PV & Storage Mid-Fall 2023

By John Benson

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1. Introduction

The prior post in the "PV and Storage…" series is summarized and linked below.

PV & Storage Late-Summer 2023

Technology

New Liquid Metal Battery System

Solar Cell Technology, into the Future

US Made Solar Cells with High Efficiency

Business

Over 150 GW of Solar Manufacturing Announced

US solar installations expected to be a record 32 GW in 2023

Projects

https://energycentral.com/c/cp/pv-storage-late-summer-2023

This Post will contain the following content:

Technology

Recent Developments in Solar Energy

Changing Light to Increase PV Efficiency

Business

Solar Module Prices Crash (in the EU)

U.S. expands solar tariffs

Projects

2. Technology

2.1. Recent Developments in Solar Energy

I subscribe to several information sources that I use for this series, but when I get close to the posting date, and the sources have not come up with a reasonable candidate for an article for this section, I need to get my sidekick involved (Microsoft Bing Generative AI), and pose a question. The question that yielded the primary article below was "What are some recent advancements in photovoltaic technology?" The primary reference it came up with was "Recent Developments in Solar Energy Technology" (see the reference below).[1] Although not verbatim, it's pretty darn close. The bad news is that it's a bit older than I like for a subject that starts with "recent," but it had three snippets that I found useful, and these are below.

[1] Ben Pilkington, AZO Cleantech, "Recent Developments in Solar Energy Technology, June 30, 2022, https://www.azocleantech.com/article.aspx?ArticleID=1593

There have been increased developments in solar energy technology in recent years. More viable commercial collar energy platforms are becoming available in more areas for a lower price than ever before. The solar power movement is still approaching maturity and promises exciting developments to come.

2.1.1. PV Efficiency

A team at the US National Renewable Energy Laboratory (NREL) recently highlighted a record solar cell efficiency of 39.5% under natural light conditions…

Here, we demonstrate triple-junction III-V solar cells with higher efficiencies than previous record-efficiency six-junction devices. The devices incorporate high-performance thick GaInAs/GaAsP superlattices to enable an optimal bandgap combination. These cells are most useful for area-constrained terrestrial applications and low-radiation space missions, where efficiency is critical. As these are the highest efficiency one-sun solar cells as of this writing, these cells also set a new standard for achievable efficiency across all photovoltaic technologies.[2]

Multi-junction solar cell design is guided by both the theoretical optimal bandgap combination as well as the realistic limitations to materials with these bandgaps. For instance, triple-junction III-V multi-junction solar cells commonly use GaAs as a middle cell because of its near-perfect material quality, despite its bandgap being higher than optimal for the global spectrum. Here, we modify the middle cell bandgap using thick GaInAs/GaAsP strain-balanced quantum well (QW) solar cells with excellent voltage and absorption. These high-performance QWs are incorporated into a triple-junction inverted metamorphic multi-junction device consisting of a GaInP top cell, GaInAs/GaAsP QW middle cell, and lattice-mismatched GaInAs bottom cell, each of which has been highly optimized. We demonstrate triple-junction efficiencies of 39.5% and 34.2% under the AM1.5 global and AM0 space spectra, respectively, and the global efficiency is higher than previous record six-junction devices…

Author's comment: Multi-junction solar cells offer leading-edge efficiency, but are currently not mass produced, thus their pricing is very high:

According to a report by National Renewable Energy Laboratory (NREL), the cost of a gallium arsenide multi-junction solar cell can be as high as $300 per watt. This is significantly more expensive than conventional silicon solar panels, which cost about $1 per watt for utility-scale solar cells.[3]

Nevertheless, these designs may point the way to future designs, especially as a method to upgrade existing utility-scale projects without expanding the footprint.

2.1.2. Solar Power at Night

Under what circumstances would a user need to use PV to generate electricity at night, and how would they do it. The answer to the first question is that a major weakness of existing PV projects is that they can only generate power for early peak demand period during summer (the peak demand season for most regions), but not for the late afternoon into evening.

