Republic of Iraq
Ministry of Electricity
Training & Energy Research Office
Electricity Training center -Ninawah

"Efficiency of Solar Panels and Techniques used in Manufacturing Solar Cells"

Presented by

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Who we are?

Training and Research Office

1- Ninawah

2- Baghdad

3- Hillah

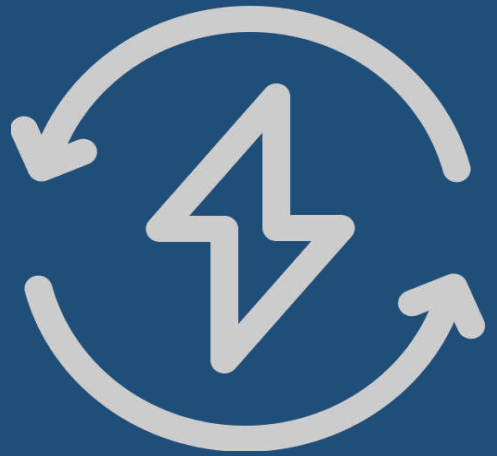
4- Nasiriyah

(The Environment):

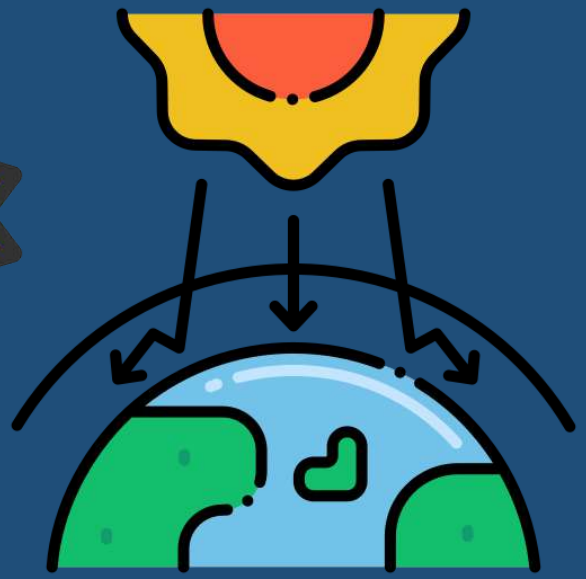
The definition of the term " Environment" according to Cambridge dictionary is the air, water, and land in or on which people, animals, and plants live

(The Energy):

It is considered a property of matter that it cannot be destroyed nor can it be created, but rather it is transformed from one form to another and comes in several forms (Potential, Kinetic, Thermal, Nuclear, Chemical, Electrical, Electromagnetic, etc….).



Global Warming



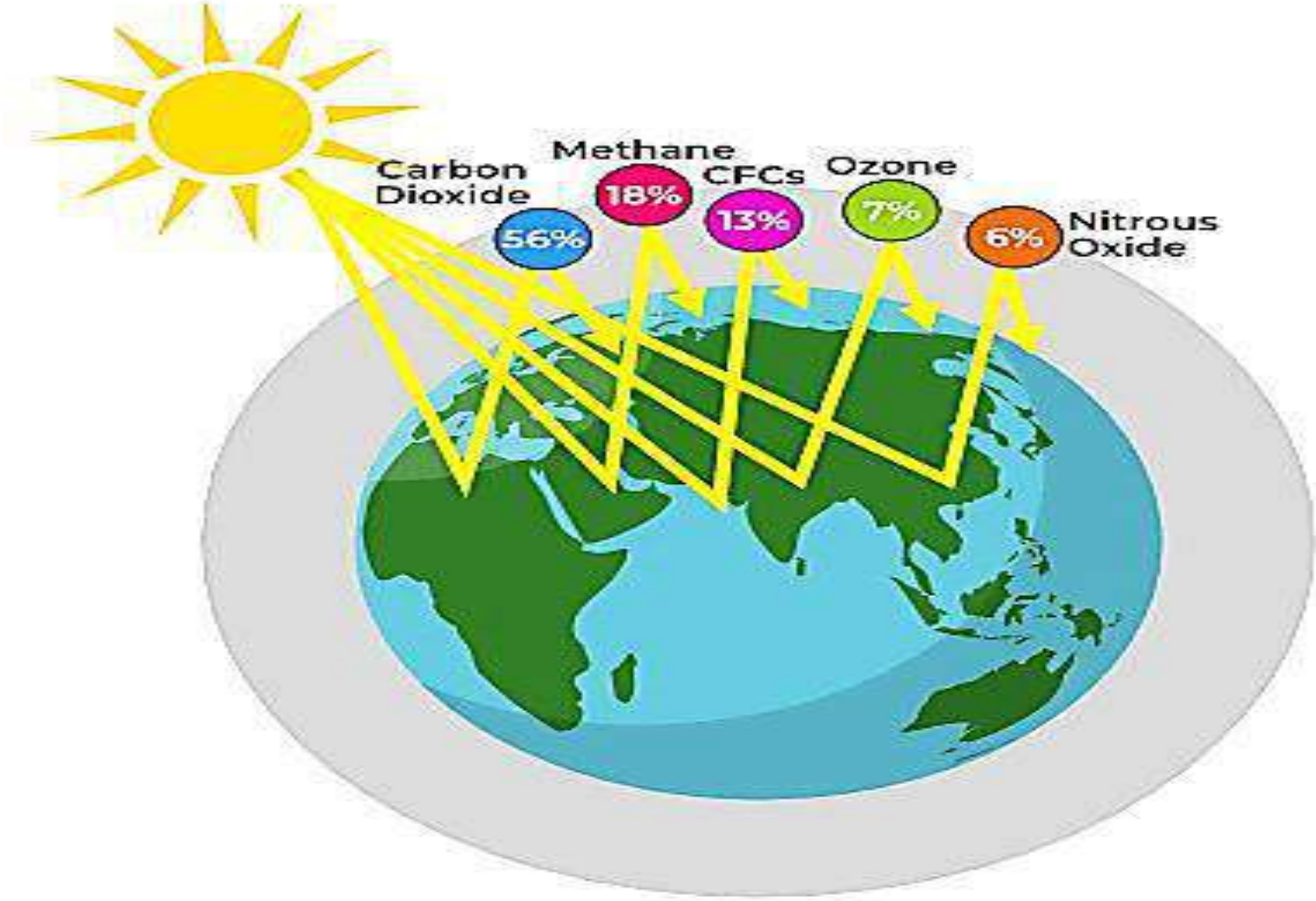
Greenhouse

Greenhouse Emission

Humans Activities

Environment and Energy

Greenhouse Gases



Generation of Power

Transmission Power

Distribution Power

A barrel of oil equivalent (BOE) is a term used to summarize the amount of energy that is equivalent to the amount of energy found in a barrel of crude oil.

It is an American unit of measurement Equals to 159.98 liter or 42 Gallons.

1 BOE = 1628.2 KWh

Environment and Energy

The amount of CO_2 emissions per kilowatt hour:

- Coal : **1000g CO_2/KWh**
- Oil : **800g CO_2/KWh**
- Natural Gas: **500g CO_2/KWh**
- Combined cycle natural gas power plants : **440g CO_2/KWh**
- Nuclear power ,wind power, hydropower and solar power are all less than **50g CO_2/KWh**

Net Zero Emission

Energy Efficiency

Using thermal Solar and Photovoltaic Panels

Sustainable Building

Environment and Energy

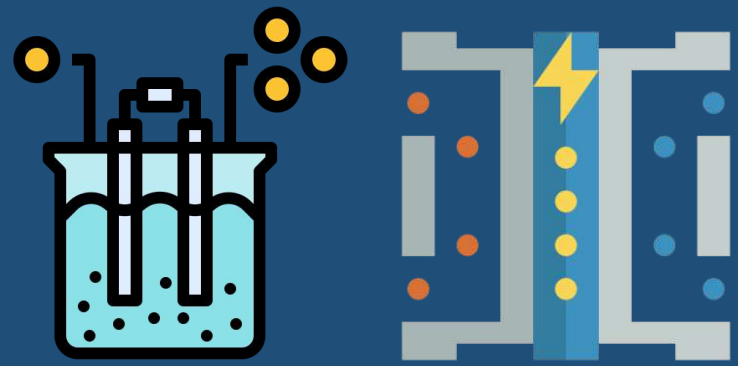
The impact and objectives of adopting the principles of energy efficiency and rationalization on the environment

Energy efficiency has effects on individuals, society and the government as a result of saving energy consumption, the most important of which are:

1. Reducing carbon emissions and reducing environmental pollution
2. Reduce energy costs by improving energy efficiency
3. Improve air quality
4. Increase economic benefits by creating job opportunities and supporting the manufacture of highly efficient equipment
5. Avoid shedding loads at peak times

Net Zero Emission

Using Micro-Hydro Power



Using Renewable Source / Green Hydrogen

Environment and Energy

H

Hydrogen 1.01

Henry Cavendish discovered the element in

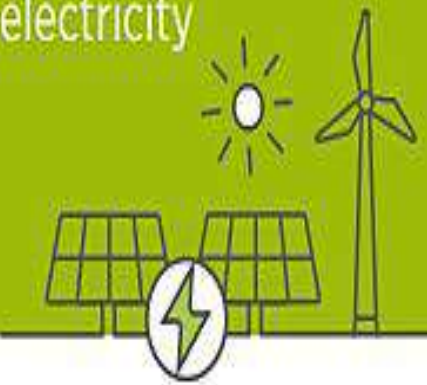
1766

Most abundant chemical structure in the universe

The first industrial water electrolyser was developed in

1888

Hydrogen means "Creator (-gen) of water (hydro-)": its combustion releases only water

Color	GREY HYDROGEN	BLUE HYDROGEN	TURQUOISE HYDROGEN*	GREEN HYDROGEN
Process	SMR or gasification	SMR or gasification with carbon capture (85-95%)	Pyrolysis	Electrolysis
Source	Methane or coal 	Methane or coal 	Methane 	Renewable electricity 

Note: SMR = steam methane reforming.

