

# PROFESSIONAL TRAINING REPORT

Sathyabama Institute of Science and Technology

(Deemed to be University)



## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

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VATIO®

# Certificate

## OF INDUSTRY INTERNSHIP

This is to certify that

**MATHESH A**

Studying 3rd Year, B.E. EEE in SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY  
has successfully completed the Industry Internship Programme at VATIO Energy India Pvt Ltd, Chennai  
through Online from 21<sup>st</sup> July to 05<sup>th</sup> August 2021 in the area of  
"Solar Photovoltaic system & its Design Practices"

Best wishes from VATIO Energy for future endeavors !



G. Rajaganesan, Director - Technical  
VATIO Energy India Pvt Ltd.



05<sup>th</sup> August 2021

Date

# SOLAR ENERGY

## Definition

- Solar energy is the energy obtained by capturing heat and light from the Sun.
- Energy from the Sun is referred to as solar energy. Technology has provided a number of ways to utilize this abundant resource.
- It is considered a green technology because it does not emit greenhouse gases.

Solar energy is abundantly available and has been utilized since long both as electricity and as a source of heat



## Classification

### Active Solar:

Active solar techniques include the use of

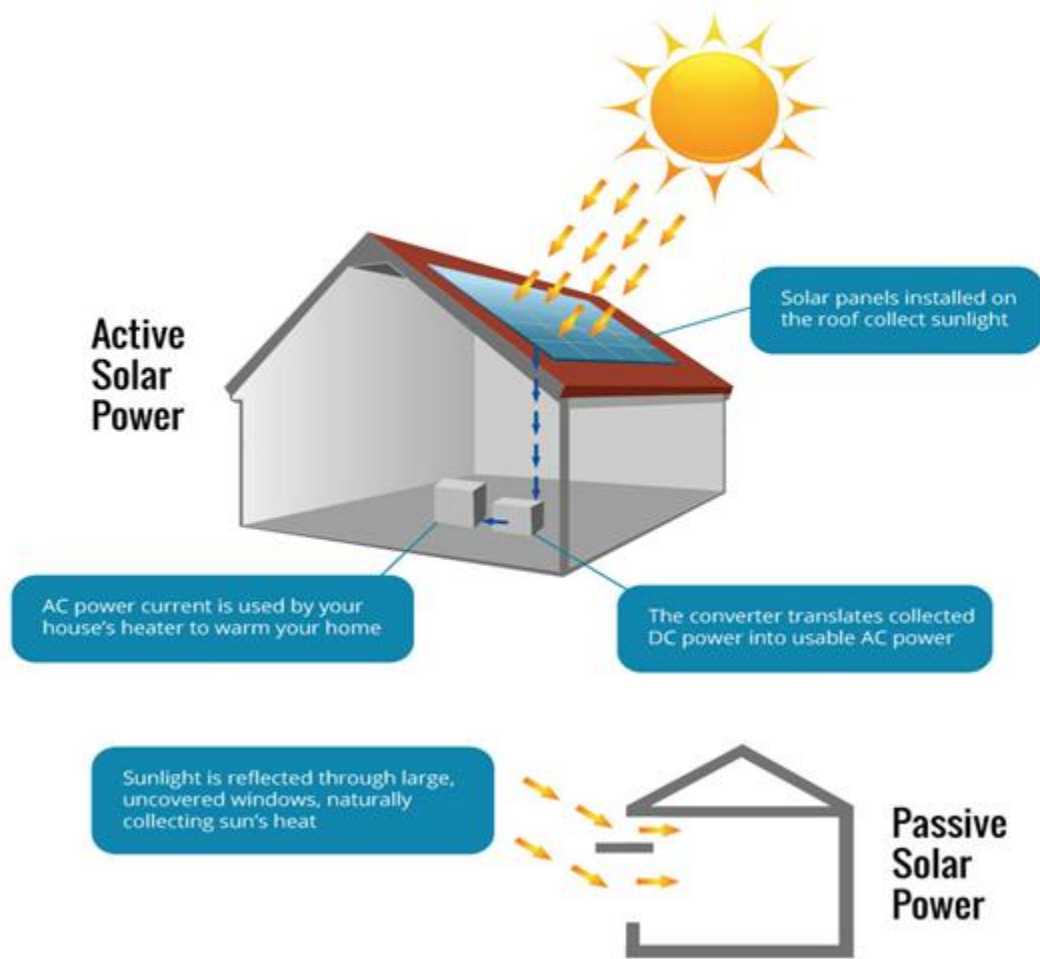
- Photovoltaic systems
- Concentrated solar power
- Solar water heating to harness the energy.
- Active solar is directly consumed in activities such as drying clothes and warming of air.

