Ministry Republic of Iraq of Higher Education
And Scientific Research
University of Babylon
Faculty of Engineering Al-Musayab
Energy Engineering Department

Optimization Of solar Energy System Selection Which Available In Iraqi Markets

By:
Harth Kareem Abbas
Mohammed Yaaqoub Abd_Ziad
Alwed Haider Abdollwahed Oraibi
Ruqaya Rahman Jabal

Supervised By:

Lecturer. Ahmed Reyadh

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Abstract

Solar energy refers to the energy collected directly from sunlight. Solar power is the conversion of sunlight into electricity, referred to as photovoltaics. Photovoltaic systems are already an important part of our lives, powering many of the small calculators and wrist watches we use every day.

Over the last few decades, the developments in solar energy applications have made it possible to use solar energy for most of our energy needs. At present, solar energy applications are well developed for heating and cooling of buildings, electricity production for stationary and mobile applications, and for environmental cleanup.

Solar technologies are broadly categorized as either passive or active, depending on how they capture, convert, and distribute sunlight. Passive solar technologies involve selection of materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of building the sun. Active solar technologies make use of photovoltaic panels, pumps, and fans to convert sunlight into useful outputs.

The research is concentrated on investigating of solar energy system at the Iraqi market and collect information regarding prices and supplied of the current at night and the day, and the warranty, and the expected lifetime of the system, and other specifications.

A questionnaire was performed to detect the alternatives evaluation criteria and their weights. Relative importance index was adopted for calculation of criteria weights.

Combinative Distance – based Assessment (CODAS) was adopted as a multi criteria optimization method for alternatives ranking. This method is ranking the alternatives depending on the Euclidean and Taxicab distance from the negative ideal solution.

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1.1 Introduction to Renewable Energy

Solar energy conversion is one of the most addressed topics in the field of renewable energy. Solar radiation is usually converted into two forms of energy: thermal and electrical energy. Solar electricity has applications in many systems such as rural electricity, water pumping, and satellite communications. A solar power system consists of solar panels, dc-dc converters, controller, and load. Charging a rechargeable battery requires a regulated dc voltage. However, the voltage supplied by a solar panel can vary significantly depending upon the day, time, weather condition, and irradiation from the sun. Since solar power is unregulated, it cannot be supplied to the load directly. Solar power is harvested and stored by charging rechargeable batteries. A dc-dc converter is connected between the solar panel and the battery to charge the battery with a regulated voltage. Therefore, solar power can be properly converted and controlled to provide required electrical power to the load, and excessive power can be sent back to the electrical grid.

1.2 Global energy and electricity consumption

Global energy consumption for 2018 was 161,248 TWh/year (British Petroleum - Annual Report 2019), while global electricity consumption in particular for 2017 was 25,721 TWh/year (IEA Report – 2017).

1.2.1 Share of renewable energy in total global energy consumption in 2018

According to the International Energy Agency, renewable energies accounted for about 17.9% of total primary energy supply in 2018, while the share of fossil fuels reached 79.9%. figure (1 – 1)

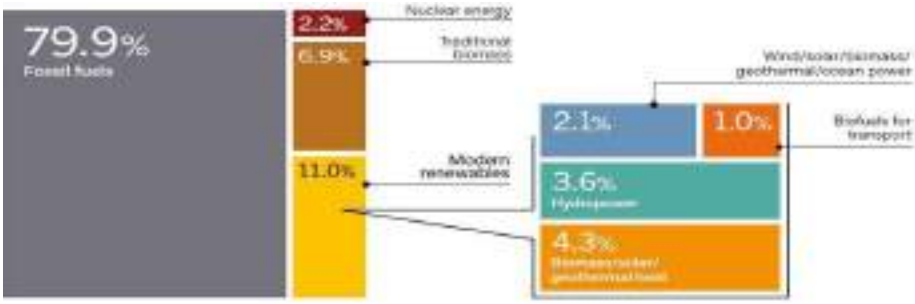

Figure (1 – 1) estimated renewable share of total final energy consumption (2018)

1.2.2 Share of renewable energy in total electricity consumption in 2019

In 2019, renewable energies contributed 27.3% of the total electricity generated around the world, and it is clear from the graph below that the largest share was hydropower with 15.9% generation, followed by wind energy with 5.9%, and solar energy with 2.8%. figure (1 – 2)

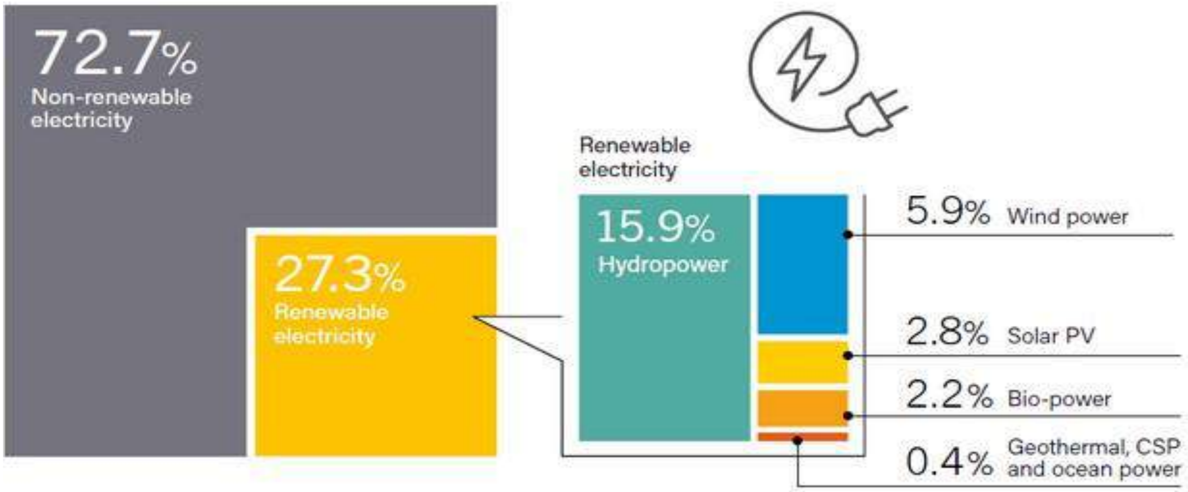

Figure (1 – 2) estimated renewable share of global electricity production, (end of 2019)

1.2.3 Installed renewable energy capacity around the world during the years 2013-2019

In the past years, installed capacity of renewable energy has witnessed significant growth, as the total installed capacity during 2019 reached more than 200 GW around the world, where the largest share of installed capacity was for photovoltaic energy, followed by wind and hydropower. Figure (1 – 3)

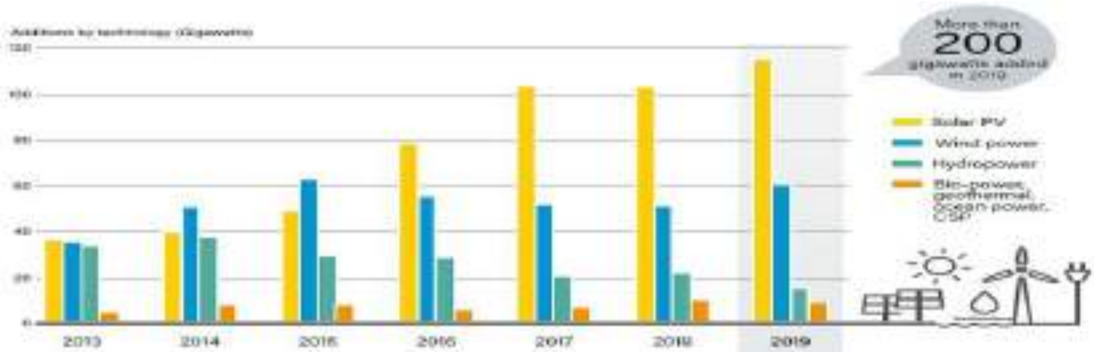

Figure (1 – 3) annual additions of renewable power capacity by technology 2013-2019

1.2.4 Renewable energy share of installed capacity globally in 2019

Renewable energy systems outperformed non-renewable systems in 2019 at the installation level, with 75% of the total installed renewable energy systems around the world. Figure (1-4)

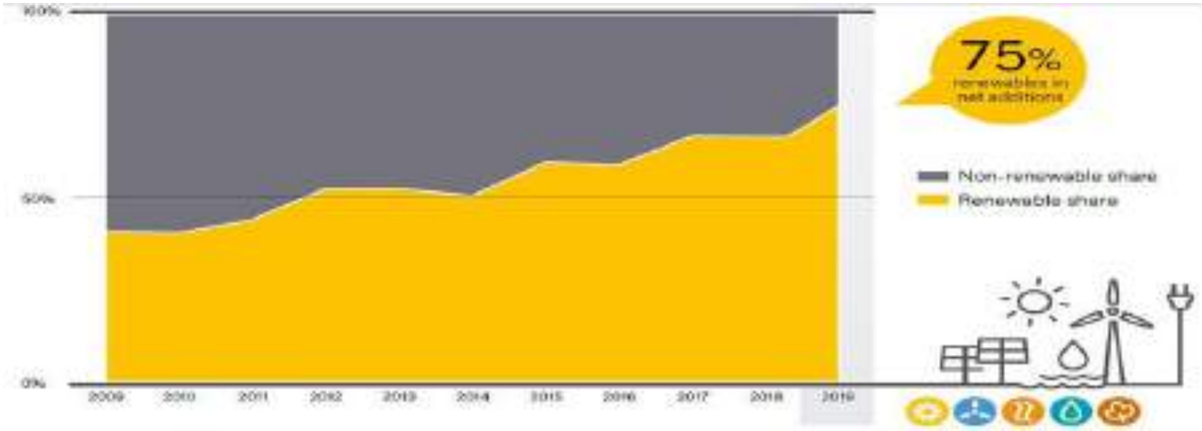

Figure (1 – 4) Renewable energy share of installed capacity globally in 2019

1.2.5 Legislations and Laws in the Renewable Energy Sector

Many countries seek to enact many laws and legislations in order to encourage the use of renewable energy, whether in the electricity generation sector (143 countries have laws on the use of renewable energy systems), and in the heating and cooling sector (23 countries have laws related to the heating and cooling sector), and many countries seek to achieve sustainable transport by encouraging reliance on electric cars, and there are about 70 countries that have enacted laws to increase reliance on electric cars and facilitate their spread. Figure (1-5)

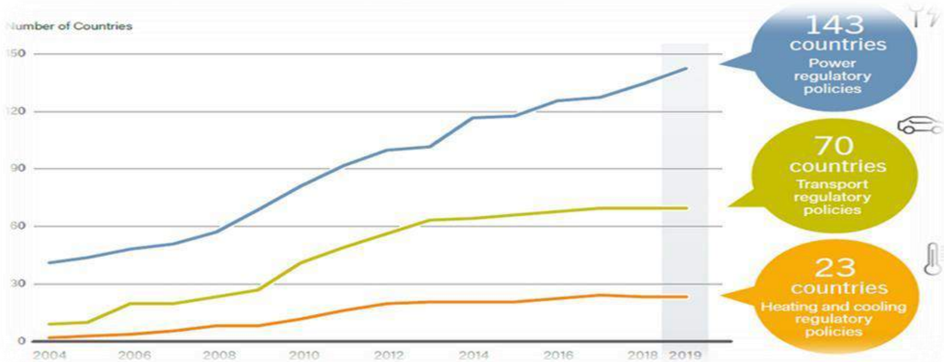

Figure (1 – 5) number of countries with renewable energy policies 2004- 2019

1.2.6 Volume of investments in the renewable energy sector from 2009 to 2019

Many investors put hundreds of billions of dollars annually into the renewable energy sector, and the value of investment for 2019 was about \$ 282 billion, an increase of 1% over 2018. Figure (1-6)

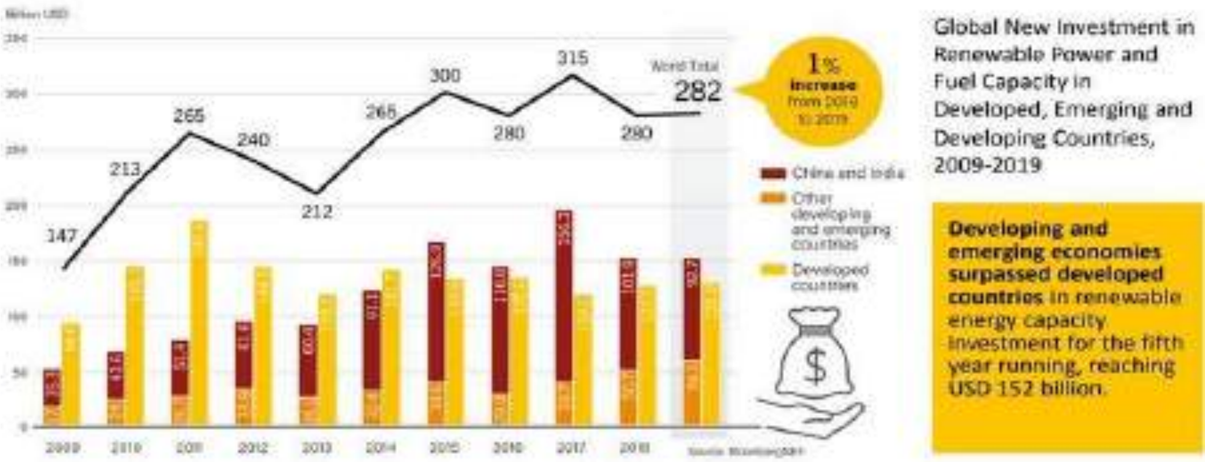

Figure (1-6) investments in the renewable energy

1.2.7 Growth of the renewable energy sector since 2013-2018

The renewable sector's growth rate was about 21.5%, which is much higher than the growth rate of conventional energy with nuclear energy, which is 5.7%. figure (1-7)

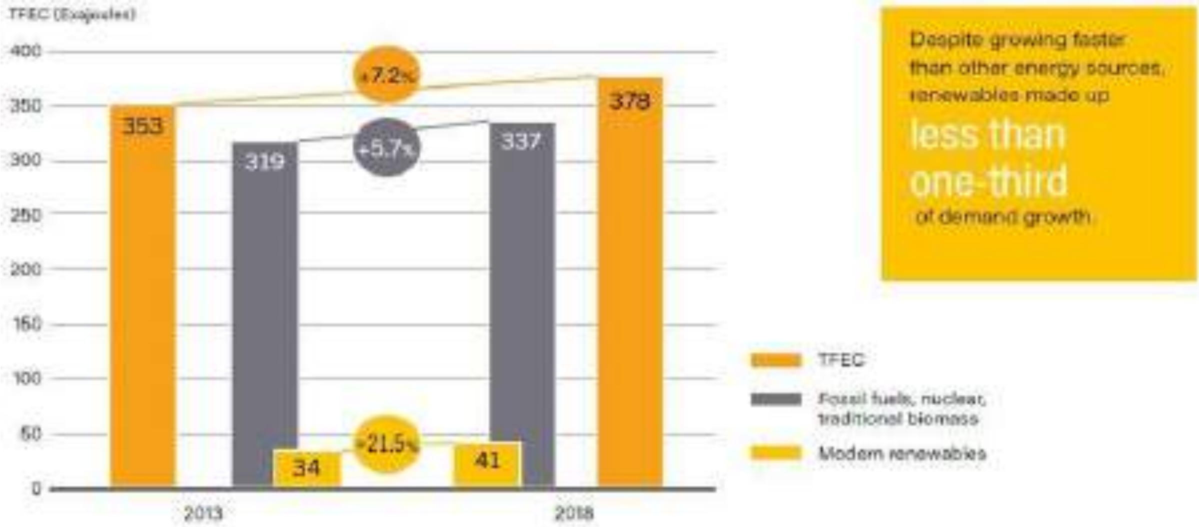

Figure (1 – 7) Estimated global growth in renewable energy compared to total final energy consumption 2013-2018

Renewable energy sector's contribution to job creation:

The number of renewable energy jobs globally is estimated at 11 million in 2018, compared to 10.2 million in 2017. Figure (1-8)

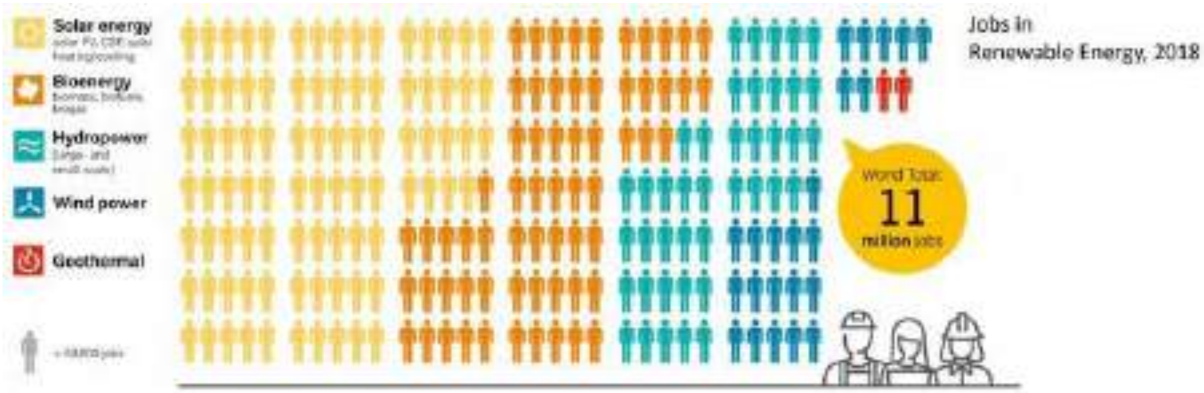

Figure (1- 8) jobs in renewable energy keep growing

2.1 Introduction to Solar Energy

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy.

Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production techniques of other semiconductor devices such as computers and memory chips.

As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. With today's production, which reached a large scale, the whole industry production of solar cells has been developed and due to low production cost, it is mostly located in the Far East.

Photovoltaic cells produced by the majority of today's largest producers are mainly made of crystalline silicon as semiconductor material which is a result of combination of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible

2.2 Advantages of photovoltaic cells

- A typical photovoltaic cell efficiency is about 15%, which means it can convert 1/6 of solar energy into electricity.
- Photovoltaic systems produce no noise.
- there are no moving parts and they do not emit pollutants into the environment.
- Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit in relation to the energy produced from fossil fuel technologies.
- Photovoltaic cell has a lifetime of more than thirty years and is one of the most reliable semiconductor products.
- Most solar cells are produced from silicon which is non-toxic and is found in abundance in the earth's crust.
- Photovoltaic systems (cell, module, network) require minimal maintenance at the end of the life cycle.
- Photovoltaic modules can almost be completely recycled.

- Photovoltaic modules bring electricity to rural areas where there is no electric power grid, and thus increase the life value of these areas.
- Photovoltaic systems will continue the future development in a directi on tobecome a key factor in the production of electricity for househol ds and buildings in general.

The systems are installed on existing roofs and/or are integrated into the facade. These systems contribute to reducing energy consumption in buildings.

A series of legislative acts of the European Union in the field of renewable energy and energy efficiency have been developed particularly promoting photovoltaic technology for achieving the objectives of energy savings and

CO_2 reduction in public, private and commercial buildings. Also, photovoltaic technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electristy suuply . figure (2-1)

Figure (2 – 1) Solar photovoltaic module

2.3 Historical overview

The photovoltaic effect has been discovered in the first half of the 19th the century in 1839. a young French physicist Alexandre Edmond Becquerel observed a physical phenomenon or effect that allows the conversion of light into electricity. The solar cells' work is based on this principle of photovoltaic effect. In the following years a number of scientists have contributed to the development of this effect and technologies through their researches the most relevant among them are Charles Fritts, Edward Weston, Nikola Tesla and Albert Einstein, who has been awarded the Nobel Prize for his work on "photoelectric effect" in the year 1904. Figure (2-2)

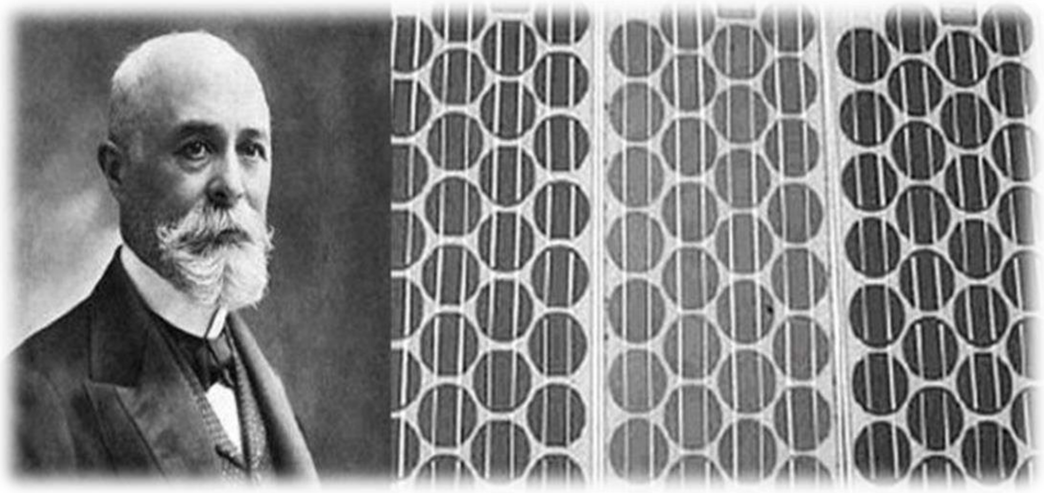

Figure (2 – 2) Alexandre Edmond Becquerel observed

However, due to high production rates, a greater development of this technology has begun only along with the development of semiconductor industry in the late fifties of the 20th century. During the sixties, the solar cells are used exclusively for supplying electricity to orbiting satellites in Earth orbit where they prove themselves as very reliable and competitive technology.In the seventies there are improvements in production Performance and quality of solar cells, while the coming oil crisis helps to reduce production costs of solar cells and open up many possibilities for their practical implementation.

Solar cells have been recognized as an excellent replacement for the supply of electricity at locations distant from the electricity grid.
The energy is supplied to wireless applications, lighthouses' batteries, various signals, telecommunication equipment and other low power electricity dependent equipment. During the eighties, solar cells have become popular as an energy source for consumer electronic devices including calculators, watches, radios, lamps and other applications with small batteries. Also, after the crisis in the seventies, great efforts have been made in the development of solar cells for commercial use in households. Independent solar cells systems (off- grid) have been developed, as well as network connected systems (on grid). In the meantime, a considerable increase in wide use of solar cells has been recorded in rural areas where electricity network and infrastructure have not been developed. Electricity produced in these areas is used for pumping water, cooling energy, telecommunications and other household appliances and everyday life needs. Photovoltaic modules technology and market development has grown rapidly by introducing incentives for the production of electricity from renewable energy sources. Figure (2-3)

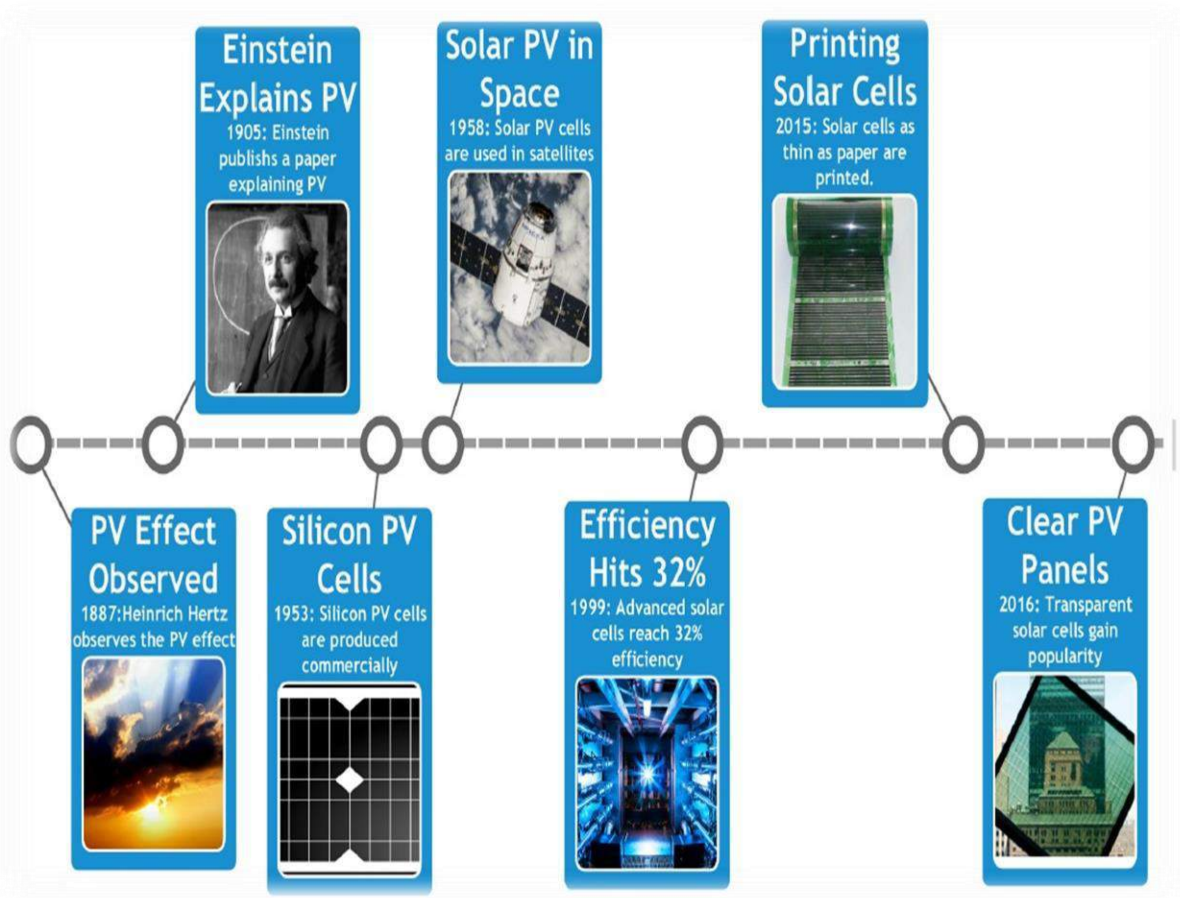

Figure (2-3) application solar energy

2.4 Solar radiation

The sun is the central star of the solar system in which the Earth is. It has a form of a large glowing ball of gas, the chemical composition of mostly hydrogen and helium, but also other elements that are in it to a lesser extent, like oxygen, carbon, iron, neon, nitrogen, silicon, magnesium and sulfur. Energy from the Sun comes to the Earth in the form of solar radiation. Nuclear reactions take place in the interior of the Sun, during which hydrogen is transformed into helium by a fusion process, accompanied by the release of large amounts of energy, where the temperature reaches 15 million °C. Part of this energy comes to Earth in form of heat and light, and allows all processes, from photosynthesis to the production of electricity in photovoltaic systems. Under optimal conditions, the earth's surface can obtain 1.000 W/m2, while the actual value depends on the location, i.e., latitude, climatological location parameters such as frequency of cloud cover and haze, air pressure, etc. Considering the sunlight and the productivity of photovoltaic systems, it is necessary to understand the following concepts: Irradiation, average density of the radiant solar radiation power, which is equal to the ratio of the solar radiation power and surface of the plane perpendicular to the direction of this radiation (W/m2), Radiation, which represents the quantity of solar radiation that is radiated on the unit surface at a given time (Wh/m2) or (J/m2). Figure (2-4)

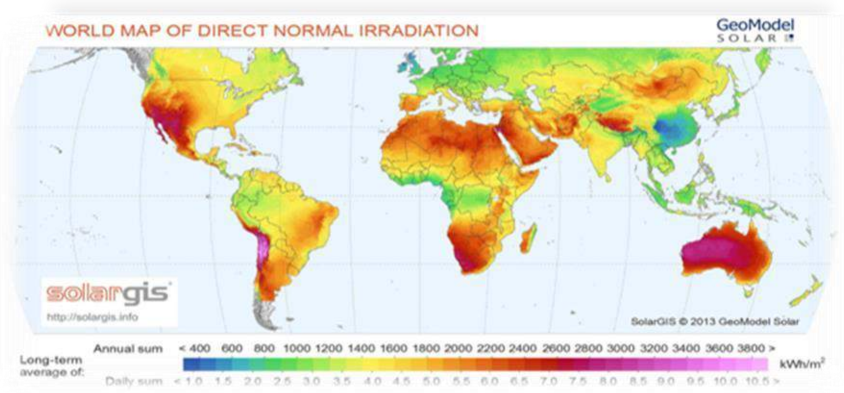

Figure (2 – 4) world map of direct normal irradiation

Besides expressing it in hourly values, it is often expressed as daily, monthly or yearly radiation, depending on the time interval. The solar radiation weakens on its way through the earth’s atmosphere due to the interaction with gases and vapors in the atmosphere and arrives at the Earth's surface as direct and diffused. Direct sunlight comes directly from the sun, while scattered or diffused radiation reaches the earth from all directions. Considering direct and diffused radiation on a flat surface, we are talking about the total radiation. In case of an inclined surface, the rejected or reflected radiation has to be added to the direct and diffused radiation. Rejected radiation can be reflected from the ground or water the largest component of solar radiation is direct, and the maximum radiation should be on a surface perpendicular to the direction of the sun's rays. the greatest radiation at any given moment is only possible if the plane is constantly referred to the movement of the sun in the sky. photovoltaic modules can be mounted in various ways, fixed at a certain angle, or may be moving to better monitor the angle of inclination of the sun during the day for greater energy yield and better results in the production of electricity. Optimal value of the inclination angle of the surface has to be determined for fixed mounted photovoltaic module. The optimum angle of inclined PV module's surfaces is the angle at which it is inclined in relation to a horizontal surface in order to obtain the highest possible annual irradiation. An optimum angle of inclination for a period or certain months in the year can also be calculated. The greatest energy yield of a fixed module system is achieved by placing the modules at the optimal annual angle. As the sunlight radiation is a highly seasonal dependent variable, the average daily radiation values to an inclined surface range from about 1 kWh/m2 in December up to 7 kWh/m2 in June, which means that we obtain a higher energy yield in summer by setting a module at a lower angle, and vice versa.

Influence of shading on solar power plant ـ the maximum electric energy is produced when sunlight directly crosses the PV modules. Shadows created by objects on the roof, wood or other surrounding buildings and skyscrapers substantially affect electricity production. The shade also negatively affects the stability of the system because modules located partially in the shade do not have a linear production of electricity, resulting in voltage changes and inverter disturbances. If only one cell in a module is located in the shade, it can reduce the power of all modules by 75%.

2.5 Solar Constant

It is the ability of solar radiation falling vertically on an area of square meters of the atmosphere and is equal to 1350 w / m², but this ability decreases when it reaches the surface of the earth, due to the absorption and scattering ofsolar radiation in the Earth's atmosphere to become the capacity of solar radiation vertically on an area of square meters of the earth equal to 1000 w / m². figure (2-5)

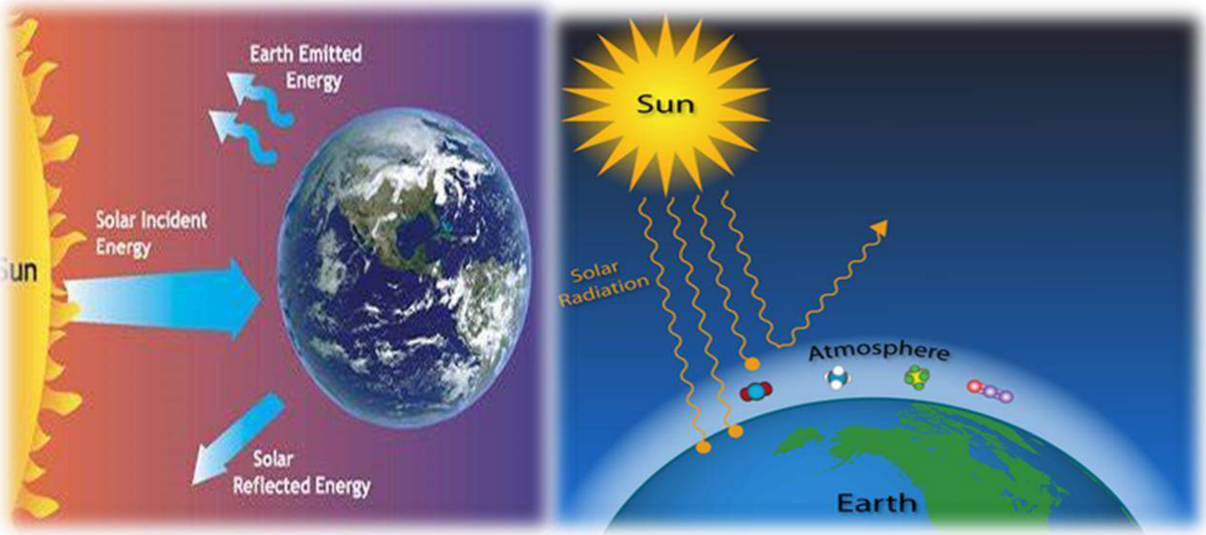

Figure (2-5) solar radiation

2.6 Solar Thermal Applications

Solar hot air system glass panels are placed on the roof of the house, and by taking advantage of the thermal energy of the sun to heat the air inside the glass panels, then hot air is pumped into the house. It is worth noting that these systems have become uncommon and began to become extinct due to their low efficiency. Figure (2-6)

