

# Proceedings of the PV Reliability Workshop

February 21 – 25, 2022



The 2022 PV Reliability Workshop (PVRW) was held virtually from February 21-25, 2022.

These proceedings collect the oral and poster presentation recordings from the workshop. Click on the linked titles of poster and oral presentations in the pages below to view a recording of those presentations.

If a talk or poster title is not linked to a video, no recording was submitted to the PVRW organizers for that presentation. In the interest of promoting frank conversation, the organizers chose to not record the panel discussions in the plenary sessions, so you will not find recordings of these in the proceedings.

If you have any questions, please contact [pvrw.admin@nrel.gov](mailto:pvrw.admin@nrel.gov).

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Kent WHITFIELD  
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## AGENDA – Monday, 21 February 2022

8:00am

### Session 1: Portfolio and Field performance – Availability and Degradation

- Opening remarks – Teresa Barnes, NREL
- [PV fleets performance data initiative](#) – Chris Deline, NREL
- [Module technology trends and supply chain issues in 2022](#) – Frédéric Dross, Senergy Technology Services
- [Correlating lab results to field data: findings, challenges, opportunities](#) – Tristan Erion-Lorico, PV Evolution Labs
- Live question and answer period

### Poster Session A

10:15am

### Session 2: Extreme Events and Resilience

- Cell, beyond interrupted– James Papazis, G3 Insurance
- Measuring and managing hail risk – Steve Fox, Marsh McLellan
- Panel: Extreme weather events – James Papziz, G3 Insurance, Steve Fox, Marsh McLellan, Patrick Smith, National Grid Renewables, Ingrid Repins, NREL, Hamid Gerami, DNV, Laurie Burnham, Sandia National Laboratories
- Live question and answer period

### Poster Session A Awards

## Poster Session A – Monday, 21 February 2022

**Notes:** **DuraMAT** posters are indicated with **red** titles.

The letter indicates the **SESSION**, the first number indicates the **FLOOR**, and the second number indicates the **TABLE**.