### **Passive Solar:**

Passive solar techniques includes

- Orienting a building to the Sun
- Selecting materials with favourable thermal mass or light-dispersing properties
- Designing spaces that naturally circulate air.

## Active and Passive Solar system



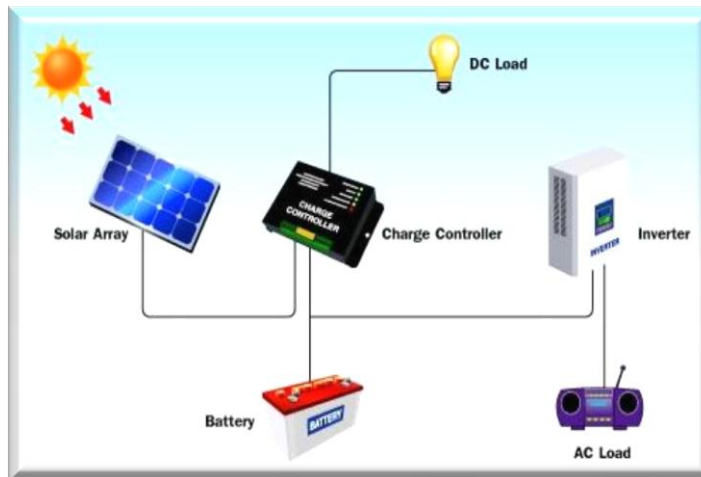
## Conversion of Solar Energy

There are two conversion methods

- (i) Solar Photovoltaic
- (ii) Solar Thermal

**Solar Photovoltaic:**

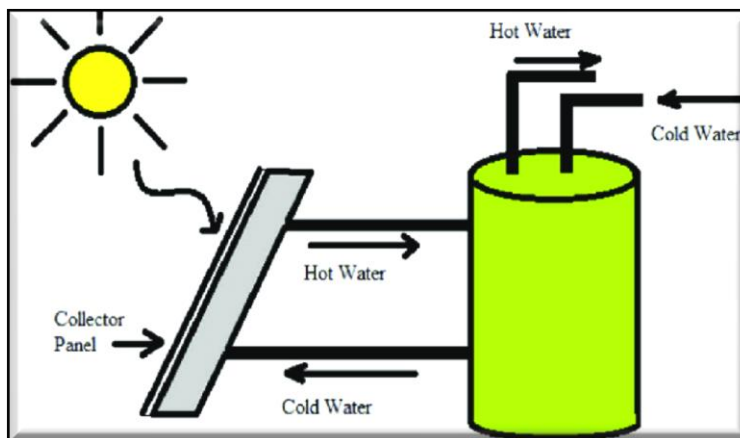
- (i) The method of obtaining electricity from sunlight is referred to as the Photovoltaic method.
- (ii) This is achieved using a semiconductor material.



### **Solar Thermal:**

The other form of obtaining solar energy is from heat produced by sun, which give two forms of energy tapping methods.

- The first is solar concentration - to drive thermal turbines.
- The second method is heating and cooling systems

