

PVSC 50 Daily Highlights Wednesday June 14, 2023

Welcome to the third day of the 50th IEEE Photovoltaic Specialists Conference!

Sun Run

This morning started off very early for some with the 35th PVSC Sun Run at 6:30 am, organized by Martha Lenio. Congratulations to the top finisher over-all (and in the men's category), Corson Teasley, the top finisher in the women's category, Tanja Jawinski, and the top team PVMAD! Thanks to all the volunteers that helped make the run a success this year! Also: there are some lost & found items at the Registration desk. If you are missing a gray long-sleeve top, or a water bottle in a light-weight bag, go see if they are yours.

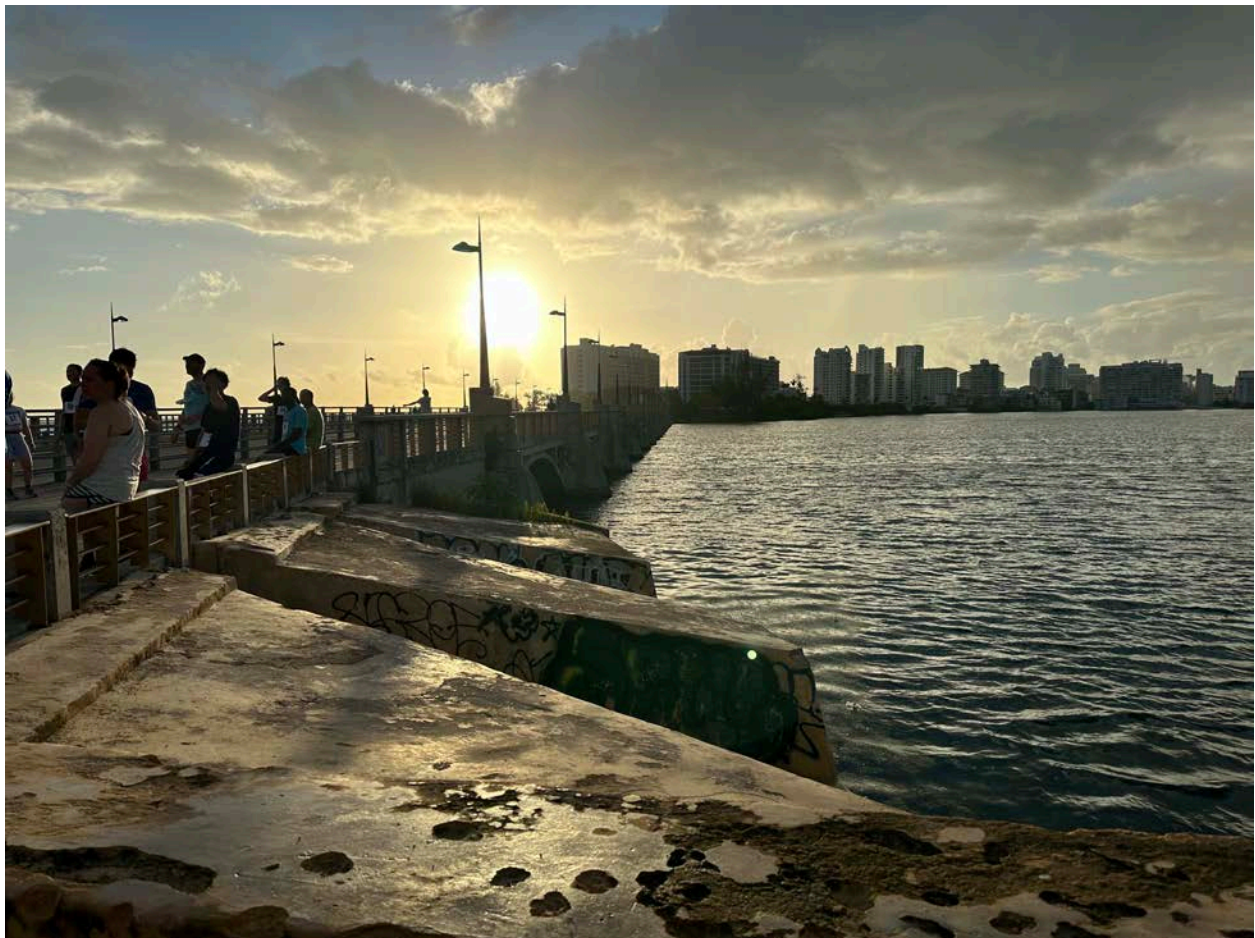


Image: Runners await the start of the race as the sun rose over Laguna del Condado.