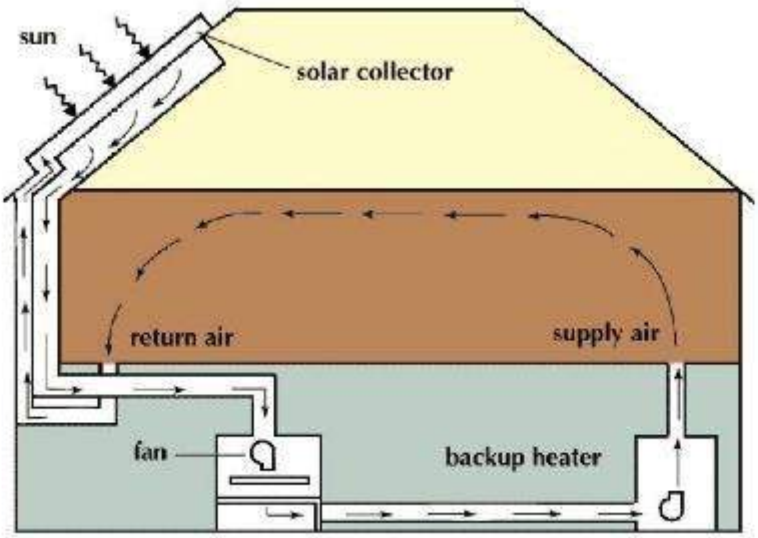

Figure (2 – 6) Solar Hot Air Systems

In this technology, the thermal energy of the sun is used by heating water and using hot water in home applications without high operational costs, and we notice in the graph below an increase in the capacity of installed water heating systems from 2009 to 2019around the world. Figure (2-7)

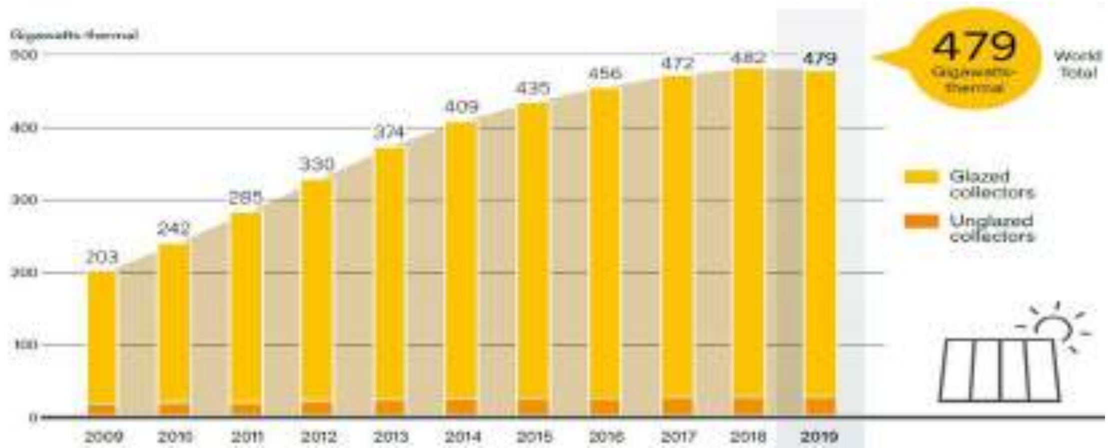

Figure (2 – 7) solar water heating collector's global capacity 2009-2019

Concentrated Solar Power (CSP)

In these systems, the thermal energy of the sun is used and converted into electrical energy by heating a solution to produce high-pressure steam that moves turbines connected to generators or Stirling engines using several techniques, which are as follows:

1.Parabolic Dishes:

A set of mirrors is installed in the form of a saucer similar to the reception dish of televisions and the dish is in the form of a parabola and thus the reflected radiation is concentrated at a single point called the burner of the dish where the solution is located. All these mirrors are installed on axes and are equipped with a tracking system that tracks the movement of the sun during the day to be able to collect the maximum amount of solar radiation.

2.Solar Power Towers:

This type of station is based on a tower located in the middle of a number of a certain type of reflective mirror called Heliostat where solar radiation is reflected from the mirrors towards a thermal receiver at the top of the tower. The solution is heated to a temperature of about 600 ° C and the heat and pressure of the solution is used to generate steam, which in turn moves the turbines and generates electricity.

3.Parabolic Troughs:

The reflective mirrors in this system are parabola, and a tube passes parallel to the middle of the mirrors where the mirrors reflect solar radiation towards the tube inside which a heated liquid passes and acts as a heat exchanger to generate steam to feed the turbine. There are many types of liquids used and the use of thermal oil up to 393 degrees Celsius has recently become widespread.

4.Linear Fresnel systems:

Reflectors are placed directly on the ground and are directed towards a pipe inside which the heat exchanger liquid passes in a similar way to troughs with parabola.

The graph below shows the installed capacity of CSP systems from 2009 to 2019, and we note the year-on-year increase in installed capacity from 3.4 GWh in 2019, bringing the total installed to 21.2 GWh. Figure (2-8)

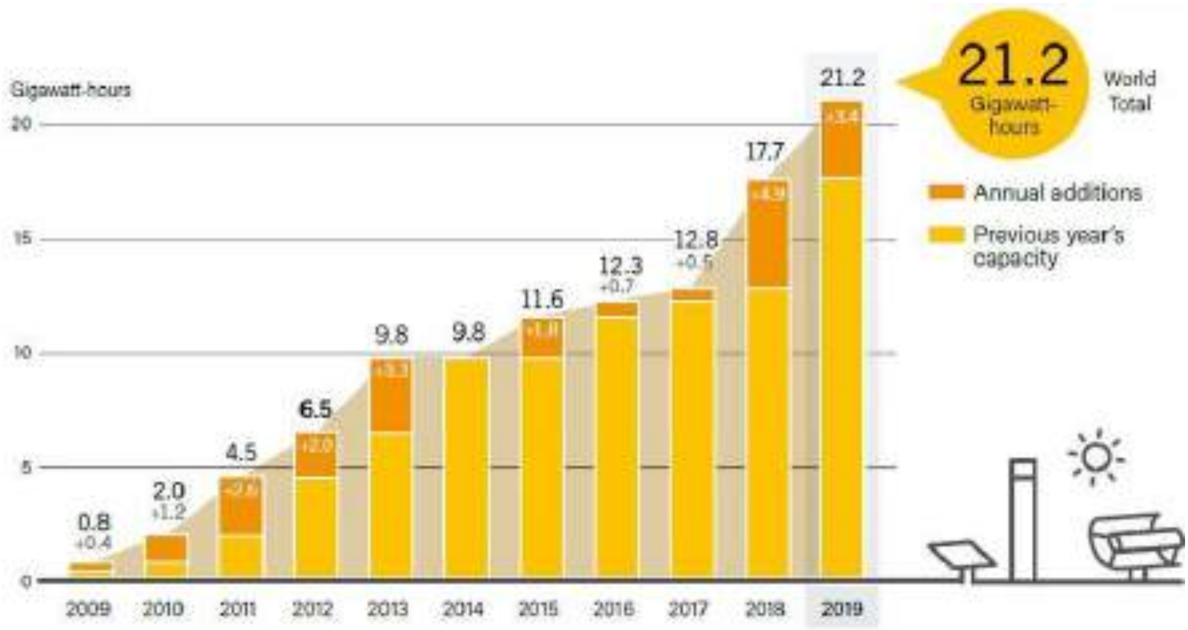

Figure (2. 8) the installed capacity of CSP systems from 2009 to 2019

Chapter Three **Solar Energy System**

3.1 Functioning of the photovoltaic cells

The word photovoltaic, consists of two words: photo, a Greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed i.e., the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. the particles of light are called photons. Photons are massless particles moving at light speed. The energy of the photon depends on its wavelength and the frequency, and we can calculate it by the

Einstein's law, which is: E=H*V

where:

E ₋ photon energy h ₋ Planck's constant = 6.626×10

− 34Js

V ₋ photon frequency

In metals and in the matter generally, electrons can exist as
valence orasfree
Valence electrons are associated with the atom, while the free electrons can move freely.in order for the valence electron to become free, he must get the energy thatis greater than or equal to the energy of binding. Binding ene rgy is the energy by which an electron is bound to an atom in one of the ato mic bonds. In the case of photoelectric effect, the electron acquires the r equired enery by the collision with a photon.

Part of the photon energy is consumed for the electron getting free from the influence of the atom which it is attached to, and the remaining energy is converted into kinetic energy of a now free electron. Free electrons obtained by the photoelectric effect are also called photoelectrons The energy required to release a valence electron from the impact of an atom is called a work out and it depends on the type of material in which the photoelectric effect has occurred.
The equation that describes this process is as follows:

HV= Wi, + Eking where:

HV - photon energy

Wi, - work out

Eking - kinetic energy of emitted electron

The previous equation shows that the electron will be released if the photon energy is less than the work output.

The photoelectric conversion in the PV junction. PV junction (diode)is a boundary between two differently doped semiconductor layers; one is a P-type layer (excess holes), and the second one is an n-type (excess electrons) At the boundary between the P and the N area, there is a spontaneous electric field, which affects the generated electrons and holes and determines the direction of the current. Figure (3-1)

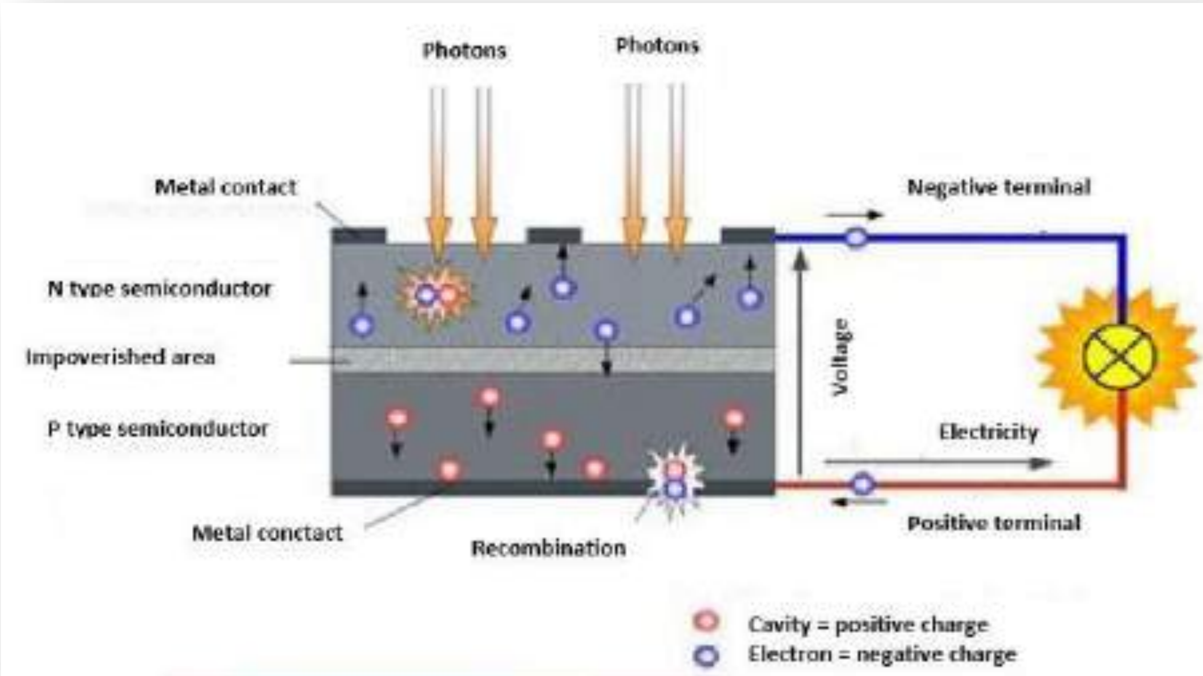

Figure (3-1) Functioning of the photovoltaic

To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons, i.e. electricity. All charged particles, photoelectrons also, move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction (diode).It was pointed out for the semiconductors that, along with the free electrons in them, there are cavities as charge carriers, which are a sort of a byproduct in the emergence of free electrons. Cavities occurs whenever the valence electron turns into a free electron, and

this process is called the generation, while the reverse process, when the free electron fills the empy
spaces - cavity, is called recombination. If the electron- cavity pairs occur away from the impoverished areas it is possible to recombine before they are separated by the electric field. Photo electron sand cavities in semiconductors are accumulated at opposite ends, therey creating an electromotive force. If a consuming device is connected to such a system, the current will flow, and we will get electricity. In this way, solar cells produce a voltage around 0,5_0,7 V, with a current density of about several tens of mA/cm2 depending on the solar radiation power as well as on the radiation spectrum. The usefulness of a photovoltaic solar cell is defined as the ratio of electric power provided by the PV solar cells and the solar radiation power. Mathematically, it can be presented in the following relation:

$$\eta = \frac{Pel}{Psol} = \frac{U * I}{E * A}$$

where:

Peel - Electrical output power

Pool - Radiation power (sun)

U - Effective value of output voltage

I - Effective value of the electricity output

E - Specific radiation power (for example W/m2)

A - Area

The usefulness of PV solar cells ranges from a few percent to forty percent. The remaining energy that is not converted into electrical energy is mai nly converted into heat energy and thus warms the cell. Generally, the incre ase in solar cell temperature reduces the usefulness of PV cells.

Standard calculations for the energy efficiency of solar photovoltaic cells are explained below. Energy conversion efficiency of a solar photovoltaic cell (η "ETA") is the percentage of energy from the incident light that actually ends up as electricity. This is calculated at the point of maximum power, Pm, divided by the input light irradiation (E, in W/m2), all under standard test conditions (STC) and the surface of photovoltaic solar cells (AC in m2).

$$\eta = \frac{PM}{E * AC}$$

STC - standard test conditions, according to which the reference solar radiation is 1.000 W/m2, spectral distribution is 1.5 and cell temperature 250C. figure (3-2)

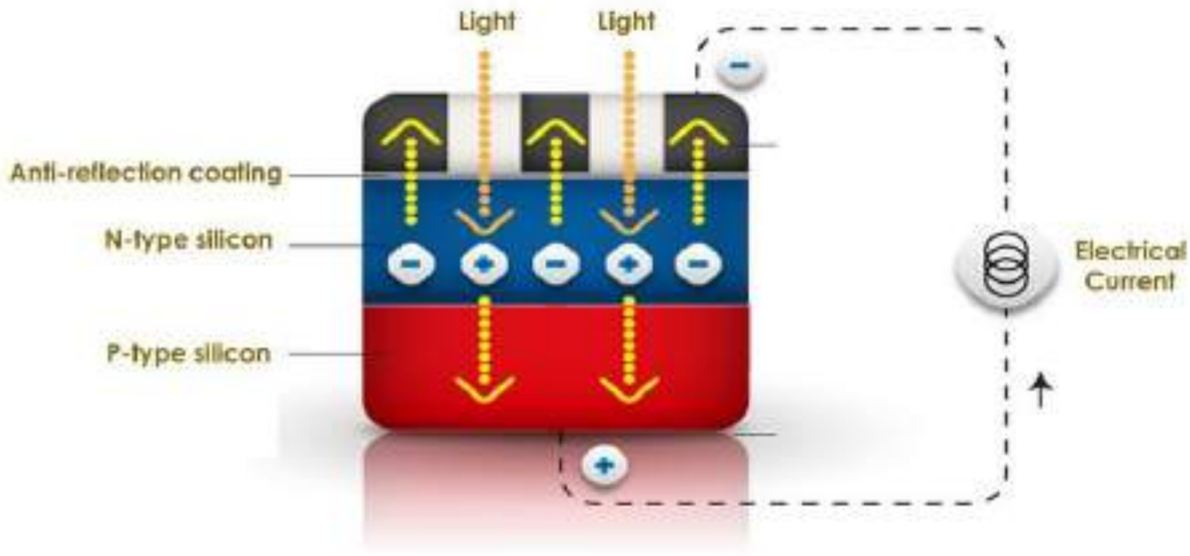

Figure (3- 2) how do the solar cells work

3.2 Types of solar photovoltaic cells:

Figure (3-3) photovoltaic cell

Electricity is produced in solar cells which, as noted, consist of more layers of semi conductive material When the sun's rays shine down upon the solar cells the electromotive force between these layers is being created, which causes the flow of electricity. The higher the solar radiation intensity the greater the flow of electricity.The most common material for the production of solar cells is silicon. Silicon is obtained from sand and is one of the most common elements in the earth's crust, so there is no limit to the availability of raw materials.

Solar cell manufacturing technologies are:

• monocrystalline,

• polycrystalline, • Bar- crystalline silicon,

• thin- film technology.