- A.1.1** **Mihail Bora**, Laura Spinella, Sergiu Pop, Reinhold Dauskardt, and Ziyi Pan, [Water content imaging for reliability testing of photovoltaic module packaging](#)
- A.1.2** **Naila M Al Hasan**, Rachael Arnold, Bruce King, David Miller, Jimmy Newkirk, Emily Rago, Laura Schelhas, Archana Sinha, Kent Terwilliger, Michael Thuis, Soňa Uličná, Kurt van Durme, [Arrhenius analysis of the degradation modes in emerging photovoltaic backsheets](#)
- A.1.3** Rachael L Arnold, Imran S Khan, Joshua Morse, Chuanxiao Xiao, Robert R White, and **David C Miller**, [A custom high-throughput optical mapping instrument for accelerated stress testing of PV module materials](#)
- A.1.4** **David L Young**, Timothy J Silverman, Nicholas Bosco, [Laser-welded edge seals for glass/glass modules](#)
- A.1.5** Namrata Salunke, **Hoi Ng**, Mike Kempe, Peter Hacke, Jimmy Newkirk, Aidan Ravnik, [Advanced material development to support low-LCOE 25-year flexible photovoltaic modules](#)
- A.1.6** **Stefan Mitterhofer** and Xiaohong Gu, [A finite element model to simulate backsheet cracking and its application to fragmentation of AAA backsheets](#)
- A.1.7** **Shu-Tsung Hsu** and Yean-San Long, [Experimental study of mechanical loads and deformation on photovoltaic module at different wind speeds](#)
- A.1.8** **Soňa Uličná**, Archana Sinha, David C Miller, Laura T Schelhas, Michael Owen-Bellini, [Degradation of encapsulants for application in glass/glass PV modules after accelerated aging](#)
- A.1.9** **Michael Owen-Bellini**, Martin Springer, Timothy J Silverman, Nick Bosco, [Mechanical models for 50-year lifetime PV modules](#)
- A.1.10** **Patrick Thornton**, Oliver Zhao, Ziyi Pan, Jared Tracy, Kaushik Roy-Choudhury, Paul Roraff, Michael Mooney, Archana Sinha, Laura T. Schelhas, Mihail Bora, Reinhold Dauskardt, [Advancing fundamental understanding of adhesion degradation within bifacial solar module materials – polyolefin encapsulants and SmartWire assemblies](#)
- A.1.11** **Dana B Sulas-Kern**, Michael Owen-Bellini, Laura Schelhas, Soňa Uličná, Paul Ndione, Helio Moutinho, Steve Johnston, [Degradation pathways in glass/glass bifacial PV with emerging encapsulants and half-cut cells](#)
- A.2.1** **Quanzhi Wang**, Yuanjie Yu, Yangdong Ni, Hongliang Lin, Lianli Yang, Jean-Nicolas Jaubert, [Improvement of the module super high load capacity and multiple installation methods in rooftop application through Finite Element Method \(FEM\) calibrated with mechanical load tests](#)
- A.2.2** **Peter Hacke**, Nick Bosco, James Hartley, David C Miller, and Chuanxiao Xiao, [Evaluation of emerging module interconnect technologies](#)
- A.2.3** **Ziyi Pan**, Mihail Bora, Laura T Schelhas, Reinhold Dauskardt, [Advancing scalable spray plasma processing for lightweight transparent back lamination in bifacial modules](#)
- A.2.4** **Jiqi Liu**, Sameera Nalin Venkat, Jennifer L Braid, Xuanji Yu, Brenton Brownell, Xinjun Li, Jean-Nicolas Jaubert, Kaushik Roy Choudhury, Laura S Bruckman, Roger H French, [Performance losses and activated mechanisms in monofacial and bifacial, double-glass and glass-backsheet photovoltaic modules with PERC cells, under accelerated exposures](#)
- A.2.5** **Stephanie L Moffitt**, Po-Chang Pan, Michael D Kempe, Jared Tracy, Kaushik R Choudhury, Yimin Mao, Paul D Butler, Behrang H Hamadani, Xiaohong Gu, [Investigating solar panel defect mechanisms in polymer packaging materials](#)
- A.2.6** **Soshana Smith**, Stephanie Moffitt, Stefan Mitterhofer, Song-Syun Jhang, Stephanie Watson, Li-Piin Sung, LaKesha Perry, Deborah Jacobs, Xiaohong Gu, [Material characterization and long-term durability of glass/transparent backsheet coupons for bifacial photovoltaics](#)

- A.2.7** *Ian M Slauch, Rishi E Kumar, Tala Sidawi, Jared Tracy, Rico Meier, David P Fenning, Mariana I Bertoni, [In-situ mapping of deformation in crystalline silicon modules: Understanding the effects of viscoelasticity](#)*
- A.2.8** *Remi Aninat, Pelin Yilmaz, Klaas Bakker, Thomas Weber, Mirjam Theelen, [Coring and unpackaging for comprehensive defect characterisation in commercial CIGS modules](#)*
- A.2.9** *Samuel Ellis, Larry Maple, **Tushar Shimpi**, Ryan Rhule, Kurt L Barth, Design of experiments on PIB dispensed parameters for corner radius of*

edge seal for application in encapsulation of thin film solar module

- A.2.10** *Rishi E Kumar, Tala Sidawi, Ian Slauch, Rico Meier, Mariana I Bertoni, David P Fenning, [Moisture ingress and distribution in bifacial silicon photovoltaics](#)*
- A.2.11** *Joe Karas, Naila Al Hasan, Jenya Meydbrey, Robert Flottesmesch, Jim Rand, Dirk Jordan, Max McPherson, Mason Reed, Teresa Barnes, [Trends in field and laboratory performance of photovoltaic modules and materials](#)*

