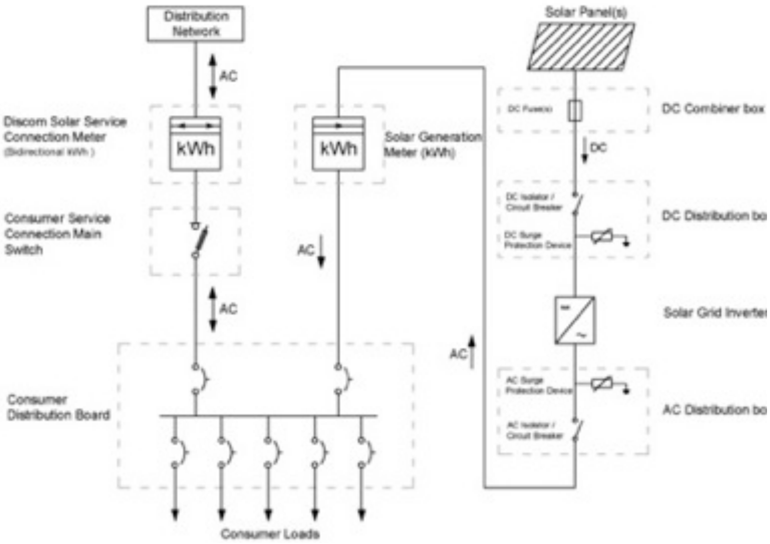
AC Connecting Lead Cable

The alternating-current lead line links the AC output of the solar grid inverter to the building's distribution board through the AC distribution board with protection devices. In the case of a three-phase inverter, the connection to the low-voltage grid is made using a five-core cable. For single-phase inverters, a three-core cable is used.

Connection to the Main Distribution Board of the building

The AC output of the solar grid inverter is connected to the building's electrical system after the TANGEDCO service connection meter and main switch on the load side. The Solar grid inverter output has to be connected to a dedicated module in the Main Distribution Board (MDB) of the building. It shall not be connected to a nearby load or socket point of the building. The following typical wiring diagram shows all the components discussed above and their respective connections.

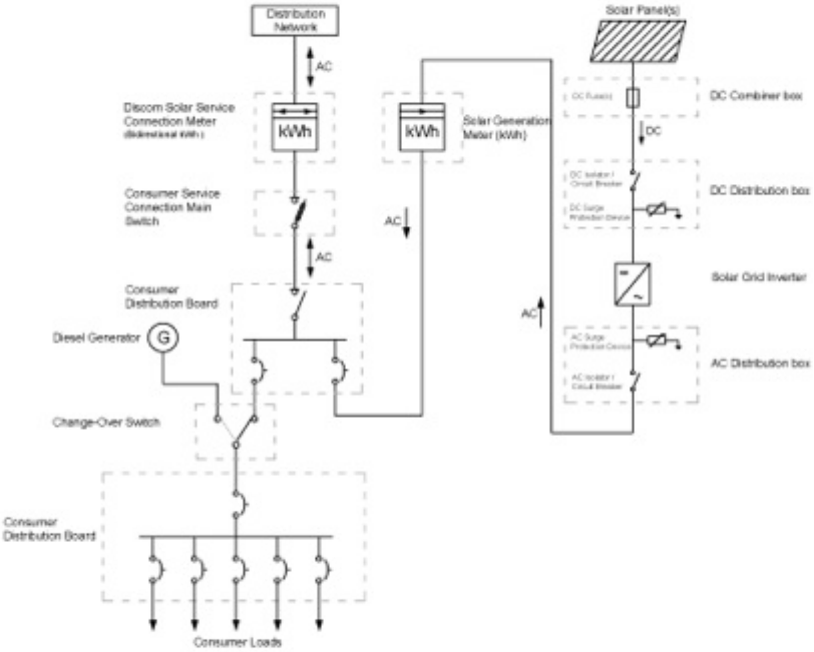
Figure 14 Typical Wiring Diagram



Connection of the Solar System in Case of Diesel Generator Backup

For buildings or loads with diesel generator backup, the wiring of the solar grid inverter has to be such that the Solar grid inverter cannot run in parallel with the diesel generator. This means that the solar grid inverter must be connected to a separate distribution board on the grid side of the automatic or manual change-over switch as shown in the below diagram.

Figure 15 Wiring Diagram with Generator Connection



This is to prevent damage of the inverter or diesel generator in case of a mismatch between solar energy produced, load energy requirement and diesel generator capacity.

Quality of the Main Distribution Board and Safety Considerations

As stated before, the solar grid inverter has to be connected to a dedicated module of the main distribution board of the building. One dedicated MCB or switch-fuse has to be available for the connection of the solar system and one dedicated AC cable has to run from the AC distribution board near the solar grid inverter to the Main Distribution Board.

The Main Distribution Board, the dedicated MCB or switch fuse and the service connection wiring should all be capable of carrying the solar grid inverter AC output current.
It is the duty of the Energy Manager to make sure that the Main Distribution Board is in a condition to accommodate connection with the solar grid inverter, before the installation of the Solar PV system.

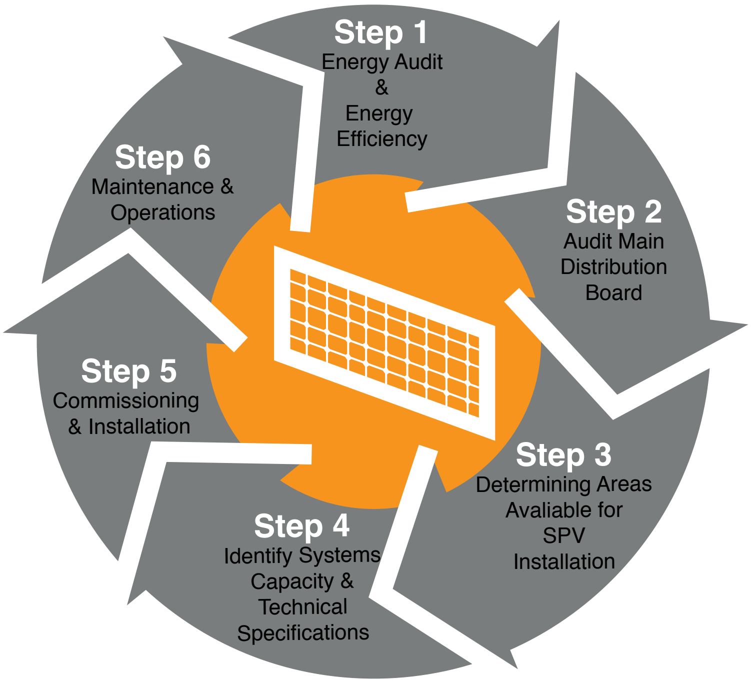
The inspection of the Main Distribution Board and service connection wiring has to take place during the initial site visit, to allow enough time for the planning and implementation of corrective measures before the installation and commissioning of the solar PV system.
Details about the site survey follow in the next chapter

Picture 19 A Main Distribution Board NOT appropriate for connecting a Solar system

Picture 20 A Main Distribution Board appropriate for connecting a Solar system

Steps for Solar PV Installation

Figure 16 Steps for Implementing Solar PV Installations



Audit of Main Distribution Board

The Main Distribution Board of the building is essential for the success of the project. Therefore, before considering any SPV installation the Municipal Energy Manager needs to inspect the MDB of the building or facility for which a SPV installation has been planned.