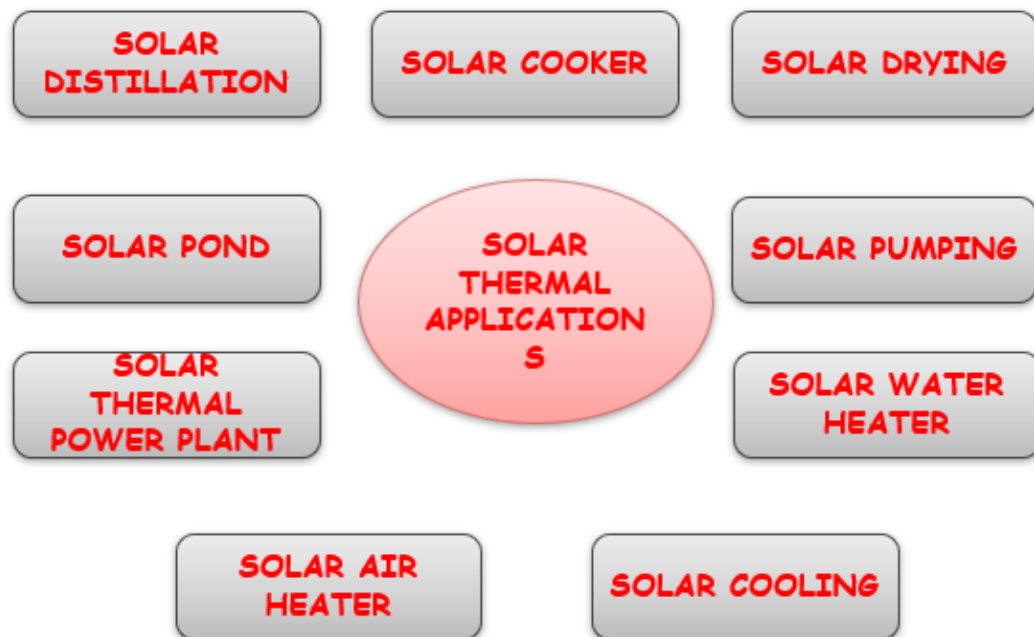


## Applications

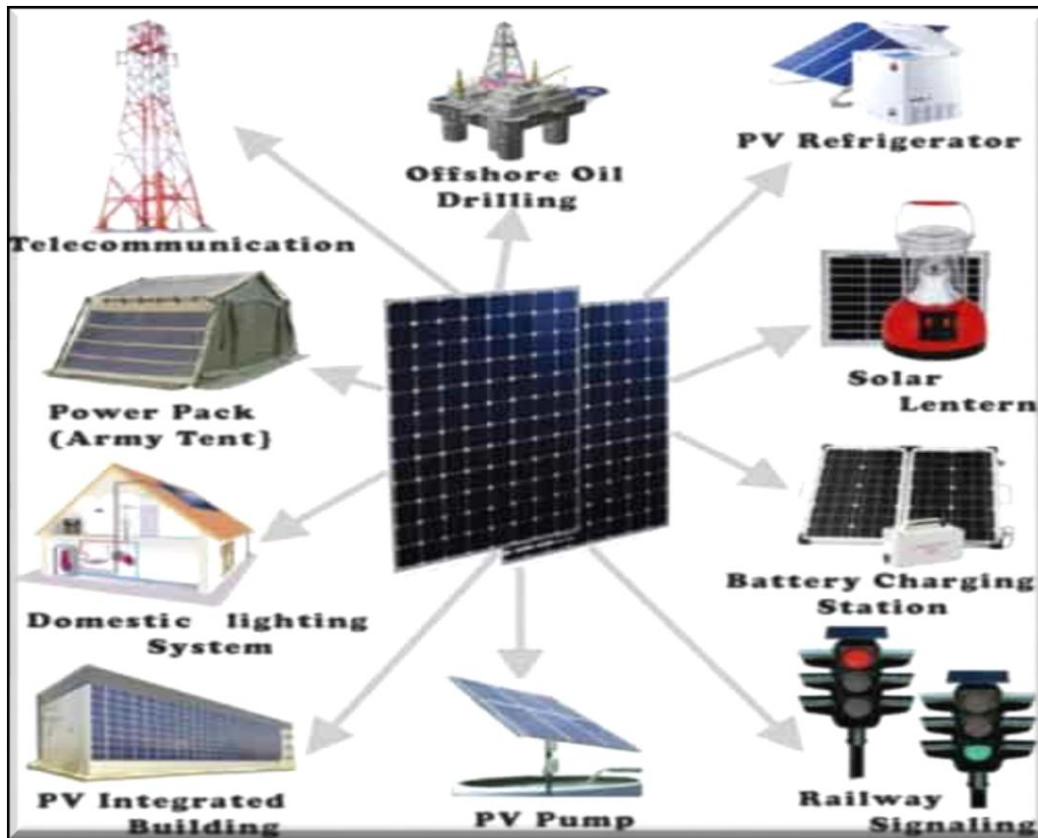
Solar collector which are widely used for