Cells made from crystal silicon (Si), are made of a thinly sliced piece (war), a crystal of silicon (monocrystalline) or a whole block of silicon crystal s (multicrystalline); their efficiency ranges between 12% and 19%. Figure (3-4)

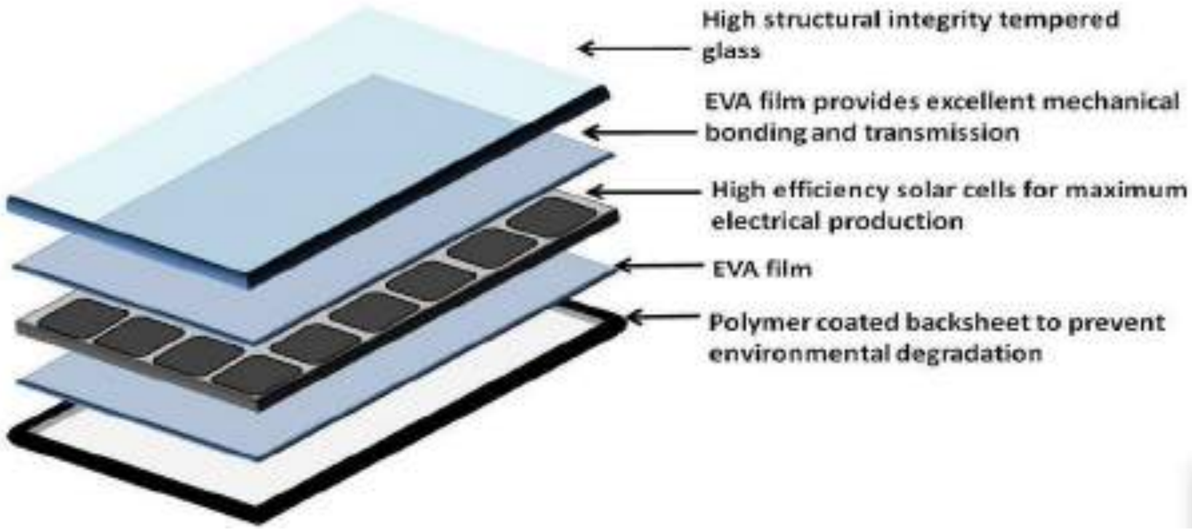

Figure (3-4) Solar panel layer

3.3 Standard Modules

The solar panel is composed in order from top to bottom Front cover: It is made of scissor glass and has a high conductivity in the optical field to allow the largest amount of rays to pass through it. Front wrapping layer: makes transparent and electrically insulatiing thermoplasticy.. polymer,themost commonly used materials are EVA or POE.

* Photovoltaic cell

* Rear wrapping layer: It is very similar to the front medical

Back sheet: It is made of plastic materials and is intended to protect the board.

Frame: It is usually made of aluminum.

3.3.1 Monocrystalline Si cells

conversion efficiency for this type of cells ranges from 13% to 17% and can generally be said to be in wide commercial use. In good light conditions it is the most efficient photovoltaic cell. This type of cell can convert solar radiation of 1.000 W/m2 to 140 W of electricity with the cell surface of 1m2. The production of monocrystalline Si cells requires an absolutely pure semiconducting material. Monocrystalline rods are extracted.

3.3.2 from the molten silicon and sliced into thin chips (wafer)

Such type of production enables a relatively high degree of usability. Expected lifespan of these cells is typically 25_30 years and, of course, as well as for all photovoltaic cells the output degrade is somewhat over the years. Figure(3-5)

Figure (3- 5) Monocrystalline Si cells

3.3.3 Multicrystalline Si cells this type of cell can convert solar radiation of 1.000 W/m2 to 130 W of electricity with the cell surface of 1m-2m. The production of these cells is economically more efficient compared to monocrystalline. Liquid silicon is poured into blocks, which are then cut into slabs. During the solidification of materials crystal structures of various sizes are being created, at whose borders some defects may emerge, making the solar cell to have a somewhat lower efficiency, which ranges from 10% zo 14%. The lifespan is expected to be between 20 and 25 years. Figure (3-6)

Figure (3-6) Multicrystalline Si cells

Ribbon silicon has the advantage in its production process in not needing a wafer cutting (which results in loss of up to 50% of the material in the process of cutting). However, the quality and the possibility of production of this technology will not make it a leader in the near future. The efficiency of these cells is around 11%.

3.3.4 In the thin

film technology the modules are manufactured by piling extremely thin lay ers of photosensitive materials on a cheap substrate such as glass, stainless steel or plastic. The process of generating modules in thin film technology has resulted in reduced production costs compared to crystalline silicon technology, which is somewhat more intense. Today's price advantage in the production of a thin- film is balanced with the crystalline silicon due to lower efficiency of the thin- film, which ranges from 5% to 13%. The share of thin- film technology on the market is 15% and constantly increasing, it is also expected an increase in years to come and thus reduce the adverse market ratio in relation to the photovoltaic module of crystalline silicon. Lifespan is around 15- 20 years. There are four types of thin- film modules (depending on the active material) that are now in commercial use:

3.3.4.1 Amorphous silicon (a- Si)

Amorphous Si Cells: Cell efficiency is around 6%, a cell surface of 1m2 can convert 1.000 W/m2 of solar radiation to about 50 watts of electric energy. Progresses in research of this type of module have been made and it is expected a greater efficiency in the future. If a thin film of silicon is put on a glass or another substrate it is called amorphous or thin layer cell. The layer thickness is less than 1 micron; therefore the lower production costs are in line with the low cost of materials. However, the efficiency of amorphous cells is much lower compared to other cell types It is primarily used in equipment where low power is needed (watches, pocket PCs) or, more recently, as an element in building facades. Figure (3-7)

Figure (3- 7) thin- film, amorphous silicon

3.3.4.2 Cadmium Tellurium (Cadet)

Cadmium tellurium (Cadet) cells: Cell efficiency is around 18%, a cell surf ace of 1m2 can convert solar radiation of 1.000 W/ m2 to 160 W of electriy laboratory conditions. Cadmium telluride is a fusion of metal cadmiumand tellurium semimetal. It is suitable for use in thin photovoltaic modules due to the physical properties and low -technology manufacturing. Despite these advantages it is not widely used due to cadmium toxicity and suspected carcinogenicity. Figure (3-8)

Figure (3-8) Cadet thin- film

3.3.4.3 Copper indium gallium selenide (CIS, CIGS):

CIS cells have the highest efficiency among the thin_film cells, which is about 20%. This cell type can convert solar radiation of 1.000 W/m2 to 160 W of electricity with the cell surface of 1 m2 in laboratory conditions.

3.3.4.4Thermos sensitive solar cells and other organ cells (DSC)

The development of these organic cells is yet to come, since it is still tes ting and it is not increasingly commercialized. Cell efficiency is around 10%. The tests are going in the direction of using the facade integrated systems, which has proven to be high -quality solutions in all light radiation and all temperature conditions. Also, a great potential of this technology is in low cost compared to silicon cells. There are other types of photovoltaic technologies that are still developing while others are to be commercialized. Regardless of the lifespan, the warranty period of today's most common commercial photovoltaic modules is 10 years at 90% power output, and 25 years at 80% power output. Figure (3-9)

Figure (3-9) CIS thin- film

3.3.5 Half Cut Cells

Semi-solar cells are obtained by finely cutting mono or poly silicon photovoltaic cells in the middle.

Semi-cell technology helps in increasing the efficiency of solar panels by reducing the losses resulting from the resistance of the cell, with the cell being divided into two halves, we get half a cell that owns half the current that the entire cell has, and the losses are proportional to the square of the current, so the value of the losses will decrease by 75%, and thus increase the output capacity of the solar panel. Figure (3-10)

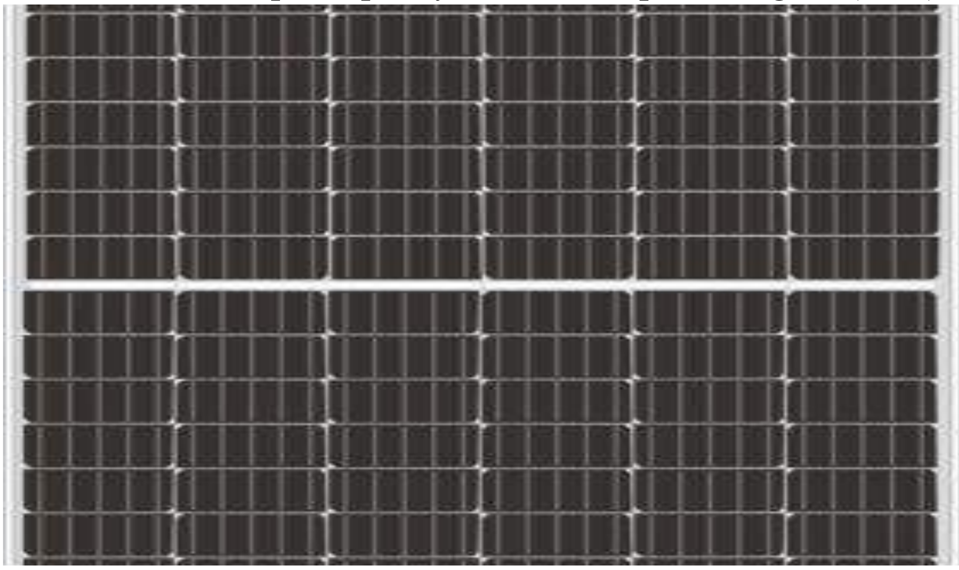

Figure (3-10) half cut cells

By doubling the number of cells in the solar panel, the cells are connected in a different way than in conventional panels so that the values of current and potential difference remain similar to full-cell panels, so the panel is separated from the middle and the two middles are intertwined with each other in parallel as shown in the following figure: figure (3-11)

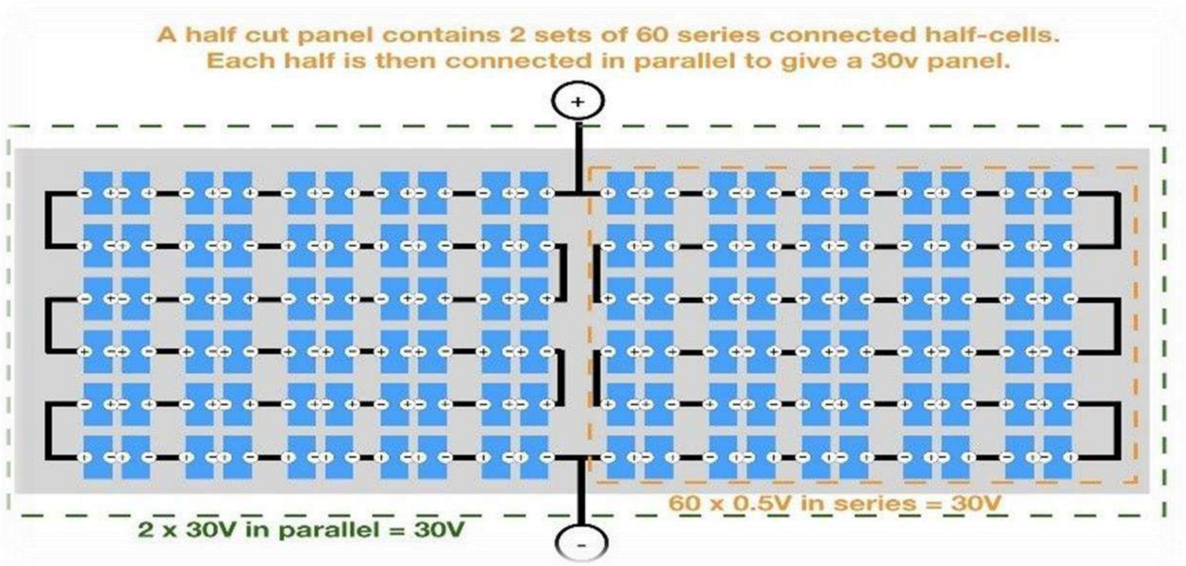

Figure (3-11) half cut panel

This connection method helps to mitigate the impact of shading, as we notice when comparing the connection in the traditional panel with the half-cell panel, that in the traditional panel, the solar cells are connected to each other sequentially and distributed over several rows, and when one cell of the row is subjected to shading, the entire shaded cell row stops producing energy.

In general, there are three rows of cells in normal panels, so we lose onethird of the panel's ability to produce energy when one row stops producing.

Although the half-cells are also connected sequentially, cutting the cells in the middle causes the number of cells on the solar panel to double (120 cells instead of 60 cells in a whole panel, for example), which in turn doubles the number of rows of cells on the solar panel.

In a half-cell board, the number of rows will double (6 instead of 3) because they are connected to the middle instead of the ends, so when one cell is shaded from one of the six rows, this row will stop producing energy, so the productivity of the board will decrease by only one-sixth. Figure (3-12)

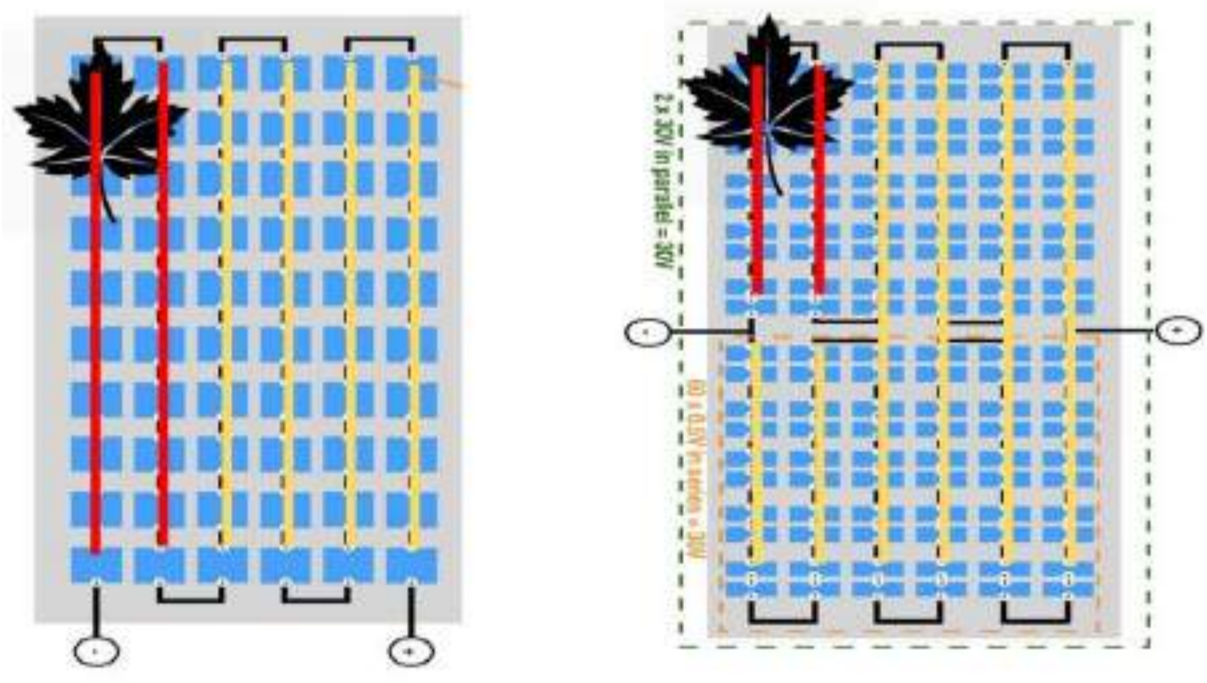

Figure (3- 12) half cut shading

3.3.6 PERC Cells

This name is an abbreviation for "Passivated Emitter Rear Cell" or for "Passivated Emitter Rear Contact"

The main difference between PERC cells and conventional cells is the presence of a passivation layer on the back surface of the cell, and this layer is a material on the back surface of the cell that offers three benefits in terms of the efficiency of the solar cell (reflecting light through the cell, reducing electron recombination, reducing heat absorption) and adding this layer significantly raises the efficiency of cells and its use has become widespread until this technology is available to all companies as a basic option. Figure (3-13)

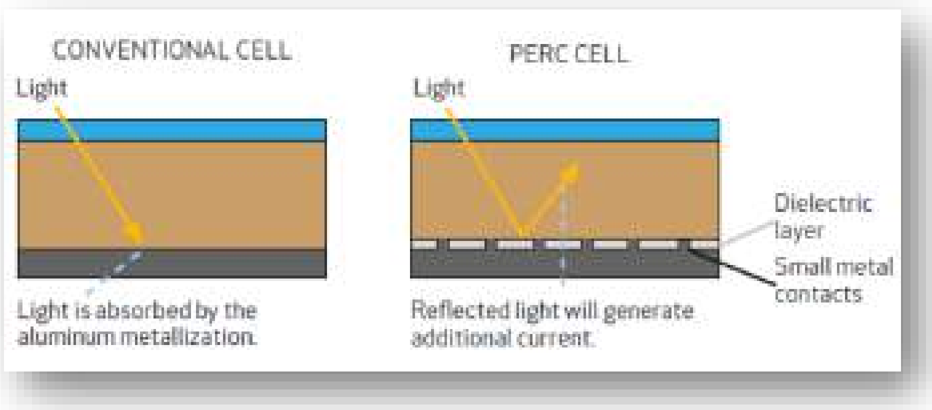

Figure (3-13) perc cell

3.3.7 Bifacial PV Cells

They are solar cells in which the back layer is transparent and allows light to pass through as well, this technology helps to receive light radiation from the front and back sides and convert the energy carried by these rays into electrical energy. Thus, we benefit more from the solar radiation that falls on the front of the cells as well as the reflected solar radiation that reaches the back of these cells. This technology has contributed to raising the efficiency and productivity of solar photovoltaic cells by up to 25% under certain conditions. Figure (3-14)

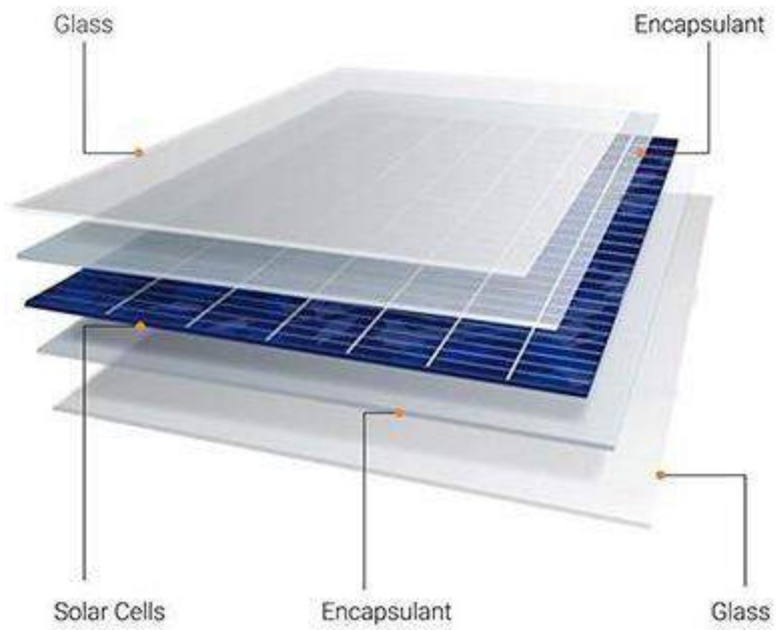

Figure (3- 14) bifacial panel

3.3.7.1 Installation of double-sided cells

The method of installing solar panels consisting of double-sided cells depends on the type of panels, the panels usually are:

* Framed Solar Panels.

