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RENEWABLE ENERGY & SEMICONDUCTOR REFRESHER

BERGEN GROUP NEWS LETTER

CONTENTS

SCREEN-POTENTIAL SHOW STOPPER OF PLI PV PROGRAM OF INDIA

In silicon wafer based solar cell technology, there are three major technological steps which decide the performance of the cell:

1. **Emitter formation**
2. **Passivation**
3. **Metallisation**

Emitter formation involves mainly the thermal impurity diffusion process in furnaces. Currently Low Pressure (LP) diffusion process is in vogue whether it is Phosphorus or Boron diffusion.

Passivation, in currently mainstream P-Mono PERC technology is a process to deposit dielectrics on both front and rear sides of the cells. The process used for these depositions is Plasma Enhanced Chemical Vapour Deposition (PECVD) carried out generally again in furnaces.

Metallisation is the process through which solar cells are contacted by metals on both sides (Typically front side by silver and backside by aluminium) to extract the current from the cell to the external circuit. Today's metallisation of silicon solar cells is still dominated by flatbed Screen Printing mainly because of its reliable and cost-effective production capabilities. Screens are made on the stainless-steel wire mesh employing photosensitive emulsion by photolithography techniques.

This process is very critical in providing a conductive grid with a minimum amount of resource consumption at an ever-increasing demand for finer line widths. The continuous effort of industrial and scientific community has led to tremendous progress over the last 20 years, demonstrating an average reduction rate for the finger width of approximately 7 micron per year with the latest highlight of achieving widths of 19 micron, which were around 120 microns in 2006-7-time frame. However, further reduction will become a major challenge because commonly used metal pastes are not able to penetrate arbitrary small opening structures. In addition to pastes, the screen architecture also plays a crucial role when an optimised paste screen interaction is desired.

Study predicts the point when commonly used wire materials will fail to provide sufficient meshes for future solar cell metallization tasks. Therefore, novel wire materials (e.g., The use of carbon nanotubes) with very high ultimate tensile strengths are expected to be used for printing contact fingers with width below 10 microns.

India is currently in the process of setting up between 25-30 GW Silicon Solar Cell manufacturing in coming 3-4 years under the PLI scheme. This capacity would require huge quantity of screens as one screen prints approximately 20-30 thousand wafers at an average. India does not have any manufacturing capacity of screens and obviously no research and development base in this critical technology. It is, therefore, imperative to pay attention to this important aspect of solar manufacturing on urgent basis, otherwise Indian industries may face the problem of non-availability of screens and technological lag compared to their competitors worldwide specifically China where currently almost all screen manufacturing is concentrated.

Rajinder Kumar Kaura
Chairman and Managing Director

LPCVD - FAVOURED TOPCon TECHNOLOGY

To date, industrial screen-printed TOPCon solar cells on n-type substrates are based on Low Pressure Chemical Vapour Deposition (LPCVD) a-Si/poly-Si technology. Typically, the silicon layers that are predominantly amorphous in nature are first deposited and then subjected to a high temperature annealing step in order to form polycrystalline silicon (poly-Si) layer with mixed fraction of amorphous and crystalline phases.

LPCVD is used as one of the important processes established in the semiconductor facilities to deposit highly conformal layers of a-Si/poly-Si at low -pressure conditions. The main advantages of this technology are:

1. **Good thickness distribution along the wafer and the boat,**
2. **Pin-hole free layers with good step coverage,**
3. **Maintaining the impurity profile previously formed in the wafer due to the relatively low temperature of deposition close to 600 degree centigrade.**
4. **Large number of wafers per batch, and**
5. **Option of in-situ doping with constant doping profile.**

It is important to mention here that before deposition of a-Si/poly-Si layers, an in-situ thin tunnel oxide is thermally grown. The thermal tunnel oxide formed inside the LPCVD furnace is reported to be stable enough to withstand the typical temperatures (850-900 degree centigrade) used in POCl3 diffusion (in ex-situ case).

The deposited a-Si/poly-Si layers can be doped either in-situ or ex-situ POCl3 tube diffusion process. In in-situ process phosphine gas (PH3) gas is used, however, inclusion of PH3 flux is reported to lower the deposition rate by several times (approximately 36%). It appears that ex-situ process may be preferable, but it will require separate set of furnaces. The COO comparison of both the processes favours the ex-situ process as COO in this case is about 15% lower.

