Section One: Solar Energy

1. What Is Solar Energy?

Solar energy is energy that comes from radiation emitted by the Sun. It can be converted into electricity or heat using different technologies.

Photovoltaics (PV) converts sunlight directly into electrical energy. When light particles (photons) strike a solar cell, electrons move and create a current.

Why it's green:

- Solar energy is a renewable energy source because sunlight is naturally replenished.
- It produces electricity without burning fuel, so it reduces greenhouse gas emissions.

2. How Photovoltaic Cells Work

Important Terms

- Photon — A particle of light energy.
- Semiconductor — Material (like silicon) that controls electron flow.
- Electric field — Pushes electrons in one direction.

3. Main Components of a Solar Power System to generate electricity

Solar Panels

- Made from many PV cells connected together.
- Convert sunlight into DC electricity.

Inverter

- Converts DC electricity to AC electricity.
- Essential for household use and grid connection.

Battery (Optional)

- Stores excess electricity for use at night or during cloudy periods.

Mounting & Wiring

- Panels are angled toward the sun for maximum efficiency.

4. Types of Solar Energy Technologies

Photovoltaic (PV)

- Generates electricity directly.
- Used in homes, solar farms, and small devices.

Solar Thermal

- Uses sunlight to produce heat.
- Example: Solar water heaters.

Concentrated Solar Power (CSP)

- Uses mirrors to focus sunlight to create steam and drive turbines.

5. Advantages of Solar Energy

✅ Renewable and abundant
✅ Low greenhouse gas emissions
✅ Reduces electricity bills
✅ Scalable (small rooftops → large solar farms)

Extra Insight:

- After installation, operating costs are relatively low.
- Can increase energy independence.

6. Disadvantages and Challenges

⚠️ Weather dependent — output drops in cloudy conditions
⚠️ High initial installation cost
⚠️ Requires space and sunlight exposure
⚠️ Energy storage may be needed

7. Efficiency and Performance Factors

Solar panel performance depends on:

- Sunlight intensity
- Panel angle and orientation
- Temperature (very high heat reduces efficiency)
- Shading
- Panel type

Typical efficiency:

- Residential panels: about 15 to 23%

8. Solar Energy and the National Grid

Electricity must be converted to AC to enter the grid.

Why AC?

- Power stations and appliances operate using alternating current.
- AC travels long distances more efficiently.

Grid Integration Concepts

- Net metering: exporting extra electricity.
- Smart grids: balancing supply and demand.

9. Environmental Impact

Positive:

- Reduces carbon emissions.
- Minimal air pollution.

Considerations:

- Manufacturing panels uses energy and materials.
- Recycling panels is an emerging issue.

10. Solar energy systems used for heating water

Rooftop Solar Water Heater Systems

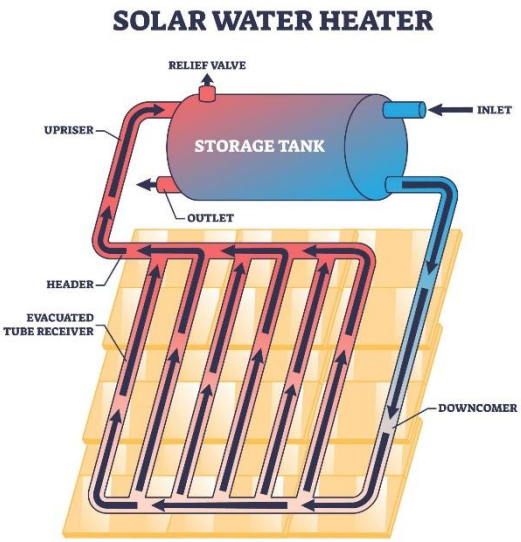
These systems are common on houses. The flat panels absorb heat from sunlight, warming water that flows into a storage tank.

How it works

- Sunlight heats the collector panel.
- Water (or heat-transfer fluid) inside pipes warms up.
- Hot water rises into a tank and is stored for home use.

👉 Many homes use **non-concentrating collectors** mounted at an angle to capture sunlight efficiently.

Solar Water Heating System Diagrams (How Heat Moves)



Typical components including

- Solar collector
- Circulating pump
- Heat exchanger
- Storage tank
- Pipes carrying hot and cold water

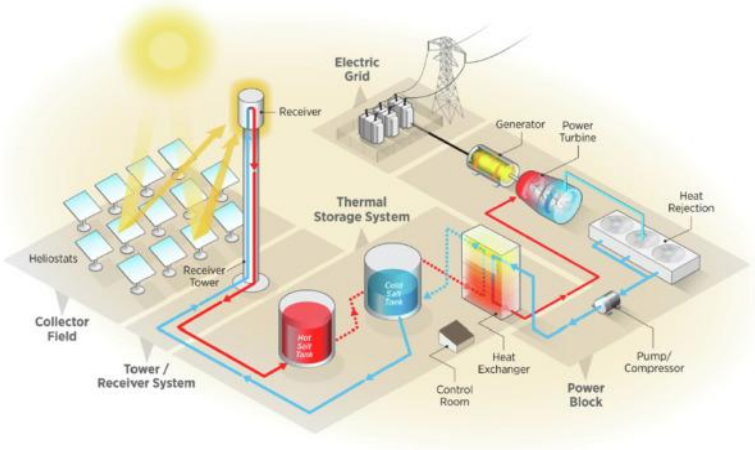
Solar collectors absorb heat and transfer it to water or fluid, which circulates to a tank for later use.