* Frameless Solar Panels.

Panels with an outer frame are easy to install compared to others, as they can be installed on the same stands as traditional solar panels, taking into account the absence of parts that cause shading from the back face, while frameless panels require the use of special collectors «Clamps» equipped with a rubber layer to prevent damage to the glass.

As for the junction case, in order to avoid the problem of shadow from the back, it was moved from the middle of the panel to the end of the solar panel, while also reducing its size.

3.3.7.2 Factors that increase the percentage of radiation absorbed from the back layer

* Increase the reflectivity of the project land, as the surface is sometimes painted white or epoxy.

* Lifting the fixation structure off the ground to increase the area that allows reflected rays to enter.

* Increase the distance of the spaces between the rows of panels to increase the area that allows reflected rays to enter.

Note: In systems that use solar panels consisting of double-sided cells, it is not possible to predict with certainty the amount of power generated from the back surface, and therefore it is not possible to determine the output currents from the solar panel, and to avoid this problem during the design, the engineer designs the system on the basis of the maximum current with a high design corrective rate, which increases the cost of the project.

3.4 The evolution of solar panels

In the previous paragraph, we talked about the development that took place at the level of the photovoltaic cell, but here we will talk about the development at the level of the solar panel, and these are some of the technologies at the level of the photovoltaic panel.

3.4.1 Paving Technology

This technology helps reduce the wasted spaces between solar cells, as the cells are paved side by side, thus optimizing the use of the panel space. Figure (3-15)

Figure (3-15) Paving Technology

3.4.2 Shingling Technology

In this technology, the end of the first cell is installed with the end of the next cell in order to reduce the spaces between solar cells, but this technology has not proven its usefulness so far, due to the need to use adhesives to install cells, which may become obsolete due to climatic conditions of heat and humidity. Figure (3-16)

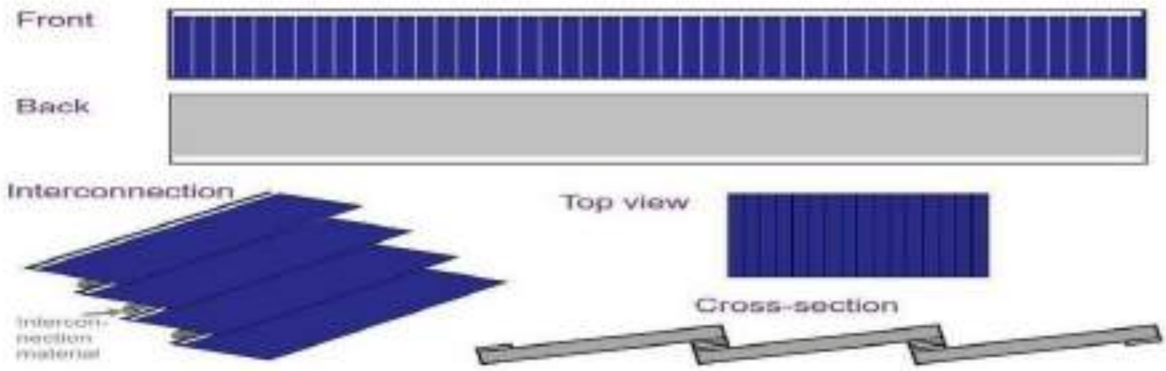

Figure (3. 16) Shingling Technology

3.4.3Tiling Ribbon Technology

It is a similar technique to its predecessor, but by replacing the use of adhesives, connecting wires (pass bars) are used to connect cells to each other. Figure (3-17)

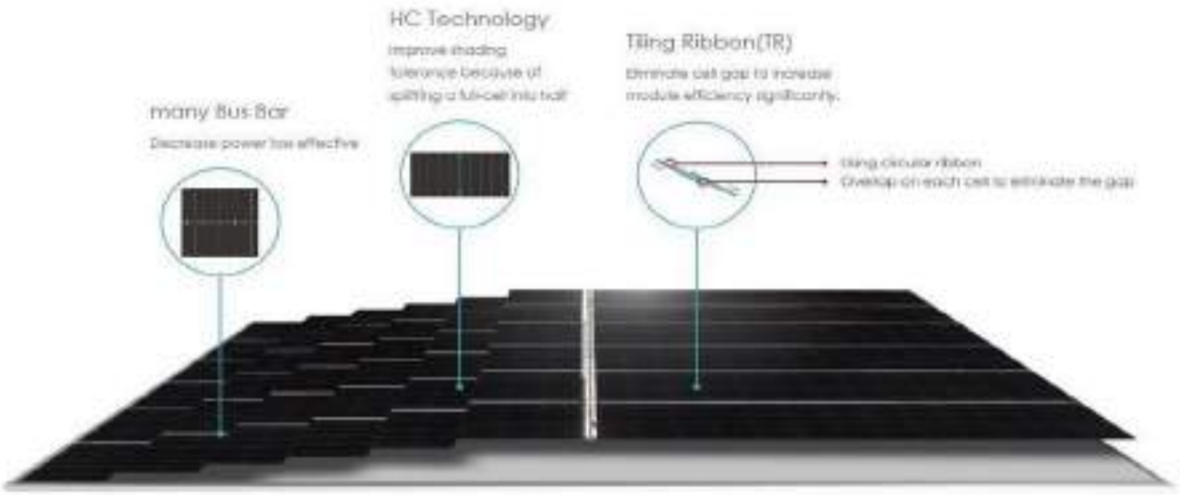

Figure (3. 17) Tiling Ribbon Technology

3.4.4 The evolution of solar panels

There are many measurements of solar cells starting from M0 and ending with G12, and many companies seek to increase the dimensions of the solar cell in order to increase the dimensions of the solar panel as a whole, and thus increase the capacity of the electrical panel.

The following picture places all measurements that are adopted in the manufacture of cells: figure (3-18)

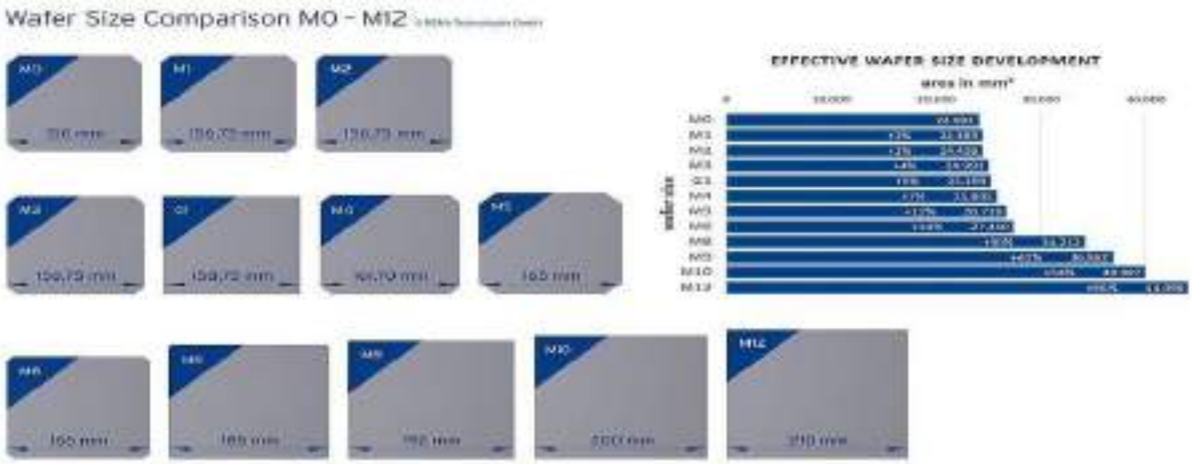

Figure (3- 18) panel size

3.5 Inverter

Inverter: is a system that converts unidirectional voltage waveform (DC form) into a bidirectional voltage waveform (AC form). In general, there are seven types of inverters used in solar systems.

1. Central inverter
2. String inverter
3. String inverter with power optimizer
4. Micro inverter
5. Hybrid inverter
6. Inverter with charger
7. Simple inverter

We will discuss about each type of inverters used in the solar system

3.5.1 Central inverter

Figure (3-19) Central Inverter

These inverters are characterized by their high capacity up to (4MW). These types of inverters are used in on-grid systems. In the solar system, one central inverter is used, where all string of solar panels are connected to it to convert the continuous voltage into alternating voltage as depicted in figure 3-17

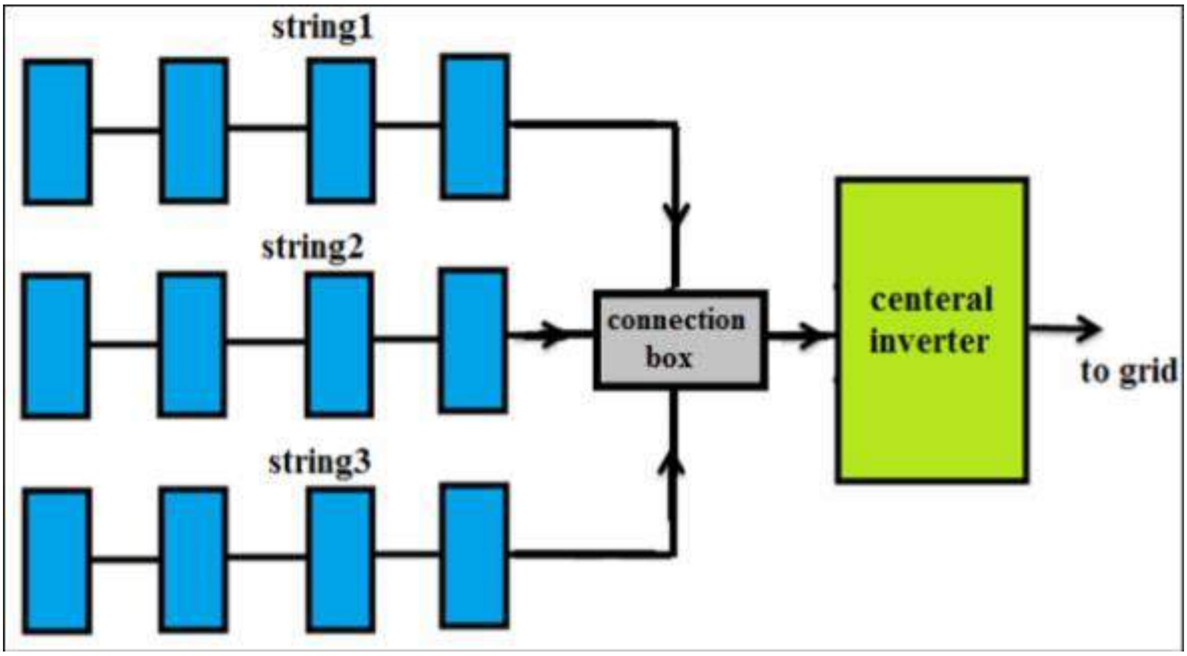

Figure (3-17) The connection of the solar panel to the central inverter

In the case of large systems, the use of one central inverter is the most appropriate choice in terms of cost and ease of installation, but the use of this type of inverter has some drawbacks, such as; It is difficult to maintain compared to other types of inverters A malfunction in the central inverter leads to the system being out of service, as most of the time there is no backup central inverter. A decrease in the performance of one of the panels (in case it is exposed to shade) leads to a decrease in the power generated by the system. Therefore, When choosing this type, you must take into account the absence of reasons for shade such as tall buildings and large trees, as well as the solar panels should not be left for a long time without cleaning them from the dust

3.5.2String inverter

Figure (3-20) String inverter

This inverter has a lower price and easy to maintain compared to the central inverter, so it is the preferred choice in most on-grid solar energy systems. But one of the disadvantages of using this type of inverter is if one of the panel in the string exposed to the shade, the electric power generated from the string will be decrease, therefore, it must be ensured that there are no shadow causes. Figure 3-19 presented the connection of the solar system with the string inverter. Figure (3-21)

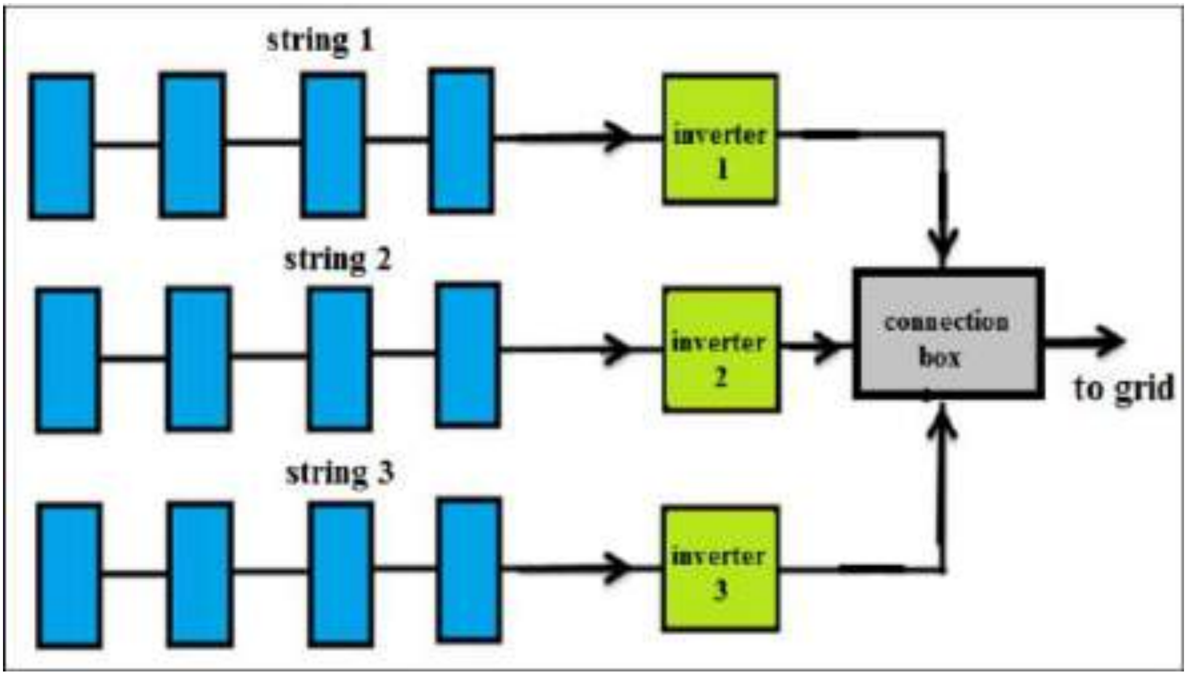

Figure (3-21) Solar system connection with the string inverter

3.5.3String inverter with power optimizer

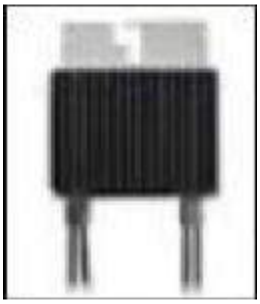

Figure (3-22) power optimize dvice

Each solar panel is connected to the power improvement device, which is a device that consists of a system that raises the DC generated voltage from the panel and operats using the (MPPT) technique. The shade or decreased performance of one of the panels does not affect the performance of the rest of the panels since the panels are not connected with each other. Figure 3-20 depicted the connection of the solar system with power optimize. Figure (3-23)