- Domestic household
- Hot-water heating and
- Space heating

## Applications - Solar thermal



## Applications - Solar Photovoltaic



## Solar photovoltaic system design

Solar photovoltaic system or Solar power system is one of renewable energy system which uses PV modules to convert sunlight into electricity. The electricity generated can be stored or used directly, fed back into grid line or combined with one or more other electricity generators or more renewable energy source. Solar PV system is very reliable and

clean source of electricity that can suit a wide range of applications such as residence, industry, agriculture, livestock, etc.

Solar PV system includes different components that should be selected according to your system type, site location and applications. The major components for solar PV system are solar charge controller, inverter, battery bank, auxiliary energy sources and loads (appliances). PV Modules: Converts sunlight into DC electricity. Solar Charge Controller: Regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life. Inverter: Converts DC output of PV panels or wind turbine into a clean AC current for AC appliances or fed back into grid line. Battery: Stores energy for supplying to electrical appliances when there is a demand.

**Inverter sizing:** An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery. For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting. For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for

safe and efficient operation.i.e. Total watt of all appliances =  $18+60+75 = 153\text{W}$ .For safety it should be 25-30% more. So the value of inverter rating is 190W

- Inverter efficiency for state-of-the art brand products is 98% and higher.
- The market share of string inverters is estimated to be 64%. These inverters are mostly used in residential, small and medium commercial applications in PV systems up to 150 kWp. The market share of central inverters, with applications mostly in large commercial and utility-scale systems, is about 34%.

A small proportion of the market (about 1%) belongs to micro-inverters (used on the module level). The market share for DC / DC converters, also called "power optimizers", is estimated to be 5% of the total inverter market.

- Trends: Digitalisation, Repowering, new features for grid stabilization and optimization of self- consumption; storage; utilization of innovative semiconductors (SiC or GaN) which allow very high efficiencies and compact designs; 1500 V maximum DC string voltage.

## **Solar PV Technology Basics**

Solar cells, also called photovoltaic cells, convert sunlight directly into electricity. Photovoltaics (often shortened as PV)

gets its name from the process of converting light (photons) to electricity (voltage), which is called the *photovoltaic effect*. This phenomenon was first exploited in 1954 by scientists at Bell Laboratories who created a working solar cell made from silicon that generated an electric current when exposed to sunlight. Solar cells were soon being used to power space satellites and smaller items such as calculators and watches. Today, electricity from solar cells has become cost competitive in many regions and photovoltaic systems are being deployed at large scales to help power the electric grid.

### **Silicon Solar Cells**

The vast majority of today's solar cells are made from silicon and offer both reasonable prices and good efficiency (the rate at which the solar cell converts sunlight into electricity). These cells are usually assembled into larger modules that can be installed on the roofs of residential or commercial buildings or deployed on ground-mounted racks to create huge, utility-scale systems.

- Material usage for silicon cells has been reduced significantly during the last 16 years from around 16 g/Wp to about 3 g/Wp due to increased efficiencies, thinner wafers and diamond wire sawing as well as larger ingots.
- The Energy Payback Time of PV systems is dependent on the geographical location: PV systems in Northern Europe need around 1.2 years to balance the input energy, while PV systems in the South equal their energy input

after 1 year and less, depending on the technology installed and the grid efficiency.

- A PV system located in Sicily with wafer-based Silicon modules has an Energy Payback Time of around one year. Assuming 20 years lifespan, this kind of system can produce twenty times the energy needed to produce it.

### Thin-Film Solar Cells

Another commonly used photovoltaic technology is known as thin-film solar cells because they are made from very thin layers of semiconductor material, such as cadmium telluride or copper indium gallium diselenide. The thickness of these cell layers is only a few micrometers—that is, several millionths of a meter.