The following points are critical for the safety of the system and should be thoroughly checked:

- All cable connections must be tightened and securely fastened.
- All cables must be properly insulated, the insulation should not be damaged.
- The MCB's, isolators, connectors, switches and other components must be in working condition.
- The cables must be routed properly and fastened to avoid damage of the cables.
- The earthing of the building has to be intact and connected to all relevant connections within the MDB.
- The housing of the MDB has to be connected to the earth conductor.
- The MDB must be clean and free of any insects, small animals, etc.
- The immediate surrounding of the MDB has to be kept clean and free to allow access at any time.

The following criteria are a prerequisite for the connection of the Solar system:

- A dedicated Miniature Circuit Breaker (MCB) or switch-fuse module for the solar system has to be provided.
- This MCB or switch-fuse has to be connected to the main bus in the Main Distribution Board as shown in the wiring diagram in figure 13.

The Energy Manager should check all the above points thoroughly and use a check-list to document eventual faults and to delegate the work of rectifying the faults to the electrician in charge.

Determining the Area Available and Usable for the Solar PV System

The second task for the Energy Manager is to find a suitable area to place the Solar PV modules. There are mainly four options for mounting the solar PV modules:

- RCC roof top
- Corrugated sheet roof
- Elevated structure
- Ground mounting

Refer to the respective chapter in this document for details on the mounting structures.

Criteria for the available area for Solar PV

The area for the Solar PV modules has to fulfill the following criteria:

- It has to be big enough to place the Solar PV modules of the desired total output power (as a thumb-rule: 1kW needs around 120 sqft / 12m2).
- The supporting surface or structure has to be strong enough to hold the weight of the solar PV modules and the additional mounting structure (incl. concrete weights if applicable).
- In case the solar mounting structure is physically fastened to the substructure (e.g. corrugated sheet roof), the substructure must be strong enough to withstand the lifting forces of high wind-speeds.
- The area has to be shade-free throughout the year. Details on how to determine the shaded areas and shade-free areas are explained in the following chapter.
- A dedicated location for the solar grid inverter(s) has to be available near by.
- The location of the solar system has to be as close as possible to the Main Distribution Board of the building to reduce cable lenght.

Tasks of the Energy Manager

The following tasks have to be fulfilled by the Energy Manager in order to determine the correct area available:

1. Determine the direction of south in order to understand the path of the sun during the day and across the seasons. Therefore a compass has to be carried along.
2. Shade analysis (see next chapter)
3. Measurement of the available shade-free area: it is important to measure only the area which
   can actually be used for the placement of the solar PV modules. Keep in mind that there has to be a gap between the edge of the roof and the array of solar PV modules of at least 1m. A long measuring tape (15m) has to be carried along for the measurements. All measurements have to be documented in a sketch drawing.
4. A suitable location of the solar grid inverter(s) has to be found and inspected. The approximate distance to the solar array area should be determined and documented.
5. Digital photos of the available area, the surrounding buildings, trees or other shading objects, the location for the solar grid inverter, should be taken. Therefore a digital camera of appropriate quality has to be brought along.

The outcome of the site survey should be a sketch of the area with all relevant measurements, including the roof, the shading objects, heights of nearby objects, the direction of south. The sketch should be backed up by detailed digital photos.
This documentation is necessary to make a decision on the size of solar PV system that can be installed in this particular location.
How to take this decision and how to use the tool provided therefore, will be discussed in a later chapter.

Shading Analysis for the Solar PV System

The performance of a Solar PV system can be inhibited by shade on the solar PV modules. Shading can be classified as temporary and as a result of the location or as a result of the building.

Temporary shading

Typical temporary shading deals with factors such as leaves, bird droppings, dust and other types of soiling. Dust, leaves, etc. can collect on the modules and soil them, causing shading. Soiling becomes lower the better the module's self-cleaning system works. Self-cleaning means the washing away of soiling by flowing rainwater. This will be sufficient with a tilt angle of 12° or more. As it doesn't rain regularly in Tamil Nadu, it is advised to manually clean the solar PV modules at certain intervals. See also the chapter on operation and maintenance.

Shading resulting from Location
Shading from location accounts for all shading produced from the building's surroundings. Neighboring buildings, trees, and even distant tall buildings can shade the system. Overhead lines running over the building also have a particular negative effect, casting a small but effective moving shadow.

Picture 21 Shading from Trees

Shading resulting from the Building

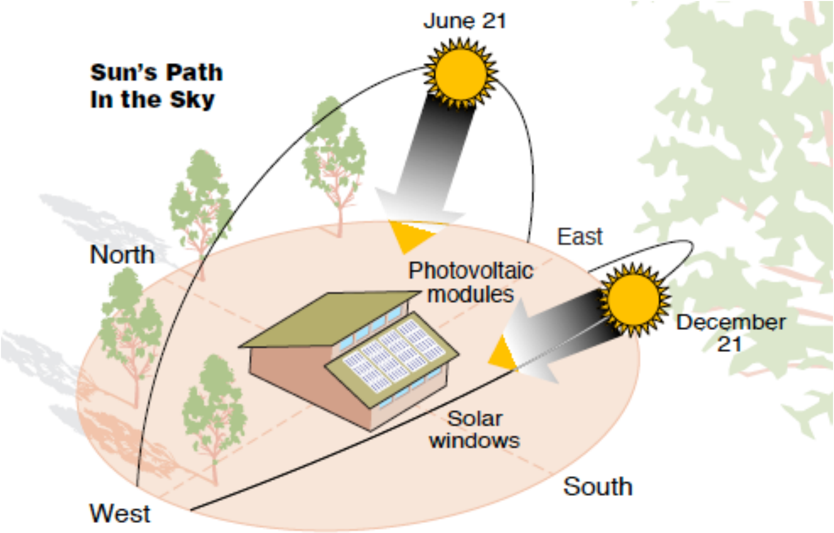
Shading resulting from the building involves direct shadows, and should therefore be viewed as particularly critical. Particular attention should be paid to chimneys, water tanks, antennas, lightning conductors, satellite dishes, roof and façade protrusions, offset building structures, etc. Some shading can be avoided by moving the solar PV array or the object causing the shading (e.g. satellite dish).