✅ **Quick Study Tip:**

Solar panels that make electricity are called *photovoltaic (PV)* panels, but the ones in these images are **solar thermal collectors** — they produce **heat**, not electricity.

11. Concentrated Solar Power (CSP) systems

Solar Power Tower (Heliostat CSP)



These images show a **solar power tower**, one of the most common CSP designs.

What you're seeing

- Thousands of mirrors (called *heliostats*) reflect sunlight toward a receiver at the top of a tower.
- The intense heat produces steam that spins a turbine to generate electricity.

📚 Study note:

- Power towers often use **molten salt** to store heat, allowing electricity production even after sunset.

🔆 Parabolic Trough CSP Plants

These long-curved mirrors are called **parabolic trough collectors**.

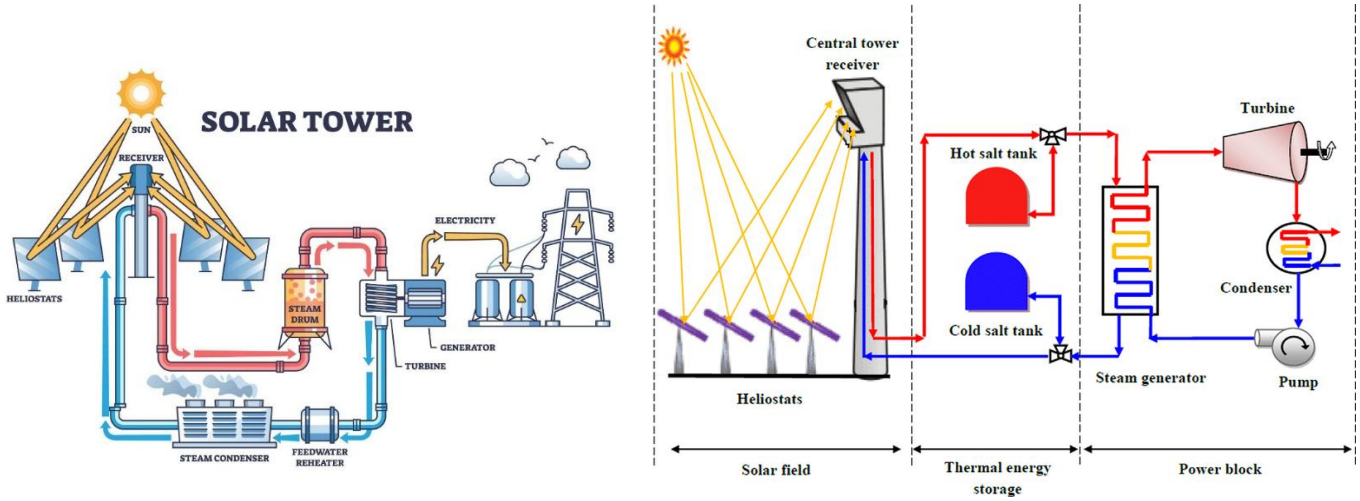
Key features

- Curved mirrors focus sunlight onto a pipe (receiver tube).
- A heat-transfer fluid inside the pipe absorbs heat and produces steam.

📚 Study note:

- This is one of the oldest and most widely used CSP technologies worldwide.

🧿 CSP System Diagram (How It Works)



Main parts of CSP

- Heliostats (mirrors)
- Receiver
- Heat transfer fluid
- Steam turbine
- Generator

The mirrors concentrate sunlight onto a receiver, where heat is collected and converted into electricity through a turbine system.

What Happens to the Heat in CSP?

CSP systems use mirrors to concentrate sunlight into **very high temperatures** (often 400 °C to 1000 °C depending on the design). That thermal energy can be used in several ways:

a. Generating Electricity (Most Common Use)

- The heat boils water → creates steam → spins a turbine → generates electricity.
- This is similar to coal, gas, or nuclear plants — except the heat source is sunlight.

So electricity is basically a secondary product of the heat.

b. Thermal Energy Storage (Heat Stored for Later)

One of CSP's biggest advantages is that the heat can be stored.

- Many CSP plants use molten salt tanks.
- The hot salt stores thermal energy for hours after sunset.
- Later, the stored heat produces steam to keep electricity flowing at night.

This makes CSP different from photovoltaic (PV) solar panels, which stop producing when the sun goes down.

c. Industrial Heat Applications

The high temperatures from CSP can be used directly without converting to electricity.

Examples:

- Steel or cement production
- Chemical manufacturing
- Oil refining
- Food processing (drying, pasteurisation)

Industries need large amounts of heat, so CSP can replace fossil-fuel burners.

d. Desalination & Water Treatment

In hot regions, CSP heat can power:

- Seawater desalination
- Distillation systems
- Water purification

e. District Heating (Less Common but Possible)

Some CSP projects use heat for:

- Heating buildings
- Providing hot water to communities

This is similar to solar thermal heating but at a much larger scale.

👉 CSP produces heat first — electricity is just one use of that heat.

You can remember it like this:

- CSP = Sunlight → Heat → (Electricity OR Direct Heat Uses)
- PV panels = Sunlight → Electricity directly

✅ Quick revision tip:

- CSP uses heat from concentrated sunlight.
- Solar panels (PV) use light to make electricity directly.