Thin-film solar cells can be flexible and lightweight, making them ideal for portable applications—such as in a soldier's backpack—or for use in other products like windows that generate electricity from the sun. Some types of thin-film solar cells also benefit from manufacturing techniques that require less energy and are easier to scale-up than the manufacturing techniques required by silicon solar cells.

### III-V Solar Cells

A third type of photovoltaic technology is named after the elements that compose them. III-V solar cells are mainly constructed from elements in Group III—e.g., gallium and indium—and Group V—e.g., arsenic and antimony—of the

periodic table. These solar cells are generally much more expensive to manufacture than other technologies. But they convert sunlight into electricity at much higher efficiencies. Because of this, these solar cells are often used on satellites, unmanned aerial vehicles, and other applications that require a high ratio of power-to-weight.

### **Next-Generation Solar Cells**

Solar cell researchers at NREL and elsewhere are also pursuing many new photovoltaic technologies—such as solar cells made from organic materials, quantum dots, and hybrid organic-inorganic materials (also known as perovskites). These next-generation technologies may offer lower costs, greater ease of manufacture, or other benefits. Further research will see if these promises can be realized.

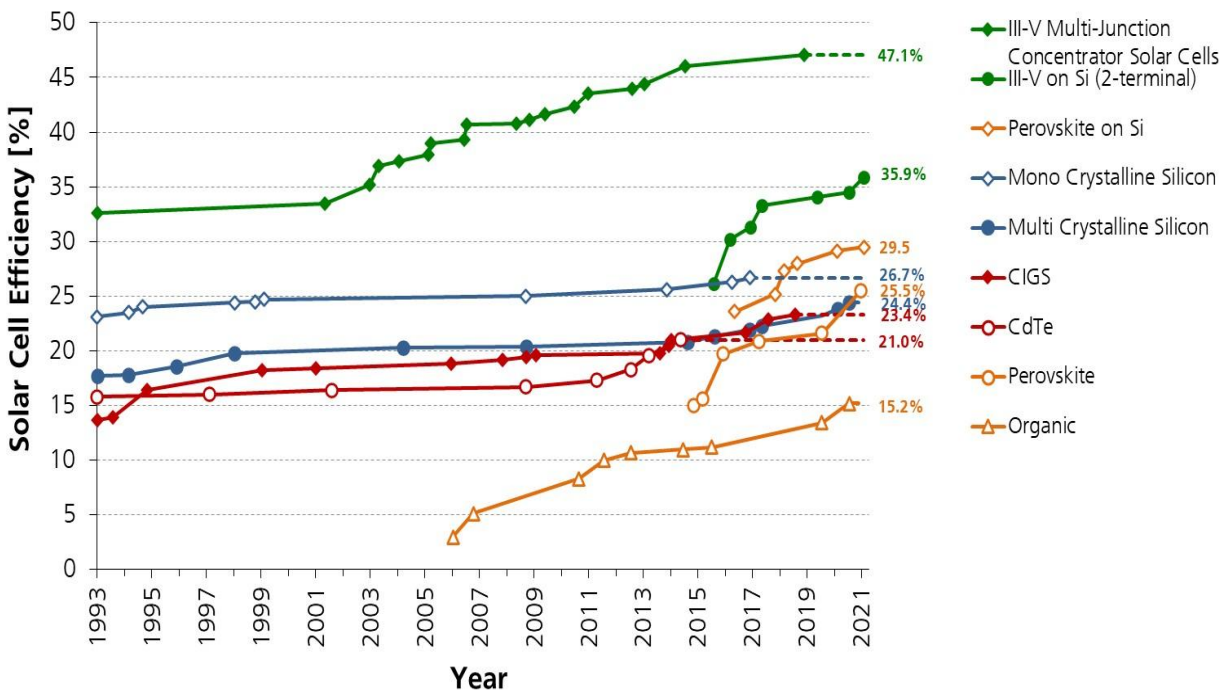
### **Solar Cell Types**

A solar cell (also called photovoltaic cell or photoelectric cell) is a solid state electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage or resistance, vary when exposed to light.

The following are the different types of solar cells.