Meanwhile, the TOPCon process routes that are based on alternative a-Si deposition technologies are currently being investigated in research facilities and are expected to be ready for mainstream production in the near future. Plasma Enhanced Chemical Vapour Deposition (PECVD) is a well know-proven technology in PV industry to deposit dielectric passivation layers, and one of the most promising candidates for a-Si deposition. In fact, it is predicted in ITRPV that it may soon be adopted in place of LPCVD technology. In PECVD process the in-situ doping of the a-Si layer is without any overheads as in the case of LPCVD, it reduces the deposition rate. However, in case of PECVD technology, the key challenge is to avoid blistering in thick layers (>100nm). Other technologies being explored for a-Si/poly-Si layer in TOPCon technology are Atmospheric Chemical Vapour Deposition (APCVD) and sputtering (Physical Vapour Deposition-PVD) techniques.

There are efforts going on to find out alternative processes for growing tunnel-oxide as well. An appealing candidate is O3 based oxidation induced by dissociation of O2 by UV light sources. This highly cost-effective method is able to form thermally stable stoichiometric SiOx layers for high efficiency TOPCon cells and potentially can be easily mounted at the end of the wet chemical cleaning tool to insure a lean process flow. Plasma based oxidation is also a promising approach to form in-situ and thermally stable SiOx layer using a PECVD tool, which can be simultaneously used to deposit a-Si layers.

It may, therefore, be noted that at present best approach available for TOPCon technology is with in-situ thermally grown tunnel oxide in LPCVD furnace followed by intrinsic a-Si/poly-Si layers deposition and doping it ex-situ by POCL3 in separate LP furnace. LP POCl3 furnaces currently being used in p-mono PERC technology to form the emitters can very well be employed for this purpose.

Dr. D.N. Singh
Chief Executive Officer

NEWS UPDATE

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Govt Approves Infusion of Rs 1000 Cr Additional Equity in SECI; NTPC Tenders BOS Package For 300 MW of Interstate Solar Projects

Govt. of India has recently approved infusion of additional Rs. 1000 Cr. equity into Solar Energy Corporation of India Ltd. (SECI), a Schedule-A CPSE under the Ministry of New and Renewable Energy (MNRE). The additional equity will strengthen the company's Balance Sheet and enable SECI to undertake critical investments in the Renewable Energy (RE) sector.

The equity infusion comes at a time when the Govt. is prioritizing a shift of India's Energy generation towards Clean Energy sources, and focusing on harnessing renewable energy, such as solar and wind, which are abundantly available in the country. Rapid transition to RE will not only abate the pollution and climate change concerns being faced by the country and globally, but also reduce India's dependence on Energy imports.

India's RE Sector to Employ One Million People by 2030, Says Study

India's renewable energy sector could potentially employ around one million people by 2030, which would be ten times more than the existing workforce of an estimated 1.1 lakh (110,000) employed by the sector, according to an independent study released by the Council on Energy, Environment and Water (CEEW), Natural Resources Defense Council (NRDC) and Skill Council for Green Jobs (SCGJ).

The study 'India's Expanding Clean Energy Workforce' highlighted that most of the new jobs would be generated by small-scale renewable energy projects such as rooftop solar and mini and micro-grid systems compared to utility or large-scale projects like solar parks

Indonesia To Set Up $4 Billion Industry For Polysilicon

Indonesia to set up a $4 billion industry for polysilicon to boost the production of solar panels. Polysilicon is a key material used for making solar panels. The prices of polysilicon grew to a 10 year high last year.

Indonesia plans to generate around 5.3 GWs capacity of solar energy by 2030. Many solar plants are under construction in the country which includes an $800 million plant in Batang, Central Java which will start its operation around July 2022. This plant will produce 40,000 tons of polysilicon.

The second plant is $3.2 billion which is located in North Kalimantan with a production capacity of 160,000 tons of polysilicon. With these plants, the country can have an excess supply which will allow a smooth installation of solar panels.

Recently, Masdar, one of the world's leading renewable energy companies, announced the formation of a joint venture (JV) with PT Mitrabara Adiperdana Tbk (Mitrabara), a conglomerate focused on the energy sector, to target the fast-growing commercial & industrial (C&I) segment of the renewable energy market in Indonesia.

NEWS UPDATE

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Risen Energy Intends To Build Solar Factory With US$ 7B Investment

Inner Mongolia may soon see a huge investment from Risen Energy, which intends to construct a solar manufacturing complex. The estimated investment for the complex is deduced to be CNY 45 billion (US$7 billion) which will create materials from industrial silicon to PV modules.

