<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Introduction – Solar Energy</td>
<td>68</td>
</tr>
<tr>
<td>5.2</td>
<td>Profile of the Solar Equipments</td>
<td>69</td>
</tr>
<tr>
<td>5.2.1</td>
<td>Solar Water Heater</td>
<td>69</td>
</tr>
<tr>
<td>5.2.2</td>
<td>Solar cooker</td>
<td>74</td>
</tr>
<tr>
<td>5.2.3</td>
<td>Solar Lighting System</td>
<td>78</td>
</tr>
<tr>
<td>5.3</td>
<td>Solar Energy – the global scenario</td>
<td>80</td>
</tr>
<tr>
<td>5.4</td>
<td>Solar Energy – Indian scenario</td>
<td>81</td>
</tr>
<tr>
<td>5.4.1</td>
<td>Policies, measures and regulations</td>
<td>86</td>
</tr>
<tr>
<td>5.5</td>
<td>Solar Energy in Maharashtra</td>
<td>88</td>
</tr>
<tr>
<td>5.5.1</td>
<td>Solar Power – status and plans</td>
<td>90</td>
</tr>
</tbody>
</table>
CHAPTER - V
SOLAR ENERGY PROFILE

5.1 Introduction - Solar Energy

Solar energy refers to sources of energy that can be directly attributed to the light of the sun or the heat that sunlight generates (Bradford, 2006). Solar energy in the form of sunlight is readily available source of energy since existence of the earth. Solar energy is known to us as heat and bright and can be used in two ways i.e. to produce the heat and to crop electrical energy. Solar energy technologies can be classified as: Passive and Active,

a) **Passive solar energy**– This type of technology collects the energy without converting the heat or light into other forms, for example, maximizing the use of day light or heat through building design (Bradford, 2006).

b) **Active solar energy**– This type of technology harness solar energy to store it or convert its form for other applications and can be broadly classified into two groups: (i) Photovoltaic (PV) and (ii) Solar thermal.

The **PV technology** converts light energy contained in solar light into electrical energy when light falls upon a semiconductor material, causing electron excitation and strongly enhancing conductivity (Sorensen, 2000). There are two types of PV technology currently available in the market; they are: (a) Crystalline silicon-based PV cells and (b) Thin film technologies; made out of a range of different semi-conductor materials, including amorphous silicon, cadmium-telluride and copper indium gallium diselenide.

**Solar thermal technology** uses heat in solar radiations, which can be used further for either thermal or heating application or for generation of electricity. Accordingly, it can be divided into two categories: (i) Solar thermal non-electric and (ii) Solar thermal electric. The former includes applications as agricultural drying, solar water heaters, solar air heaters, solar cooling systems and solar cookers. The latter refers to use of solar heat to produce steam for electricity generation, also known as **concentrated solar power** (CSP). Four types of CSP
technologies are currently available in the market: Parabolic Trough, Fresnel Mirror, Power Tower and Solar Dish Collector (World Bank, 2011).

5.2 Profile of the Solar Equipments considered for the study

Researcher had considered for his study; the solar equipments which are affordable and available in the market very easily and has lot of potential to be used by common man. Those equipments are –

a) Solar water heater

b) Solar Cooker

c) Solar lighting system

5.2.1 Solar Water Heater

India is blessed with solar energy in large quantity at no cost. The solar light falling on the surface of the earth can be easily utilized for the benefit of human beings. One of the popular devices that harnesses the solar energy is the solar water heating system (SWHS).

Figure No. 5.1
Solar Water Heater
A solar water heater consists of a collector to collect solar energy and an insulated tank for storage of hot water. The solar light falling on the collector coated with special coating transfers the heat to the pipes underneath the absorber panel. The water passing through the pipes gets heated up and is delivered to the storage tank. The re-circulation of the same water through the absorber panel in the collector raises the temperature to 80°C (Maximum) on a bright sunny day. The total system with solar collector, storage tank and pipelines is called a solar water heating system.

Broadly, solar water heating systems are of two categories: closed loop system and open loop system.

In the closed loop system, heat exchangers are used to protect the system if it is used with hard water from bore wells or water with freezing temperatures in cold regions. The action of heat exchanger will protect the collectors’ tubes from scaling and blocking the path or developing cracks. These types of systems are generally costlier than the others.

In the open loop system, the water or liquid to be heated directly flows through collector tubes through either thermo-siphon or forced circulation system. These types of systems which use thermo-siphon effect are simple and relatively less expensive. They are suitable for domestic and small institutional systems where water available is treated and is potable in quality (soft water). The forced circulation system uses electrical pumps to circulate the water in the system.