Picture 22 Design Default: Shading from the Building

Shading Analysis

To assess the shading resulting from the location a shading analysis is performed. For this, the shadow outline of the surroundings is recorded. In order to understand how objects in or near your location might cast a shadow on the proposed area for the solar modules, it is essential to know the sun's path in the sky. The sun travels from east to west during the day. The path it takes changes according to season. In Tamil Nadu the sun path is to the south in winter and to the north in summer.

Picture 23 Sun path according to Seasons

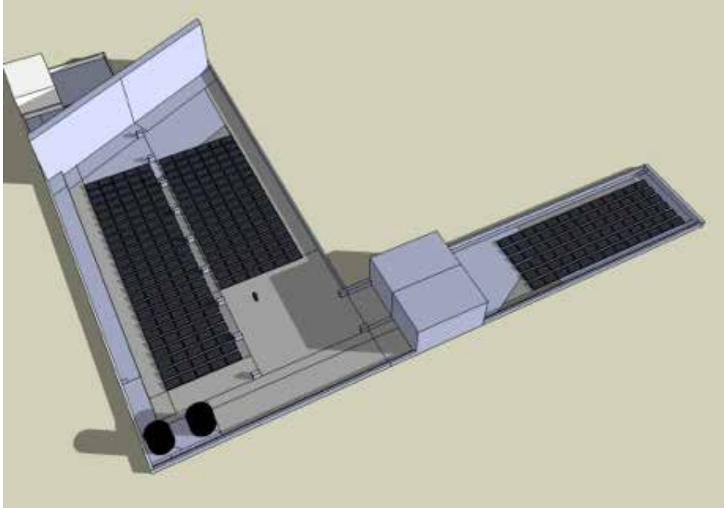


For the assessment of shading on the proposed area, the following tasks have to be performed by the Energy Manager:

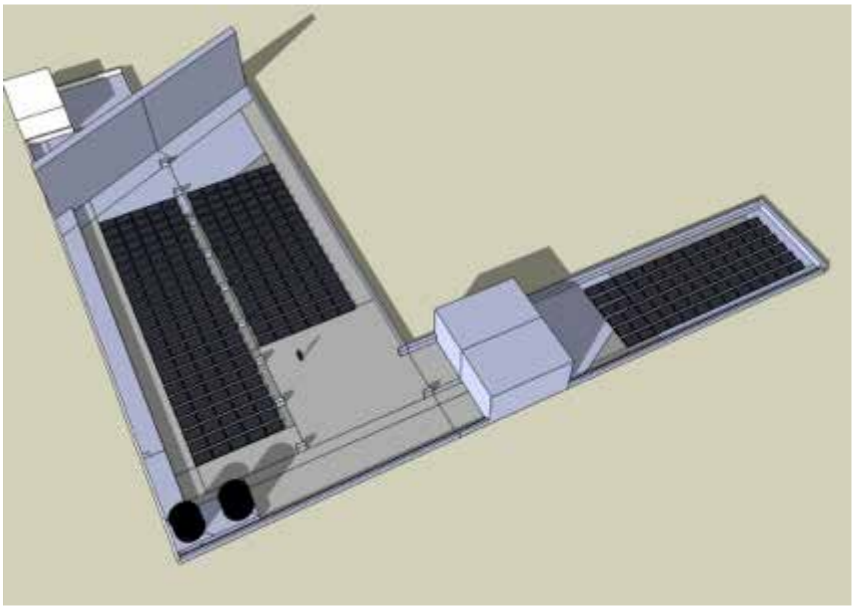
1. Determine the direction south by using a compass.
2. Determine where the sun rises and where it sets.
3. Assess the sun's path during summer and winter.
4. Identify any tall objects (trees, buildings, water tanks, etc.) which could cast a shadow on the proposed area through the sun's path.
5. Document these tall objects with their location and approximate height on the sketch of the area.
6. Also document approximately the shade cast on the proposed area.
7. Taking into account the shaded areas, document the shade-free area available and suitable for the installation of the solar PV system.

The following figures show how a detailed site survey sketch was transformed into a 3D model for shade analysis. It shows the shading of the building in the morning and in the afternoon on 21 of December. The solar arrays were arranged in a way to avoid shading throughout the day

Picture 24 Shading Simulation Using 3D-software at 8:20 am on 21st December



Picture 25 Shading Simulation Using 3D-software at 4:30 pm on 21st December



Identify System Capacity and Technical Specifications

Having identified the shade free area available for SPV installations the Energy Manager will calculate the maximum solar PV capacity potential for the given area. He will also determine the ideal system capacity needed based on the buildings annual energy consumption (after energy efficiency interventions) and then make an informed decision of which solar PV system capacity to select. Chapter 3 refers to the PREM Solar PV System Capacity Calculator a simple tool to assist the Energy Manger to arrive at an informed decision.

The following steps are necessary:

Having identified the shade-free area available for SPV installations, the Energy Manager will calculate the maximum solar PV capacity potential for the given area. He will also determine the ideal system capacity needed based on the building's annual energy consumption (after energy efficiency interventions) and then make an informed decision about which solar PV system capacity to select. Chapter 3 refers to the PREM Solar PV System Capacity Calculator - a simple tool to assist the Energy Manger to arrive at an informed decision.

The following steps are necessary:

1. Calculate the surface area in square meters based on the site survey sketch.
2. Collect the data on the annual energy consumption of the building/facility (be fore and after energy efficiency measures taken, refer to chapter 1).
3. Use the PREM Solar PV Capacity Calculator and enter the above-mentioned data. It will give a recommended maximum capacity of the proposed solar PV system. Details on how to use the Calculator are mentioned in chapter 3.
4. Combine the Solar PV system templates to arrive at the recommended maximum capacity. Details on this task are given below.
5. Include the combined templates as technical specifications into the tender document.
6. Incorporate in the tender document.

PREM provides the Energy Manger with 10 templates for the technical specifications of standard system sizes provided. The PREM Solar PV Technical Specifications are available under: www.xxx These templates are based on the most commonly used system sizes and on the sizes of solar-grid inverters available in the market.

The standard system sizes are:

- 250 W
- 1 kW
- 3 kW
- 5 kW
- 8 kW
- 10kW
- 15 kW
- 20 kW
- 30 kW
- 50kW

Most likely, the recommended system size from the PREM Solar PV Capacity Calculator will not match exactly with one of the above-mentioned templates. In this case the system sizes can be combined in a modular way.

Example:
The PREM Solar PV Capacity Calculator has recommended a system size of 40kW. This is the system size for which you want to create a tender document.
As there is no Template for 40 kW, some of the existing templates have to be combined. Of course there are several ways to combine the existing templates to come to 40 kW.