- Copper indium gallium selenide solar cells (CI(G)S)
- Crystalline silicon solar cell (c-Si)
- Float-zone silicon

- Dye-sensitized solar cell (DSSC)
- Gallium arsenide germanium solar cell (GaAs)
- Hybrid solar cell



### PV Market: Global

- Photovoltaics is a fast-growing market: The Compound Annual Growth Rate (CAGR) of cumulative PV installations including off-grid was 34% between year 2010 to 2020.
- In year 2020 producers from Asia count for 95% of total c-Si PV module production. China (mainland) holds the

lead with a share of 67%. Europe contributed with a share of 3%; USA/CAN with 2%.

- Wafer size increased enabling larger PV module size allowing a power range from +600 W per module.
- In 2020, Europe's contribution to the total cumulative PV installations amounted to 22% (compared to 24% in 2019). In contrast, installations in China accounted for 33% (same value as the year before).
- Si-wafer based PV technology accounted for about 95% of the total production in 2020. The share of mono-crystalline technology is now about 84% (compared to 66% in 2019) of total c-Si production.
- Market shifts from subsidy driven to competitive pricing model (Power Purchase Agreements PPA).

### **Solar Cell / Module Efficiencies**

- The record lab cell efficiency is 26.7% for mono-crystalline and 24.4% for multi-crystalline silicon wafer-based technology. The highest lab efficiency in thin film technology is 23.4% for CIGS and 21.0% for CdTe solar cells. Record lab cell efficiency for Perovskite is 25.5%.
- In the last 10 years, the efficiency of average commercial wafer-based silicon modules increased from about 15% to 20%. At the same time, CdTe module efficiency increased from 9% to 19%.

■ In the laboratory, best performing modules are based on mono-crystalline silicon with 24.4% efficiency. Record efficiencies demonstrate the potential for further efficiency increases at the production level.

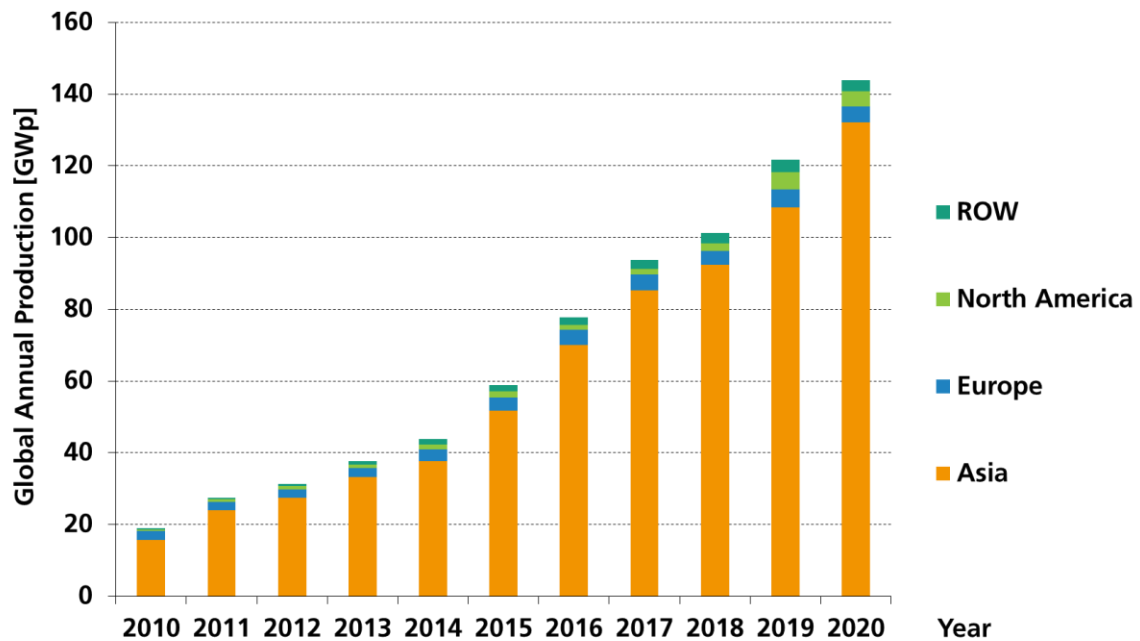
■ In the laboratory, high concentration multi-junction solar cells achieve an efficiency of up to 47.1% today. With concentrator technology, module efficiencies of up to 38.9% have been reached.