Based on the collector, solar water heaters can be of two types: Flat Plate Collectors (FPC) Solar Water Heaters and Evacuated Tube Collectors (ETC) Solar Water Heaters.

5.2.1.1 Flat Plate Collectors (FPC) Solar Water Heaters

In flat plate type collector there are small copper tubes connected to thin copper plate are connected together and then connected to tank. Thin copper plates are coated black to absorb more of the heat. These types of collectors have the largest heat absorbing area and this same area causes the heat loss back to atmosphere. This limits the heating capabilities of these types of collectors to less than 80°C.
Working: -The heat energy in solar radiation is absorbed by blackened metallic absorber (selectively coated) sheets with built in copper tubes to carry water. The absorbed heat is transferred to the water. The heated water rises upwards because of thermo-siphon effect. This circulation continuous throughout the day and hot water gets stored in insulated storage tank. Thus heated water can be utilised for various purposes like bathing, cooking, washing etc.

Main characteristics of this type of systems are:

- Resistance to large variations in temperature
- Resistance to leakage from any part of the system
- Stable and durable
- Easy to install
- Efficient in energy conversion.

Above mentioned characteristics are required to be fulfilled by the collector as per the existing BIS standard IS-12933-2003.
5.2.1.2 Evacuated Tube Collectors (ETC) Solar Water Heaters

This type of solar water heater has a collector which consists of number of glass tubes called as Evacuated tube collector (ETC); this tube is made of double layer borosilicate glass tubes evacuated for providing insulation. The vacuum between two tubes acts as insulation. The outer tube is transparent and the inner tube is coated black with selective material. This helps absorption of solar radiation and transfers the heat to the water which flows through the inner tube. The cross section is shown in the above diagram. Because of the vacuum between two tubes the heat absorbed by the inner tube does not get dissipated in the atmosphere hence efficiency of this type of system is better than flat plate collector type.

**Figure No. 5.3**

Evacuated Tube Collectors (ETC) Solar Water Heaters

---

**Working:** - Water in this type of system is allowed to flow in the inner tube where it gets heated up due to absorption of heat. Hot water goes in to storage tank due to circulation caused by thermo-siphon effect.

5.2.1.3 Uses of solar water heating system:

Widespread utilization of solar water heaters can reduce a significant portion of the conventional energy being used for heating water in homes, factories and other commercial and institutional establishments. Following table shows the applications of solar water heating systems –
Table No. 5.1
Sector wise application of solar water heaters

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>SECTOR</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Individual household or Domestic</td>
<td>Bathing, washing, cleaning, etc</td>
</tr>
<tr>
<td>2</td>
<td>Industries</td>
<td>Boilers, Steam generation etc</td>
</tr>
<tr>
<td>3</td>
<td>Hostels</td>
<td>Bathing</td>
</tr>
<tr>
<td>4</td>
<td>Hospitals</td>
<td>Bathing, cleaning, Washing, sterilization.</td>
</tr>
<tr>
<td>5</td>
<td>Dairies and poultries</td>
<td>Cleaning, washing.</td>
</tr>
<tr>
<td>6</td>
<td>Canteens and Messes</td>
<td>Cleaning of utensils</td>
</tr>
</tbody>
</table>

While using solar water heater one has to decide capacity of the heater. It is very important because water gets heated up during the day and is stored in the storage tank and can be utilised next day. System cannot give more hot water than its capacity. There is no standard formula for deciding required capacity. Generally on tropical terrains 20 to 25 liters of hot water is considered per person per bath so for a family of 4 members 100 LPD systems would be sufficient. Following table would give an idea for deciding capacity of water heater –

Table 5.2
For deciding capacity of solar water heater

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Place</th>
<th>Way to use</th>
<th>Hot water Reqd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>House (for bath)</td>
<td>Bucket bath</td>
<td>20-25 liters/person</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shower bath</td>
<td>30-35 liters/person</td>
</tr>
<tr>
<td>2</td>
<td>Hostels, Hospitals</td>
<td>Hot water in Bathroom</td>
<td>30-35 liters/person</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot water in common tap</td>
<td>20-25 liters/person</td>
</tr>
<tr>
<td>3</td>
<td>Hotels</td>
<td>Class C (separate tap in bathroom)</td>
<td>30 - 35 ltrs/person</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class B(with mixer shower without bath tub)</td>
<td>40 – 60 ltrs/person</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class A ( mixer shower and bath tub)</td>
<td>60 – 100 liters/person</td>
</tr>
</tbody>
</table>
5.2.1.4 Benefits of using solar water heating system:-