The most logical would be the following:
20 kW +20kW =40kW

It is also most probably the most cost effective combination as there are only 2 inverters involved, two of 20kW. The other components of the system just need to be multiplied in number to reach the desired output.

Commissioning and Installation

TThe Solar PV System Technical Specification Templates are meant to form the “Technical Specifications” part of the tender document. They are prepared in two separate documents: (1) The General Technical Specifications, which apply to any grid-connected solar PV system, and the System Technical Specifications, which are specific to a certain system size. (2)For the tender document, the General Technical Specifications have to be included once and the System Technical Specifications have to be based on the selected system capacity and the relevant system components.

Evaluating the bids

For the evaluation of the bids from a technical point of view, there is a checklist provided. This checklist contains all the essential points of the Technical Specifications of the tender document. For more please refer to Chapter 3.

Quality of Workmanship

The General Technical Specifications of the tender document reads the following:
“Solar PV modules are designed to last 25 years or more. It is therefore essential that all system components and parts, including the mounting structures, cables, junction boxes, distribution boxes and other parts also have a life cycle of at least 25 years. Therefore all works should be undertaken with the highest level of quality and workmanship. During inspection the Commissionerate of Municipal Administration and its representatives will pay special attention to neatness of work execution and conformity with quality and safety norms. Non-compliant works will have to be redone at the cost of the Installer.”

The task of the Energy Manager is to assure a thorough inspection of the work in progress as well as the final setup at the time of commissioning. Any deviation from the quality standards given in the tender document must be thoroughly inspected, properly documented (Photos) and brought to the notice of the Installer. After rectification by the Installer at his cost, the site has to be re-inspected and evaluated anew.

The General Technical Specifications specify the details about the quality of the installation. The following pictures demonstrate the level of quality of workmanship that is demanded.

Picture 26 3-phase AC Distribution Boxes with Energy Meters

Picture 27 Proper Cable Routing in Dedicated PVC Pipes Clamped on the Wall

Picture 28 Proper Cabling and Connections Inside the AC Distribution Box

Operations and Maintenance

A grid-connected solar PV system does not need any regular operation procedures by the system operator as it runs fully automatic. However, a daily check if the system is functioning is required. Only in case of faults o regular maintenance procedures, an intervention from the system operator is necessary.Total failures of solar PV systems are extremely rare. The overwhelming majority of systems work for many years without developing costly faults or need for repair.Faults and longer down times can be avoided through regular maintenance by the system operator. The following checklist can be used as a guide:

Table 22 SPV Maintenance Checklist

Daily	Inverter	-	in operation or error display?
Monthly	PV module surface area	- -	heavy soiling, leaves or bird droppings on the modules? Thorough cleaning with water!
Every six months	PV module surface area	-	Check for shading through trees and other growing plants.

CHAPTER 3

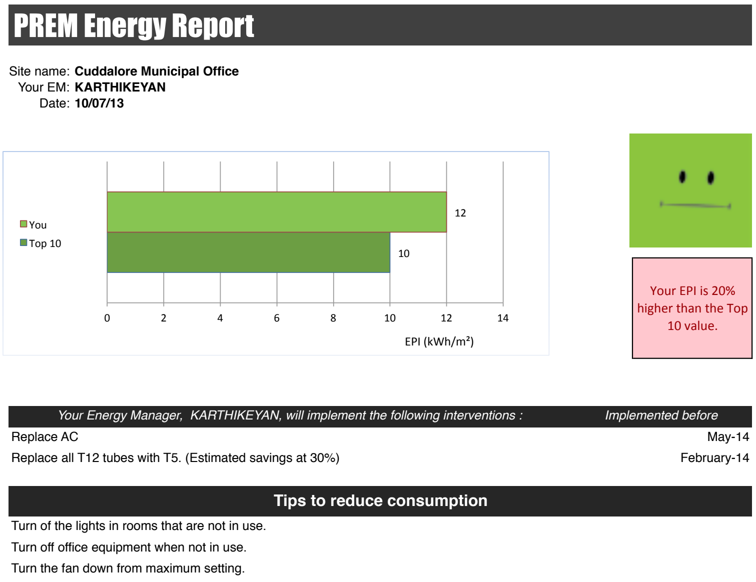
Tools for Municipal Energy Managers

Implementing PREM will demand some simple and scalable tools and templates that can be put at the disposal of the Municipal Energy Manager. This chapter introduces tools to manage energy conservation and efficiency as well as solar PV Installation programs. Those tools that have specifically been develop for the Municipal Energy Managers of Tamil Nadu.

PREM Energy Report

The PREM Energy Report is a simple tool for regular performance reporting. It is recommended that the Energy Manager uses various energy conservation initiatives for achieving energy savings. The PREM Energy Report presents one such initiative. It can be sent on a bi-monthly basis to the managers of various buildings and facilities under the municipal administration. The report compares a building's/facility's energy performance to the 10 best performing buildings/facilities of the same types (e.g. office, school, IT room) all over Tamil Nadu. Figure 1 below displays a sample report for a municipal office. The Energy Report also lists upcoming interventions planned by the Energy Manager for the respective building and gives tips for reducing a building's energy performance.

Figure 17 PREM Energy Report



PREM Energy Report

Site name: **Cuddalore Municipal Office**
Your EM: **KARTHIKEYAN**
Date: **10/07/13**

Your EPI is 20% higher than the Top 10 value.