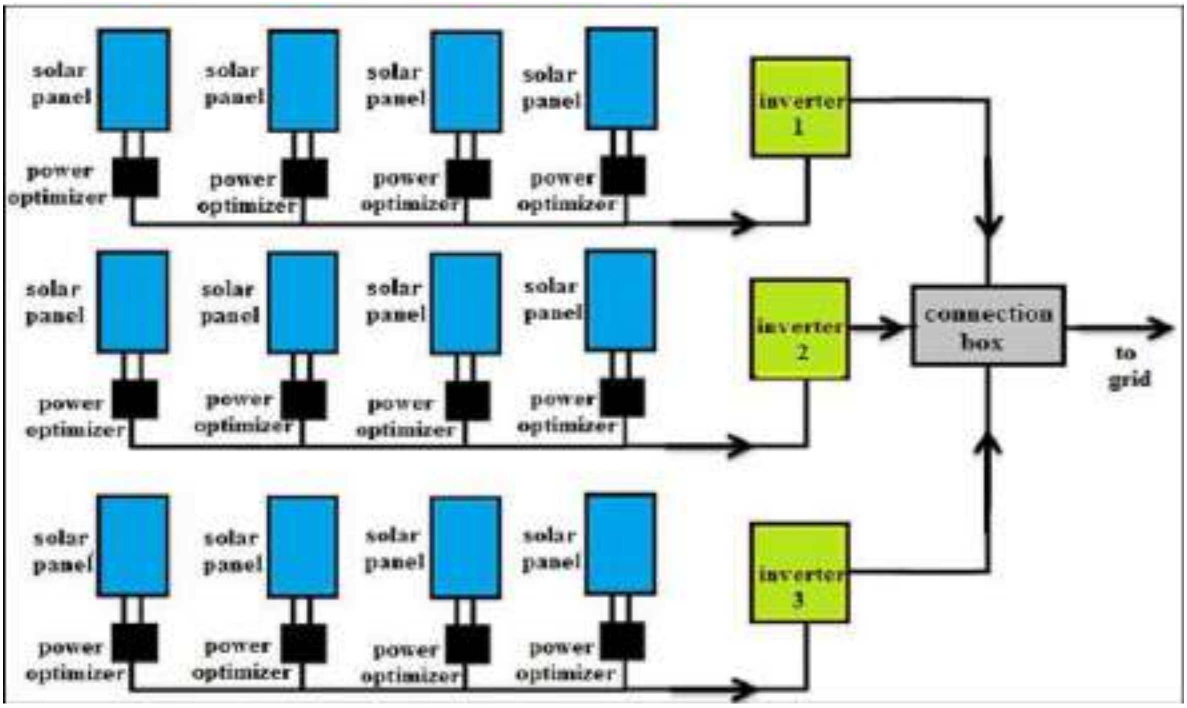

Figure (3-23) The connection of the solar system with power optimizer devices.

3.5.4 Micro inverter

Figure (3-24) Micro inverter

Each panel is connected to a microinverter that converts the continuous voltage generated from the panel into alternating voltage, so the panels are not affected with each other as they are not connected to each other. This type of inverter operates with the ongrid system, and due to use a large number of solar panel, the system becomes costly, so this type used in a sm0all systems which contains a small number of panels. Figure (3-25)

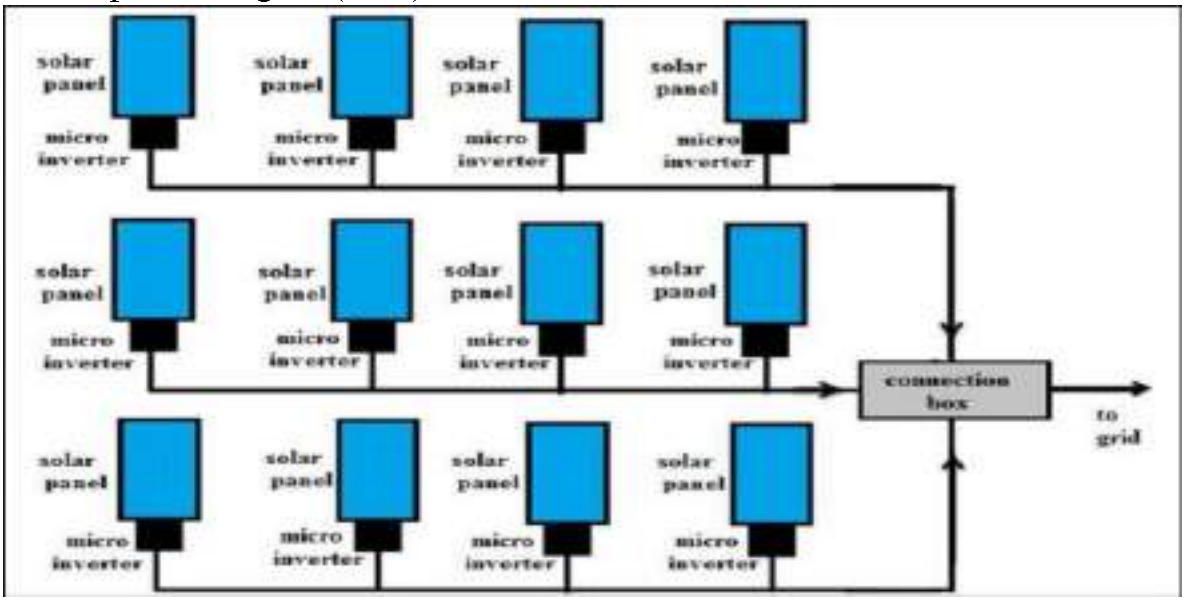

Figure (3-25) The connection of the solar system with microinvert

3.5.5Hybrid inverter

Figure (3-26) Hybrid inverter

In this type of inverters two types of energy sources are used, such as solar panels and batteries, where a series of solar panels and a series of batteries are inserted into the hybrid inverter, which in turn performs more than one function;

. Converting the voltage generated from the panels into AC voltage

.Charging the batteries from the solar panels, and if the power generated from the solar panels is insufficient to charge the batteries, the inverter charges the batteries from the main grid after converting their alternating voltage to a continuous voltage Feeding the load with electric current in the event of a power outage in the main grid If the main grid supplies the load with electricity, the inverter will give the amperes generated from the solar panels to the main grid. Figure (3-27)

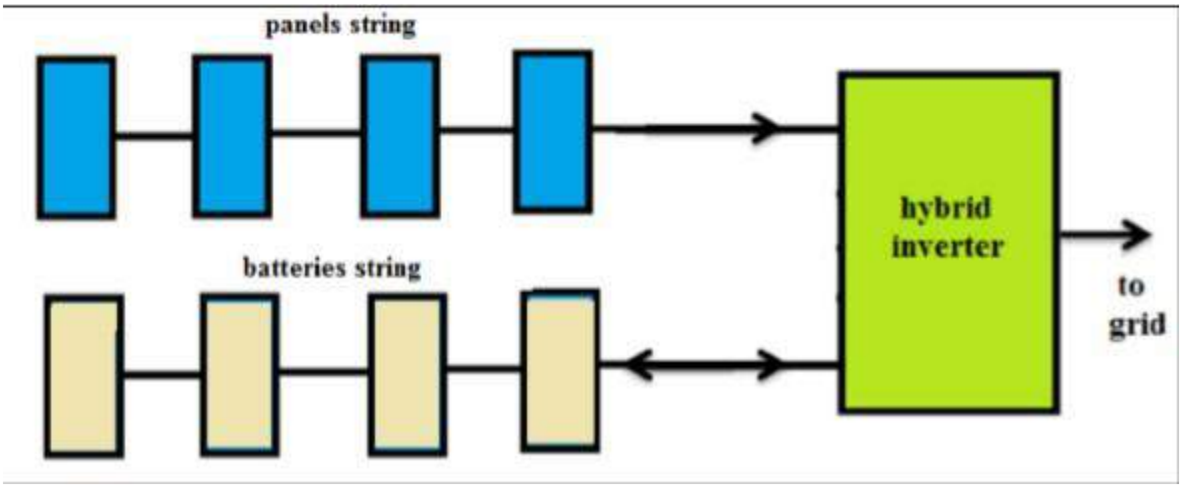

Figure (3-27) The connection of the solar system with hybrid inverter

3.5.5 Inverter with charger regulator(inverter/charger)

Figure (3-28) Inverter with charger regulator

This type of inverter performs the process of charging batteries in addition to converting continuous voltages to alternating voltages and is used in off-grid systems and stand- alone systems.

Figure 6 showed solar system connection with inverter/charger. Figure (3-29)

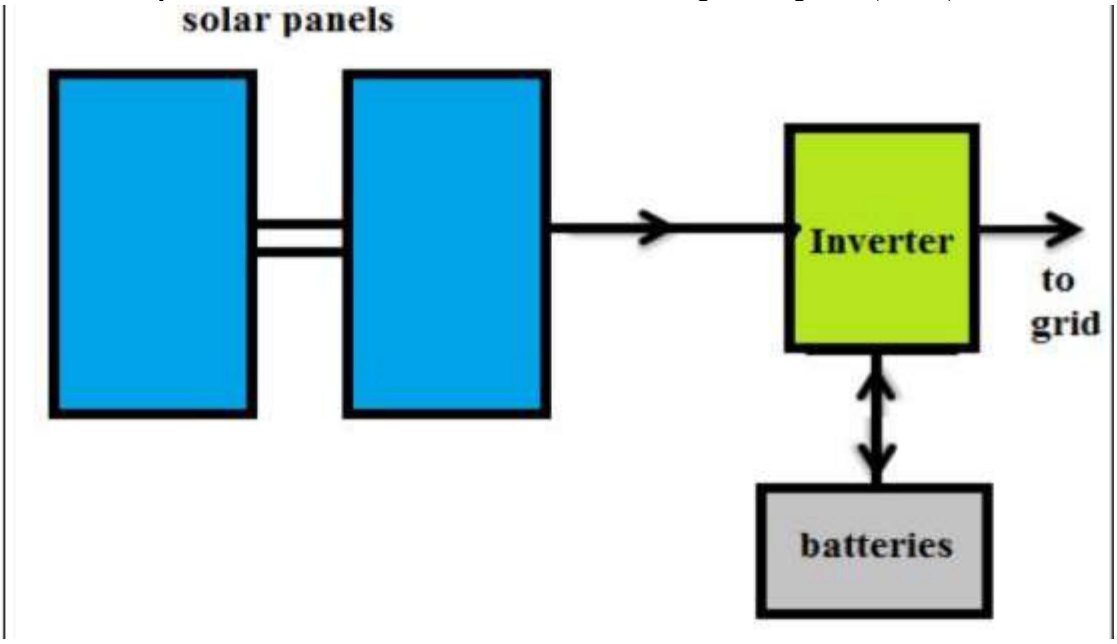

Figure (3-29) The connection of the solar system with the inverter/charger

3.5.6 Simple inverter:

Figure (3-30) Simple inverter

This inverter converts DC voltage to AC voltage only. In this case, a charge regulator (pwm) or (mppt) must be used. This type of inverter is used in stand-alone systems. Figure 3-28 depicted the solar system connection with the simple inverter. Figure (3-31)

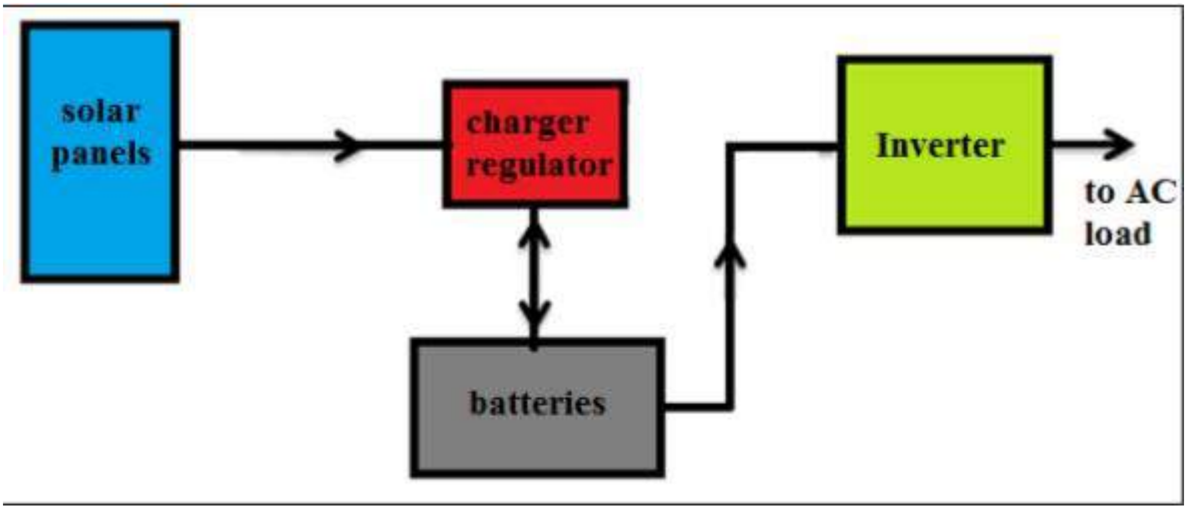

Figure (3-31) The connection of the solar system with the simple inverter

3.6 Solar Energy Batteries

Solar Batteries are a deep cycle battery used to store the direct current generated by the solar panels, which is converted into alternating current by the inverter to operate the various loads. The battery (12v) generally consists of (6) cells, each of these cells consists of, anode, cathode, and the conductive material (the electrolyte).

There are many types of solar batteries figure (3-29), which differ among themselves in the materials from which the anode and cathode are made and the type of electrolyte. Figure (3-32)

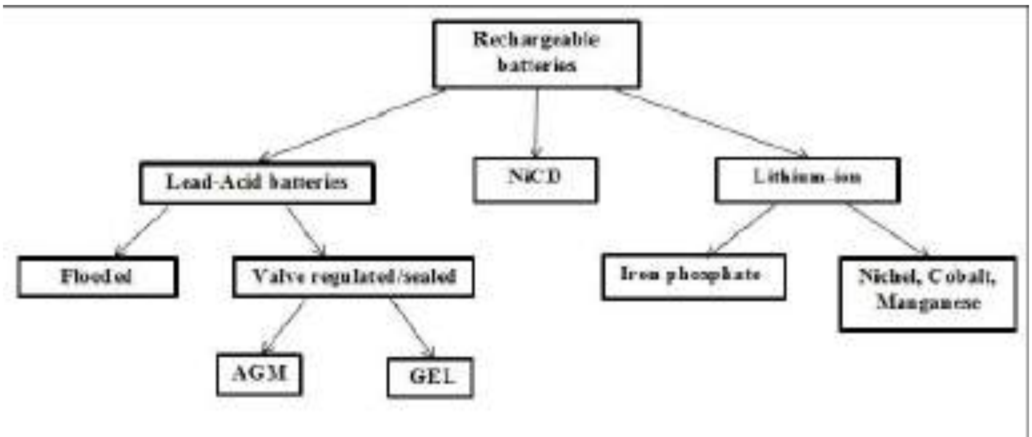

Figure (3-32) The different types of solar batteries

The most common types of solar batteries are:

1 – lead-acid batteries that include:

- Liquid lead-acid batteries (flooded)
- Gel Batteries
- AGM batteries

2- Lithium Batteries

3.6.1 The flooded batteries

It is the oldest type of batteries, the cheapest and the most widespread. It is called ―liquid because the conductive material between the anode and cathode plate is a liquid substance, which is sulfuric acid diluted with water, concentration ratio 3:1. Flooded batteries need maintenance, which includes replacing the acid and adding distilled water once or twice amonth to compensate for the water evaporating from the batteries. Figure (3-30) demonstrates the components of a single cell of a flooded battery, which consists of sponge lead which represents the cathode electrode and a clip of lead, and behind the clip a plate of dioxide Lead, which represents the anode electrode, and these cells are immersed in acid diluted with water. Figure (3-33)

Figure (3-33) The liquid lead -acid battery

3.6.2 The gel battery

A gel battery has the same design and functionality as a traditional flooded battery. The gel battery differs from the liquid battery in that the conductive material contains silica in the electrolyte, which creates a gel-like substance. The gel battery is characterized by being suitable for use in many positions due to its stability and absence of any gases emitting from it, and it is a deep cycle battery. Figure (3-34)

Figure (3-34) The gel battery

4.2.3 The AGM battery

A fiberglass material is placed between the anode and the cathode, which absorbs the electrolyte like a sponge and prevents it from leaking or evaporating. An AGM battery is a deep cycle discharge with the provision of mixing the sulfate back into the hydrogen gas, resulting in a reduction of the hydrogen released during the discharge process. Figure (3-32)

Figure (3-32) The AGM lead battery

3.6.4 The lithium battery

Anodes consist of graphite-based materials due to the low cost, wide spread, and the stability to accommodate the lithium insertion, but it carbon suffer from a low capacity, so in recent year, the carbon-based anode has been improved, and new types of anode materials, such as silicon, alloy, and metal oxides have been developed, which has improved the lifetime, capacity and performance of lithium batteries. Cathodes consist of a complex lithium compound material, such as LiCoO2 and LiFePO4. Battery performance significantly differs with different cathodes.