Solar water heating is now an established technology. Use of solar water heaters can reduce a significant part of the conventional energy being used for heating water in homes, factories and other commercial and institutional establishments. Electrical Water Heaters basically use material which offers resistance to electrical current resulting in heat generation. Direct resistive load consumes more electricity. If renewable energy sources like solar water heaters are used; significant amount of energy can be saved. Following are few benefits of using solar water heating systems-

- **Energy conservation**: A 100 LPD capacity solar water heater is used then it saves up to 1500 units of electricity annually.
- **Saves cost of power generation**: The use of 1000 solar water heaters of 100 LPD capacity each, can contribute to saving of 1 MW during peak load.
- **Reduction in global warming**: A solar water heater of 100 LPD capacity can prevent emission of up to 1.5 tons of carbon dioxide per year.
- **High durability**: An average solar water heater has a life span of 15 years - 20 years.
- **Payback period**: 2-4 years

5.2.2 Solar Cooker –

A solar cooker is a device which uses the energy of direct sunlight to cook food. The majority of solar cookers in use are fairly cheap, low-technology devices. As they use no fuel and no operating costs, many organizations are spreading their use worldwide in order to reduce fuel costs and air pollution, and to slow down the deforestation caused for gathering firewood for cooking. Solar cooking is a form of outdoor cooking.

5.2.2.1 Advantages of using solar cooker –

- There no recurring everyday expenditure on fuel. If used on regular basis, three or four LPG cylinders per year can be saved.
- Saves time. User can be free to do other things as cooking does not require supervision.
- There is no direct heat given to food hence no fear of scorching.
- Ensures better and more nutritious cooked food.
- Solar cooking is pollution free and conserves conventional energy.
- Solar cookers have very long life.
- Simple and very safe to use.

A solar cooker cooks food with the help of solar energy, and saves conventional fuels. It supplements cooking fuel like kerosene, LPG, wood, but does not replace it. It is an ideal device for cooking during most of the year except on cloudy days. Lot of research and development activities are going on in the development of new techniques for solar cooking. Based on the design and use solar cooker are broadly classified in to 3 types they are as follows –

a) Box Type Solar Cooker
b) Dish / parabolic type solar cooker
c) Community solar cooker or Indoor solar cooker

5.2.2.2 Box type solar cooker –

A box-type solar cooker consists of an outer box made of fiber glass or aluminum sheet, a blackened aluminum tray, a double glass lid, a reflector, insulation, and cooking pots.

Figure 5.4
Box type solar cooker
The blackened aluminum tray is fixed inside the box, with insulating material in between to prevent heat loss from all sides. A double glass lid with toughened glass acts as the cover of the cooking tray. A reflecting mirror, fitted on the inside of the outer box cover, reflects the solar radiation and helps in increasing the solar energy input. The cooking pots are made of steel or aluminium and painted black on the outer side (MNES, 2012).

**Working:** - Solar cooker is equipment which is used for outdoor cooking. The location can be a place where ample solar radiation is available. The cooker should be facing direct towards the sun. Food to be cooked is kept in the small black coloured boxes and they are kept in the tray inside the box and glass lid is closed. The angle of mirror reflector (100 – 120 degrees) should set such that the reflection of the Sun light from the sun falls on the boxes kept in the tray. This ensures the heat energy is given to the boxes kept in the tray. Cooking takes place very slowly in a natural way. Normally it takes 2 to 2.5 hours to cook every day food like Rice, Dal and Curry. Ideal cooking timing would be 11 am to 04 pm.

### 5.2.2.3 Dish / parabolic solar cooker –

A dish / parabolic solar cooker uses a parabolic dish to focus the solar radiation. This type of solar cooker is known as an ‘SK-14’ type of cooker, and is useful for large families. A typical dish solar cooker has an orifice diameter of 1.4 m and a focal length of 0.28 m. The reflecting material used in this type of cooker is anodized aluminium sheet, with reflectivity more than 80%.

**Figure No. 5.5**

*Dish / parabolic solar cooker*
The cooker has to face the sun and can be adjusted manually every 15 to 20 minutes. The cooker can boil two to three litres of water in half an hour. The temperature at the bottom of the vessel could reach 350–400 °C, which is sufficient for roasting, frying, and boiling. This cooker can meet the needs of about 15 people, and can be used from 10 am to 04 pm during the day (MNRE, 2011).

**Working:** - this type of solar cooker needs more attention than box type as it needs adjustment every 15 – 20 minutes. A cooking vessel is kept in bracket made at the focal point of the parabola. Solar light reflected is focused and concentrated at this point which heats up the vessel. The assembly is attached with wheels to facilitate change in direction during the process. This cooker can be used on the terrace or in the open space without shadow.

The life of the cooker is 20 –25 years due to metallic parts used. The reflecting surface needs a change in 5 – 6 years as the reflectivity gets reduced. If used for small enterprises and food cooked for 10 -15 people it saves almost up to 10 LPG cylinders.