Types of hydrogen

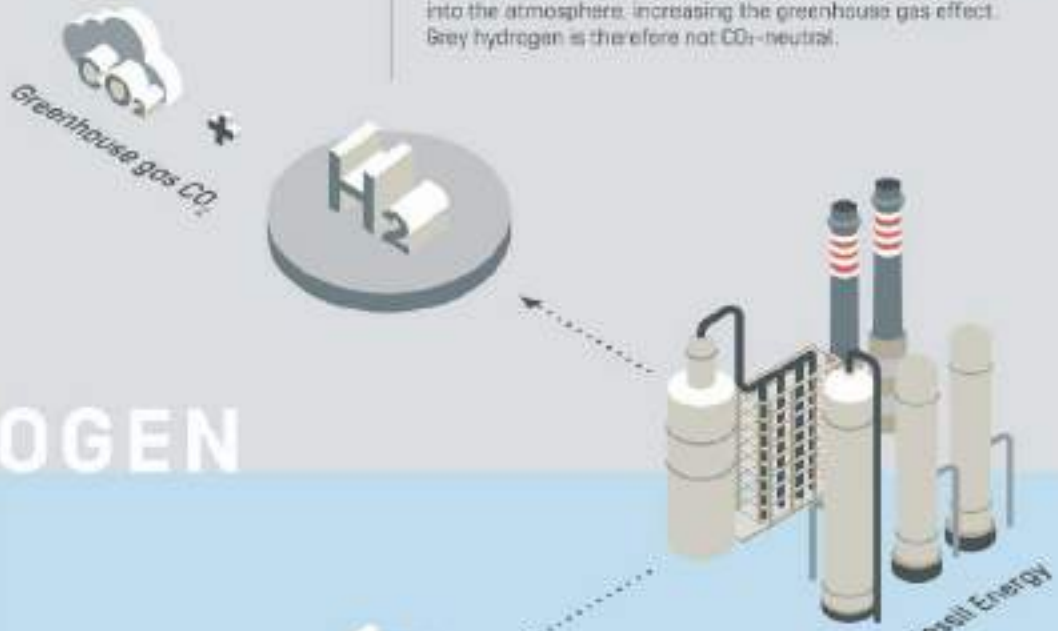
Green Hydrogen

Production of green hydrogen is CO_2-free. The electricity for the electrolysis of water comes from renewable energies. This means that no harmful greenhouse gases are released.

HYDROGEN

Grey Hydrogen

Grey hydrogen is produced using fossil energy sources such as natural gas, which is converted into hydrogen and CO_2 at high temperatures (steam reforming). In the process, the CO_2 is released into the atmosphere, increasing the greenhouse gas effect. Grey hydrogen is therefore not CO_2-neutral.



Turquoise Hydrogen

Turquoise hydrogen is produced by the thermal splitting of methane (methane pyrolysis). Solid carbon results as a by-product. The prerequisites for the process's CO_2-neutrality are heat from a high-temperature reactor using renewable energy sources and a permanent bonding of the carbon. During natural gas and methane exploration and transport, methane escapes (known as methane leakage).

Blue Hydrogen

Blue hydrogen, like grey hydrogen, is produced from hydrocarbons (especially natural gas). However, the CO_2 is captured and stored underground (known as carbon capture and storage, CCS). For blue hydrogen, no additional CO_2 is released into the atmosphere. Methane escapes during natural gas and methane exploration and transport (known as methane leakage).

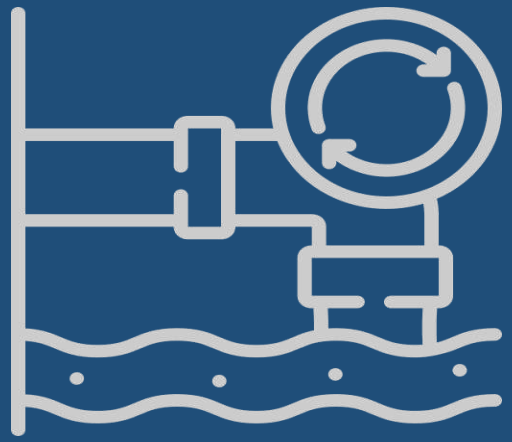
ALSTOM
22 Dec 2023 ·

We are happy to announce that we will supply the first #hydrogen trains to the Italian region of Puglia, Italy for Ferrovie del Sud Est and...
See more

Environment and Energy

Net Zero Emission

Vegetative cover.



Using modern technologies to treat industrial water and Sewage water.

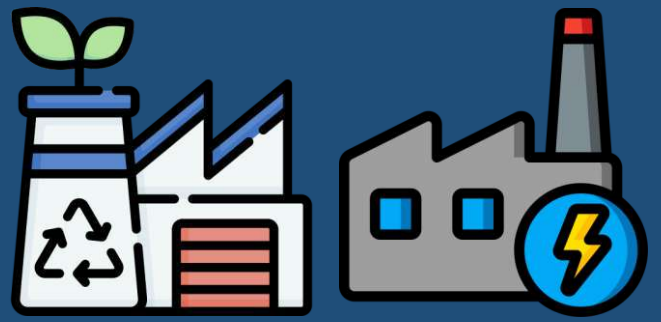
Recycling.

Environment and Energy

Environment and Energy

Net Zero Emission

Using technologies to improve combustion and reduce emissions, such as DLN incinerators, adding chemicals to fossil fuels, and using gas disposal techniques. SO_X NO_X CO_X



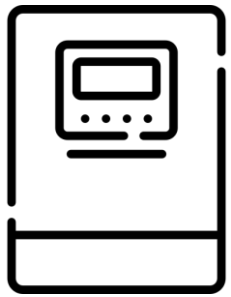
Transitioning the operation of power stations operating on fossil fuels to using gas

Environment and Energy

Solar system components

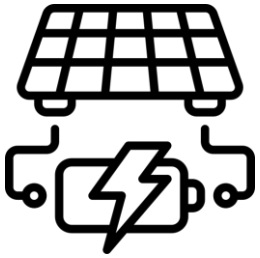
5

Inverters



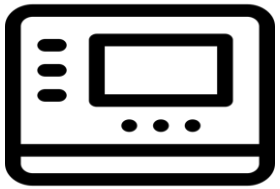
4

Battery



3

Charge Controller

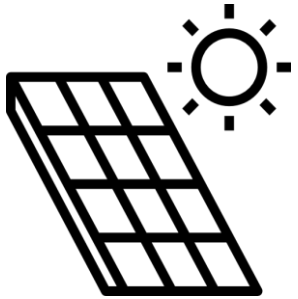


2

Multi contact MC4,MC6

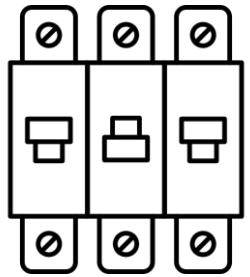
1

Solar Panel



6

Protection Devices



1- Types of Solar Panels:

1-1 Mono-facial solar panel.

1-2 Bi-facial solar panel.

Mono-facial

Bifacial

Solar panels

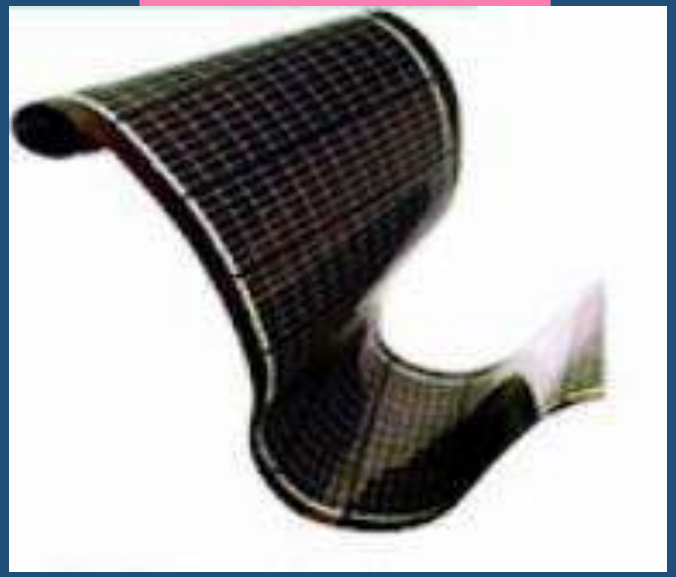
1 (Mono Crystalline)

2 (Poly Crystalline)