Cathode has been fabricated from lithium material blending with conductive material such as carbon due to low impedance because of high diffusion coefficient and high ionic conductivities compared with other materials compound. The electrolyte in lithium batteries includes three types liquid electrolyte, semisolid electrolyte, and solid-state electrolytes. Liquid electrolyte consists of lithium salts such as., LiBF4, LiPF6, LiN(CF3SO2)2, and LiBOB, which are dissolved in organic carbonates such as, ethylene carbonate, propylene carbonate, ethyl methyl carbonate, dimethyl carbonate, and their mixtures. While, the semisolid electrolyte, and solid-state electrolyte are composed of lithium salts as the conducting salts and high-molecular- weight polymer matrices such as, polyvinylidene fluoride and poly (ethylene oxide). Figure (3-33)

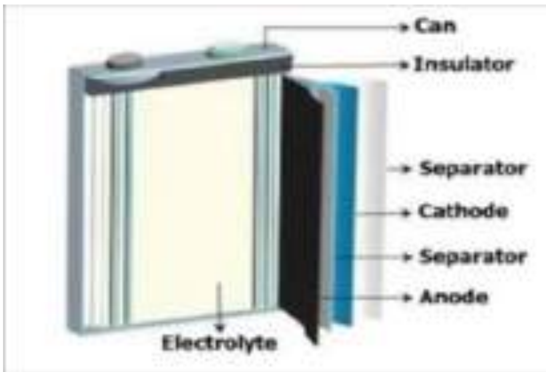

Figure (3-33) Lithium-ion battery

	Lead-acid battery	Jel battery	AGM battery	Lithium battery
Maintenance	Need	No need	No need	No need
Depth of discharge	50%	75%	50%	80%
Lifespan	3-5 year	6-8 year	6-8 year	20 year
Cost	150$	300$	250$	2000$
Charge temperature	-0°C to 50°C	-20°C to 50°C	0°C to 50°C	0°C to 45°C
Discharge temperature	-30°C to 70°C	-40°C to 60°C	-20°C to 60°C	–20°C to 60°C
Storage temperature	-20°C to 60°C	-40°C to 60°C	-20°C to 60°C	-20°C to 60°C
Energy density	30W.h/kg	40W.h/kg	50W.h/kg	50-260W.h/kg

Table (3-1) Comparison of different types of batteries

3.7 The most important information about Batteries The effectivity and performance of the battery depend on the following parameters:

1. Capacity of battery
2. Efficiency of battery
3. Depth of discharge

Battery capacity the amount of energy that the battery can storage. If a battery of (12v) has a capacity of (500 A.h) , the energy can be storage with this battery is:

Energy = Voltage * Current * Time
= 12v * 500A.h
= 6000w.h

3.7.1 Battery efficiency
It is the ratio of the output energy from the battery to the input energy that the battery needs to charge. If the energy that the battery needs to charge is (6000 wh) and the energy that can be obtained from this battery is (4800 wh), then the efficiency of this battery is:
Battery efficiency = (output energy) / (input
energy) * 100%
= (4800 w.h) / (6000 w.h) * 100%
= 80%

3.7.2 Depth of Discharge (DOD)
It is the amount of capacity that can be obtained from the battery capacity. If the depth of discharge is equal to 50% for a battery whose capacity is (60Ah), then the amount of capacity that can be get it fro this battery is: = 60A.h * 0.5
= 30Ah
The time required for charging the batteries When the solar panels used to charge the battery, the time required for charging the battery is equal to (capacity of the battery / panel current) If the panel(9A) used in charging the battery (200A.h) then the time that required to charge the battery = = 22.22h

3.8 Series and parallel connection of batteries
The batteries are connected in parallel or in series to obtain the required current and voltage Figure (3-34) shows four batteries each one of (12v , 100Ah) connected in series

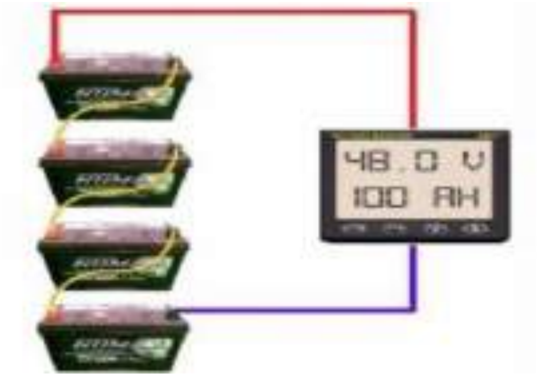

Figure (3-34) Series connection of batteries

and Figure (3-35) obvious these four batteries connected in parallel

Figure (3-35) Parallel connection of batteries

At the present time, due to the rise in temperatures over the past years, it is necessary to take into account the impact of temperatures on the performance of the battery when choosing the appropriate battery for working on design. Temperature, have a significant effect on the performance, and the safety of the solar batteries. As the temperature of the battery increases the chemical reactions inside the battery also quicken, and increased storage capacity of the battery. It was found that an increase in temperature from 25 0C to 45 0C led to a 20% increase in maximum storage capacity, but an available capacity decrease over time, and the lifecycle of the battery is decreased over time. Lithium battery has better volume and weight and is relatively cheaper to maintain but the initial cost is higher, and it is more temperature sensitive. Flooded batteries and Jel batteries are the most using in Iraq because they are more cost-effective, its price is just 1/4~1/6 of the lithium battery cost with an acceptable limit of the discharge depth (DOD) and it is suitable for high temperature work.

4.1 Data Collection

Data was collected regarding the solar systems available in the Iraqi market, which includes the components of each solar panel, the used battery, the inverter, the charging regulator, the supplied voltage, the current, the processing time, whether or not it needs national electricity, the amount of current supplied day and night, in addition to the price of each system. It took place during a field trip to the Iraqi market in the governorates of Hilla, Karbala, and the governorate of Baghdad, specifically in Al-Sinaa Street, which is the largest market for electrical and electronic devices in Iraq.

Table (4-1) Data Collection

Project	Power supply during day	Power supply at night	System Price	Current Provided Time	Guarantee Period	Design Lifetime
	Benefit	Benefit	Cost	Benefit	Benefit	Benefit
S1	12	6	4022	8	3	5
S2	20	12	7350	9	2	5
S3	12	6	3900	5	2	5
S4	20	12	6500	6	12	32
S5	12	6	4000	4	12	32
S6	20	12	7344	7	10	32
S7	13.5	8.5	5440	6	8	15
S8	18.5	9	6800	3	8	15
S9	13.5	6	3750	3	7	10
S10	14	8	4125	3	15	20
S11	13.5	6	3875	5	13	20
S12	20.5	11	13900	7	7	10
S13	23.5	12	10350	8	14	20
S14	13.5	7	1660	8	16	20
S15	13.5	7	8328	7	7	10
S16	12	10	7540	8	7	10
S17	23.5	13	41600	5	10	12
S18	13.5	6	22840	6	10	12

4.2 Design of Questionnaire Form

The Questionnaire form needs to be carefully designed according to experts' recommendations. A number of personal and group meetings (face-to-face and virtual) were held with experts to formulate questionnaire form paragraphs.

The questionnaire form is consisting of two main parts the first one is specified to respondents' personal information, and the second part is assigned to sample or respondents' opinions related to solar systems evaluation factors. The questionnaire was designed in Arabic language as shown in figure (4 – 1).

The questionnaire sample is chosen as a probability sampling (simple random sampling). This type of questionnaire sample considers each respondent's opinion has equal weight which means equal respondent probability.

جامعة بابل

كلية الهندسة / المسيب

قسم الهندسة الطاقة

تهديكم اطيب التحيات . . . .

نضع بين ايديكم إستبانة لبحث علمي خاص بإكمال مشروع تخرج طلبة كلية الهندسة / المسيب – جامعة بابل. راجين ابداء رأيكم فيما يتعلق بفقرات الاستبانة وتقبلوا منا فائق الشكر والتقدير.

الاسم (اختياري):

العمر:

التحصيل الدراسي والاختصاص:

سنوات الخبرة في مجال الاختصاص:

سؤال/ فيما لو رغبت بشراء ونصب واستخدام منظومة طاقة شمسية خاصة بمنزلك او محل عملك.

فما تقييمك لاهمية العوامل المذكورة ادناه من حيث أهمية كل عامل في اختيار المنظومة المناسبة.

العوامل	التقييم				
1. الكلفة الاولية	مؤثر جدا ☐	مؤثر ☐	متوسط ☐	ضعيف التاثير ☐	غير مؤثر ☐
2. زمن التجهيز	مؤثر جدا ☐	مؤثر ☐	متوسط ☐	ضعيف التاثير ☐	غير مؤثر ☐
3. التيار المجهز نهارا	مؤثر جدا ☐	مؤثر ☐	متوسط ☐	ضعيف التاثير ☐	غير مؤثر ☐
4. العمر الافتراضي للمنظومة	مؤثر جدا ☐	مؤثر ☐	متوسط ☐	ضعيف التاثير ☐	غير مؤثر ☐
5. التيار المجهز ليلا	مؤثر جدا ☐	مؤثر ☐	متوسط ☐	ضعيف التاثير ☐	غير مؤثر ☐
6. مدة الضمان	مؤثر جدا ☐	مؤثر ☐	متوسط ☐	ضعيف التاثير ☐	غير مؤثر ☐
7. اخرى (مع تحديد العامل لطفا)	______________				
	مؤثر جدا ☐	مؤثر ☐	متوسط ☐	ضعيف التاثير ☐	غير مؤثر ☐

figure (4 – 1) The questionnaire designed in Arabic language

The respondents requested to assess the importance of each factor of solar system evaluation on a five Likert scale (Very Low, Low, Neutral, High, Very High). All proposed or alternative systems will be evaluated or ranked according to the same multi criteria environment.

Table (4– 2) Questionnaire results

Sr	Criteria	Very high	High	Neutral	Low	Ineffective
1	Power supply during the day	15	12	3	0	0
2	Power supply at night	8	6	13	2	1
3	System Price	10	8	11	0	1
4	Current Provided Time	18	8	4	0	0
5	Guarantee Period	3	21	5	0	1
6	Design Lifetime	22	5	3	0	0

4.1.1 Relative Importance Index

The ranking of selection factor is determined using Relative Importance Index (RII) by equation (4 – 1) depending on the respondents' opinion (Gündüz et al., 2013).

$$\mathbf{RII} = \frac{\sum \boldsymbol{fi \times n}}{\boldsymbol{A \times N}}$$ Eq. (4– 1) (Gündüz et al., 2013)

Where:

RII: Relative importance Index
fi: criteria frequency
n: Respondent opinion value (5 for Very High, 4 for High, 3 for Neutral, 2 for Low, 1 for Very Low)
A: Respondent opinion higher value (equal to 5)
N: Sample Size

Table (4 – 3) RII calculation

Sr	Criteria	RII	Criteria Weights
1	Power supply during the day	0.88	17.74%
2	Power supply at night	0.72	14.52%
3	System Price	0.77	15.59%
4	Current Provided Time	0.89	18.01%
5	Guarantee Period	0.77	15.46%
6	Design Lifetime	0.93	18.68%

4.1.2 Combinative Distance Based Assessment (CODAS)

Combinative distance-based assessment (CODAS) is a multi-criteria decision-making method founded by (Ghorabaee, 2016). This method ranking alternatives depending on distance between each alternative, and the negative ideal solution. The distance calculated into two components with varied ratio for each one of them. Euclidean distance is used as the major distance method component, while taxicab distance method is the minor component. The inputs should be quantitative matrix consist from list of alternatives with numerical values according to predefined list of criteria. Even more the preference between ranking or selection criteria are translated by individual criteria weight (Wei et al., 2021).

The best alternative should have higher distance value from negative ideal solution.

4.1.3 Data Normalization

In order to justify the different value ranges for each input data and handle it forward with optimization process. The normalization equations defer depending on criteria behaviour whether it benefit or non-benefit criteria as shown in Eq. (4– 2). CODAS technique adopts one of linear normalization procedures in order to process data on the same approach (Ghorabaee, 2016).

$$\bar{X} = \begin{cases} \dfrac{X_{ij}}{Max\,X_{ij}} & \text{for benefit criteria} \\ \dfrac{Min\,X_{ij}}{X_{ij}} & \text{for cost criteria} \end{cases}$$

Eq. (4 – **2**)

(Lei, 2021)

The normalized matrix will be used to applying criteria weights using equation (6 – 3). This step will produce weighted normalized matrix that consider the base matrix for alternatives ranking.

Eq. (4 – 3)

$$Weighted\ normalized\ \bar{X}_{ij} = W_j \times \bar{X}_{ij}$$

(Biswas and Pamučar, 2021)

Where W_j is criteria weights with a range (0 – 1) and summation of criteria weights are equal to one otherwise the weights need to be normalized before multiply by matrix. The weights can be detected by consultants, or organization owner (Biswas and Pamučar, 2021).

Table (4-4) Data Normalization

Project	Power supply during day	Power supply at night	System Price	Current Provided Time	Guarantee Period	Design Lifetime
	Benefit	Benefit	Cost	Benefit	Benefit	Benefit
	15.59%	15.46%	17.74%	14.52%	18.68%	18.01%
min/max	23.50	13.00	1660	9	16	32
	Normalization					
S1	0.510638298	0.461538462	0.412729985	0.888888889	0.1875	0.15625
S2	0.85106383	0.923076923	0.22585034	1	0.125	0.15625
S3	0.510638298	0.461538462	0.425641026	0.555555556	0.125	0.15625
S4	0.85106383	0.923076923	0.255384615	0.666666667	0.75	1
S5	0.510638298	0.461538462	0.415	0.444444444	0.75	1
S6	0.85106383	0.923076923	0.226034858	0.777777778	0.625	1
S7	0.574468085	0.653846154	0.305147059	0.666666667	0.5	0.46875
S8	0.787234043	0.692307692	0.244117647	0.333333333	0.5	0.46875
S9	0.574468085	0.461538462	0.442666667	0.333333333	0.4375	0.3125
S10	0.595744681	0.615384615	0.402424242	0.333333333	0.9375	0.625
S11	0.574468085	0.461538462	0.428387097	0.555555556	0.8125	0.625
S12	0.872340426	0.846153846	0.11942446	0.777777778	0.4375	0.3125
S13	1	0.923076923	0.160386473	0.888888889	0.875	0.625
S14	0.574468085	0.538461538	1	0.888888889	1	0.625
S15	0.574468085	0.538461538	0.19932757	0.777777778	0.4375	0.3125
S16	0.510638298	0.769230769	0.220159151	0.888888889	0.4375	0.3125
S17	1	1	0.039903846	0.555555556	0.625	0.375
S18	0.574468085	0.461538462	0.07267951	0.666666667	0.625	0.375

4.2 Negative Ideal Solution

The core index of CODAS method is determining the negative ideal solution for alternatives regarding to each criterion which will be used to asses alternatives. In another word, all alternatives will be ranked depending on the distance measured from respective values of each alternative to negative ideal limits of each criterion. The idea come from whenever going away from negative solutions, better solutions will be gained. The negative ideal solution can be calculated for each criterion is shown in Eq. (4– 4) (Zhou et al., 2018).

$$r_{ij} = min\, W_j\, \overline{X}_{ij}$$ Eq. (4 – 4) (Zhou et al., 2018)

Where:

r_{ij} is the negative ideal solution for each criterion,

W is criterion weight,

$\bar{}_{ij}$ is the normalized data of alternative (i) and criterion (j).

Table (4-5) Negative Ideal Solution

	W X					
S1	0.079608511	0.071353846	0.073222427	0.129066667	0.035025	0.028140625
S2	0.132680851	0.142707692	0.040068109	0.1452	0.02335	0.028140625
S3	0.079608511	0.071353846	0.075512974	0.080666667	0.02335	0.028140625
S4	0.132680851	0.142707692	0.045307785	0.0968	0.1401	0.1801
S5	0.079608511	0.071353846	0.07362515	0.064533333	0.1401	0.1801
S6	0.132680851	0.142707692	0.040100844	0.112933333	0.11675	0.1801
S7	0.089559574	0.101084615	0.05413614	0.0968	0.0934	0.084421875
S8	0.122729787	0.107030769	0.043308912	0.0484	0.0934	0.084421875
S9	0.089559574	0.071353846	0.078533493	0.0484	0.081725	0.05628125
S10	0.092876596	0.095138462	0.071394085	0.0484	0.175125	0.1125625
S11	0.089559574	0.071353846	0.076000155	0.080666667	0.151775	0.1125625
S12	0.135997872	0.130815385	0.021187094	0.112933333	0.081725	0.05628125
S13	0.1559	0.142707692	0.028454164	0.129066667	0.16345	0.1125625
S14	0.089559574	0.083246154	0.17741	0.129066667	0.1868	0.1125625
S15	0.089559574	0.083246154	0.035362704	0.112933333	0.081725	0.05628125
S16	0.079608511	0.118923077	0.039058435	0.129066667	0.081725	0.05628125
S17	0.1559	0.1546	0.007079341	0.080666667	0.11675	0.0675375
S18	0.089559574	0.071353846	0.012894072	0.0968	0.11675	0.0675375

4.3 Euclidean and Taxicab Distance

The distance between two points can be measured into various methods. one of the methods is founded by Euclid (considered the father of geometry) an ancient Greek scientist interested in geometry, mathematics and logic. Euclidean method depends on Pythagorean theorem that consider the square distance between two points is equal to summation of square difference between points Cartesian coordinates. In another words, the distance in optimization methods or techniques are using Euclidean distance related to distance measuring issues which shown on Eq. (4 – 5) (Liberti et al., 2015).

The other distance measure used is taxicab distance which is equal to absolute difference of Cartesian coordinates between alternatives, and negative ideal solution. This method having many titles like Manhattan distance, and city block distance that not considered the shortest distance between points (Badi et al., 2017). It's calculated as summation of segments that connected the two points, as shown in Eq. (4 – 5), and Eq. (4 – 6).

$$Ed_i = \sqrt[2]{\sum_{j=1}^{j}\left(rij - \min r_{ij}\right)^2}$$

Eq. (4 – 5) (Liberti et al., 2015)

$$\mathrm{Tc_i} = \sum_{j=1}^{j}\left|r_{ij} - \min r_{ij}\right|$$

Eq. (4 – 6) (Badi et al., 2017)

Where:

Ed_i is Euclidean distance for alternative (i) from negative ideal solution, Tc_i is Taxi distance for alternative (i) from negative ideal solution.

Table(4-6),(4-7) Euclidean and Taxicab Distance

Project	Power supply during day	Power supply at night	System Price	Current Provided Time	Guarantee Period	Design Lifetime
	Benefit	Benefit	Cost	Benefit	Benefit	Benefit
	15.59%	15.46%	17.74%	14.52%	18.68%	18.01%
MIN	0.079608511	0.071353846	0.007079341	0.0484	0.02335	0.028140625

	Eudicaltion distance						
S1	0	0	0.004374908	0.006507111	0.000136306	0	**0.105**
S2	0.002816673	0.005091371	0.001088259	0.00937024	0	0	**0.136**
S3	0	0	0.004683162	0.001041138	0	0	**0.076**
S4	0.002816673	0.005091371	0.001461414	0.00234256	0.013630563	0.023091652	**0.22**
S5	0	0	0.004428345	0.000260284	0.013630563	0.023091652	**0.203**
S6	0.002816673	0.005091371	0.00109042	0.004164551	0.00872356	0.023091652	**0.212**
S7	9.90237E-05	0.000883919	0.002214342	0.00234256	0.004907003	0.003167579	**0.117**
S8	0.001859444	0.001272843	0.001312582	0	0.004907003	0.003167579	**0.112**
S9	9.90237E-05	0	0.005105696	0	0.003407641	0.000791895	**0.097**
S10	0.000176042	0.000565708	0.004136386	0	0.023035651	0.007127053	**0.187**
S11	9.90237E-05	0	0.004750079	0.001041138	0.016492981	0.007127053	**0.172**
S12	0.00317976	0.003535675	0.000199029	0.004164551	0.003407641	0.000791895	**0.124**
S13	0.005820391	0.005091371	0.000456883	0.006507111	0.01962801	0.007127053	**0.211**
S14	9.90237E-05	0.000141427	0.029012533	0.006507111	0.026715903	0.007127053	**0.264**
S15	9.90237E-05	0.000141427	0.000799949	0.004164551	0.003407641	0.000791895	**0.097**
S16	0	0.002262832	0.001022662	0.006507111	0.003407641	0.000791895	**0.118**
S17	0.005820391	0.006929922	0	0.001041138	0.00872356	0.001552114	**0.155**
S18	9.90237E-05	0	3.38111E-05	0.00234256	0.00872356	0.001552114	**0.113**

	Taxi distance						
S1	0	0	0.0661	0.0807	0.0117	0	**0.158**
S2	0.05307234	0.071353846	0.033	0.0968	0	0	**0.254**
S3	0	0	0.0684	0.0323	0	0	**0.101**
S4	0.05307234	0.071353846	0.0382	0.0484	0.1168	0.152	**0.48**
S5	0	0	0.0665	0.0161	0.1168	0.152	**0.351**
S6	0.05307234	0.071353846	0.033	0.0645	0.0934	0.152	**0.467**
S7	0.009951064	0.029730769	0.0471	0.0484	0.0701	0.0563	**0.261**
S8	0.043121277	0.035676923	0.0362	0	0.0701	0.0563	**0.241**
S9	0.009951064	0	0.0715	0	0.0584	0.0281	**0.168**
S10	0.013268085	0.023784615	0.0643	0	0.1518	0.0844	**0.338**
S11	0.009951064	0	0.0689	0.0323	0.1284	0.0844	**0.324**
S12	0.056389362	0.059461538	0.0141	0.0645	0.0584	0.0281	**0.281**
S13	0.076291489	0.071353846	0.0214	0.0807	0.1401	0.0844	**0.474**
S14	0.009951064	0.011892308	0.1703	0.0807	0.1635	0.0844	**0.521**
S15	0.009951064	0.011892308	0.0283	0.0645	0.0584	0.0281	**0.201**
S16	0	0.047569231	0.032	0.0807	0.0584	0.0281	**0.247**
S17	0.076291489	0.083246154	0	0.0323	0.0934	0.0394	**0.325**
S18	0.009951064	0	0.0058	0.0484	0.0934	0.0394	**0.197**

4.4 Relative Assessment Matrix

The alternatives ranking is depended relative assessment matrix that calculated according to Eq. (4 – 7).

Eq. (4– 7)

$$q_i = (Ed_i - Ed_n) + \psi\, (Ed_i - Ed_n) \times (Tc_i - Tc_n)$$

(Lei et al., 2021) Where:

n ∈ (1, 2, . . ., n), ψ is threshold function which apply the balance between Euclidean and Taxicab that used to measure the difference.

The founder of this method is detected (ψ) value within range (0.01 – 0.05), and recommend its value equal to 0.02. The final ranking is made according to summation of relative assessment matrix for each alternative shown in Eq. (4 – 8). Whenever higher value of Q_i for a specific alternative it will be ranked as better solution (Ghorabaee et al., 2017).

$$Q_i = \sum_{n=1}^{i} q_i$$

Eq. (4 – 8)

(Ghorabaee et al., 2017)

Table (4-8) Relative Assessment Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	
S1	0	-0.03049651	0.029342976	-0.11436993	-0.09814821	-0.10645086	-0.0117	-0.0069	0.008	-0.0819	-0.0666	-0.0186	-0.1056	-0.157704855	0.007984656	-0.0133	-0.05	-0.0079	-0.8244
S2	0.030613515	0	0.060047918	-0.08417314	-0.06784122	-0.07623116	0.0188	0.0236	0.0386	-0.0516	-0.0362	0.0119	-0.0754	-0.127616843	0.038587383	0.0172	-0.0196	0.0226	-0.2765
S3	-0.02927523	-0.05968032	0	-0.14332381	-0.12719649	-0.13542125	-0.0409	-0.0361	-0.0213	-0.111	-0.0957	-0.0478	-0.1346	-0.186584167	-0.021274787	-0.0425	-0.0791	-0.0372	-1.3489
S4	0.115849227	0.084935991	0.145513562	0	0.016623817	0.007999066	0.1038	0.1087	0.1239	0.033	0.0484	0.0969	0.0088	-0.043710286	0.12378695	0.1023	0.0651	0.1078	1.2497
S5	0.098908466	0.068105427	0.128478387	-0.01653867	0	-0.00856426	0.087	0.0918	0.1069	0.0163	0.0317	0.08	-0.0077	-0.06012306	0.106839828	0.0854	0.0484	0.0909	0.9477
S6	0.107774148	0.076883815	0.137421958	-0.00799509	0.008604072	0	0.0958	0.1006	0.1158	0.025	0.0404	0.0888	0.0008	-0.051687959	0.115716713	0.0942	0.0571	0.0997	1.1049
S7	0.011736791	-0.01884508	0.041153671	-0.1029455	-0.08665954	-0.09500704	0	0.0048	0.0197	-0.0704	-0.055	-0.0069	-0.0942	-0.146380112	0.019727906	-0.0016	-0.0384	0.0038	-0.6155
S8	0.006933618	-0.02362679	0.036333173	-0.10767159	-0.0914046	-0.09973753	-0.0048	0	0.0149	-0.0752	-0.0598	-0.0117	-0.0989	-0.151084686	0.014925609	-0.0064	-0.0432	-0.001	-0.7014
S9	-0.00799418	-0.03848115	0.021345092	-0.12233448	-0.10613014	-0.11441588	-0.0197	-0.0149	0	-0.0899	-0.0746	-0.0266	-0.1136	-0.165671108	-1.18954E-06	-0.0213	-0.058	-0.0159	-0.9681
S10	0.082518272	0.051754897	0.112061246	-0.03279227	-0.01630005	-0.02482412	0.0706	0.0754	0.0905	0	0.0154	0.0637	-0.024	-0.076351214	0.090461345	0.069	0.0321	0.0745	0.6538
S11	0.067038505	0.036312925	0.096555714	-0.04814178	-0.03169362	-0.04017963	0.0552	0.06	0.075	-0.0154	0	0.0482	-0.0394	-0.091676226	0.074992562	0.0536	0.0166	0.059	0.3761
S12	0.018683896	-0.01192318	0.048120233	-0.09608787	-0.07977766	-0.08814456	0.0069	0.0117	0.0267	-0.0635	-0.0481	0	-0.0873	-0.139545253	0.026672221	0.0053	-0.0315	0.0107	-0.4911
S13	0.106963047	0.076070088	0.136613935	-0.00881673	0.007782603	-0.00082075	0.095	0.0998	0.115	0.0241	0.0396	0.088	0	-0.052514936	0.114907411	0.0934	0.0563	0.0989	1.0903
S14	0.160006533	0.128984516	0.189745428	0.04378194	0.060531654	0.051798425	0.1479	0.1528	0.168	0.0769	0.0924	0.1409	0.0526	0	0.167913449	0.1463	0.1091	0.1519	2.0416
S15	-0.0079983	-0.0385056	0.021360463	-0.12241517	-0.1061998	-0.11449125	-0.0197	-0.0149	1E-06	-0.09	-0.0746	-0.0266	-0.1137	-0.165780896	0	-0.0213	-0.058	-0.0159	-0.9687
S16	0.013343681	-0.01723226	0.042753779	-0.101315	-0.08502981	-0.0933785	0.0016	0.0064	0.0213	-0.0688	-0.0534	-0.0053	-0.0925	-0.144738039	0.021331068	0	-0.0368	0.0054	-0.5864
S17	0.050334294	0.019640216	0.079832623	-0.06474043	-0.04833481	-0.05678232	0.0385	0.0433	0.0583	-0.032	-0.0166	0.0316	-0.056	-0.108261774	0.058302666	0.0369	0	0.0423	0.0763
S18	0.007958542	-0.02257671	0.037333264	-0.10655107	-0.09029617	-0.09862387	-0.0038	0.001	0.016	-0.0741	-0.0587	-0.0107	-0.0978	-0.149926173	0.015942558	-0.0054	-0.0421	0	-0.6822

The final ranking of the alternatives is performed according to the values of preference index shown in the table below

Table (4-9) Result of Relative Assessment Matrix

Project	Pref. Index	Rank
S14	2.041619159	1
S4	1.24968608	2
S6	1.104946364	3
S13	1.090274322	4
S5	0.947721916	5
S10	0.653754841	6
S11	0.376125832	7
S17	0.076284594	8
S2	-0.276527456	9
S12	-0.491100137	10
S16	-0.586385934	11
S7	-0.615472752	12
S18	-0.682221025	13
S8	-0.701353408	14
S1	-0.824433402	15
S9	-0.968079508	16
S15	-0.968705118	17
S3	-1.348942537	18

CHAPTER FIVE CONSCLUSION AND RECOMMENDATION

5.1 Conclusion

1. Selection of photovoltaic energy system must be considered multi criteria process.
2. The selection criteria (اذكر عوامل التقييم)
3. Codas can be adopted to optimize selection of better photovoltaic energy system.
4. Codas is depend on calculating higher distance from worst negative ideal solution.

5.2 Recommendations

In the end, we recommend that when starting a new project, whether it is for a company or a home, and it is related to solar energy systems, we recommend using the Combinative Distance-Based Assessment (CODAS) method. It is a distinctive and accurate method that saves you time and effort in choosing the best organization, as well as to avoid the wrong choice that will expose you to future risks because of

References:

- Anwar, S. (Ed.). (2012). Handbook of research on solar energy systems and technologies. IGI Global.
- Camacho, E. F., & Berenguel, M. (2012). Control of solar energy systems. IFAC proceedings volumes, 45(15), 848-855.
- Goetzberger, A., & Hoffmann, V. U. (2005). Photovoltaic solar energy generation (Vol. 112). Springer Science & Business Media.
- Kalogirou, S. A. (2004). Environmental benefits of domestic solar energy systems. Energy conversion and management, 45(18-19), 3075-3092.
- Miranda T. (2010), *"Designing a national renewable electricity standard: five key components",* Washington, DC: Carnegie Endowment for International Peace, http://carnegieendowment.org/files/renewable_electricity_standard.pdf; [25.07.2014].
- Mitchell, R.K. Agle, B.R. and Wood, D.J. (1997), "Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts", *Academy of Management Review*, 22(4): 853-886.
- Musango, J.K. and Brent, A.C. (2011), "A conceptual framework for energy technology sustainability assessment", *Energy for Sustainable Development* 15(1): 84-91.
- Norberg-Bohm, V. (2000), "Creating incentives for environmentally enhancing technological change: lessons from 30 years of US energy technology policy", *Technological Forecasting and Social Change*, 65(2): 125-148.
- Peidong, Z. Yanli, Y. Jin, S. Yonghong, Z.Lisheng, W. and Xinrong, L. (2009), "Opportunities and challenges for renewable energy policy in China", *Renewable and Sustainable Energy Reviews* 13(2): 439-449.
- Peng, W. Hisham, Z. and Pan, J. (2010), "Household level fuel switching in rural Hubei", *Energy for sustainable development* 14(3): 238-244.
- Pinkse, J. and Van Den Buuse, D. (2012), "The development and commercialization of solar PV technology in the oil industry", *Energy Policy* 40:11-20.
- Popp, D.Hascic, I. and Medhi, N. (2011), "Technology and the diffusion of renewable energy", *Energy Economics* 33(4): 648-662.
- Rabaia, M. K. H., Abdelkareem, M. A., Sayed, E. T., Elsaid, K., Chae, K. J., Wilberforce, T., & Olabi, A. G. (2021). Environmental impacts of solar energy systems: A review. Science of The Total Environment, 754, 141989.
- Reuter, W.H. Szolgayová, J. Fuss, S. and Obersteiner, M. (2012), "Renewable energy investment: Policy and market impacts", *Applied Energy* 97:249-254.
- Ritchie, J. Lewis, J. and Elam, G. (2003), "Designing and selecting samples", In Jane Ritchie and Jane Lewis (Eds.) "Qualitative research practice", A guide for social science students and researchers (pp.77-108) Thousand Oaks, CA: Sage.
- Ritchie, J.andSpencer, L. (2002), "Qualitative data analysis for applied policy research", *the qualitative researcher's companion,* 305-329.
- Rogger, C.Beaurain, F. and Schmidt, T.S. (2011), "Composting projects under the clean development mechanism: Sustainable contribution to mitigate climate change", *Waste Management,* 31(1): 138-146.
- Sadorsky, P. (2012), "Modelling renewable energy company risk", *Energy Policy* 40: 39-48.

- Shen, X., Tian, Z., Fan, R., Shao, L.,Zhang, D., Cao, G., ... & Bai, Y. (2018). Research progress on silicon/carbon composite anode materials for lithium-ion battery. Journal of Energy Chemistry, 27(4), 1067-1090.
- Sirin, S. and Ege, A. (2012), “Overcoming problems in Turkey's renewable energy policy: How can EU contribute?”, *Renewable and Sustainable Energy Reviews* 16(7):4917-4926.
- Song, Y.W. (2011), “The effect of renewable energy policies on renewable energy production”, *Atlantic Economic Journal 39*(2): 195-196.
- Taylor, J. and Van Doren, P. (2002), “Evaluating the case for renewable energy: Is government support warranted?”, *Policy Analysis* 422.
- Tinbergen, J. (1952), “On the theory of economic policy”, North-Holland, Amsterdam.
- Usher, E. (2008), “*Creating the Climate for Change–Building Capacities to Mobilise Investments, background document for the Tenth Special Session of the Governing Council of UNEP”,* In Global Ministerial Environment Forum, The Principality of Monaco, p. 20-22.