**5.2.2.4 Community solar cooker or Indoor solar cooker –**

The community solar cooker too has a parabolic reflector like dish solar cooker. However, it is larger than the dish parabola, and is known as a Scheffler cooker. The distinctive feature of this cooker is that it is possible to cook using solar energy within the kitchen itself. It has a large reflector ranging from 7 to 12 m² of area. (MNRE, 2010).

**Figure 5.6**

*Community solar cooker or Indoor solar cooker*
**Working:** The major reflector is positioned outside the kitchen so that it reflects solar light into the kitchen through an aperture made in its north wall. Another reflector further concentrates the rays on to the bottom of the cooking vessel (painted black).

The temperature at the bottom is so high (350 to 400 °C) that the food can be cooked quickly. Thus, the community solar cooker gives feeling of a conventional cooking device. The difference is that instead of conventional fuel like kerosene, LPG or firewood, it uses solar energy inside the kitchen.

The cooker is provided with a mechanical system to automatically track the sun. The user has to set the reflector only once in the morning and the system tracks the sun throughout the day. It is possible to change the curvature of the parabolic reflector by shifting two arms provided in the reflector frame, required for seasonal adjustment.

It is possible to cook for about 40–50 persons with this cooker. One item may take about 01 to 1.5 hours to cook, depending on the type of dish and solar radiation available. In areas where solar insolation is good, it is possible to cook both meals of a day. Due to its design it is possible to make almost all traditional dishes, including chapatee, purees, etc.. The cooker can be used to heat/boil water.

**5.2.3 Solar lighting system**

Solar lighting system uses photovoltaic principle in its applications. Photovoltaic is the technical term for solar electric. Photo means "light" and voltaic means "electric". PV cells are usually made of silicon, an element that naturally releases electrons when exposed to light. Amount of electrons released from silicon cells depend upon intensity of light incident on it. The silicon cell is covered with a grid of metal that directs the electrons to flow in a path to create an electric current. This current is guided into the wire that is connected to a battery or DC appliance (Taylor, 1983). There are various solar photovoltaic applications these are discussed below.
5.2.3.1 Solar Home Lighting System
This system consists of a solar panel, a battery; electronic system to operate lights and fans (for AC appliances Inverter is used). This system is especially useful for houses at remote places, farm houses etc.

5.2.3.2 Solar street Lighting
This equipment is specially designed for outdoor uses. This is integrated unit consisting of one solar PV panel, lamp post, battery with housing attached to pole, and lamp. This comes in the form of kit and can be installed at any place. Lights are automatically switched on and switched off depending on surrounding light.

5.2.3.3 Solar Lanterns
This is a small portable device which looks like a lantern used in olden days. This unit consists of a small PV panel, battery (mostly sealed Maintenance Free) and electronic device with lamp. The light is sufficient to illuminate a small room. This device is very popular among rural population.

5.2.3.4 Solar water pumps
In this system water pump is driven by the solar energy. This system consists of a array of PV panels mounted on a specially designed stand and motor pump. It can pump the water from bore well, open well and ponds etc.

5.2.3.5 Solar fencing
This is recent development in the field of solar energy. Area where land, crops and housing colonies are under the threat of infiltration by wild animals such as wild boar, bear, deer and foxes; this system is installed. This fencing is powered by solar energy and gives mild shock to the animals for a moment, intensity of shock is well controlled and is not lethal.

5.2.3.6 Solar traffic lighting systems
There are various applications in the traffic lighting system. Solar traffic lighting systems has varied range of products designed to fulfill the requirement of traffic systems lighting. It includes traffic signals, flashing lights at crossings or
dividers, lights, fans and public address system for traffic control booth. The major advantage of this system is that it works during the power failure also.

**5.2.3.7 Hybrid power projects with windmills**

These systems work in coordination with each other. Wind energy with the help of wind turbine gets converted into electrical energy and is stored in battery along with this during day time solar PV panel also converts solar light energy into electrical energy and stored in the battery. Energy stored in the battery can be used to run electrical appliance in household system.

**5.3 Solar Energy – The global scenario**

Solar energy worldwide is gaining importance due to awareness spread by various organizations working at world, country and regional level. World population is aware of continuously depleting fossil fuel reserves and is now searching for the better and better ways of using renewable energy resources. 20th century has witnessed the rise of Non Conventional Energy source industry. Solar energy being available in such ample quantity gained more popularity. This budding solar energy industry of the 1970s and early 80s collapsed due to the sharp decline in oil prices and a lack of sustained policy support (Bradford, 2006). Solar energy markets have regained momentum since early 2000, exhibiting exceptional development recently. The total installed capacity of solar based electricity generation capacity has increased to more than 40 GW by the end of 2010 from almost negligible capacity in the early nineties (REN21, 2011).