## AGENDA – Tuesday, 22 February 2022

### 8:00am **Session 3: Field Characterization and O&M**

- Data science approaches for PV field analysis – Jen Braid, [Sandia National Laboratories](#)
- [Autonomous drone EL mapping for solar PV asset management](#)– Karl Bedrich, Quantified Energy Labs
- [UV fluorescence testing of residential and ground-mount solar panels](#) – Andrew Gabor, BrightSpot Automation
- Big picture from large scale imaging data sets – Rob Andrews, Heliolytic
- Live question and answer period

### Poster Session B

### 10:15am **Session 4: Impacts of Extended Accelerated Testing – 63209 and test lab protocols**

- [Experience on extended module testing data on IEC TS 63209-1](#) – Lukas Jakisch, TÜV Rheinland
- [Impacts of extended accelerated testing - 63209 and test lab protocols](#) – Nancy Phillips, Independent
- [Module useful-life assessment and financial impacts](#)– Henry Hieslmair, DNV
- Live question and answer period

### Poster Session B Awards

## Poster Session B – Tuesday, 22 February 2022

**Notes:** **DuraMAT** posters are indicated with **red** titles.

The letter indicates the **SESSION**, the first number indicates the **FLOOR**, and the second number indicates the **TABLE**.

**B.1.1 William Sekulic**, Chris Deline, Byron McDanold, Josh Parker, [Long-term PV damage testing](#)

**B.1.2 Ian Marius Peters**, Jens Hauch, Christoph Brabec, [How sustainable is PV module repowering?](#)

**B.1.3 Tadanori Tanahashi**, Yuki Tsuno, Kazuaki Ikeda, Takashi Oozeki, [Snow-removing behavior on the photovoltaic modules with a built-in film heater](#)

**B.1.4 Xin Chen**, Todd Karin, **Anubhav Jain**, [Assessing factors underpinning PV degradation through data analysis](#)

**B.1.5 Bruce H King**, Elizabeth Palmiotti, Joshua Stein, Ashley Maes, [DuraMAT fielded module study](#)

**B.1.6 Sara Bouguerra**, Kamel Agroui, Ismail Kaaya, Ahmed Bouraiou, Mohamed Rédha Yaiche, [Prediction of PV module lifetime and energy yield in different locations using the acceleration factor for short circuit current degradation](#)

**B.1.7 Steve Johnston** and William B Hobbs, [Long-term monitoring of new cell cracks using ultraviolet fluorescence imaging](#)

**B.1.8 Wei Yang**, Daniel Fregosi, Michael Bolen, Kamran Paynabar, [PV fault diagnosis using physics-driven machine learning](#)

**B.1.9 Matthew Brown**, **Silvana Ovaite**, Michael D Kempe, [Ray-tracing irradiance simulation approach to exploring UV-degradation in backsheets](#)

**B.1.10 Robert R White**, Nicholas Wunder, Nalinrat Guba, Alicia Key, Rachel Hurst, Ashlee Vise, Chris Webber, Anubhav Jain, [DuraMAT Data Hub: a new phase](#)

**B.1.11 E Ashley Gauding**, Steve W Johnston, Dana B Sulas-Kern, Mason J Reed, James A Rand, Robert Flottemesch, Timothy J Silverman, Michael G Deceglie, [Investigation of underperformance in fielded N-type monocrystalline silicon photovoltaic modules](#)

**B.1.12 Claudia Buerhop**, Tobias Pickel, Oleksandr Stroyuk, Ian Marius Peters, Jens Hauch, [Impact of backsheet versatility on the insulation resistance in PV systems](#)

**B.2.1 Chun-Sheng Jiang**, Steve Johnston, E Ashley Gauding, Michael G Deceglie, Robert Flottemesch, Chuanxiao Xiao, Helio R Moutinho, Dana B Sulas-Kern, John Mangum, Mowafak M Al-Jassim, Ingrid L Repins, [Series resistance degradation of silicon solar cells investigated by nm-scale resistance imaging](#)