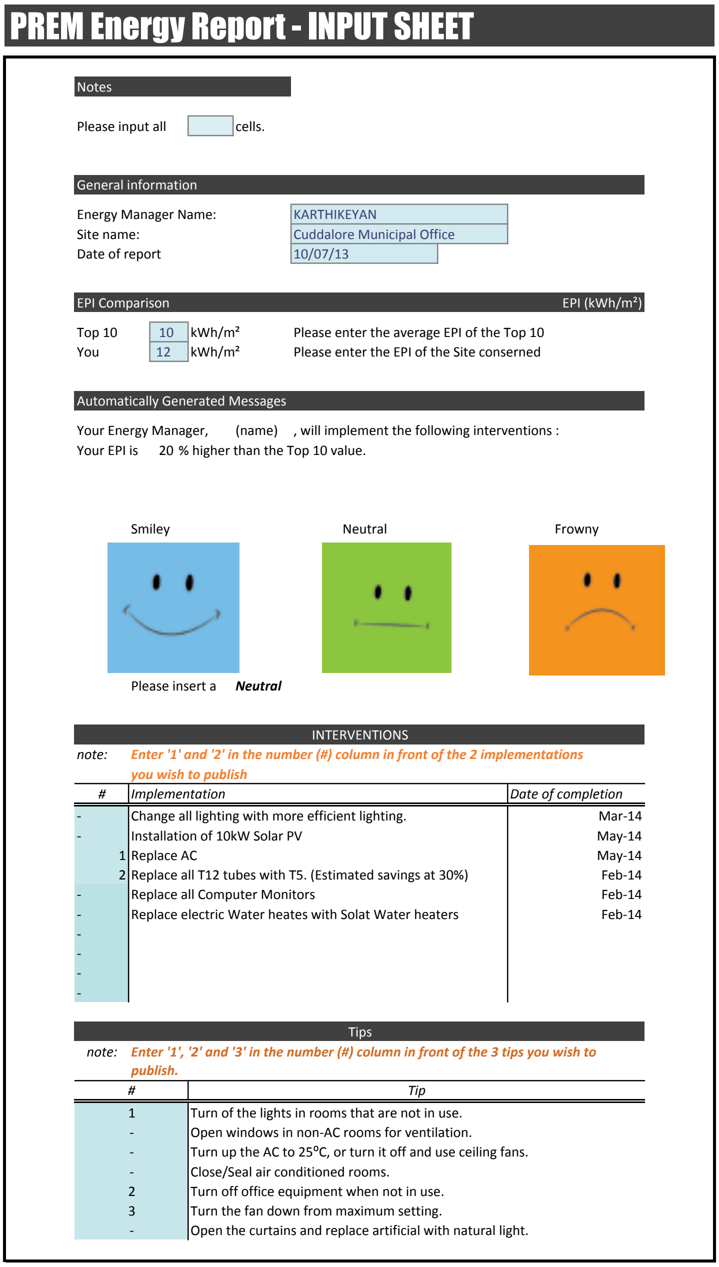
Your Energy Manager, KARTHIKEYAN, will implement the following interventions :	*Implemented before*
Replace AC	May-14
Replace all T12 tubes with T5. (Estimated savings at 30%)	February-14

Tips to reduce consumption

Turn of the lights in rooms that are not in use.
Turn off office equipment when not in use.
Turn the fan down from maximum setting.

The excel file for PREM Energy Report Template can be downloaded under:
https://www.dropbox.com/sh/6s4ctf30m8c2tmc/BbnTxtdGzq

Figure 18 Input Sheet for Periodic Energy Report



PREM Energy Report - INPUT SHEET

Notes

Please input all ☐ cells.

General information

Energy Manager Name: KARTHIKEYAN
Site name: Cuddalore Municipal Office
Date of report 10/07/13

EPI Comparison			EPI (kWh/m²)
Top 10	10	kWh/m²	Please enter the average EPI of the Top 10
You	12	kWh/m²	Please enter the EPI of the Site conserned

Automatically Generated Messages

Your Energy Manager, (name) , will implement the following interventions :
Your EPI is 20 % higher than the Top 10 value.

Smiley Neutral Frowny

Please insert a ***Neutral***

INTERVENTIONS

note: ***Enter '1' and '2' in the number (#) column in front of the 2 implementations you wish to publish***

#	*Implementation*	*Date of completion*
-	Change all lighting with more efficient lighting.	Mar-14
-	Installation of 10kW Solar PV	May-14
1	Replace AC	May-14
2	Replace all T12 tubes with T5. (Estimated savings at 30%)	Feb-14
-	Replace all Computer Monitors	Feb-14
-	Replace electric Water heates with Solat Water heaters	Feb-14
-		
-		
-		
-		

Tips

note: ***Enter '1', '2' and '3' in the number (#) column in front of the 3 tips you wish to publish.***

#	*Tip*
1	Turn of the lights in rooms that are not in use.
-	Open windows in non-AC rooms for ventilation.
-	Turn up the AC to 25°C, or turn it off and use ceiling fans.
-	Close/Seal air conditioned rooms.
2	Turn off office equipment when not in use.
3	Turn the fan down from maximum setting.
-	Open the curtains and replace artificial with natural light.

PREM Energy Audit Field Sheet

The PREM Energy Audit Field Sheet provides the Energy Manager with a simple and effective tool for capturing and quantifying a building's type and quantity of electric appliances. The data collected via the Energy Audit field sheet helps establishing a baseline for which energy efficiency interventions can be planned.The excel file for PREM Energy Audit Field Sheet can be downloaded under:

https://www.dropbox.com/sh/6s4ctf30m8c2tmc/BbnTxtdGzq

Figure 19 PREM Energy Audit Field Sheet

ENERGY AUDIT FIELD SHEET

Facility name :		Service Connection No.	
Address:		Number of phase :	
Facility Type:		Electricity tarrif type.:	
Total Carpet area of facility:		Number of people in facility:	
Name of contact person on site:		Audit performed by:	
Phone number of contact person on site		Date :	

Building name	Room/ facility name	Lenght	Width	Device Type	Ballast (only for light)	Regulator type (only for fans)	Tonnage (TR) only for AC)	Load	Number	Running hours/day	Running days/year	Comment

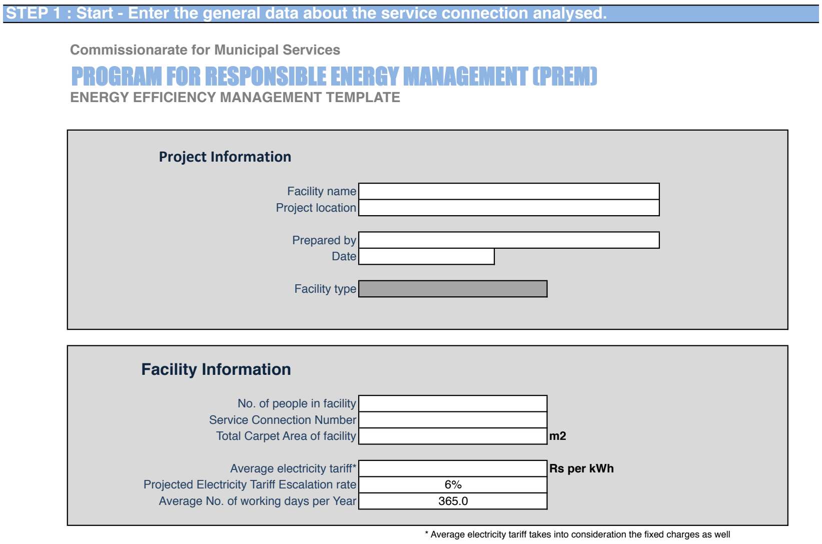
PREM Energy Efficiency Management Template

Entering the data gained during the Energy Audit and captured in the Energy Audit Field Sheet provides the Municipal Energy Manager with a potential Best Case proposal for fans, lighting and air conditioning and its respective payback period.