Solar energy has potential that exceeds the entire world’s energy demand. Despite this technical potential and the recent growth of the market, the contribution of solar energy to the global energy supply mix is still negligible (IEA, 2009).

Global demand for renewable energy continued to rise during 2011 and 2012, despite the international economic crisis, ongoing trade disputes, and policy uncertainty and declining support in some key markets. Renewable energy supplied an estimated 19% of global final energy consumption by the end of 2011, the latest year for which data are available. Of this total, approximately 9.3% came from traditional biomass, which is used primarily for cooking and
heating in rural areas of developing countries. Useful heat energy from modern renewable sources accounted for an estimated 4.1% of total final energy use; hydropower made up about 3.7%; and an estimated 1.1% was provided by power from wind, solar, geothermal, and biomass, and by bio-fuel. (See Figure 5.7) renewables are a vital part of the global energy mix (REN21, 2013)

**Figure 5.7**


5.4 Solar Energy – Indian Scenario

India has huge potential of Renewable Energy (RE) resources such as wind, solar, hydro etc. Most of the renewable capacity is in the renewable potential rich states of Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan and Himachal Pradesh. These states contribute more than 80 to 90 % of total renewable capacity installations in the country.

**Figure 5.8**

Renewable Capacity Potential in India
Among various renewable energy resources, India possesses a very large solar and wind energy resource which is seen as having the large potential for the future. Solar Potential in India is about 20-30 MW/sq km (i.e. >100 GW).

At presently renewable energy contributes about 9% (12.6 GW) of total installed electricity capacity in India. The result achieved in the renewable energy sector during 10th five year plan (2002-07) was positive and it provided the regulatory authorities with the optimism to initiate major reforms in renewable energy power sector. Even the current five year plan outlines a target of generating additional 14-20 GW of electricity from renewable source of energy. It identifies solar power generation as one of the means to achieve it. If the trend during tenth five year plan (2002-07) was to promote & generate electricity from wind power plants then perhaps current five year (2007-12) plan will be known for generation of electricity from solar power plants. The advantages of renewable energy are expected to contribute significantly in the developmental process (Ravi, 2012).

At the global level when growth is observed; India is not opting out from her responsibilities towards environment. The Government of India recognizes that development of local, renewable resources is critical to ensure that it is able to meet both its economic and environmental objectives. The Indian Government has exclusive Ministry dealing with renewable energy sources. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country. Earlier it was called as Ministry of Non-conventional Energy Sources (MNES) but in 2006 it is renamed as Ministry of New and Renewable Energy. The Indian economy has experienced tremendous growth over the past several years. Energy, in all its forms, underpins both past and future growth. For the Indian economy to continue this trajectory, India needs to address its energy challenges, which cross all sectors and impact all citizens (Arora, 2010).

On average, the country has 300 sunny days per year and receives an average hourly radiation of 200 MW/km2. The India Energy Portal estimates that around 12.5% of India’s land mass, or 413,000 km2, could be used for harnessing solar energy (TERI, 2012). Though India has potential for using solar technologies to supply electricity, India also can reduce electricity demand through increased
uses of solar water heaters (SWH), which can be installed on terrace or rooftops of houses.

Although India already has a strong solar cell production industry, until now, there has not been a high demand for them in the domestic market. India’s installed solar power capacity of 15.2 MW at the end of June 2010 was based entirely on PV technology with approximately 20% of the capacity being used for off-grid applications. (Arora, 2010) Currently, more attention is being paid to large-scale solar PV projects. In Phase 1 of JNNSM, which ends in 2013, India aims to install 500 MW of grid-connected solar PV power. (MNRE, 2012)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Capacity Installed (MW)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal</td>
<td>93,838</td>
<td>54.47</td>
</tr>
<tr>
<td>Hydro</td>
<td>37,367</td>
<td>21.69</td>
</tr>
<tr>
<td>Renewable</td>
<td>18,842</td>
<td>10.94</td>
</tr>
<tr>
<td>Gas</td>
<td>17,456</td>
<td>10.13</td>
</tr>
<tr>
<td>Nuclear</td>
<td>4,780</td>
<td>2.77</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>172,283</strong></td>
<td><strong>—</strong></td>
</tr>
</tbody>
</table>

(Source: MNRE Annual Report 10-11)

In April 2002, renewable energy based power generation installed capacity was 3497 MW which was 3% of the total installed capacity in the country. It is very clear from the Table No.5.3 that contribution of renewable energy has reached 18,842 MW, which is almost 11% of the total installed capacity of 1,72,283 MW. The increase is almost 4 times. Major contribution in renewable comes from wind power which is about 70% of the total capacity and solar power contribution is only 0.17%. (MNRE, 2011)