The company stated in a December 27 filing with the Shenzhen stock exchange that the factory will be capable of producing 10 GW of solar cells, 3 GW of modules, 200,000 tons of industrial silicon, and 150,000 tons of polysilicon each year. The manufacturing plant will be constructed in two stages.

Risen intends to spend CNY 25.2 billion ($3.9 billion) to build 3.5GW of solar and 1.6GW of wind, as well as an on-site energy storage system, to circumvent rising electricity prices. However, the filing did not specify if the manufacturing plant's whole operation will be powered entirely by sustainable energy sources.

Italy introduces 11-month retroactive incentive cut on PV systems over 20 kW

The Italian government today introduced a new package of measures to help consumers and businesses reduce their energy bills that includes a retroactive cut on the incentives the Italian energy Agency GSE pays to the owners of PV systems exceeding 20 kW in size under the Conto Energia Program.

The new provisions were included in a decree published today in the country's official journal. The incentive cut will apply only for the period from February 1, 2022, to December 31, 2022, and will reduce the tariffs paid by the GSE to PV system operators depending on the zonal energy price, with the incentive reduction being proportional to the increase in energy prices.

The new rules apply only to existing installations under the Conto Energia program, which expired in 2014, and not those built under net metering program outside of the scheme.

Chinese PV Industry Brief: Longi raises wafer prices

Coal India Limited (CIL) has recently announced forming two wholly-owned subsidiaries for undertaking solar photovoltaic manufacturing and renewable energy projects.

While CIL Solar PV Limited has been incorporated for manufacturing in the solar value chain (ingot-wafer-cell-module), CIL Navikarniya Urja Limited has been formed for renewable energy projects, CIL said in a BSE filing.

In a green push, the state-owned company had earlier announced that it would invest ₹56.50 billion ($763 million) by March 2024 to develop 14 solar projects to help power its mining operations.

NEWS UPDATE

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IREDA and Goa Shipyard Ltd signs MoU for Rooftop Solar Power Projects

The MoU was signed by Shri Pradip Kumar Das, Chairman & Managing Director (CMD), IREDA and Cmde. Bharat Bhushan Nagpal, CMD, GSL in the presence of senior officials.

Under the MoU, IREDA will assist GSL to set-up a rooftop solar power project at the headquarter of the company situated in Vasco da Gama, Goa. IREDA will also extend its techno-commercial expertise to GSL for Environmental & Social (E&S) due diligence of rooftop solar and other RE projects as per the internationally accepted E&S standards. After setting up a rooftop solar power project at its building, GSL will be able to bring down the expenditure on electricity and reduce its carbon footprint as well.

NTPC Declares Amara Raja, L&T And Jackson Winners Of 735 MW Solar Project

Amara Raja Group, Larsen & Toubro (L&T), and Jackson Group are awarded the winners of NTPC's bidding for a balance of system (BoS) package for the 735 MW Nokh solar project in Rajasthan, which was announced in March 2020.

For the first, second and third blocks of each 245 MW, Larsen & Toubro quoted a tariff of Rs 16.25 million per MW, Amara Raja Group quoted a tariff of Rs 17.14 million per MW, and Jackson Group offered a tariff of Rs 17.86 million to deliver a BoS package, respectively.

The proposal submission deadline was extended until August 2020 after the initial declaration of the tender. Following that, NTPC renewed the tender in November 2021, and in the most recent tender, the bidders' average yearly turnover criteria were raised.

In the revised tender document, for the first block, the average annual turnover of bidders was increased to Rs 900 million, while for the second block, it was increased to Rs 1.8 billion.

Turkey Installs 1148 MW Capacity Of PV In 2021

In the third quarter of 2021, 150 MW capacity was registered in Turkey and the total installed solar capacity grew to 7815 MW. Turkey has net-metered rooftop PV which was introduced in 2020 May.

In 2019, a report predicted that Turkey could install a 38 GW capacity of solar energy by 2030. Another study suggested more than 20 GW will be added by 2026 in the country.

Recently, Swiss Solar also planned to install a 1.5 GW capacity of the bifacial PV module annually with 3 production lines in Turkey. In the first phase of the project, the production area will be finalized, purchase and installation of the 3 PV module lines will take place at 450 Wp, 500 Wp, and 545 Wp.