PREM Energy Efficiency Management Template can be downloaded under:.

https://www.dropbox.com/sh/6s4ctf30m8c2tmc/BbnTxtdGzq

Figure 20 PREM Energy Efficiency Management Tempate - Input Sheet



STEP 1 : Start - Enter the general data about the service connection analysed.

Commissionarate for Municipal Services

PROGRAM FOR RESPONSIBLE ENERGY MANAGEMENT (PREM)

ENERGY EFFICIENCY MANAGEMENT TEMPLATE

Project Information

Facility name
Project location

Prepared by
Date

Facility type

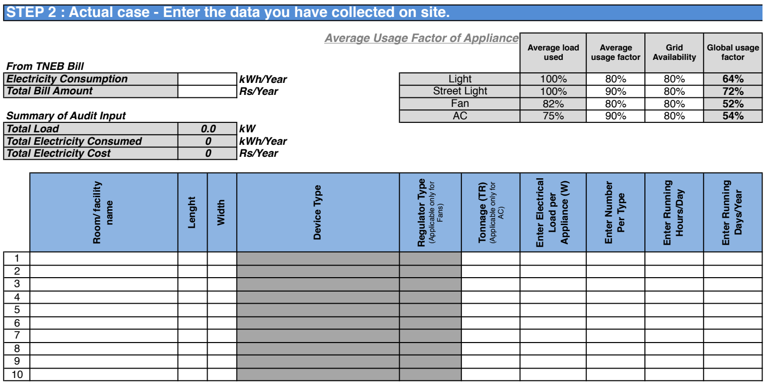
Facility Information

No. of people in facility
Service Connection Number
Total Carpet Area of facility m2

Average electricity tariff* Rs per kWh
Projected Electricity Tariff Escalation rate 6%
Average No. of working days per Year 365.0

* Average electricity tariff takes into consideration the fixed charges as well

Figure 21 PREM Energy Efficiency Management Tempate Input sheet for Fixtures and Appliances



STEP 2 : Actual case - Enter the data you have collected on site.

Average Usage Factor of Appliance

	Average load used	Average usage factor	Grid Availability	Global usage factor
Light	100%	80%	80%	**64%**
Street Light	100%	90%	80%	**72%**
Fan	82%	80%	80%	**52%**
AC	75%	90%	80%	**54%**

From TNEB Bill

Electricity Consumption		***kWh/Year***
Total Bill Amount		***Rs/Year***

Summary of Audit Input

Total Load	***0.0***	***kW***
Total Electricity Consumed	***0***	***kWh/Year***
Total Electricity Cost	***0***	***Rs/Year***

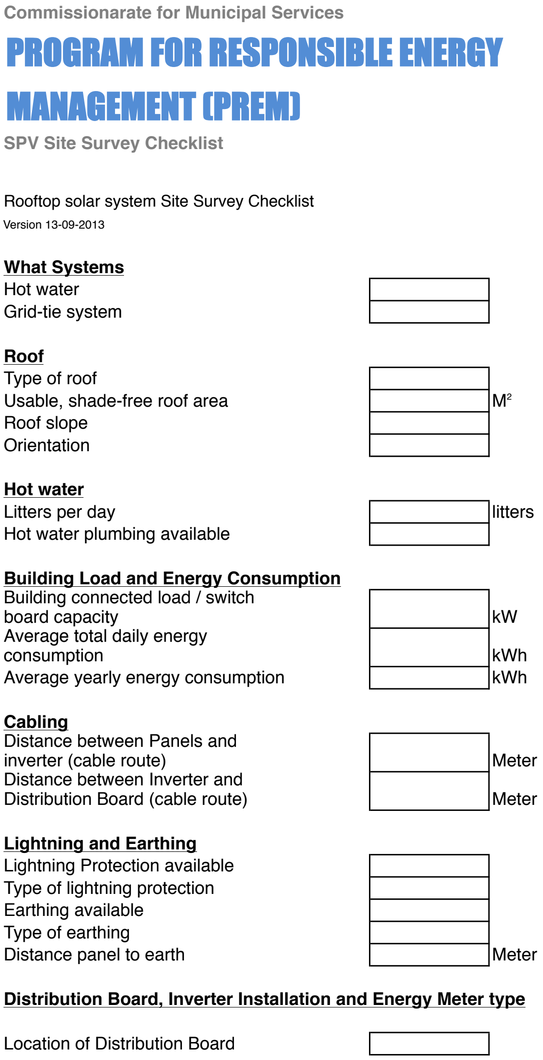
	Room/ facility name	Lenght	Width	Device Type	Regulator Type (Applicable only for Fans)	Tonnage (TR) (Applicable only for AC)	Enter Electrical Load per Appliance (W)	Enter Number Per Type	Enter Running Hours/Day	Enter Running Days/Year
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

The PREM Solar PV Site Survey Checklist

This checklist (see Figure 22) will help the Municipal Energy Manager in a systematic collection of required data during the site visit for the planning of Grid-Tied Solar PV systems on Municipal buildings and facilities. The excel file for PREM Solar PV Survey Check list can be downloaded under:

https://www.dropbox.com/sh/wbseka9i3g63oa0/3jDbFO8Whl

Figure 22 PREM SPV Site Survey Checklist



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PROGRAM FOR RESPONSIBLE ENERGY MANAGEMENT (PREM)

SPV Site Survey Checklist

Rooftop solar system Site Survey Checklist
Version 13-09-2013

What Systems

Hot water	
Grid-tie system	

Roof

Type of roof	
Usable, shade-free roof area	M^2
Roof slope	
Orientation	

Hot water

Litters per day	litters
Hot water plumbing available	

Building Load and Energy Consumption

Building connected load / switch board capacity	kW
Average total daily energy consumption	kWh
Average yearly energy consumption	kWh

Cabling

Distance between Panels and inverter (cable route)	Meter
Distance between Inverter and Distribution Board (cable route)	Meter

Lightning and Earthing

Lightning Protection available	
Type of lightning protection	
Earthing available	
Type of earthing	
Distance panel to earth	Meter