MNRE has in its annual report of 2010-11 given details of estimated renewable energy potential and cumulative achievements under different programmes as on 31.1.2011 which are given in Table No.5.4. It is very clear from the table that Solar Energy in all forms is not utilised to the available potential.
India has huge potential for Solar Water Heaters in the residential, commercial and industrial sectors. MNRE has estimated the total SWH potential to be approximately 40 million m² of collector area, and as of June 2010, installations had reached just over 3.5 million m² of collector area. The targets for 2012 and 2022 are to reach collector area of 5 million m² and 20 million m², respectively. Government support for SWH deployment is available as capital and interest subsidies. The Indian government is also supporting market development and awareness building through capacity building and outreach activities (Arora, 2010).

Table No. 5.4

Estimated Renewable Energy Potential and Achievements

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Programme / system</th>
<th>Estimated potential</th>
<th>Achievement during 2010-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Biomass Power</td>
<td>16881</td>
<td>143.50 MW</td>
</tr>
<tr>
<td>2</td>
<td>Wind Power</td>
<td>45195</td>
<td>1376.83 MW</td>
</tr>
<tr>
<td>3</td>
<td>Small Hydro Power</td>
<td>15000</td>
<td>218.00 MW</td>
</tr>
<tr>
<td>4</td>
<td>Cogeneration -bagasse</td>
<td>5000</td>
<td>257.00 MW</td>
</tr>
<tr>
<td>5</td>
<td>Waste to Energy</td>
<td>2700</td>
<td>7.50 MW</td>
</tr>
<tr>
<td>6</td>
<td>Solar Power</td>
<td>50 MW/sq.Km</td>
<td>20.09 MW</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>2022.92 MW</strong></td>
</tr>
<tr>
<td>7</td>
<td>Biomass (non-bagasse)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Biomass Gasifier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Energy recovery from waste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Solar PV Power plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Hybrid Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Watermills</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>90.588 Mweq</strong></td>
</tr>
<tr>
<td></td>
<td><strong>(II) DECENTRALISED RENEWABLE ENERGY SYSTEM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Family type Biogas Plants (nos)</td>
<td>120 lakh</td>
<td>73281</td>
</tr>
<tr>
<td>14</td>
<td>Solar Photo Voltaic Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>i) Street lighting systems (nos)</td>
<td></td>
<td>1471</td>
</tr>
<tr>
<td></td>
<td>ii) Home lighting system (nos)</td>
<td></td>
<td>37279</td>
</tr>
<tr>
<td></td>
<td>iii) Solar lanterns (nos)</td>
<td></td>
<td>3898</td>
</tr>
</tbody>
</table>
Solar Thermal Programme

i) Solar Water Heating system - collector area (m²) 140 million 
ii) Solar Cooker (nos) 0.50 millions

Solar PV Pumps (nos)

(III) REMOTE VILLAGE ELECTRIFICATION 959 Villages

(IV) OTHER PROGRAMMES

17 Energy Parks 3 nos
18 Aditya Solar Shops 9 nos
19 Battery Operated Vehicles 1 nos

(Source: MNRE Annual Report 2010-11.)

In India solar water heater installations are concentrated in two states—Karnataka and Maharashtra (65%) and more than 95% of households in India with SWH are located in urban areas. A 2010 SWH market assessment estimates that 85% of installed SWH are functioning (MNRE, 2010).

With an increasingly favorable regulatory and policy environment and a growing number of entrepreneurs and project developers, India has been ranked by Ernst and Young as the third most attractive country for renewable energy investment in the world (RECAI, 2011). Asset finance (renewable energy finance projects) and the public market are still the dominant forms of renewable energy financing in India; venture capital and private equity transactions are still limited in India due to the risks associated with renewable energy technologies. The confidence of domestic commercial banks providing loans to renewable projects is still limited; however, this is changing thanks to growing awareness and more and more favorable government policies and targets (Arora, 2010).

Government after realizing the need of a financing agency dedicated to only renewable energy sources had set up the organization ‘IREDA’ – Indian renewable Energy Developing Agency. IREDA is a Public Limited Government Company established in 1987, under the administrative control of Ministry of New and Renewable Energy (MNRE) to promote, develop and extend financial assistance for renewable energy and energy efficiency/conservation projects with the motto: "ENERGY FOR EVER "The main objectives of IREDA are (IREDA, 2012):
a) To give financial support to specific projects and schemes for generating electricity and/or energy through new and renewable sources and conserving energy through energy efficiency.

b) To maintain its position as a leading organization to provide efficient and effective financing in renewable energy and energy efficiency/conservation projects.

c) To increase IREDA’s share in the renewable energy sector by way of innovative financing.

d) Improvement in the efficiency of services provided to customers through continual improvement of systems, processes and resources.

e) To strive to be a competitive institution through customer satisfaction.