[2] Ryan M. France, et al, NREL, Posted to Joule, "Triple-junction solar cells with 39.5% terrestrial and 34.2% space efficiency…," 4/2022, https://www.cell.com/joule/fulltext/S2542-4351(22)00191-X?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS254243512200191X%3Fshowall%3Dtrue#%20

[3] Bing generative AI referencing: Chris Meehan, Solar Reviews, "NREL Developing Improved Tech to Lower Costs for Multi-Junction Solar Cells," July, 2018, https://www.solarreviews.com/blog/nrel-developing-tech-lower-cost-multi-junction-solar-cells

Radiated energy from the sun heats the planet's crust substantially in the day. However, energy is generally lost to the atmosphere and cold surrounding space.[1]

In new research published in the journal ACS Photonics, a team of photovoltaics engineers at UNSW Sydney, Australia, demonstrated a successful test run of their new device, capable of converting this thermal energy into electricity.

A power generating device called a thermo-radiative diode was used, which operates with infrared energy in a similar way to night vision goggles, but scaled up.

Author's comment: Imagine a utility scale project using single-axes trackers and bifacial; PV modules. Except the "front/top" face of the module would be conventional PV, and the back/bottom would be use the thermo-radiative diode (TRD) described above. During the normal daytime the conventional PV would generate a large majority of the power, but fugitive solar radiation would heat up the ground, and the TRD would capture the heat (infrared) light coming from the ground. Just before and after sunset the trackers would position the modules to best capture the heat-light from the ground and extend the net-production into the early evening. However, this nighttime production would probably be minimal compared to using battery energy storage systems (BESS) to mitigate the variability, so perhaps its best use would be to reduce the BESS size.

2.1.3. Commercially Available Perovskite Solar Cells

Perovskite was first put to use in a solar cell in 2009. The University of Manchester scientists in the UK released details of a new record-breaking perovskite cell in 2016.

Perovskite crystals are approximately one-fifth more efficient than silicon when converting the sun's energy into electricity. However, the first perovskite-based panels were prohibitively fragile and had a short operable lifetime.

Engineers from Princeton University recently introduced the first perovskite solar cell with a commercially viable lifetime. This is a significant step toward making perovskite photovoltaics a standard fixture in solar installations across the world.

The engineers believe that the device can work at above standard rates of efficiency for the current solar power industry for at least 30 years. The current batch of commercial solar energy technology only reaches a maximum lifespan of around 20 years.

As well as being highly durable, the perovskite device also meets and exceeds solar panel efficiency standards. Silicon-based solar cells have dominated the solar energy market since they were first introduced in 1954, but the new perovskite cell may mark the end of silicon's solar supremacy.

Perovskite crystals can be manufactured at room temperatures and with significantly less energy than silicon. This makes them cheaper to produce and more sustainable.

Due to their flexibility – as opposed to silicon's stiffness and opacity – perovskite crystals can also be used for curved, arced, or domed solar panels.

The Princeton engineers showed how perovskite's fragility could be overcome with a novel accelerated aging technique that could extend solar cell potential beyond silicon's limits.

2.2. Changing Light to Increase PV Efficiency

I encountered an article in IEEE Spectrum that describes a method for changing the frequency/color of light. The reason this will strongly increase the efficiency of PV was best explained by this article. The process used by authors of Reference 4 is called up-converting photons, and I will let readers read the full article through the link in the reference for a good explanation of this process.

Sunlight offers abundant photons spanning a wide range of energies, from the ultraviolet through the visible spectrum and into the infrared. Yet we use only a fraction of the available photons. That's why a typical single-junction solar cell—a cell made of one layer of light-absorbing material—has a theoretical efficiency limit of just 34 percent; typical commercial solar cells today are only 15 to 20 percent efficient. The single largest source of this loss is a mismatch between the colors of incoming light and the colors of light that can be used by a solar cell.[4]

To understand this situation, remember that photovoltaic cells are made of semiconductors, materials that possess an energy bandgap. When energy is applied, electrons will move from the valence band (the ground state) to the conduction band (the excited state) and can be harnessed as electrical energy.

If a photon whose energy matches the bandgap of the semiconductor hits a solar cell, this process proceeds smoothly: The incident photon generates an excited electron that is effectively captured to generate electricity. If a photon has an energy greater than the bandgap of the material—as is the case for all visible light for most photovoltaic materials in use—the incident photon generates an electron higher in energy. This excited electron then rapidly relaxes to an energy equal to the bandgap, and all the excess energy is lost as heat, a waste for the solar cell. Even worse, photons with less energy than the bandgap cannot do anything productive at all, and simply pass through the semiconductor unabsorbed.

This presents a difficult trade-off for the solar-cell designer: Wider bandgaps will lose less as heat but absorb fewer photons, while narrower bandgaps will absorb more of the available photons but lose more as heat. Silicon, the ubiquitous light-absorbing photovoltaic material that makes up more than 90 percent of today's photovoltaic market, sits in the sweet spot of this trade-off. Still, even the best experimental silicon solar cells leave almost three-quarters of the available sunlight power unharvested.

This frustrating state of affairs has long inspired scientists and engineers, including us, to search for a better approach.

One promising idea is to use multiple absorber materials to create a stack of solar cells in which each semiconductor is paired with a particular portion of the solar spectrum. Designing these cells can be tricky. For instance, in one configuration, each sub-cell must output the same amount of current; otherwise, efficiency will be limited to that of the worst-performing sub-cell. Currently, the most efficient device made using three light absorbers under standard illumination—that is, without using lenses or other concentrators—has an efficiency of 39.5 percent.

[4] Tracy H. Schloemer and Daniel N. Congreve, IEEE Spectrum, "The Practical Power of Fusing Photons," 19 Sep, 2023, https://spectrum.ieee.org/photon-upconversion

But we think that changing the color of light can further boost efficiencies: Instead of trying to match the cell to the incoming light, we can match the light to the cell.

That means we convert the photons below the solar cells' bandgap to harvestable, higher-energy photons. In the last few years in our lab at Stanford and in collaboration with other scientists around the world, we have successfully up-converted low-energy infrared photons—which often can't be used by today's solar cells—into productive yellow photons that can. And we translated this chemistry, originally developed in a beaker, into a thin-film material…

3. Business

3.1. Solar Module Prices Crash, and No End in Sight

That the article below is from a European Site, and the market dynamics are much different in the US, although module pricing is, to some extent, a global market.

We have all been asking ourselves for some time now: How far can photovoltaic module prices go down before the bottom is finally reached? Apparently, there is still room for further drops, as all prices have fallen again this month. On average, prices in all module categories have been corrected downwards by around 10%. Never before in the history of photovoltaics have panel prices plummeted so significantly in such a short space of time. For a month or two now, the values have been below the previous all-time low of 2020 and even more so below the production costs of most manufacturers. Generating profit margins seems to be a thing of the past for the time being and for many of them it is now just a matter of minimizing damage or even survival.[5]

How could we come to this, and what are the causes of this self-destructive trend?

First of all, it should be noted module prices had risen more than 50%, in some cases, between October 2020 and October 2022, which is not due to technological developments, but primarily due to the pandemic-related supply shortage coupled with a simultaneous increase in demand. Ultimately, many players in the photovoltaic market made very good money – at the expense of the end consumers. Until recently, photovoltaic system prices were higher than they had been for a long time. Now things have completely changed, which inevitably leads to a drop in prices. The speed and intensity of this change, however, surprise even experienced market participants.

After the shortage issues of the past two years, many installers and wholesalers made generous forecasts and ordered new goods as if there was no tomorrow. The producers, predominantly from Asia, reacted and increased their capacities. Global production capacity usually exceeds the actual expected demand by 30% to 50%, so that fluctuations can be quickly compensated for. The production lines are then ramped up or down as needed. Recently, however, this mechanism has gotten a bit out of hand as many manufacturers have had to switch their cell and module production very quickly from p-type PERC technology to n-type TOPCon, due to patent rights problems in individual regions. However, since the sales restrictions did not apply worldwide, new capacities were built up for TOPCon without replacing and shutting down old PERC lines.

[5] Martin Schachinger, PVXchange, "Market Analysis September 2023 - Solar module prices crash, and no end in sight," Sep 27, 2023, https://www.pvxchange.com/Market-Analysis-September-2023-Solar-module-prices-crash-and-no-end-in-sight

The prospects appeared to be good in the long term thanks to the supposedly permanently high costs of conventional energy sources. Unfortunately, European politicians were very good at replacing old fossil fuel sources with new ones at short notice, so the suffering from skyrocketing energy costs quickly fell. The pandemic also seems to have finally been overcome and the average European can travel without restrictions again. Not least due to high inflation, many people who recently wanted to invest in photovoltaic systems are now becoming more reluctant. The fact that interest rates on loans continue to rise doesn't make the decision any easier. The consequence of all the factors listed is a collapse in demand so that the photovoltaics industry has not yet emerged from the summer slump even in mid-September.