Distribution Board, Inverter Installation and Energy Meter type

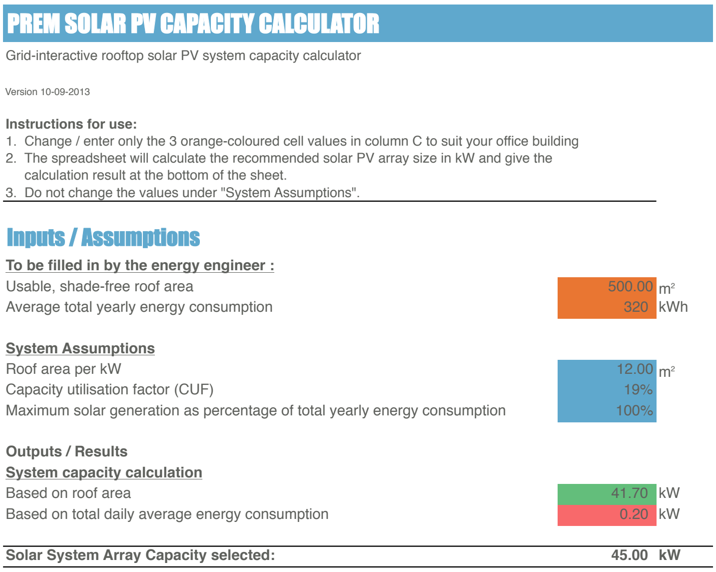
Location of Distribution Board	

PREM Solar PV Capacity Calculator

The PREM Solar PV Capacity Calculator provides the Municipal Energy Manager with two SPV system capacity options to be considered for installation on the selected site/ roof. The first capacity option is based on the maximum shade-free (rooftop) area available whereas the second option is based on the building's/ facility's annual energy consumption. Figure 23 shows the Solar PV Capacity Calculator. The excel file for PREM Solar PV Capacity calculator can be downloaded under:

https://www.dropbox.com/sh/wbseka9i3g63oa0/3jDbFO8Whl

Figure 23 PREM Solar PV Capacity Calculator



PREM SOLAR PV CAPACITY CALCULATOR

Grid-interactive rooftop solar PV system capacity calculator

Version 10-09-2013

Instructions for use:

1. Change / enter only the 3 orange-coloured cell values in column C to suit your office building
2. The spreadsheet will calculate the recommended solar PV array size in kW and give the calculation result at the bottom of the sheet.
3. Do not change the values under "System Assumptions".

Inputs / Assumptions

To be filled in by the energy engineer :

Usable, shade-free roof area	500.00	m^2
Average total yearly energy consumption	320	kWh

System Assumptions

Roof area per kW	12.00	m^2
Capacity utilisation factor (CUF)	19%	
Maximum solar generation as percentage of total yearly energy consumption	100%	

Outputs / Results

System capacity calculation

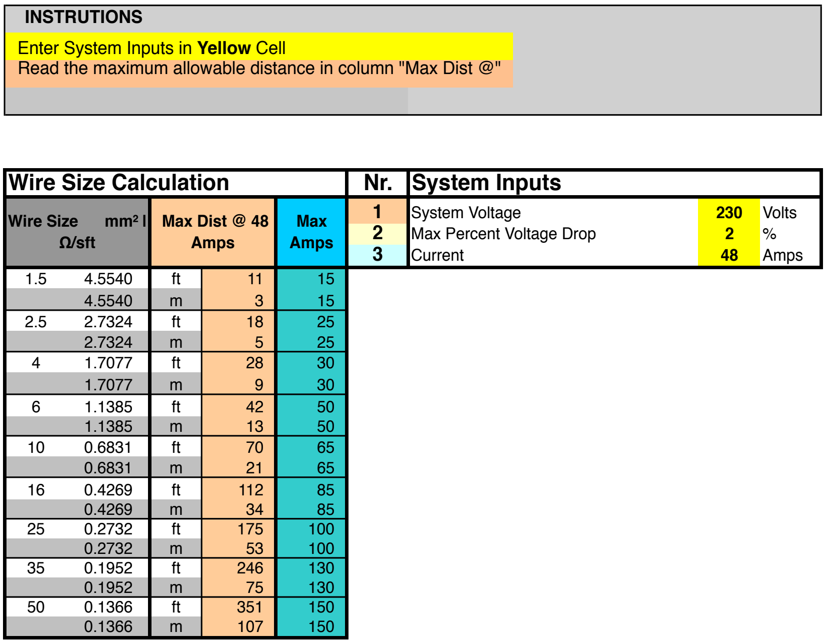
Based on roof area	41.70	kW
Based on total daily average energy consumption	0.20	kW
Solar System Array Capacity selected:	**45.00**	**kW**

PREM Solar PV Wire Size & Voltage Drop Calculator

The PREM Solar PV Wire Size and Voltage Drop Calculator provides the Municipal Energy Manager with the appropriate wire size for the given SPV system configuration (see figure 24). PREM Solar PV Wire Size & Voltage Drop Calculator can be downloaded under:

https://www.dropbox.com/sh/wbseka9i3g63oa0/3jDbFO8Whl

Figure 24 Wire Size & Voltage Drop Calculator



INSTRUTIONS

Enter System Inputs in **Yellow** Cell

Read the maximum allowable distance in column "Max Dist @"

Wire Size Calculation				
Wire Size mm² l	**Ω/sft**	**Max Dist @ 48 Amps**		**Max Amps**
1.5	4.5540	ft	11	15
	4.5540	m	3	15
2.5	2.7324	ft	18	25
	2.7324	m	5	25
4	1.7077	ft	28	30
	1.7077	m	9	30
6	1.1385	ft	42	50
	1.1385	m	13	50
10	0.6831	ft	70	65
	0.6831	m	21	65
16	0.4269	ft	112	85
	0.4269	m	34	85
25	0.2732	ft	175	100
	0.2732	m	53	100
35	0.1952	ft	246	130
	0.1952	m	75	130
50	0.1366	ft	351	150
	0.1366	m	107	150

Nr.	System Inputs		
1	System Voltage	**230**	Volts
2	Max Percent Voltage Drop	**2**	%
3	Current	**48**	Amps

The PREM Solar PV System Templates

The PREM Solar PV System Templates provide the Municipal Energy Manager with a selection of 10 plug and play Solar PV system configurations that can be used and combined based on the results gained in the Solar PV Capacity template. Figure 25 shows the proposed standard sizes and their appropriate mounting options. PREM Solar PV System Templates can be downloaded under:
https://www.dropbox.com/sh/z1x1hjxdm00zida/bezpqWRpF2

Figure 25 Capacities PREM Solar PV System Templates

System Size	Flat Concrete Roof	Corrugated Sheet Roof	Elevated Structure	Ground Mounting
250Wp	X	X		X
1kWp	X	X	X	X
3kWp	X	X	X	X
5kWp	X	X	X	X
10kWp	X	X		X
15kWp	X	X		X
20kWp	X	X		X
30kWp	X	X		X
50kWp	X	X		X

PREM Checklist for the Evaluation of Bids

The PREM Checklist for the Evaluation of Bids provides the Energy Managers with a comprehensive list of all relevant technical details mentioned in the General Technical Specification document in form of a checklist. This can be used to evaluate the incoming bids on their compliance with the technical specifications of the tender document. The PREM Checklist for the Evaluation of Bids can be downloaded under:
https://www.dropbox.com/sh/z1x1hjxdm00zida/bezpqWRpF2

PREM Monitoring Platform

The PREM Monitoring Platform provides a continuous reporting, management and evaluation tool to the Municipal Energy Manager as well as to the Commissionerate of Municipal Administration. The platform allows comparison to the top 10 best performing regions, corporations and municipalities, buildings and energy managers.