5.4.1 Policies, measures and regulations

The Government of India had tried very hard for last two decades to start solar projects but the success rate is very less. The Tenth Plan (2002–2007) targeted the installation of 5 MW of solar PV; however, only 1 MW was installed during that period. The Eleventh Plan (2008–2012) originally established a combined target of 50 MW (Planning Commission, 2012) for both solar PV and CSP, and, in spite of an INR 15 (USD 0.30) feed-in tariff over 12 years offered by MNRE, no new projects were built due to the relatively high cost (Arora, 2010). India’s current policies to promote renewable power are discussed below-

a) **JNNSM – Jawaharlal Nehru National Solar Mission** – The Jawaharlal Nehru National Solar Mission was launched on the 11th January, 2010 by the Prime Minister. The Mission has set the ambitious target of deploying 20,000 MW of grid connected solar power by 2022 is aimed at reducing the cost of solar power generation in the country through (i) long term policy; (ii) large scale deployment goals; (iii) aggressive R&D; and (iv) domestic production of critical raw materials, components and products, as a result to achieve grid tariff parity by 2022. Mission will create an enabling policy framework to achieve this objective and make India a global leader in solar energy (MNRE, 2010).
b) **State policies** – Other than these national efforts independent states are devising their own policies to promote solar energy. Various nodal agencies are formed at state level to support MNRE and IREDA.

According to MNRE annual report the ministry had taken certain initiatives so that renewable energy devices satisfy the energy needs of the people. These new initiatives include: (MNRE, 2011)

i. **Solar mission operationalised:** The Ministry issued guidelines for (i) new grid projects, (ii) small grid projects, (iii) off-grid solar applications; and (iv) technical performance and domestic content requirements of solar projects.

ii. **Ladakh Project:** This is a new Renewable Energy Initiative for this area to reduce diesel consumption. The project proposes to meet power requirements through small/micro hydel and solar photovoltaic power projects/systems, use of solar thermal systems for meeting water heating/space heating/cooking requirements and set up green houses to increase vegetable production.

iii. **Community Cookstoves Initiative:** A pilot demonstration project has been taken up to demonstrate the potential of larger efficient biomass cookstoves for community applications such as Anganwadi, Mid-day Meals in Schools, Dhabas etc. in eight identified States. The project is being implemented in association with State Nodal Agencies (SNAs) and NGOs.

iv. **BOOT model for Cogeneration Projects:** 21 Bagasse cogeneration projects have been taken up through BOOT (Build, Own, Operate, Transfer) model in cooperative sector sugar mills.

v. **Solar Cities/Green Buildings:** The Ministry operationalised the GRIHA rating scheme. Independent Society “ADARSH” established by Ministry for implementation of rating system. Ten Cities to be developed as ‘Pilot Solar Cities’, Four Cities will be developed as ‘Model Solar Cities’ and 50 new Small townships/Campuses being promoted as green Renewable Energy townships under the Solar Cities Programme.

vi. **Micro-hydel scheme:** The Ministry has sanctioned support for 3547 water mills in 9 states. So far 1414 water mills have been setup. The Ministry
also sanctioned 28 micro hydel projects (up to 100 kW) under the new scheme announced in February 2009.

vii. **Tail-end Power projects**: Tail end power plants up to 1-2 MW where power can be fed to 11 KV grid are accorded with highest priority. It is expected that this would reduce the transmission losses by 5-7%. This concept is already included in the Solar Mission.

### 5.5 Solar Energy in Maharashtra:

Among the renewable sources of energy, solar energy has a huge potential for power generation in Maharashtra. There are 250-300 days of clear sun with an available average radiation of 4 to 6 kWh/sq.meter over a day. There is a capacity to generate 1.5 million units/MW/year through solar photovoltaic systems & up to 2.5 million units/MW/ year through solar thermal systems (MEDA, 2012).

In Maharashtra, Solar Plants (900MW) are envisaged in districts of Osmanabad (360 MW), Yavatmal (150 MW), Nandurbar (150 MW) and Chandrapur (150 MW) etc. Wind Farms (11000 MW) are envisaged in districts of Sangli (2100 MW), Satara (1700 MW), Ahmadnagar (1450 MW), Kolhapur (1100 MW), Dhule/N’bar (1500 MW), Solapur (900 MW), Pune (650 MW) as well as some of the quantum in districts of Amravati, Nashik, Sindhudurg & Beed (PGCI, 2012).