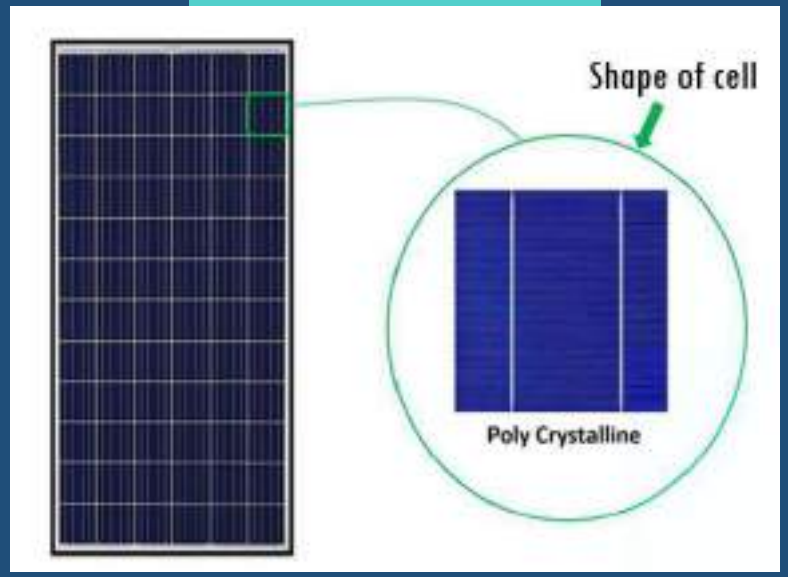
3 (Amorphous Silicon Cell) or (Thin Film)

Types of Panels

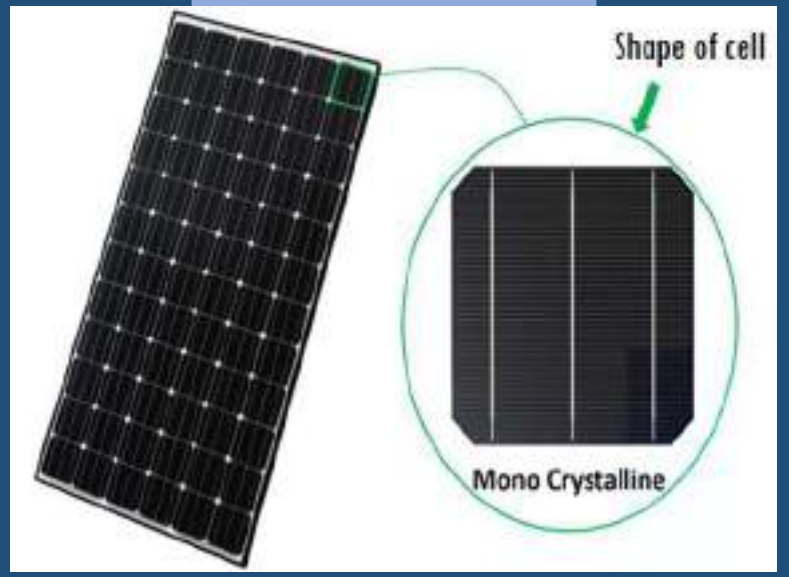
3



2



1



illustrative example

(Efficiency of solar panels):

The engineer and technician must differentiate between two terms:

- **Nominal Power of Solar Panel.**
- **The Efficiency of Solar Panel.**

The power of the solar panel, for example (415 watts), represents the highest power (Pmax) that this panel can give under standard conditions.

Standard Test Conditions (STC) for Solar Panels

1

Cell Temperature

25°C (77°F)

2

Solar Irradiance

1000 W/m^2

3

Air Mass

AM 1.5

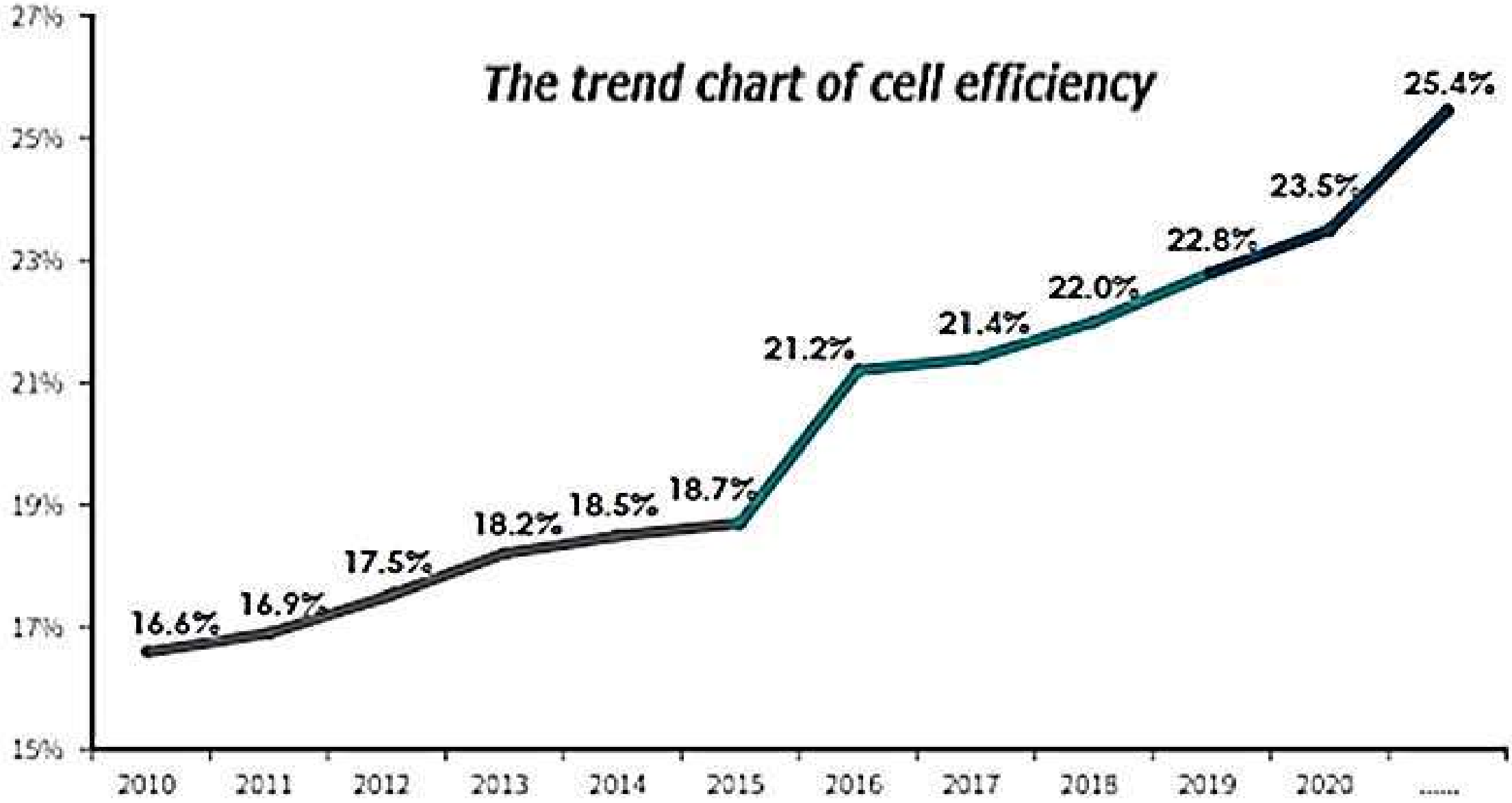
Solar panel efficiency % *

$$\text{Efficiency (\%)} = \frac{\text{Pmax}}{(\text{Area} \times 1000\text{W/m}^2)} \times 100$$

* at STC = Irradiance 1000W/m²

- Pmax = Max panel power (W)
- Area = Panel area (m^2)

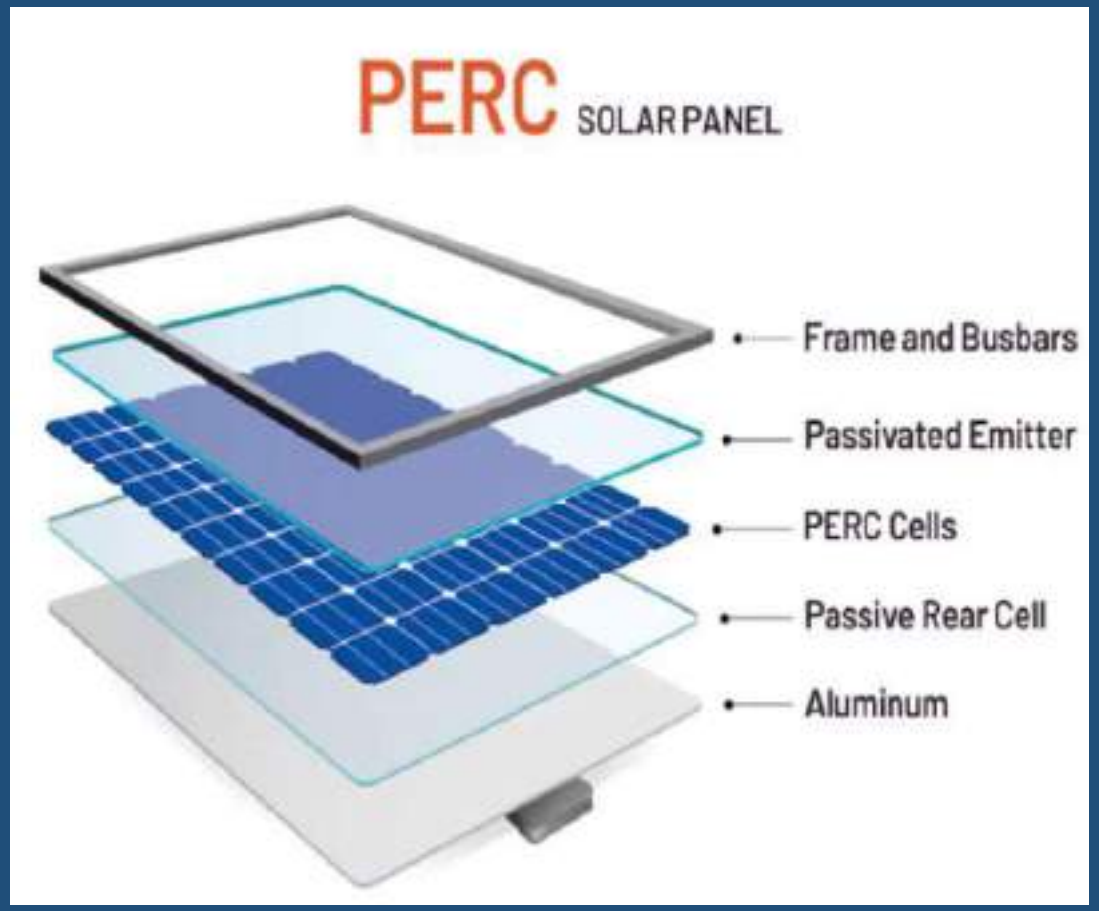
Efficiency of solar panels

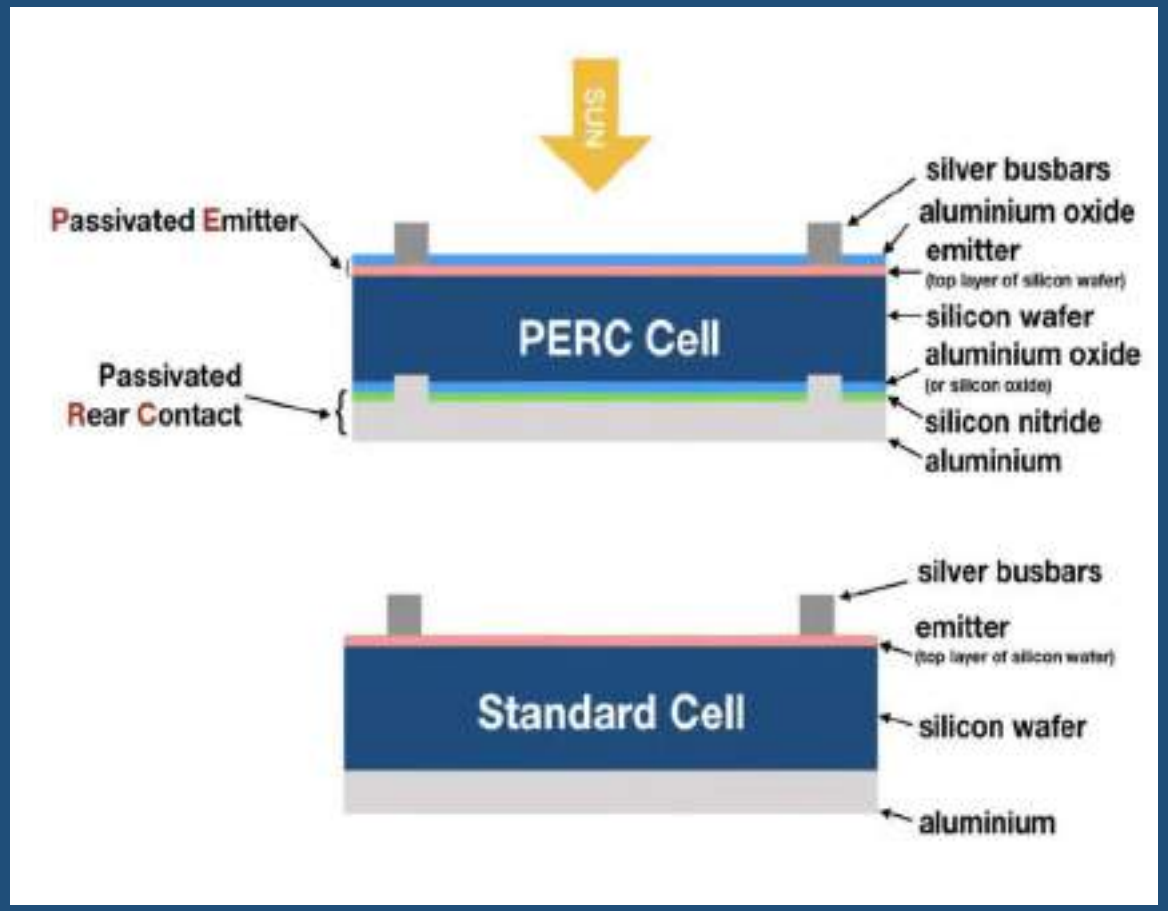


Solar PV technology: The trend chart of cell efficiency

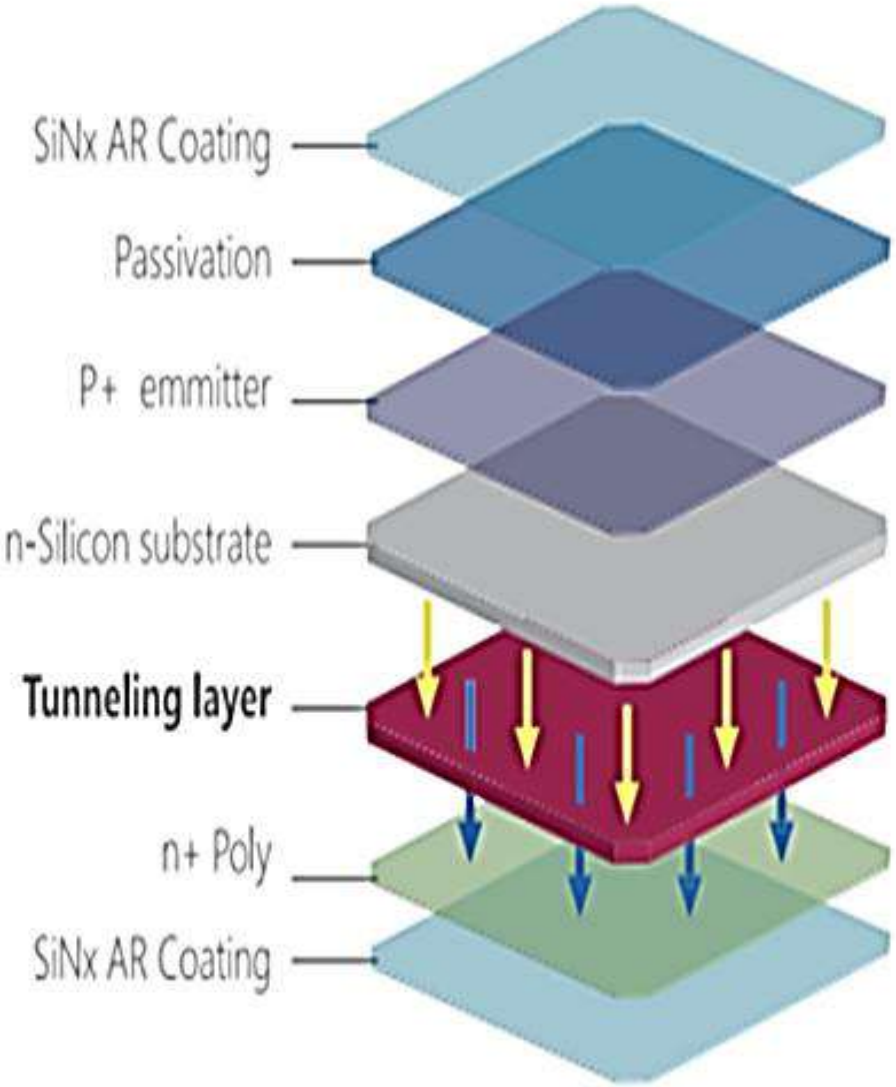
Efficiency of solar panels

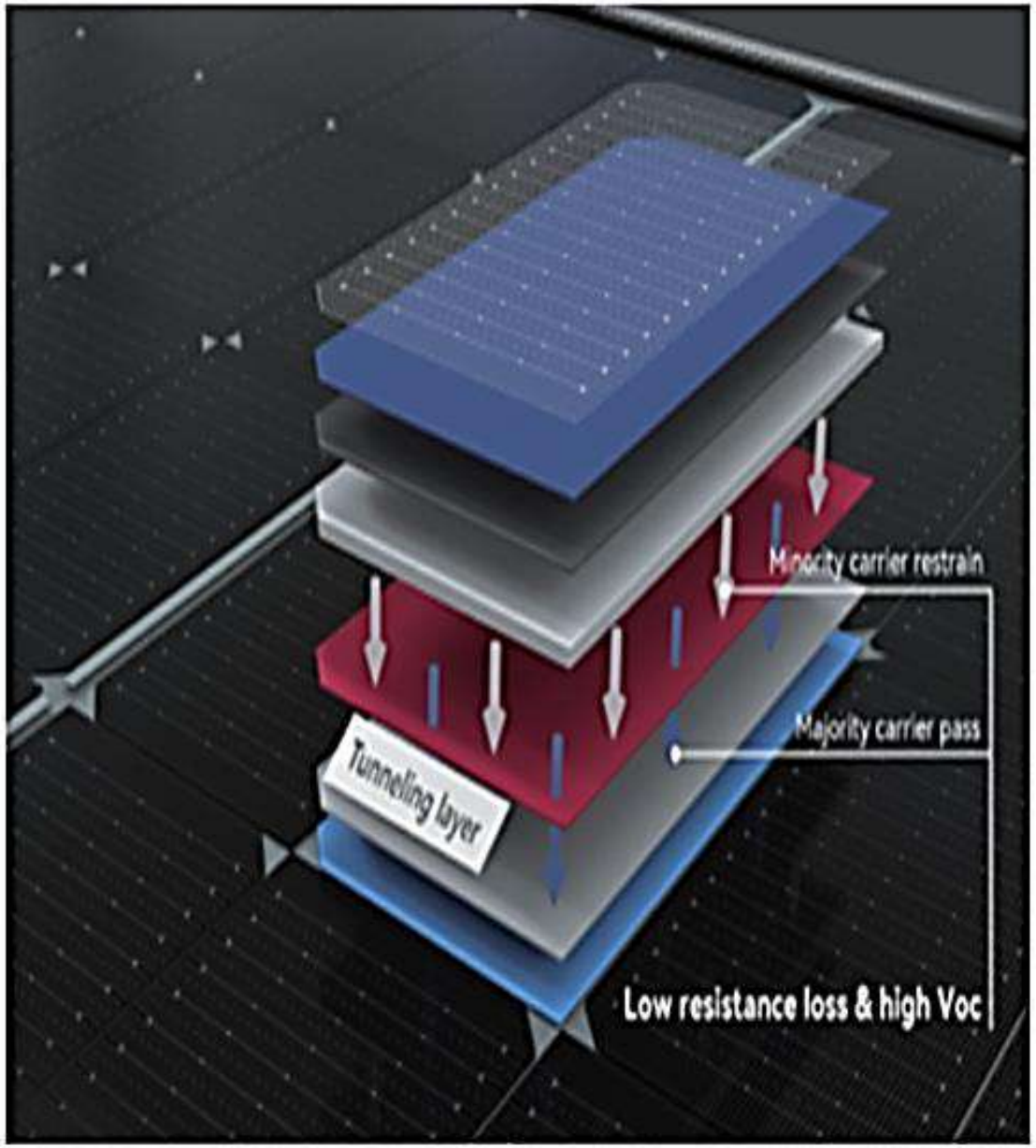
Passivated Emitter Rear Contact (PERC)

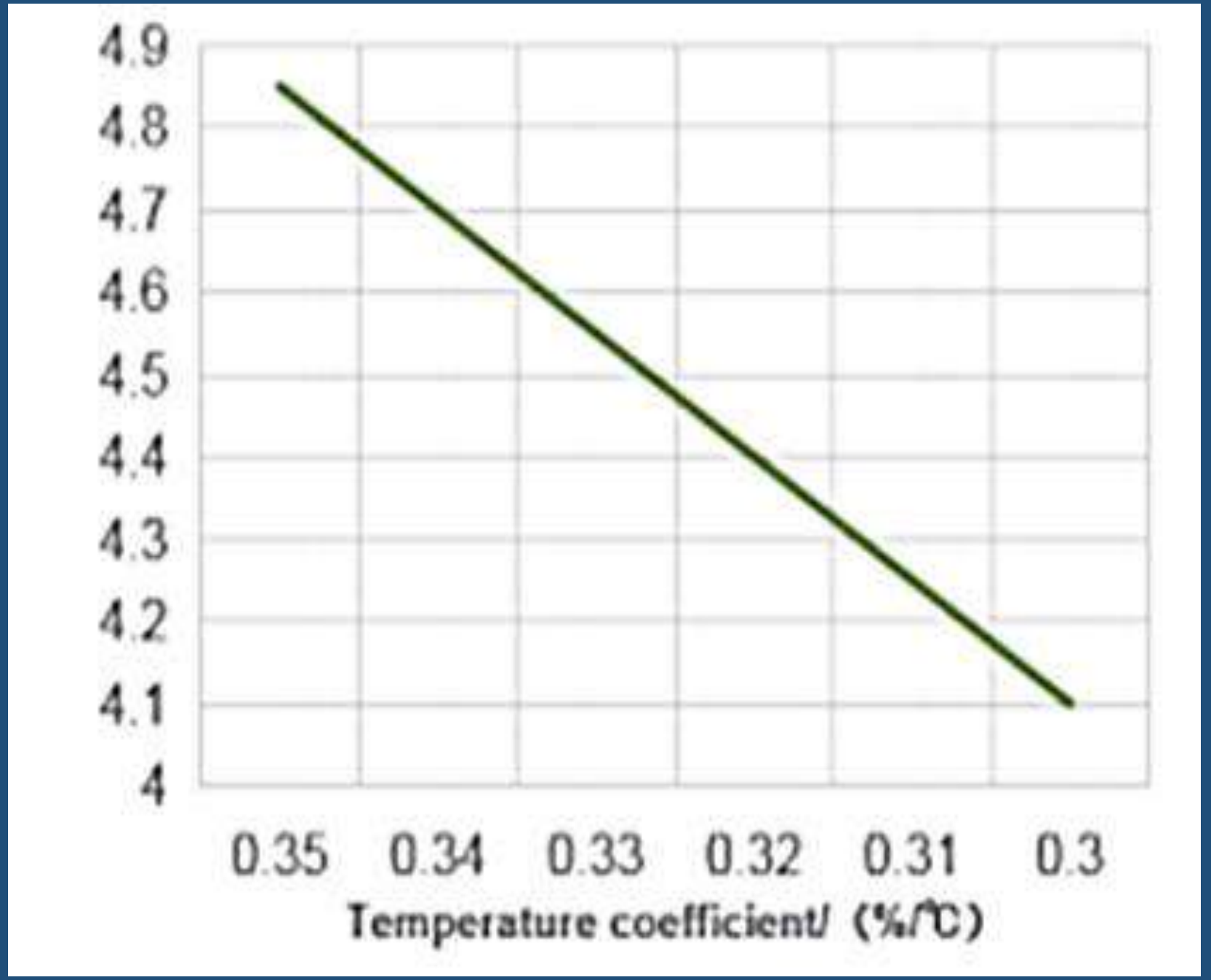




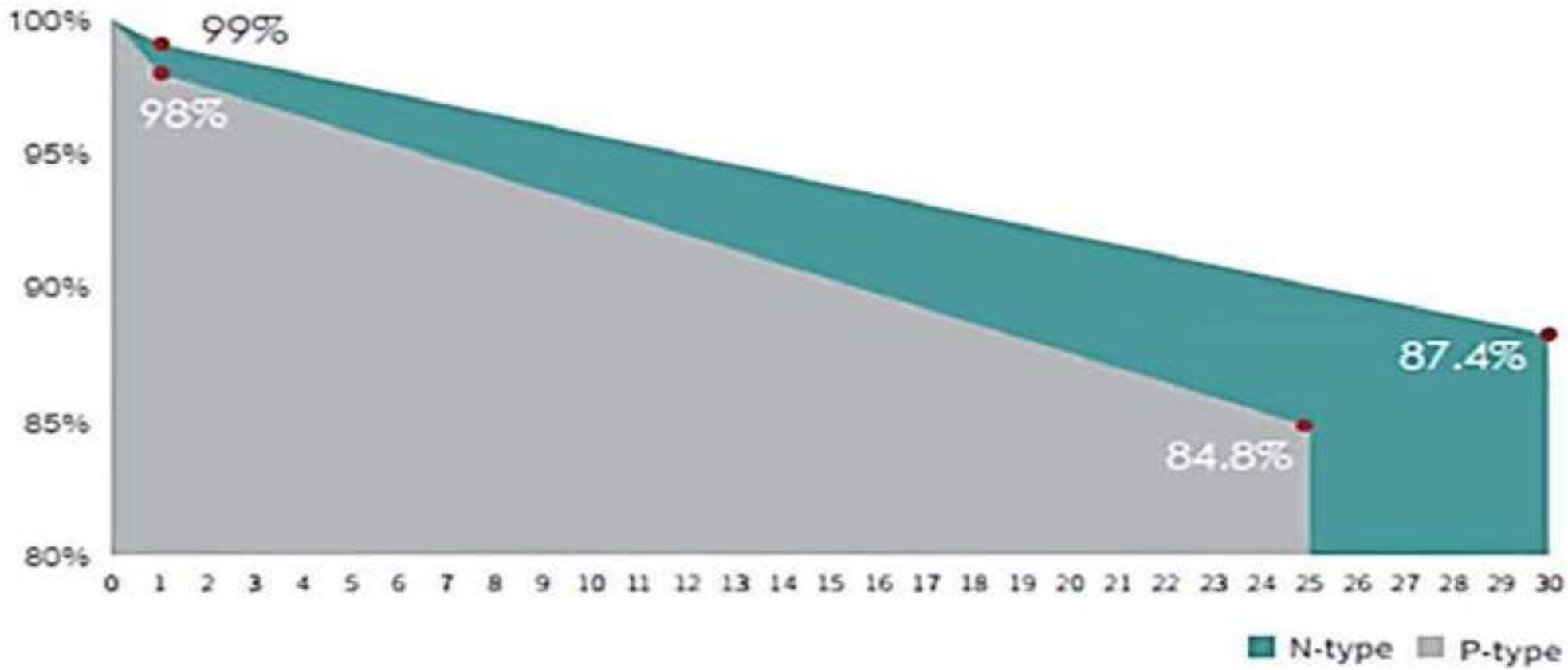
Efficiency of solar panels


TOPCon
SiNx AR Coating
Passivation
P+ emmitter
n-Silicon substrate
Tunneling layer
n+ Poly
SiNx AR Coating


Majority carrier restrain
Majority carrier pass
Tunneling layer
Low resistance loss & high Voc



Efficiency of solar panels

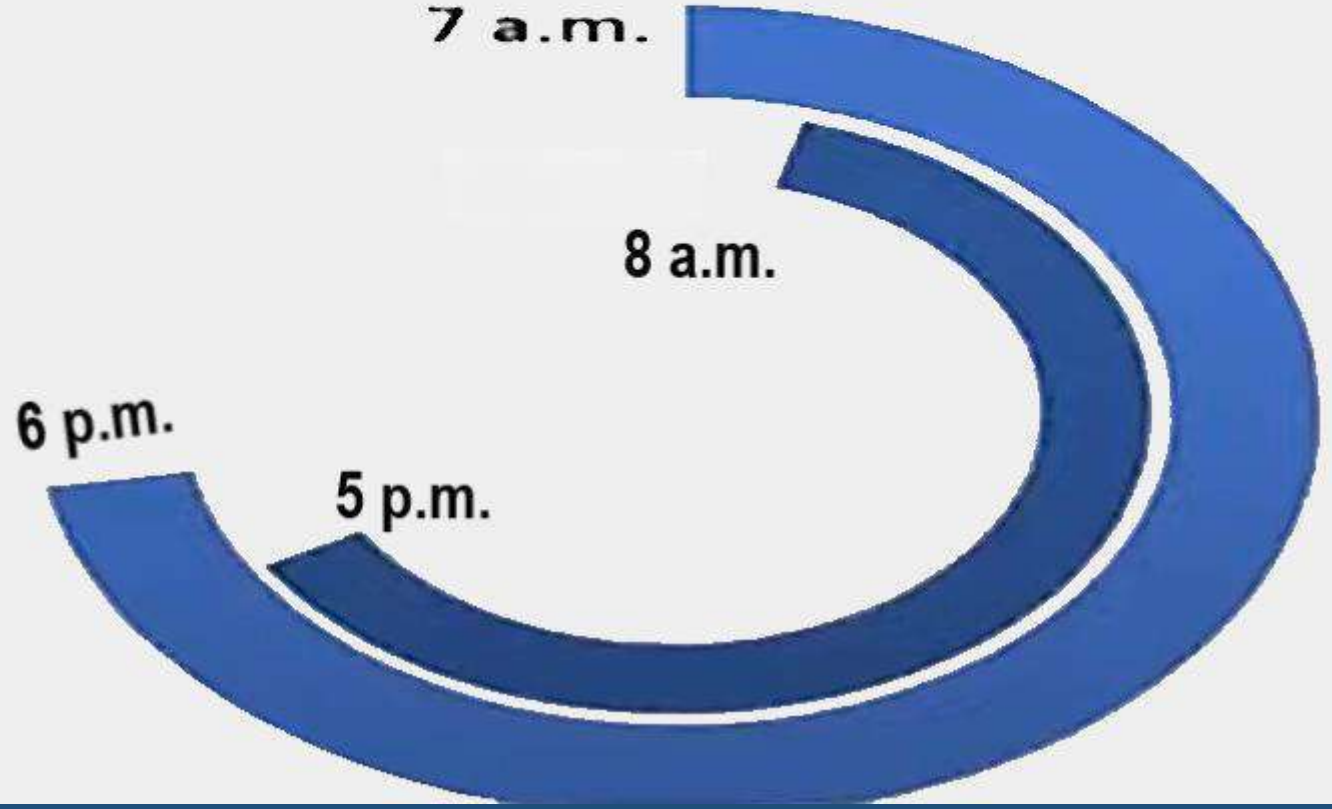


First year degradation⩽ 1%

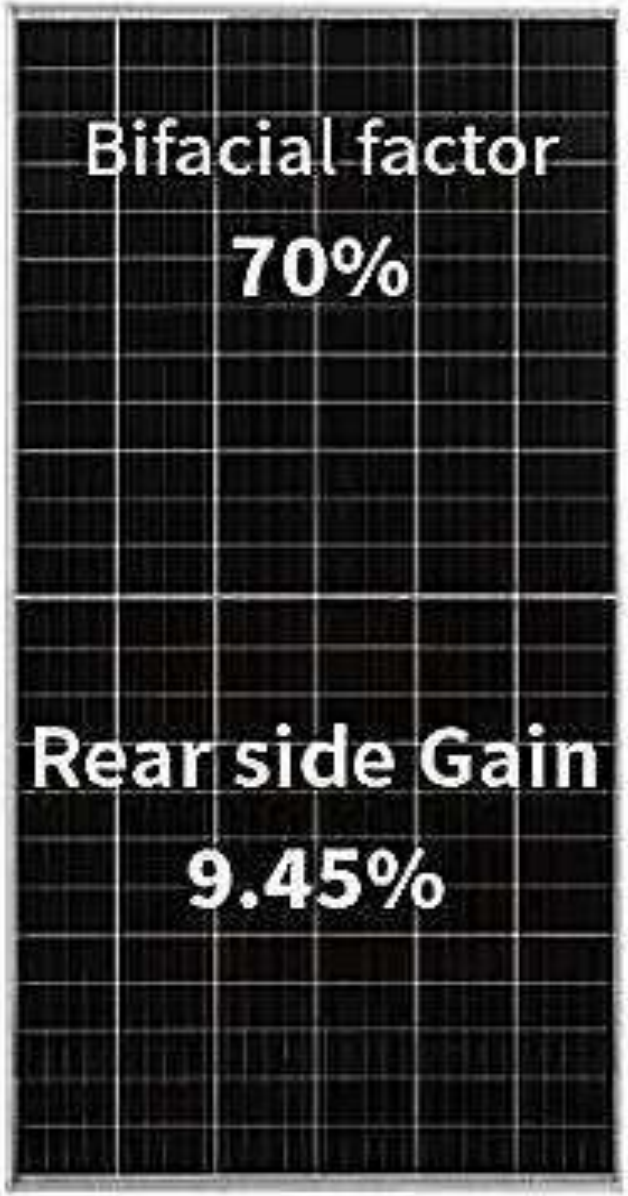
The linear degradation (2~30 years)⩽ 0.4%

N–Type Vs. P– Type

Better Low Light Performance



Light Performance

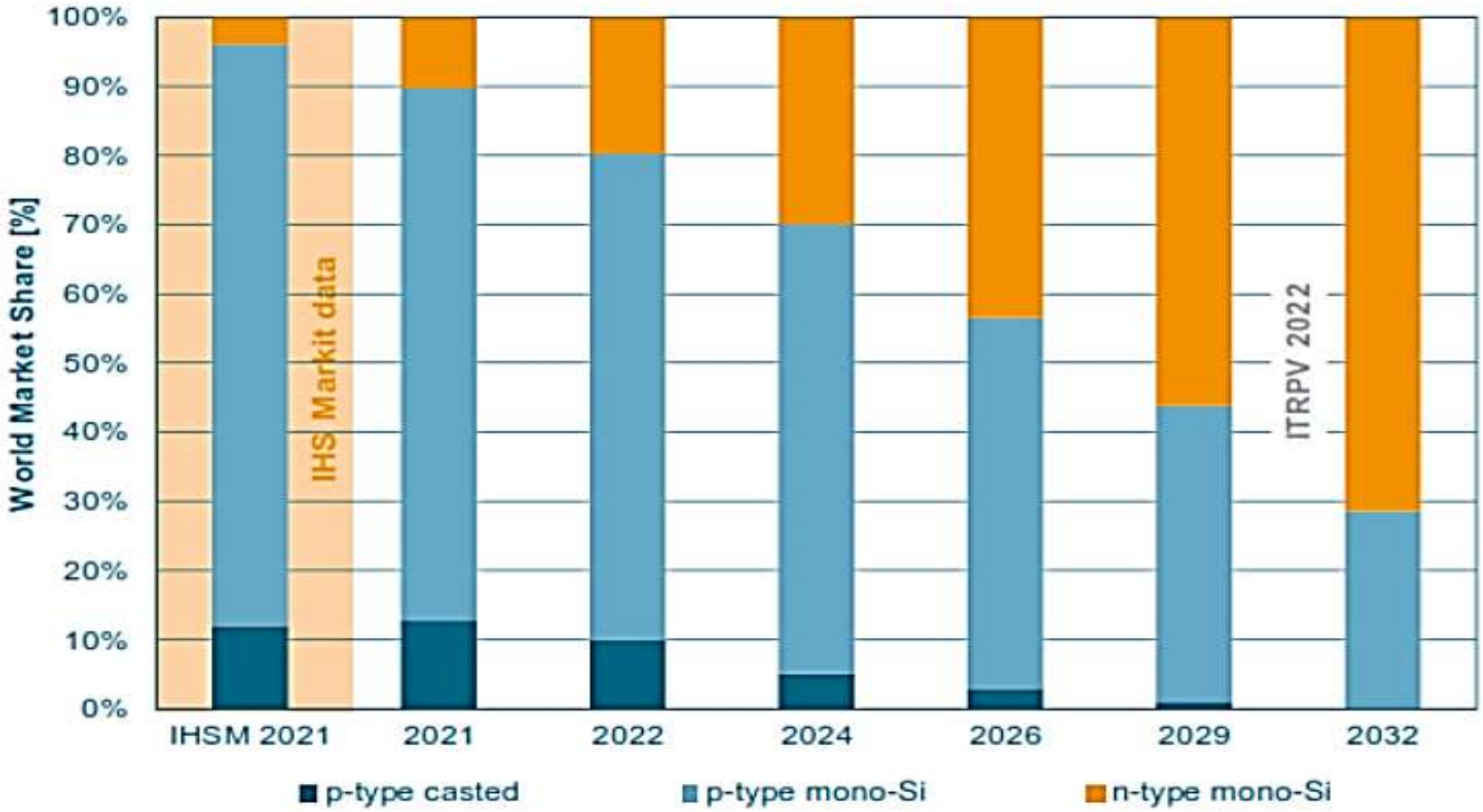


P-type

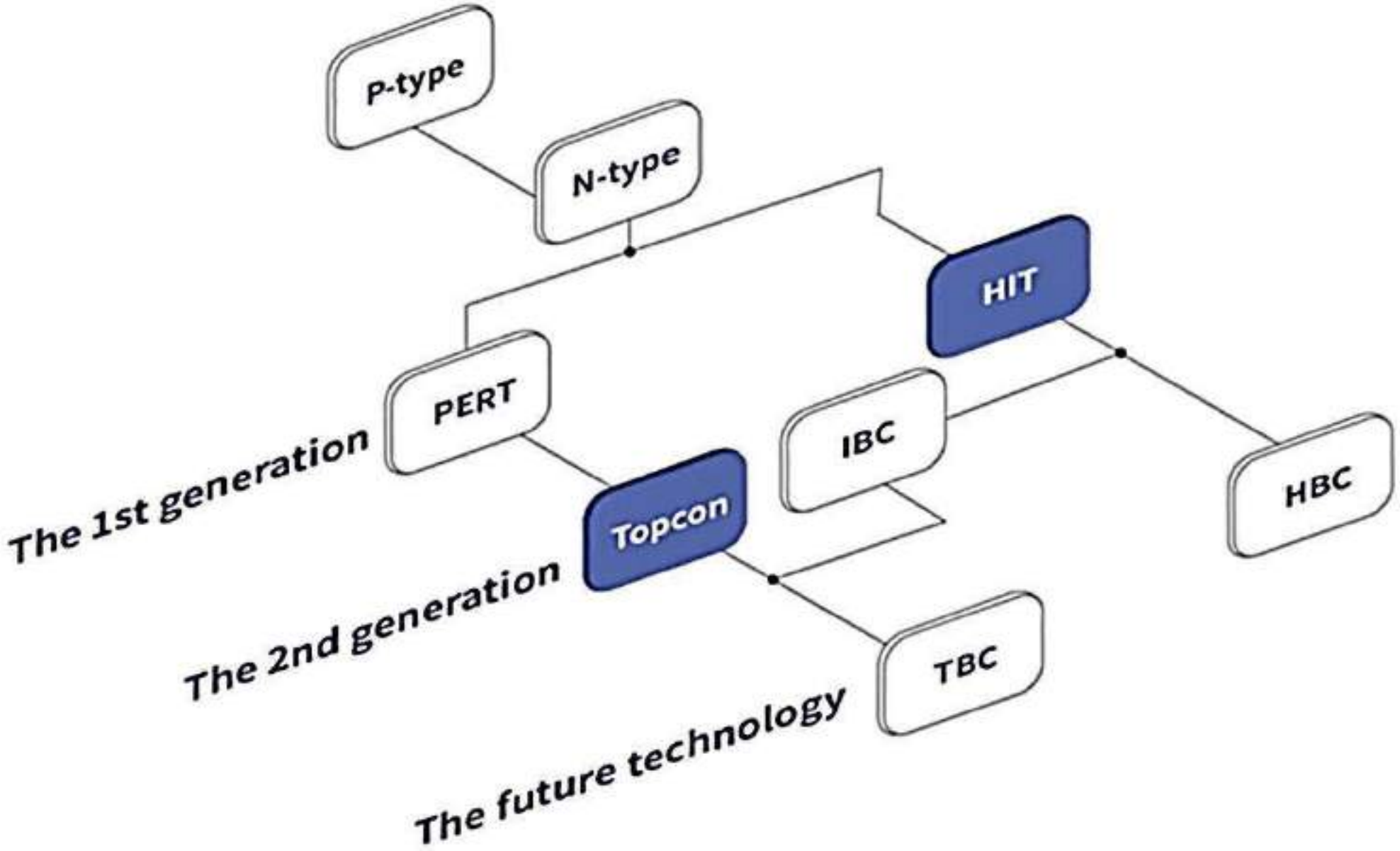
N-type

Bificial factor

Different wafer material types

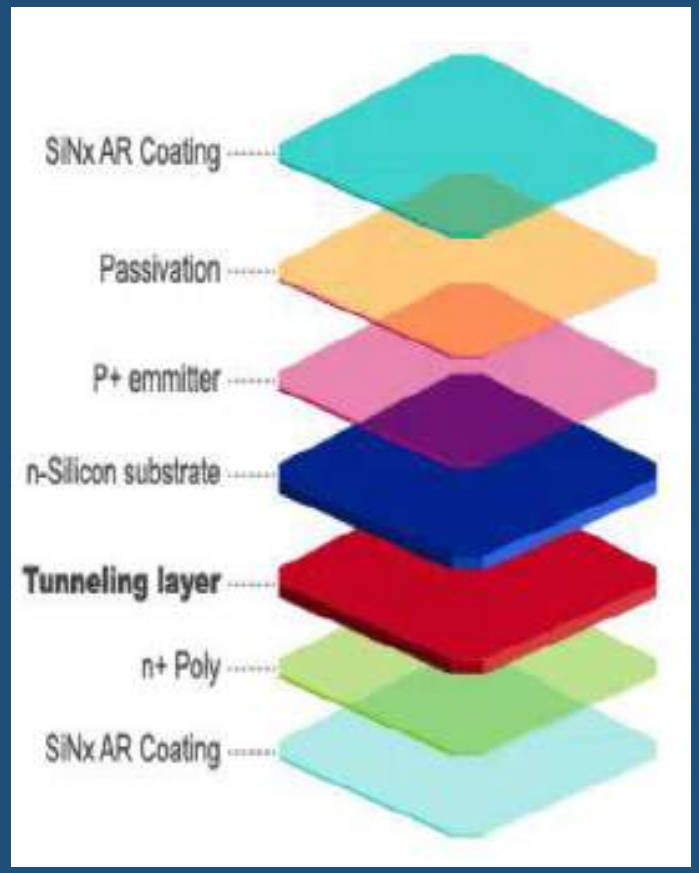


World Markets

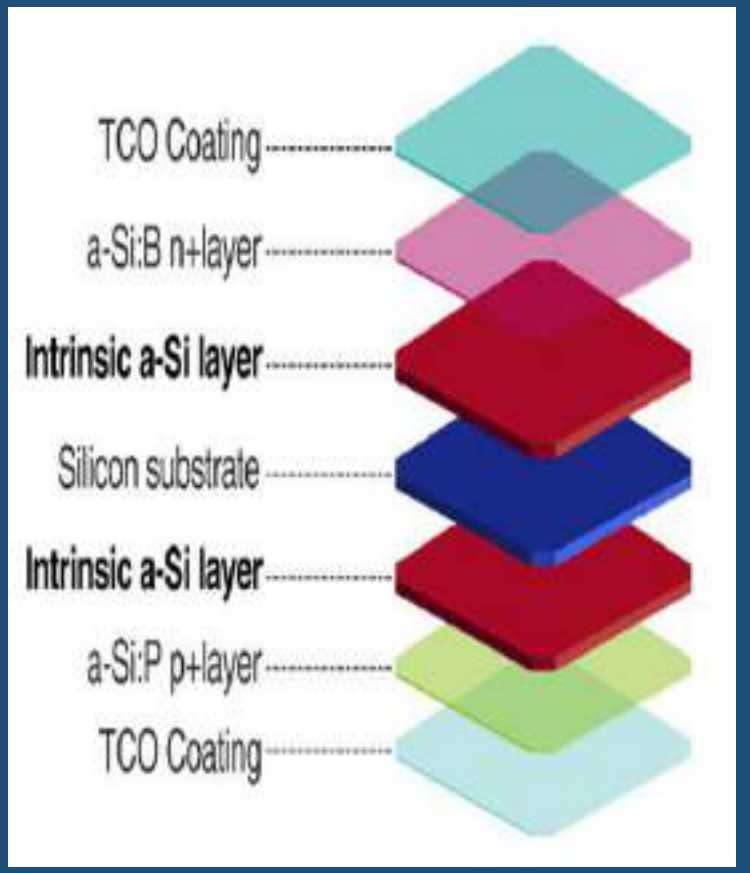

P-type
N-type
HIT
PERT
IBC
HBC
Topcon
TBC
The 1st generation
The 2nd generation
The future technology

Through the Figures below, we illustrate the difference between the (PERC) technology , (TOPCon) and (Heterojunction) technologies.

PERC Technology



TOPCon Technology



Heterojunction Technology

Technologies

If we look at the figure below, what are the layers that make up a P–Type PERC solar cell?

It consists of the following:

We also note that there are five layers:

1- ANTI-REFLECTION COATING to prevent light reflection to ensure the largest amount of light reaches the cell.

2- The n layer, which carries electrons

3- The (P) layer, which contains holes and is thicker than the (N) layer, is therefore called the (P-Type) cell.

4-(Rear Passivation)

5-ANTI-REFLECTION COATING

PERC Technology

PERC

As for the cells manufactured using (TOPCon) technology, they consist, as shown in the figure below, of essentially seven layers. These layers differ from one company to another:

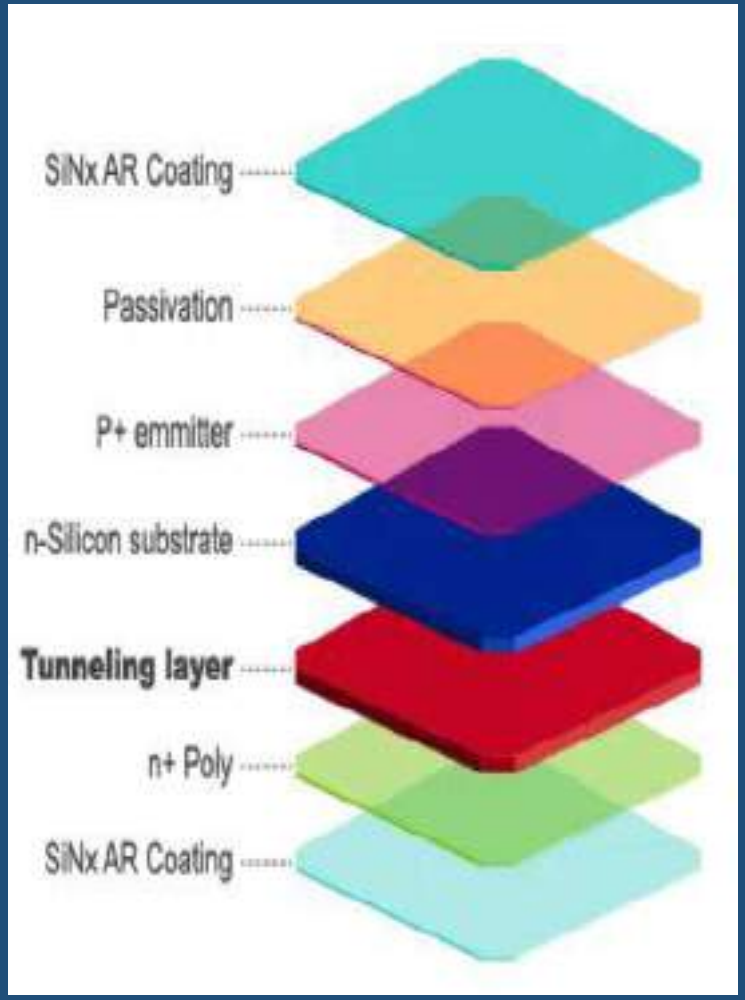
1 -Anti-Reflection Coating.

2- (Rear Passivation)

3- The (P) layer, which contains holes, is thinner than the (N) layer.

4- The (n) layer, which carries electrons and is thicker than the (P) layer, is therefore called the (N-type) cell.

5- (Tunneling Layer) is a layer of inert silicon oxide. Its function is to prevent the property of (Recombination) and thus works to increase efficiency. Because of this layer, the cell is called (TOPCon).

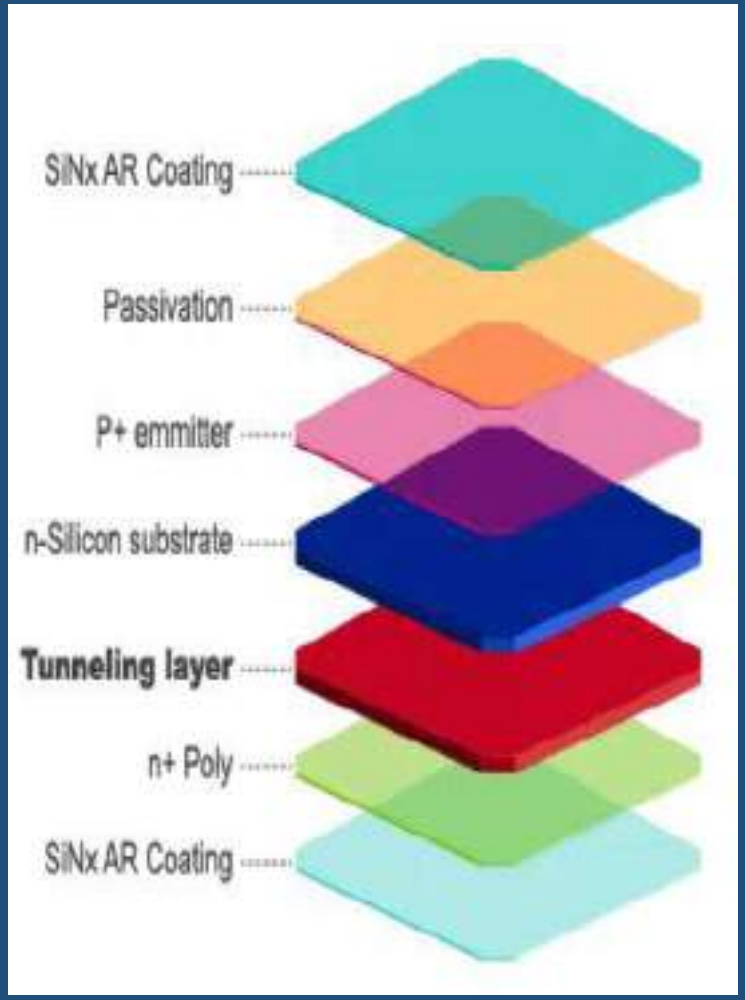


TOPCon Technology

TOPCon

6- An additional layer (Poly Silicon) to enhance conductivity and increase efficiency

7-Anti-Reflection Coating.



TOPCon Technology

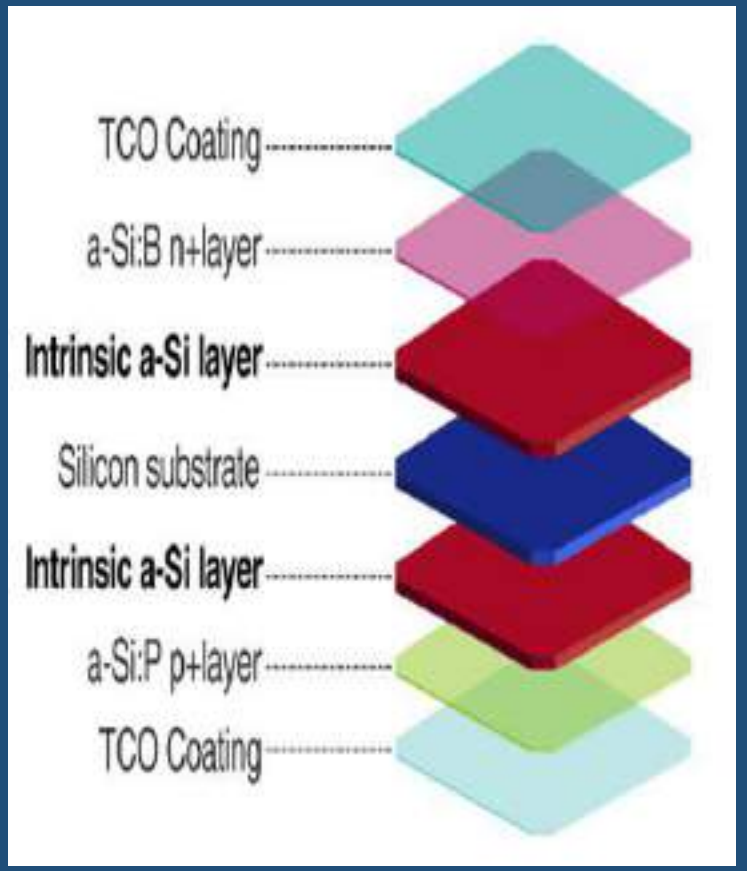
TOPCon

This technology combines the benefits of two different types of solar cells into one high-power hybrid solar cell:

crystalline silicon and

amorphous silicon thin-film.

They are made up of thin layers of N-type and P-type silicon and a thin layer of amorphous silicon in between, acting as an intrinsic layer. This results in higher conversion efficiencies and lower recombination rates.



HJT

Heterojunction Technology

As a conclusion

If you are an engineer, technician, or a person interested in solar energy systems, it is best for you in areas characterized by high temperatures, such as our country, Iraq, to choose N–Type TOPCon panels, as they are the cheapest compared to the high–priced (HIT), and they also have a low temperature coefficient, which It leads to improved efficiency, and is also characterized by the ability to produce electrical power in dim light (early morning) or before sunset, and this is what makes it in the forefront at the present time in Iraq.

Infinity
Green Power

Model Number		KD-M144
Rated Maximum Power	(Pmax)	415W
Power Tolerance	(W)	0~+5W
Current at Pmax	(Imp)	10.15A
Voltage at Pmax	(Vmp)	40.9V
Short Circuit Current	(Isc)	10.66A
Open Circuit Voltage	(Voc)	49.6V
Nominal Operating Cell Temp	(NOCT)	41℃~±3℃
Operating Temperature		-40℃~+85℃
Temperature Coeffcient	(Pmax)	-0.36%/℃
Temperature Coeffcient	(Voc)	-0.26%/℃
Temperature Coeffcient	(Isc)	0.04%/℃

Application class	Class A
Weight	22.5kg
Dimensions	2008×1002×40(mm)
Maximum System Voltage	1500V
Maximum Series Fuse Rating	20A
Cell Technology	Mono Perc-Si
Glass	Anti-scratch

All technical data at standard test condition
AM=1.5 E=1000 W/m² TC=25℃

Half-cut-cell	12-Busbar
Free-LID	Free-PID

References:

1- Saudi Forecasting Center.

2- International Renewable Energy Agency (IRENA).

3- Eng. Nasser Saber (Solana@YOUTUBE.COM)

4- Eng. Nedhal Nassar (The SOLAREST.com)

5- International Technology Roadmap for Photovoltaic (ITRPV).

Thanks for your Attention

Eng.Sarmad Janderma