NEWS UPDATE

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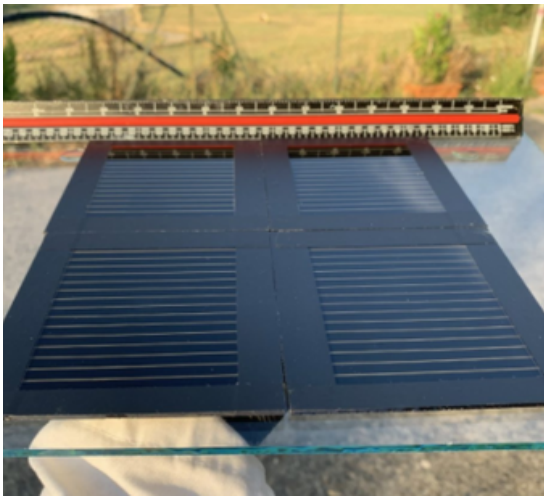
Perovskite solar module with 18.45% efficiency via co-solvent dilution strategy



An international research team has developed a perovskite solar module with an active area of 45.6 cm2 through a co-solvent dilution strategy that dilutes perovskite precursors to a low concentration.

"The new technique allows a reduction in the use of toxic solvents and the concentration of lead in the precursors," the research's corresponding author, Aldo di Carlo, told pv magazine. "These key elements may facilitate the transfer of the perovskite solar cell technology to commercial production."

The module was fabricated with methylammonium lead iodide (MAPbI3) perovskite solar cells via low-cost spin coating, which applies a uniform film onto a solid surface using centrifugal force and a liquid-vapor interface.

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NEWS UPDATE

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Siemens Energy To Generate Electricity With Green Energy Sources By 2023

Siemens Energy presented its Sustainability Report for the fiscal year 2021. The company aims to ensure greater transparency on its sustainability performance. The report showcases what the company achieved in the previous fiscal year in the environmental, social, and governance (ESG) areas while indicating where Siemens Energy can further improve.

To honor its responsibility and to consider the importance of its products and solutions for decarbonizing energy systems worldwide, Siemens Energy will henceforth report the emissions of GP's sold products during their entire use phase (scope 3 downstream). By 2030, these emissions are to be reduced by nearly one-third. Already last year, the highly regarded Science Based Targets initiative (SBTi) verified that Siemens Energy's emission reduction targets comply with the Paris Agreement and thus contribute to limiting global warming to the extent stipulated in the agreement.

As early as 2023, all the electricity used at Siemens Energy will be green energy. In fiscal 2021, green electricity accounted for 76 percent of the company's total electricity use. Siemens Energy has also set the ambitious target of achieving a reduction of 30 percent per euro purchase value in relative scope 3 upstream emissions in the supply chain by 2030.

India's NTPC tenders 500 MW/3,000 MWh of energy storage projects

NTPC Renewable Energy Limited, a wholly-owned subsidiary of NTPC Limited, has invited global bids to develop interstate transmission system (ISTS) connected energy storage solutions of a cumulative 500 MW with 3,000 MWh of storage capacity anywhere in India. The projects shall be awarded through international competitive bidding followed by reverse auction.

NTPC REL will sign a 25-year energy storage service agreement on an annual fixed charge basis with the selected developers.

The developer is required to set up an energy storage project on a "build-own-operate" (BOO) basis. The energy storage system shall be charged by the renewable power generated by NTPC REL from any of its projects. NTPC REL shall utilize the energy storage facility on an "on-demand" basis to meet its round-the-clock renewable power supply requirements during the peak and off-peak hours.

The project size will be a minimum of 100 MW/600 MWh. Bidders can quote capacities as follows: 100 MW/600 MWh; 200 MW/1,200 MWh; 300 MW/1,800 MWh; 400 MW/2,400 MWh; and 500 MW/3,000 MWh.

Russia deployed 233 MW of solar in 2021

Russia registered a newly installed PV capacity of 233 MW last year, which means the country reached a cumulative installed solar power capacity of over 2 GW at the end of December.

"This capacity matches with Russia's first incentive program started in 2014 and that is set to end in 2024," Anton Usachev, president of the Russian Solar Energy Association, told pv magazine. "Apart from grid-connected PV, off-grid solar installations totaling 17 MW were also deployed last year."