#### Table 5.5

<table>
<thead>
<tr>
<th>Renewable energy source</th>
<th>Potential</th>
<th>Installed Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2009-10</td>
</tr>
<tr>
<td>Wind</td>
<td>5,439</td>
<td>2,071</td>
</tr>
<tr>
<td>Small Hydro Projects #</td>
<td>733</td>
<td>219</td>
</tr>
<tr>
<td>Bagasse co-generation</td>
<td>1,250</td>
<td>299</td>
</tr>
<tr>
<td>Biomass</td>
<td>781</td>
<td>107</td>
</tr>
<tr>
<td>Urban waste</td>
<td>287</td>
<td>0</td>
</tr>
<tr>
<td>Industrial Waste</td>
<td>350</td>
<td>11</td>
</tr>
<tr>
<td>Solar Thermal &amp;</td>
<td>35/sq.km$</td>
<td>0</td>
</tr>
<tr>
<td>Solar Photovoltaic (PV)</td>
<td>49/sq.km$</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,840</strong></td>
<td><strong>2,707</strong></td>
</tr>
</tbody>
</table>

(Source : MEDA # installed by Water Resource Department, + upto December, $ Not included in total potential)
The renewable energy potential and installed capacity of renewable energy is given in above table. Wind, solar, biomass, biogas, wave, geo-thermal, etc. are the renewable, clean & eco-friendly energy sources. Maharashtra Energy Development Agency (MEDA) is the State Govt. Institution, with the broad objective to promote, develop and diffuse knowledge in the various fields of renewable energy sources has been notified as the designated agency to co-ordinate, regulate and enforce the provisions of Energy Conservation Act, 2001 within the State. Study of table no. 5.5 clearly indicates that there is huge potential for the solar energy installation and uses of solar energy equipments in Maharashtra.

The State Government has directed Maharashtra Energy Development Agency (MEDA) to co-ordinate, regulate and enforce the provisions of Energy Conservation Act, 2001 within the State. (DES, 2012)

During XIth FYP, the sanctioned pay out and expenditure incurred was Rs. 13,660 lakhs on various schemes of renewable energy implemented by MEDA. The renewable energy potential and installed capacity of renewable energy is given in Table 5.5. Projects of 3,554 MW capacity have been installed as on 31st December, 2011 by private investors with investment of ` 19,000 crore. (DES, 2012)

Solar steam cooking system (Shirdi Saibaba Sansthan), Solar Air conditioning system (Chhatrapati Shivaji Maharaj Hospital, Kalwa, Thane) and private projects at Mahindra Vehicles Manufacturing Ltd., Chakan; Bhilwadi, Sangli & Baramati are some of the initiatives taken in the State. Six cities in the State have been approved under this scheme, of which three (Nagpur, Kalyan-Dombivli & Thane) have submitted their master plan through the grants received. Nagpur is being developed as Model Solar City under this programme. MAHAGENCO has commissioned three solar power projects of five MW capacity at Chandrapur during XIth FYP and planned projects of around 540 MW during XIIth FYP. (DES, 2012).
5.5.1 Solar Power status and plans:

- MAHAGENCO’s 1 MW Solar Photovoltaic (PV), 2 MW Solar crystalline PV and 2 MW Solar Thin film PV projects at Chandrapur have been commissioned.
- The 25 MW Solar PV project at Sakri, Dhule, is expected to be commissioned in two stages viz. 10 MW by March, 2012 and 15 MW by June, 2012. Apart from this, 125 MW Solar PV project at Shivajinagar, Sakri, Dhule is expected to be commissioned by Dec., 2012.
- Tata Power project of 3 MW at Mulshi-Pune and projects of 5 MW at Chandrapur, 2 MW at Supa-Baramati& 1 MW at Bamni-Osmanabad are the private projects completed.
- During XIIth FYP, 1,305 MW Solar projects are proposed by MAHAGENCO. (DES, 2012)

It is very clear from the above information that very less attention has been given to promote domestic uses of solar energy equipments. All the nodal agencies are working towards the generation of power as requirement of power has taken the prime place. The uses of thermal energy equipments save electrical power which can be considered equally to power generated. Photo Voltaic applications of solar energy are costlier than the thermal applications.

The following map in Figure 5.9 of solar radiations available for India shows that Maharashtra state receive very good solar radiation. Major portion of Maharashtra is shown receiving fairly good solar radiation. This means there are more clear sunny days with proper solar rays’ angle. This indicates that there is a huge potential available to exploit the use of solar energy equipments.
Figure 5.9
Solar Radiation Map for India

Global Solar Radiation Map of India
Source TERI
References:


