CHAPTER TWO
SOLAR ENERGY SYSTEM

2.1 Introduction

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis.[1]

It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power.

The large magnitude of solar energy available makes it a highly appealing source of electricity. The United Nations Development Program in its 2000 World Energy Assessment found that the annual potential of solar energy was 1,575–49,837 (EJ). This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012.[2][3]

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise.

The potential solar energy that could be used by humans differs from the amount of solar energy present near the surface of the planet because factors such as geography, time variation, cloud cover, and the land available to humans limit the amount of solar energy that we can acquire.

In addition, land availability has a large effect on the available solar energy because solar panels can only be set up on land that is otherwise unused and suitable for solar panels. Figure 2.1 shows the solar radiation.

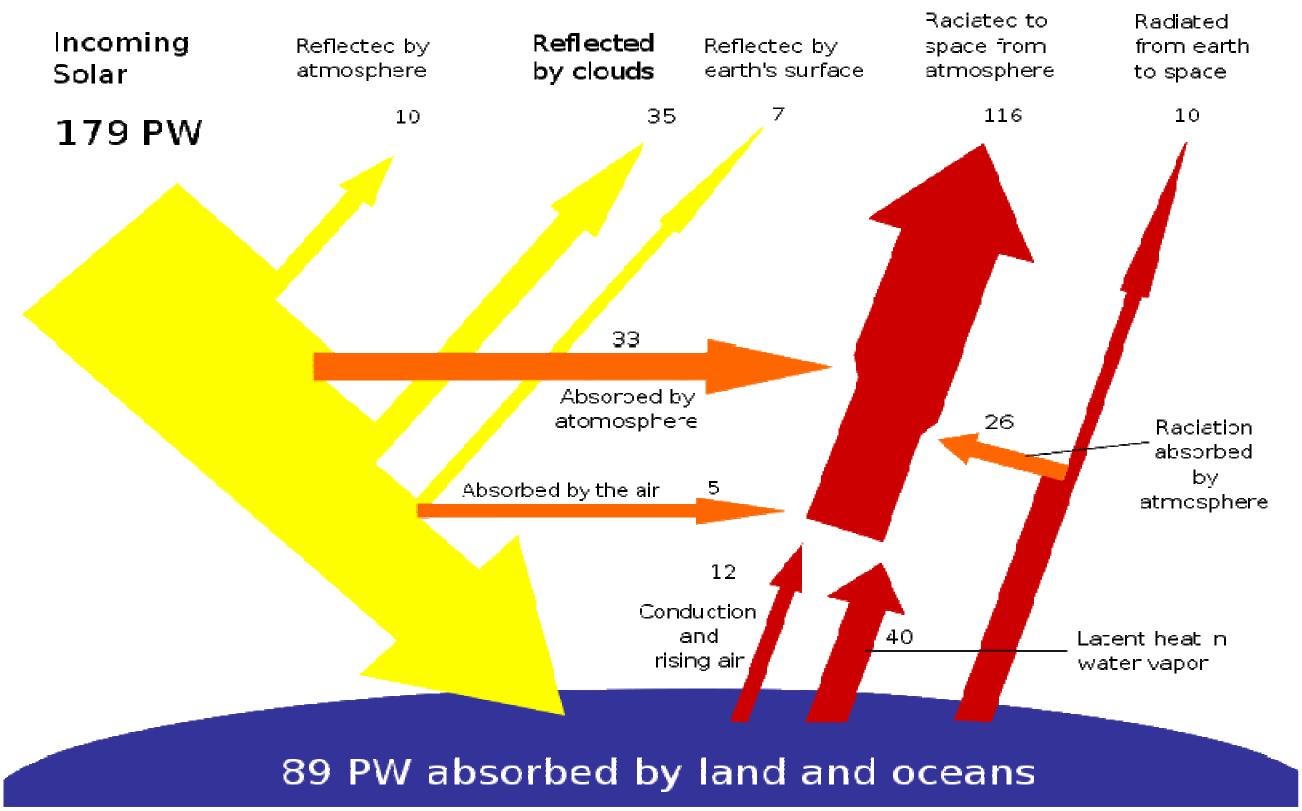

Figure 2.1: Solar radiation received by earth

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 (EJ) per year. In 2002, this was more energy in one hour than the world used in one year. Photosynthesis captures approximately 3,000 EJ per year in biomass. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined.[4]

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaic (PV), indirectly using concentrated solar power, or a combination. Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect.

Solar trackers increase the energy produced per module at the cost of mechanical complexity and increased need for maintenance. They sense the direction of the Sun and tilt or rotate the modules as needed for maximum exposure to the light.

Alternatively, fixed racks hold modules stationary throughout the day at a given tilt (zenith angle) and facing a given direction (azimuth angle). Tilt angles equivalent to an installation's latitude are common. Some systems may also adjust the tilt angle based on the time of year.

Similarly, to maximize total energy output, modules are often oriented to face south (in the Northern Hemisphere) or north (in the Southern Hemisphere). On the other hand, east- and west-facing arrays (covering an east–west facing roof, for example) may also be useful. Even though such installations might not produce the maximum possible total energy, their power output would likely be more consistent throughout the day and possibly larger during peak demand.

The price of solar electrical power has continued to fall so that in many countries it has become cheaper than ordinary fossil fuel electricity from the electricity grid since 2012, a phenomenon known as grid parity.

2.2 System Components

The solar energy components are solar panels, inverters, batteries and an auto transfer switch.

2.2.1 Solar Panels

Photovoltaic modules use light energy from the sun to generate electricity through the photovoltaic effect. Most modules use wafer-based crystalline silicon cells or thin-film cells. The structural member of a module can be either the top layer.

Figure2.2: Solar Panels

Most modules are rigid but semi-flexible ones based on thin-cells are also available. The cells are connected electrically in series, one to another to the desired voltage, and then in parallel to increase amperage. The wattage of the module is mathematical product of the voltage and the amperage of the module. The manufacture specifications on solar panels are obtained under standard condition which isn't the real operating condition the solar panels are exposed to on the installation site. [5]

Emerging, third generation solar technologies use advanced thin-film cells. They produce a relatively high-efficiency conversion for the low cost compared to other solar technologies. Also, high-cost, high-efficiency, and close-packed rectangular multi-junction (MJ) cells are preferably used in solar panels on spacecraft, as they offer the highest ratio of generated power per kilogram lifted into space. MJ-cells are compound semiconductors and made of gallium arsenide and other semiconductor materials. Another emerging PV technology using MJ-cells is concentrator photovoltaics (CPV).

There are many practical applications for the use of solar panels or photovoltaic. It can first be used in agriculture as a power source for irrigation. In health care solar panels can be used to refrigerate medical supplies. It can also be used for infrastructure.

Most solar modules are currently produced from crystalline silicon. In 2013 crystalline silicon accounted for more than 90 percent of worldwide PV production, while the rest of the overall market is made up of thin-film technologies using cadmium telluride, CIGS and amorphous silicon.[6]

Flexible thin film cells and modules are created on the same production line by depositing the photoactive layer and other necessary layers on a flexible substrate. If the substrate is an insulator (e.g. polyester or polyimide film) then monolithic integration can be used. If it is a conductor then another technique for electrical connection must be used. The cells are assembled into modules by laminating them to a transparent colourless fluoropolymer on the front side and a polymer suitable for bonding to the final substrate on the other side.

Figure 2.3 shows a comparison between the most common types of solar panels.

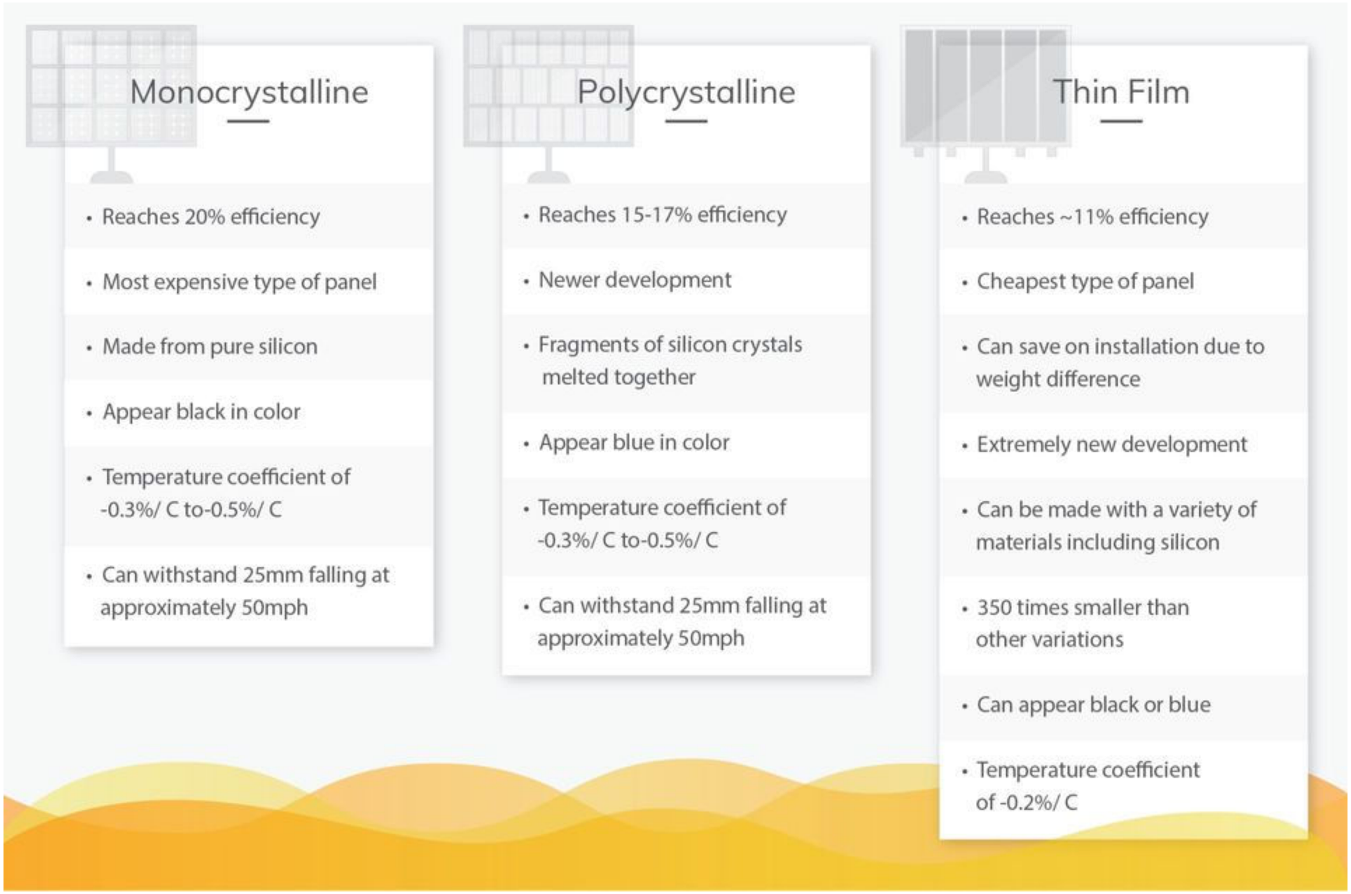

Figure 2.3: Comparison between three types of panels

The best type of solar panels depends on the purpose of the panels and where they'll be installed. For residential properties with a large roof space or property, the best choice of panels may be polycrystalline. These panels are the most affordable for large spaces and will provide enough efficiency and power. For residential properties with smaller spaces, monocrystalline may be the best choice. These panels work well for those who want to maximize their energy bills in a small space. Monocrystalline and polycrystalline panels are good fits for homes and other similar buildings. Thin-film solar panels are almost never used on homes because they are lower in efficiency. Instead, thin-film solar panels are perfect for commercial buildings that can't handle the additional weight of traditional panels. Though thin-film is less efficient, commercial roofs have more space to cover more of the roof with panels.

2.2.2 Inverters

A power inverter is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC).[7]

The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter dose not produces any power; the power is provided by the DC source.

Figure 2.4: Inverter

A power inverter can be entirely electronic or may be a combination of mechanical effects and electronic circuitry. Static inverters do not use moving parts in the conversation process.

Power inverters are primarily used in electrical power application where a high currents and voltages are present; circuits that perform the same function for electronic signals which usually have very low currents and voltages are called oscillators. Circuits that perform the opposite function, converting AC to DC, are called rectifiers.

2.2.3 Electric Batteries

A battery is a device consisting of one or more electrochemical cells to external connections for powering electrical devices such as flashlights, mobile phones and electric cars. When a battery is supplying electric power, its positive terminal is cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through external electric circuits to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high energy reactants to lower energy products, and the free energy difference is delivered to the external circuit as electrical energy.

Historically the term (battery) specifically referred to a device composed of multiple cells; however the usage has evolved to include devices composed of a single cell.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones, to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers.

Figure 2.5 shows a group of connected batteries forming a battery bank.


Figure 2.5: battery management for large scale energy storage

A battery capacity is the amount of electric charge it can deliver at the rated voltage. The more electrode material contained in the cell the greater its capacity. A small cell has less capacity than a larger cell with the same chemistry, although they develop the same open circuit voltage.

Capacity is measured in units such as amp-hour. The rated capacity of a battery is usually expressed as the product of 20 hours multiplied by the current that a new battery can consistency supply for 20 hours at 20C, while remaining above a specified terminal voltage per cell.

2.2.4 Auto Transfer Switch (ATS)

A transfer switch is an electrical switch that switches a load between two sources. Some transfer switches are manual, in that an operator affects the transfer by throwing a switch, while others are automatic and trigger when they sense one of the sources has lost or gained power.

An automatic transfer switch (ATS) is often installed where a backup generator is located, so that the generator may provide temporary electrical power if the utility source fails. Figure 2.6 shows a transfer switch.

Figure 2.6: Intelligent Transfer Switch

For example, in a home equipped with a backup generator and an ATS, when an electric utility outage occurs, the ATS will tell the backup generator to start. Once the ATS sees that the generator is ready to provide electric power, the ATS breaks the home's connection to the electric utility and connects the generator to the home's main electrical panel. The generator supplies power to the home’s electric load, but it is not connected to the electric utility lines.

2.3 Operation

Figure 2.7 shows the components of a solar power plant.

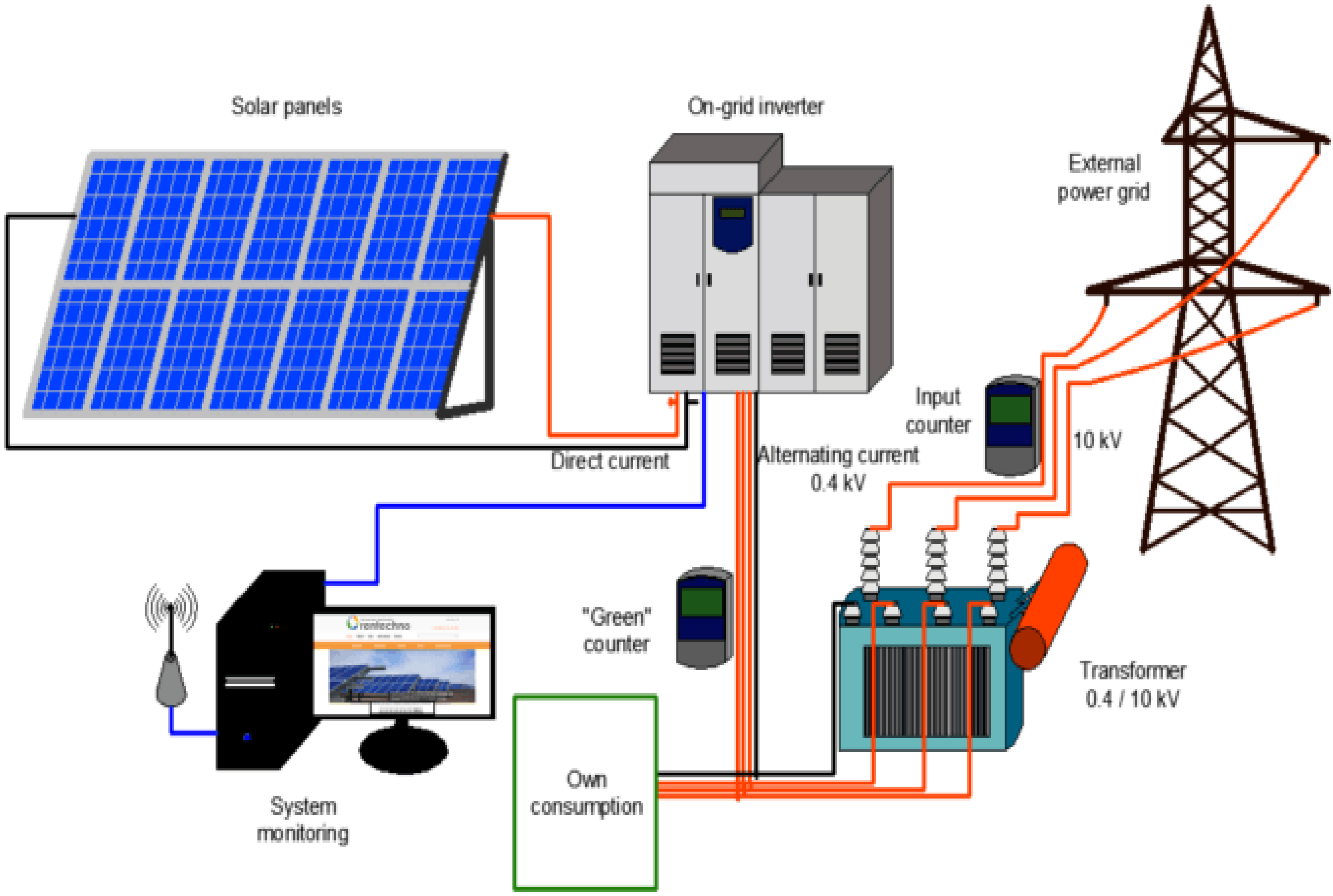

Figure 2.7: Solar Power Plant

Solar PV power plants work in the same manner as small domestic-scale PV panels or the tiny one on your calculator but on steroids.

When photons from sunlight hit the semiconductor material free electrons are generated which can then flow through the material to produce a direct electrical current.

The DC current then needs to be converted to alternating current (AC) using an inverter before it can be directly used or fed into the electrical grid.

PV panels are distinct from other solar power plants as they use the photo-effect directly without the need for other processes or devices. For example, no liquid heat-carrying agent, like water, is needed as in solar thermal plants.

PV panels do not concentrate energy they simply convert photons into electricity that is then transmitted somewhere else.