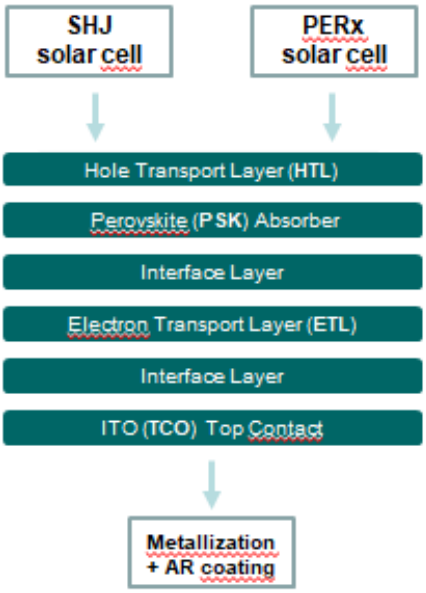
Most of the deployed capacity comes from utility scale solar plants selected in the country's tender scheme for renewables. The latest tender round was held in September when the Russian authorities allocated 775 MW of solar power at an average price of RUB 5.18 ($0.067)/kWh.

TWO TERMINAL APPROACH FOR PERx + SHJ COST-EFFECTIVE HIGH-VOLUME MANUFACTURING (HVM) PROCESS

Multiple R&D activities to combine HTL, PSK out of PbI2, CsBr, FAI, or others, ETL, TCO

- Material-wise,
- Coating Technology-wise
  - **Co-evaporation**
  - **PVD sputtering**
  - ALD
  - ...

No favorite layer stack has emerged **yet**; Therefore, **too early to define HVM equipment** for the entire process chain;
Obviously, **several processes** can/should be **combined in one system** to reduce CAPEX and OPEX;
VONARDENNE / BERGEN offers a Cluster-type **development platforms for R&D purposes;**
VONARDENNE / BERGEN scales processes on **pilot production equipment** in cooperation with customers;



PRODUCT UPDATE

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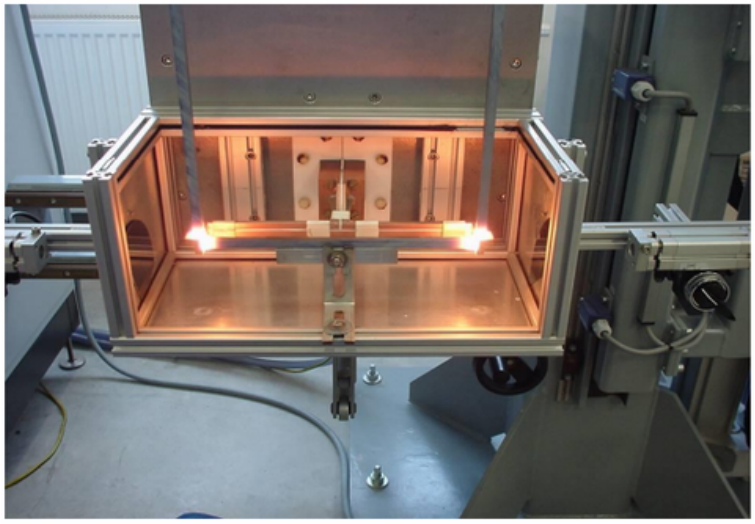
Slim rod production unit



SLIM ROD WELDING

SLIM ROD PRODUCTION

silicon products

RESEARCH ENGINEERING PRODUCTION

MARKET ANALYSIS

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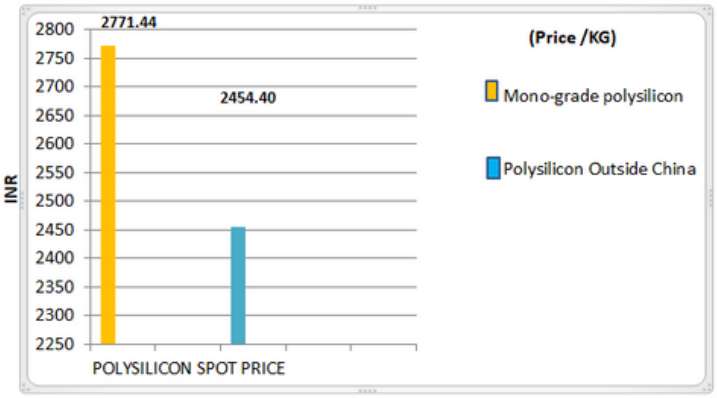
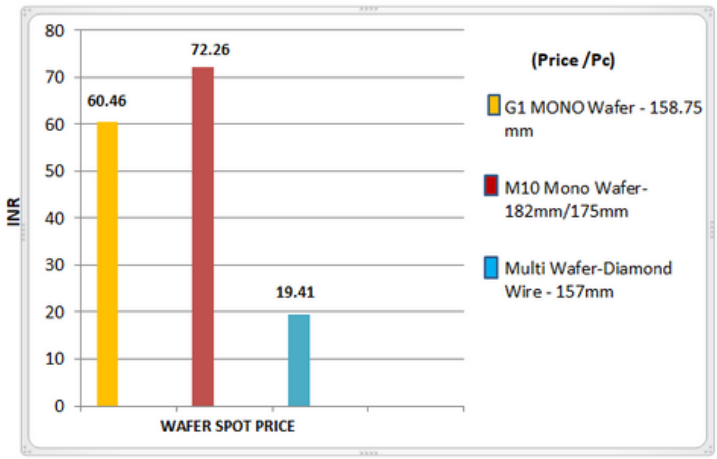
Price update