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GLOSSARY

Coefficient of Performance (COP): The efficiency of a refrigeration system is measured by its coefficient of performance (COP), and is normally given as the ratio of the refrigeration effect to the compressor power: COP = (Cooling output) / (Electrical input)

Energy Efficiency Ratio: A room air conditioner's efficiency is measured by the energy efficiency ratio (EER). The EER is the ratio of the cooling capacity (in British thermal units [Btu] per hour) to the power input (in watts). The higher the EER rating, the more efficient the air conditioner.

Energy Audit: an evaluation, monitoring and analysis of use of energy including submission of a Technical Report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption.

Energy Conservation is the deliberate practice or an attempt to save electricity, fuel oil or gas or any other combustible material, to be able to put to additional use for additional productivity without spending any additional resources or money.

Energy Efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without effecting output, consumption or comfort levels. Promotion of energy efficiency will contribute to energy conservation and is therefore an integral part of energy conservation promotional policies.

Illuminance: The illuminance or light level is the amount of light energy reaching a given point on a defined surface area, namely the luminous flux (i.e. lumens) per square meter. Illuminance is measured in lux.

Life Cycle Costing is a method of calculating the costs of an appliance over its entire lifetime. It is the period during which something remains functional.

Payback Period: The length of time required to recover the cost of an investment. The payback period of a given investment or project is an important determinant of whether to undertake the position or project, as longer payback periods are typically not desirable for investment positions. It isCalculated as: Payback Period = Cost of Project / Annual Cash Inflows.

APPENDIX

Appendix for Fans

Super Efficient Fans available on the market
Currently we could find only 2 brands selling super efficient ceiling fans, but as there is a push from BEE for the Super Efficient Equipment program, many more brands might coming up soon in this category.

SuperFan:
Launched in Dec 2012, these fans are designed and manufactured by Versa Drives (www.superfan.in), a company based in Coimbatore which has been in existence since 2010.

Table 24 Power Consumption of Superfan at Different Speed Levels

Speed	Power consumption in Watts	
	Ordinary Fan	Superfan*
Low	12	4
Medium	39	14
High	75	35

*Please note that Superfan delivers the same or higher quantities of air than ordinary fans.

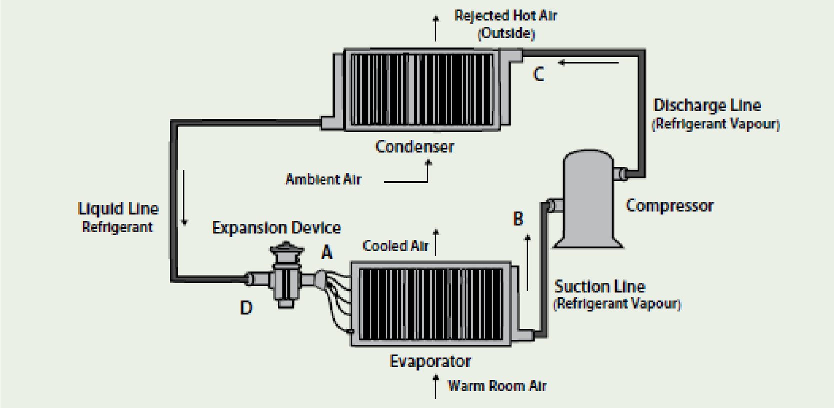
Most of the superfan models are remote controlled and thus do not require installation of a regulator. This will help save on capital expenses towards regulator.

Luxaire:
Luxaire (www.luxaire.in) is also a new brand, which was launched recently in 2013. Operating from Bangalore, they sell imported ceiling fans that are comparable to luxury ceiling fans available in Usha Hunter range. Most of their models are designer products that consume less electricity (30 Watt) and produce very low noise. With 30 Watts of energy consumption, the electricity saving is almost 60 percent. Their blades are mostly made of eco friendly wood and the company claims to be producing very eco friendly products. The operation of these fans is also through remote control, which makes them quite convenient to use.

Appendix for AC

Technical basis for AC - Principle diagram
Basic components of the system include an evaporator, compressor, condenser (air-cooled or water cooled- Room ACs are air cooled), and an expansion device, similar to that of a domestic refrigerator. A refrigerant circulates in these components.
Evaporator: The refrigerant vaporizes in the evaporator absorbing the heat from the warm room air drawn across the evaporator coil. This cools and dehumidifies the air.
Compressor: The compressor raises the pressure and temperature of the refrigerant vapors.
Condenser: The condenser condenses the refrigerant and transforms the high-pressure vapor into high-pressure liquid. Heat is rejected via outside air drawn across the condenser.
Expansion Device: The expansion device transforms the high-pressure high temperature liquid refrigerant to low-pressure low temperature mixture of refrigerant liquid and vapor.
The refrigerant goes to the evaporator, and the cooling cycle continues.

Table 26 Principle Diagram for an Air Conditioning System



Performance Terms and Definitions

Tons of refrigeration (TR): One ton of refrigeration is the amount of cooling obtained by one ton of ice melting in one day: 3024 kCal/h, 12,000 Btu/h or 3.516 thermal kW.
Net Refrigerating Capacity: A quantity defined as the mass flow rate of the evaporator water multiplied by the difference in enthalpy of water entering and leaving the cooler, expressed in kCal/h, tons of Refrigeration.
kW/ton rating: Commonly referred to as efficiency, but actually power input to compressor motor divided by tons of cooling produced, or kilowatts per ton (kW/ton). Lower kW/ton indicates higher efficiency.

Coefficient of Performance (COP): Chiller efficiency measured in Btu output (cooling) divided by Btu input (electric energy). It is a number without any units.

COP is the ratio of energies of input and output during a fixed period, it can be a month, 2 month, a year, etc.

Energy Efficiency Ratio (EER): Performance of smaller chillers and rooftop units is frequently measured in EER rather than kW/ton. EER is calculated by dividing a chiller's cooling capacity (in Btu/h) by its power input (in Watts, and includes all inputs to compressor, fan motors and controls) to operate AC at standard rating conditions. The higher the EER, the more efficient the unit.

How to size an AC

Some private manufacturers provide online calculators:
- http://www.bluestarindia.com/ac-tonnage-calculator/toncalculator.asp (sizing calculator)
- http://sharpproducts.in/downloadsupport.aspx?id=22&cid=13
- http://www.saveenergy.co.in/20-module-positions-mainmenu-44.php
  (Financial savings calculator)