Plenary Sessions:

Area 4 Plenary: Patrizio Manganiello, TU Delft, presented that PV module size is increasing for all applications with power higher than 700 W but module weight is becoming a concern on the other hand. Si Tandems are expected to reach efficiency over 26% by 2033. Currently no technology provides a sustainable way towards a multi-TW market. Reduction of Ag in contacts and In-free TCO's are the main technological key towards sustainable PV market.

Area 10 Plenary: Martin Wild, ETH Zurich, presented data from 40 climate models regarding the consistency of solar radiation changes. Solar dimming and brightening has resulted in irradiance variations on the order of 10%. These variations result from changes in the atmosphere. Air pollution patterns explain changes in global irradiance. Global climate models predict future insolation changes. Solar resource is not stable over decadal timescales. Atmospheric transmissivity is predicted to increase in Eastern US, Europe and parts of Southeast Asia. Projected PV yields are higher under a sustainable scenario than under the fossil fuel based scenario.

Keynote:

Gabriela Bunea, GAF Energy, shared details about GAF Energy's solar shingle starting with a history of solar rooftop installations through today and included comparisons between their product to traditional new roofs with separate PV arrays. The product can be installed as a certified roof by traditional roofing practices and methods. She shared videos demonstrating the durability of the shingles to walking, impacts, and weather (including 110 mph wind and rain) and brought a sample to show to the attendees. There was a lot of excitement from the audience to view the solar shingle after the talk. Roofing and solar are converging!

Technical Sessions:

Joint Area Session - Joint Session 1/6: Hybrid Perovskite Tandems

Bo He (LONGi Green Energy Technology) discussed perovskite/Si solar cells, four terminal tandems, and two terminal tandems. The four terminal tandem used a key laser scribing process, allowing an efficiency of 25.9% on a large 241 cm² 4T tandem module. 2T tandem cells were also mentioned, with an efficiency of 33.5%. Miha Kikelj (University of Ljubljana) discussed 3T tandem cells fabricated in house at the University of Ljubljana, with efficiencies around 29%. He also discussed methods to fabricate 3T cells using voltage matched strings. He also explained optimizing interconnection losses and end losses in three terminal strings. Gemma Giliberti (Politecnico di Torino, Best Student Presentation Award Finalist) demonstrated a cell configuration with a heterojunction bipolar transistor (HBT) and Top Interdigitated Contact (TIC) architecture. One highlight of the talk were some simulations that varied sheet resistance and finger length, giving the cell efficiency. Michael Rienäcker (ISFH) presented primarily on 3T perovskite/POLO2-IBC tandem cells. Optimization of both the top cell bandgap and texture as well as bottom cell leading to 728 mV iVoc. Chris Eberspacher (Tandem PV) explained the background and basics

of what Tandem PV does, including overcoming perovskite module processing challenges such as particles, pinholes, various perovskite phases, low J_{sc} , low FFs, and near scribe delamination. A 16.8% submodule efficiency, with a promising outlook for outdoor and accelerated tests, was presented. Development of a superstrate submodule using perovskites to be applied to Si modules, with extensive durability testing. Zhaoning Song (Toledo) monolithic bifacial tandems for CdSeTe improving the bifaciality of bottom cell with up to 25.4% with 0.4 albedo.

Area 2 - Advanced Junctions and Interfaces

Dengbing Li (University of Toledo) showed us that engineering the front interface of CdTe solar cells with a combination of S, Se and O₂ could potentially improve device performance. Manoj Jamarkattel (University of Toledo) presented a novel new front interface (IGO) for CdTe solar cells showing promising initial results. Combined with Dengbing Li's work it could provide interesting pathways for future CdTe devices.

Area 4 - Passivated, Carrier-Selective, and Heterojunction Contacts - 1

Christophe Allebé (CSEM) optimized the conditions for sputtered Si passivating contacts at the rear side of a full area of 6-inch n-PERT cells and showed improved cell performance. Harvey L Guthrey (NREL) demonstrated that various microscopic techniques such as EBIC, TEM, AFM, etc. are useful to characterize pinholes formed in two different types of passivated contacts; PLEO and PLENO. Matthias Junghänel (Hanwha Q CELLS) discussed the average efficiency of mass-produced Q.ANTUM NEO cells reached ~25% efficiency. It was impressive that they've been improving their cell efficiency 0.5% every year. Eric Schneiderloechner (VON ARDENNE) Optimized PVD process in their TOPcon enabled best efficiency 23.6% with Voc 716 meV. These figures of merits are in the similar level of those values achieved in cells using LPCVD. Di Yan (University of Melbourne) demonstrated improved stability of polycrystalline Si passivated contacts using TiO_x.