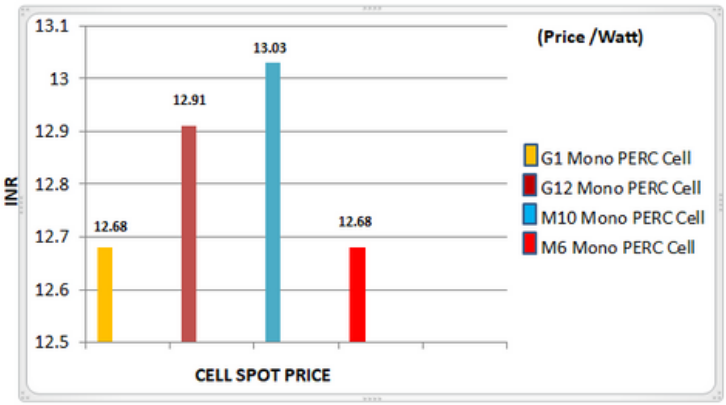
Polysilicon Spot Price Update



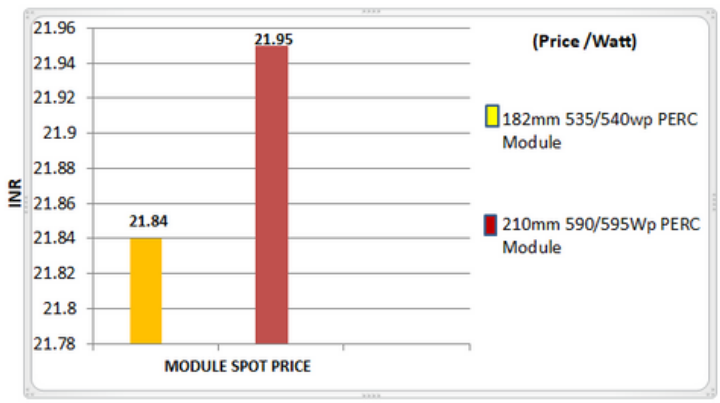
Wafer Spot Market Price Update - Multi SI/Mono G1M6



Cell Spot Market Price Update - Multi/Mono/PERC



Module Spot Price Update - Multi/Mono



Source: Energy Trend

EDITORIAL TEAM

Rajinder Kumar Kaura
CMD

With nearly 43 years of contributions in conventional and non conventional power and electronics field, he is pioneer and pathfinder in developing solar & electronic industry in India. His contributions in bridging he gap in standards of living between rural and urban population through generation of solar power and skill development has earned him tremendous respect and recognition by countries like Norway, Japan, Germany, etc. besides States and Central Organizations.

Dr. D.N. Singh
CEO

Dr. D.N. Singh is a one of the most prominent leaders in Solar PV and Semiconductor technology and widely known professional in India and abroad. He has a total of 46 years of experience in Industries, research and academia. He has published over 40 research papers in International and National journals. He has been invited speaker at PV Cell Tech and PV Module Tech international conferences. Dr. Singh is Vice President of Microelectronic Society of India, Member IEEE and Member of National Nano-Technology working group.

Dronveer Kaura
Director

After completion of academics from the Ohio State University, USA, he returned to India to share the knowledge gained in his academic and serve the nation. He founded and engaged himself and his team in Industrial Automation Projects to follow industry 4.0 standards and keep India intact and way forward in the state of art technology of Automation. Under his guidance and knowledge sharing, we could develop a efficient solution for Robot Automation in the field of automobile to boost per day production. He is currently pursuing PhD in Hydrogen Fuels & Technology.

S.K. Kaul
Vice President

Having more than 38 years of experience in the field of Manufacturing, Operation, Material Management & Factory Administration and looking after complete solutions & supply of Capital Equipment technology for the manufacturing of Printed Circuit Boards, Electronic Assemblies, Photovoltaic Cells & Photovoltaic Modules and undertaking the turnkey installation of the solar based power projects.