**B.2.2 Raymond J Wieser**, Stephanie L Moffitt, Ruben Zabalza, Xiaohong Gu, Laing Ji, Evan Boucher, Colleen O'Brien, Adam W Hauser, Greg S O'Brien, Roger H French, Michael D Kempe, Jared Tracy, Kaushik R Choudhury, Laura, [Spatiotemporal modeling of real-world backsheets degradation data](#)

**B.2.3 Xuanji Yu**, Cuiwei Wu, Ruirui Lv, Jean-Nicolas Jaubert, Guangchun Zhang, Laura S Bruckman, Roger H French, [Delamination risk prediction of POE- and EPE-encapsulated PV modules all around the world](#)

**B.2.4 Cara Libby**, Daniel Fregosi, Michael Deceglie, Timothy Silverman, Nick Bosco, Michael Owen-Bellini, Ethan Young, Xin Chen, Anubhav Jain, [Effect of cell cracks on module power loss and degradation](#)

**B.2.5 James Hartley**, [Analyzing hail impacts on PV modules using computational simulation](#)

**B.2.6 Claire Kearns-McCoy** and George Touloupas, [Cell edge microcracks: findings from post-shipment and post-installation field EL testing](#)

**B.2.7 Amir A Abdallah**, Performance of silicon heterojunction photovoltaic technology in desert climate

**B.2.8 Neolmar de M Filho**, Antônia SAC Diniz, Juliano MF da Fonseca, **Lawrence L Kazmerski**, [PV modules and snail trails in Brazil's tropical climate: observation, detection, chemistry, and performance effects](#)

**B.2.9 Asim Bisayee**, Hebin Manuel, Shubham Kumar, Mayur Nakarani, Praveen Kumar, Saran Bhaskar, Tanmay Joyashi, Shubham Thakur, Gita Kumari, **Gowri Ganesh**, Tsyuoshi Shioda, [Importance of PV reliability testing and replicating the field failures in the lab: eliminating risks from factory to field](#)

**B.2.10 Shubham Kumar**, Gowri Ganesh, Saran Bhaskar, Praveen Kumar, [Assessment of various types](#)

[of cleaning robots on PV systems based on their impact on PV module parameters](#)

**B.2.11 Peter Hacke, David C Miller, Chuanxiao Xiao,**  
[Application of acceleration science and validation for combined-accelerated stress test development](#)

## AGENDA – Wednesday, 23 February 2022

### 8:00am **Session 5: Materials Degradation and Performance**

- [Modelling of climatic degradation factors for polymers in PV modules](#) – Marcel Kühne, Hanwha QCell
- [Wind-driven and accelerated weathering of cracked cells](#) – Timothy Silverman and Mike Deceglie, NREL
- Water and deflection dynamics under solar cell operating conditions– Mariana Bertoni, Arizona State University, DuraMAT
- [Reliability of co-extruded backsheets based on polypropylene](#) – Gernot Oreski, PCCL
- Live question and answer period

### Poster Session C

### 10:15am **Session 6: Sustainability and End of Life Management**

- End of Life management of major components – Daniel Pardo, DNV
- [Decommissioning, recycling, and O&M](#) – Amanda Bybee, Amicus O&M Cooperative
- [Sustainability strategies in PV in line with the SDGs: Reinforcing effects and trade-offs](#) – Estelle Gervais, Fraunhofer ISE
- Live question and answer period

### Poster Session C Awards



## Poster Session C – Wednesday, 23 February 2022

**Notes:** **DuraMAT** posters are indicated with **red** titles.

The letter indicates the **SESSION**, the first number indicates the **FLOOR**, and the second number indicates the **TABLE**.