The quickly dwindling interest in solar power generation inevitably means that the order books of installers and project planners run empty and pre-ordered modules and inverters cannot be delivered on time. The goods are increasingly piling up at wholesalers and in the manufacturers' warehouses. There are now said to be 40 GW to 100 GW of unsold modules in European stores, primarily in the Rotterdam area. Determining an exact amount is almost impossible. However, it is enough to know that there is already about a year's supply of modules in Europe to understand the dimensions and scope of the matter. Storing these goods costs a lot of space and therefore money; losses are increasing day by day, while sales opportunities are decreasing. The pressure increases until the avalanche finally starts to slide and the first ones will begin offering their modules below purchasing or production costs. Competitors are forced to follow suit and the downward spiral is set in motion.

Now one might think that falling prices would boost demand. In many cases, the current price level for materials has not yet reached end customers or investors. For many providers, the old inventory, which was purchased at higher prices, is still too large. The wave of devaluation is also just beginning, which is why the price drop is becoming more severe from month to month. Many are still hoping to get off lightly. But the risk of being stuck with the old goods is very high. Those interested in photovoltaics also monitor prices very closely and compare offers. Accordingly, many end customers are now waiting for the offered prices to fall further and are hesitating to place an order…

3.2. U.S. expands solar tariffs, probe finds Chinese evasion

In past reporting I have pointed out that more production facilities for PV cells and modules are being built in the U.S. I expect that this build out is resulting in an over-supply in the Global Market (see the prior subsection). For one cause of this build-out, see the article below.

The United States will impose new duties on imports from some major Chinese solar panel makers after a months-long investigation found they were trying to dodge tariffs by finishing their products in Southeast Asian countries, trade officials said on Friday.[6]

[6] Nichola Groom, Reuters, "U.S. to expand solar panel tariffs after probe finds Chinese evasion," Dec 2, 2022, https://www.reuters.com/markets/commodities/us-says-solar-imports-four-southeast-asian-countries-were-dodging-china-tariffs-2022-12-02/

The preliminary decision was bad news for U.S. solar project developers that rely on cheap imports to fuel their growth, but fell short of the industry's worst fears that Washington would impose new tariffs to cover all solar shipments from the region, instead of just those from specific companies.

U.S. President Joe Biden has set a goal to decarbonize the nation's power sector - the source of around a quarter of national greenhouse gas emissions - by 2035, something that will require rapid deployment of new solar, wind and other clean energy projects.

The U.S. Commerce Department probe found that units of BYD Co Ltd (002594.SZ), Trina Solar Co Ltd (688599.SS), Longi Green Energy Technology Co Ltd (601012.SS) and Canadian Solar Inc (CSIQ.O) were circumventing existing tariffs on Chinese solar cells and panels that have been in place for a decade.

If finalized next year (2023, see comment below), the determination means those companies will be subject to duties on the products they make in Malaysia, Cambodia, Thailand and Vietnam - countries that now account for about 80% of U.S. panel supplies.

Those companies and others will face the same duty rates the United States already assesses on their Chinese-made products, officials said, noting that most of those rates are below 35%. The duties will not kick in until June of 2024 thanks to a two- year waiver from Biden earlier this year.

Author's comment: to make a very long story short, in researching this, it appears these tariffs may be restored in mid-2024 after the Commerce Department found in Aug 2023 that these violations continue, Congress agreed, but the President deferred any tariffs until mid-2024 to keep our PV market churning. Stay tuned.

4. Projects

4.1. Milagro Solar + Storage Project

EDF Renewables North America today announced the execution of a 20-year Power Purchase Agreement (PPA) with El Paso Electric (EPE). The PPA covers the output from the 150 MWac Milagro Solar and the 75 MW / 300 MWh Milagro Storage Project, which are slated for commercial operation in 2025.[7]

The Milagro Solar + Storage project, located on undeveloped private land in the Santa Teresa area of Doña Ana County, New Mexico, expects to create approximately 200 jobs during the peak construction phase. Over the operating life of the project, approximately $7.9 million in tax revenue will be generated for three school districts and Doña Ana flood control authority supported under the Industrial Revenue Bond (IRB)…

In addition to its economic benefits, Milagro Solar + Storage expects to generate approximately 469,500 MWh of clean energy annually. This is equivalent to avoiding over 333,000 metric tons of carbon (CO_2) emissions annually which represents the greenhouse gas emissions from over 74,000 passenger vehicles driven over the course of one year.