### **Price Development**

- In Germany prices for a typical 10 to 100 kWp PV rooftop-system were around 14,000 €/kWp in 1990. At the end of 2020, such systems cost only 7.4% of the price in 1990. This is a net-price regression of about 92% over a period of 30 years.

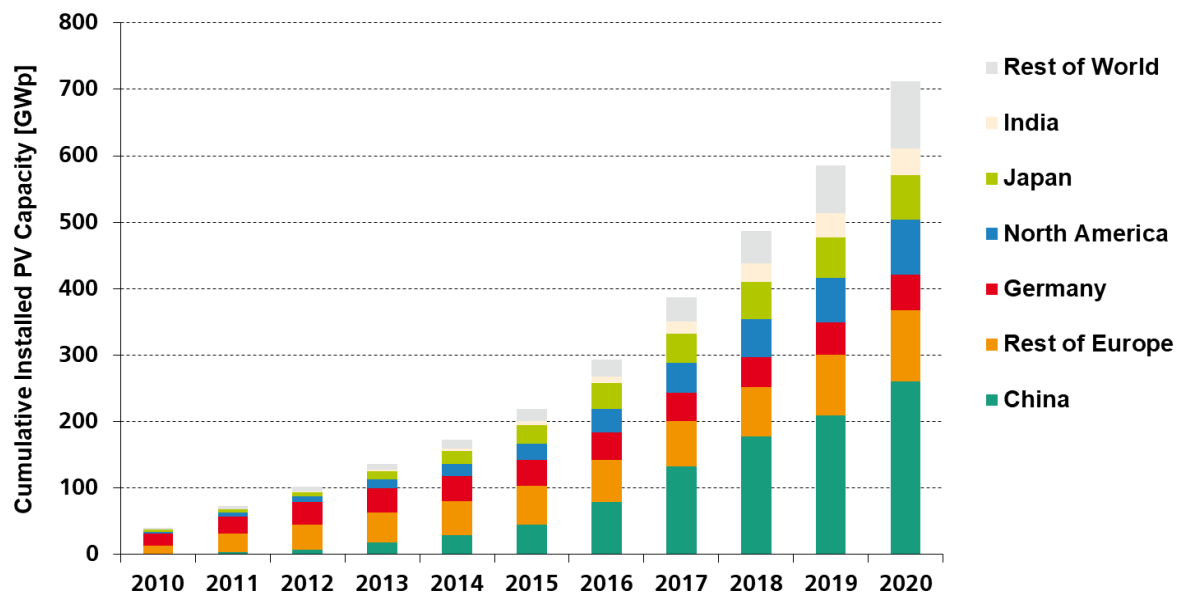
The Experience Curve - also called Learning Curve - shows that in the last 40 years the module price decreased by 26% with each doubling of the cumulated module production. Cost reduction results from economies of scale and technological improvements

## Global Annual Production



About 82% of the global PV module production was from Asia in year 2010. It increased to about 92% of total global production in year 2020. The annual production has increased by a factor of 7 in this decade.

## Global Cumulative PV Installation From 2010 to 2020



## Price Development

- Electricity costs
- Market incentives in Germany
- Costs for PV systems
- Price Learning Curve

## Further Reading References:

- [ISE EnergyCharts](#)
- [Study: Levelized Cost of Electricity - Renewable Energy Technologies](#)
- [Recent facts about photovoltaics in Germany](#)
- [Power Generation from Renewable Energy in Germany](#)
- [What will the Energy Transformation Cost? Pathways for Transforming the German Energy System by 2050](#)
- [Sustainable PV Manufacturing in Europe –An Initiative for a 10 GW GreenFab](#)
- [Meta Study: Future Crosssectoral Decarbonization Target Systems in Comparison to Current Status of Technologies](#)
- [Study: Current Status of Concentrator Photovoltaic \(CPV\) Technology](#)