Area 7 - Modelling and Predicting Energy Yield

Lelia Deville (Sandia, Best Student Presentation Award Finalist) tested different models, both steady state and transient, starting from experimental data containing climatic and electrical variables such as voltage and current at mpp. Generally, performance models perform similarly, but a location specific photovoltaic performance model improved accuracy with the largest differences happening at low irradiance levels, and input module data could be more significant than the model. Kirsten Perry (NREL) presented a goal of validating array tilt, azimuth, clipping, and shading data with a PV Validation Hub as a website for validating PV analytics algorithms that is open source. Timofey Golubev (ThermoAnalytics) discussed an artificial neural network surrogate model on physics-based temperature data shows good agreement, particularly in the Southwest and in the non-winter months, which can be used to provide studies of potential driving range extension that VIPVs could provide under different weather conditions Tim Lukas Brockmann (ISFH) presented that highly transparent encapsulation materials have differences in loss based on manufacturer but independent of backsheet color, overall the UV transparent encapsulants

reduce losses to the largest extent. Emma C. Cooper (Sandia) showed distinct power loss modes were observed in utility-scale performance data, and surprising results showing some systems operate under full snow coverage while landscape-orientation systems lose less power than portrait-orientation systems. Jabir Bin Jahangir (Purdue) discussed that bifacial 3/4 terminal tandems provide significant gains in yearly yield worldwide in all albedo conditions, while effective albedo determines the benefits of bifacial 2 terminal tandems

Area 8 - Advances in Modelling and Mitigation of Photovoltaic Soiling

The first three speakers indicated a need for better understanding of interannual and seasonal variability and uncertainty in soiling rates, and proposed the use of historic data in conjunction with models in order to capture that variability. Challenges in estimating soiling due to pollen and mold were brought to light; losses can be significant in rainy locations and do not follow a typical sawtooth pattern. Matthew Muller (NREL) analyzed the interannual variability of soiling using 25 years of weather data and found that soiling might vary from year to year; a better understanding of this variability is needed. Franco Clandestino (Virtuous-Re) presented a novel approach to optimize the cleaning schedule of utility-scale PV systems, using estimation models and data on different cleaning technologies. Kyle Seymour (Clean Power Research) reported on the benefits of using a variable soiling rate model to simulate energy losses and proposed a tuning approach to optimize the estimation. Matt Muller (NREL) explained that pollen does not behave as regular soiling. Soiling in SE USA can be resistant to rainfall cleaning (5-11% losses recovered after mechanical cleaning) and that soiling loss estimation algorithms fail in this region. Anil Kottantharayil (NREL) proposed a distributed model to calculate the module temperature from performance data which can help improve the estimation of the soiling rate as well. Luke O Jones (CREST, Loughborough University, Best Student Presentation Award Finalist) showed how polysiloxane hydrophobic coatings can reduce soiling rate compared with current coating technologies. Hydrophobic coating suffered from high initial soiling but plateaued quickly, maintained low surface energy throughout abrasion cycles, had High UV resistance but was susceptible to damp heat degradation, and can be reapplied in-situ if coatings starts to lose performance. In contrast, porous silica AR coatings are more susceptible to soiling and mechanical abrasion.

Area 9 - Power Electronics and Grid Integration - 1

Wenzong Wang (Electric Power Research Institute) discussed that microgrid is less stable with more Grid Following capacity online. The shorter the electric distance between the Grid Following (GFL) and Grid Forming (GFM) plants, the more GFL capacity can be online without instability. Hector K Lopez (Florida Atlantic University) exposed an interesting Fuzzy Logic Inference Systems (FIS) based methodology to enable P2P arbitrage between residential prosumers. Wenzong Wang (University of Central Florida) presented an analysis of the gaps between regulation and operation of grid Forming Inverters regarding the IEEE 1547 and IEEE 2800 Standards regarding to grid-forming requirements. Nayeem Ninad (CanmetENERGY) presented a methodology to coordinate the frequency-droop control in a microgrid with IBR and diesel generators. He also stated that lack of frequency restoration services in microgrids could lead to undesirable operation of DERs. Shuan Dong (NREL) presented the development of a nonlinear frequency nadir stability constraint in a unit commitment problem. Leveraging a real-world island system

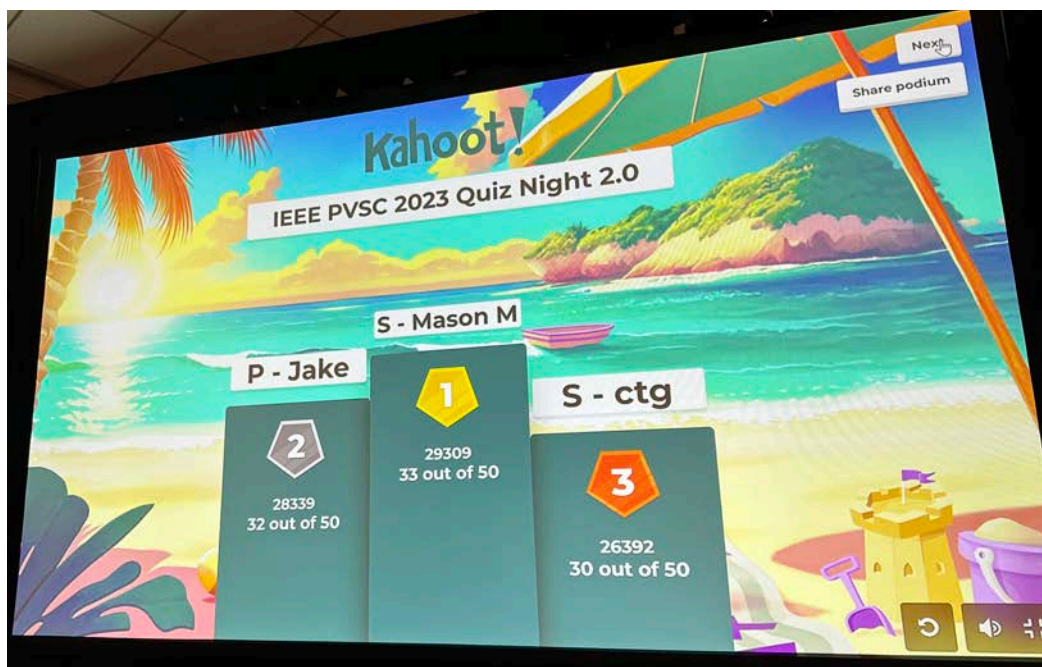
model validates that their developed stability constraints effectively secured the frequency nadir. Ramanathan Thiagarajan (NREL) talked about tests performed under commercial inverters in order to evaluate the responses under momentary events.

Special Session - Special Session - 100% Renewable Energy

This session was moderated by Ron Sinton and Marius Peters where we discussed that electricity is only the first step, we need to focus on sector coupling to transport, building, and industrial processes. Primary pressures in favor of agrivoltaics are water stress, extreme weather events, and competition for land use. 30% coverage with floating PV can reduce evaporation by 46+- 3% per reservoir while avoiding toxic algal blooms, though with possible risk of reducing dissolved oxygen, impacting fish populations.

Special Session – Quiz Night

Amit Munshi hosted a great second annual PVSC Quiz Night with questions on PV, science, and beyond. Congratulations to the winner Mason Mahaffey!



POSTER SESSION AWARD NOMINEES AND **WINNERS**:

AREA 4: THIN SILICON, INTEGRATION, CHARACTERIZATION AND MODELING

F. Saitta – Winner (Transparent Conductive Oxide Bi-layer as Front Contact for Multijunction Thin-film Silicon Solar Cells)

August Weber (Influence of Aluminum Co-Doping on Current-Induced Degradation and Regeneration Kinetics in Boron-Doped Cz PERC Solar Cells)

Steve Johnston (Capacitance Transients, Photoconductive Decay, and Impedance Spectroscopy on 19% to 22% Efficient Silicon Solar Cells)

AREA 5: ADVANCED CHARACTERIZATION FOR PHOTOVOLTAIC MODULES AND SYSTEMS

Steve Johnston – Winner (Luminescence and Thermal Imaging Applied to Half-cut-cell and Emitter-wrap-through-cell Modules)

Bernd Doll (Aerial photoluminescence imaging of PV modules)

R. Herrero (INDOOR AND OUTDOOR EVALUATION OF CURVED MODULES FOR VIPV)

AREA 7: PV MODULES, MANUFACTURING, SYSTEMS AND APPLICATIONS - 2

Armando Villa-Ignacio – Winner (Evaluating Leafy Green Production in a Colorado Rooftop Agrivoltaic System)

Kaushal Chapaneri (Self-Thermometry of PV Panels)

William B. Hobbs (Evaluation of irradiance variability adjustments for subhourly clipping correction)

AREA 8: FIELD EXPERIENCES & SOILING

Lawrence L. Kazmerski – Winner (Survey of Module Quality in Brazil Photovoltaic Deployment)

John M. Obrecht (Detection of PV Module Temperature Coefficient Using Machine Learning)

Timon Vaas

AREA 11: ENVIRONMENTAL SUSTAINABILITY AND USER BEHAVIOR, EDUCATION IN INSTITUTES OF LEARNING, AND WORKFORCE DEVELOPMENT

Heather Mirletz - Winner (Measuring Sustainability of PV in Energy Transition: Mass, Energy, and Circularity)

Henry J. Williams (Brownfields to Brightfields: The potential for landfill solar redevelopment in New York State)

Chenyang Deng (Identification of module replacements in US utility-scale photovoltaic installations)