[7] EDF Renewables Press Release, "EDF Renewables North America Signs Agreement with El Paso Electric for Solar + Storage Project," Sep 25, 2023, https://www.edf-re.com/press-release/edf-renewables-north-america-signs-agreement-with-el-paso-electric-for-solarstorage-project/

4.2. Tierra Bonita Solar Project

Ashtrom Renewable Energy, a global independent power producer and renewable energy developer, today announced the signing of a green financing totaling ~$270M with a group of five banks.

We have also entered into a pioneering agreement to sell the project tax credits to a leading U.S.-based institutional entity for an estimated value of $300 million. This follows our PPA agreement from last year to sell ~60% of the project's electricity to the CPS Energy (Aa2 Moody's) the municipal utility of San Antonio for a 20-year term."

The Tierra Bonita project is located on a ~2,400 acres site in Pecos County, Texas, with a planned capacity of ~400MWdc (306 MWac). It is currently under construction, and commercial operation is expected by Q4 2024. The project is expected to have positive environmental impact, reducing CO_2 emissions by over 500,000 tons per year.

4.3. BP Begins Construction on Its Peacock Solar Project

BP said the company has started construction on its 187MWdc (appx 140 MWac) Peacock Solar project, located 10 miles north of Corpus Christi in San Patricio County, Texas. The project is anticipated to come online in the second half of 2024.

Peacock will sell all of the electricity it generates under a long-term power purchase agreement to Gulf Coast Growth Ventures, a joint venture between ExxonMobil and SABIC.

4.4. Recurrent Closes Financing for 134 MW MISO South

Recurrent Energy, a global developer and owner of solar and energy storage assets, announced today (Sept 19) that it has closed project financing for its 134 MW (100 MWac) Liberty Solar project. The project is currently under construction in Liberty County, Texas, about 50 miles northeast of Houston, and is expected to reach operation in 2024...[8]

Previously, Recurrent Energy announced that it has secured a power purchase agreement for 100% of the project's production capacity via an aggregated virtual power purchase agreement. Liberty Solar will expand solar energy capacity in the Midcontinent Independent System Operator (MISO) region, which includes most of Liberty County where Liberty Solar is located. Solar energy currently makes up only 1% of the resource mix in MISO.

4.5. Plus Power advances five energy storage facilities

Plus Power LLC on Tuesday said it secured an additional $1.8 billion for standalone battery storage via five projects aimed at stabilizing the U.S. electrical grid while accommodating more solar and wind energy.[9]

[8] EE Online, "Recurrent Energy Closes $120 Million in Project Financing and $80 Million in Tax Equity for 134 MW MISO South Project," Sep 20, 2023, https://electricenergyonline.com/article/energy/category/solar/142/1040852/recurrent-energy-closes-120-million-in-project-financing-and-80-million-in-tax-equity-for-134-mw-miso-south-project.html#:~:text=Recurrent%20Energy%2C%20a%20global%20developer%20and%20owner%20of,and%20is%20expected%20to%20reach%20operation%20in%202024

[9] Reuters, "Plus Power raises $1.8 billion for standalone battery storage," Oct 18, 2023, https://www.reuters.com/business/energy/plus-power-raises-18-billion-battery-project-2023-10-17/

The company also announced $707 million in financing for the 250-megawatt Sierra Estrella Energy Storage facility in Avondale, Arizona, making it the largest standalone energy storage project financing. The transactions will support construction of BESS facilities in the Salt River Project in Arizona as well as in the ERCOT market in Texas.

The Sierra Estrella facility is one of two battery storage projects the Salt River Project (SRP) announced in fall of 2022 with Plus Power, with both projects scheduled to come online by summer of 2024. The other, a 90 MW / 360 MWh project is called Superstition Energy Storage, which is planned for Gilbert, Ariz.

The completed transactions were financings totaling $884 million to support construction of 700 MW of batteries on the ERCOT grid in Texas in the Ebony, Anemoi and Rodeo Ranch energy storage projects. Plus Power reports that while the Ebony and Anemoi projects are expected to operate as merchant resources in the ERCOT wholesale market…