**C.1.1** *Joseph Karas and Ingrid L Repins*, [Results from an international interlaboratory study on light- and elevated temperature-induced degradation](#)

**C.1.2** *John Wohlgemuth*, PV standards activities of IEC

**C.1.3** *Max Köentopp and C Monokroussos*, [Update on IEC TS 63342 – Light and elevated temperature-induced degradation \(LETID\) test for c-Si modules](#)

**C.1.4** *George Kelly and Sumanth Lokanath*, [IEC TC 82 status](#)

**C.1.5** *Roger Hill*, [IEC technical specification for the operation of a PV power system, including reliability](#)

**C.1.6** *Steve Hogan and George Kelly*, [The status of IECRE system certification schemes](#)

**C.1.7** *Paul F Robusto*, [IEC 63163 consumer product specification](#)

**C.1.8** *Cecile Molto*, [PID-p on bifacial PV modules](#)

**C.1.9** *Ingrid L Repins, Timothy J Silverman, Michael G Deceglie, David C Miller, Dirk C Jordan*, [Pareto analysis framework for prioritizing PV reliability research activities](#)

**C.1.10** *Peter Clawin, Max B Köntopp, T Göttermann, W Engler*, [Quality-controlled PV \(QCPV\) - a new manufacturing quality control program based on IEC 63209](#)

**C.1.11** *Stefan Wendlandt*, [Risk analysis on technologies beyond PERC](#)

**C.1.12** *Colin Sillerud*, [Mechanical load testing for modern module designs](#)

**C.2.1** *Colleen O'Brien, Liang Ji, Benjamin Gaudet*, [Determination of acceptable PV module temperature threshold for the reverse current overload test](#)

**C.2.2** *Wayne Li, Chris Powicki, Cara Libby*, [Environmental considerations in photovoltaic module design, manufacturing, and customer support](#)

**C.2.3** *Nicholas Riedel-Lyngskær, Jan Vedde, Peter Poulsen, Sergiu Spataru*, [Measuring irradiance with large-format reference modules](#)

**C.2.4** *Roger Ona Ona and Hansung Kim*, [Predicting the delamination of Mo/SS interface in CIGS solar cells](#)

**C.2.5** *Philippe Nivelle, Jef Poortmans, Michael Daenen*, [Accelerating thermal cycling of photovoltaic modules: an in-situ approach](#)

**C.2.6** *Hebin Manuel, Gowri Ganesh, Tanmay Joyashi*, [Precision I-V measurement of a PV module](#)

**C.2.7** *Mayur Nakarani*, Importance of quality control and proficiency testing in solar PV value chain

**C.2.8** *Lukas Jakisch*, Experience on extended module testing data on IEC TS 63209-1

**C.2.9** *Ed Hurley*, [Managing the shift to ultra-large modules](#)

**C.2.10** *Chiara Barretta, A Brandstätter, P Lechner, D Geyer, J Wittfoth, A Gok, AB Paç, G Oreski*, [Design and testing of PV modules based on glass-glass configuration to achieve extended lifetime](#)

**C.2.11** *Dave Compaan and James Cormican*, [Quantifying the impacts of racking structure on bifacial gain](#)

**C.2.12** *Dhiaeddine Melliti*, [Combining imaging and monitoring data for PV plant diagnostics](#)

## AGENDA – Thursday, 24 February 2022

### 8:00am **Session 7: Inverters, Trackers, BOS**

- Operations and maintenance considerations for PV+ storage – Nicole Jackson, [Sandia National Laboratories](#)
- [Evaluating the durability of balance of systems components using combined-accelerated stress testing](#) – David Miller, NREL
- [Semiconductor components and PV system safety](#) – Greg Ball, Tesla
- [High wind speed PV module failures: measured pressures and forces](#) – David Kresse, Nextracker
- Live question and answer period

### Poster Session D

### 10:15am **Session 8: Photovoltaics and Storage**

- [Meeting the challenges with safety certification of grid scale energy storage systems](#) – LaTanya Schwalb, UL
- Battery Safety – Matt Paiss, [Pacific Northwest National Laboratory](#)
- PV + storage – Victoria Carey, [New Jersey Economic Development Authority](#)
- Live question and answer period

### Poster Session D Awards

## Poster Session D – Thursday, 24 February 2022

**Notes:** **DuraMAT** posters are indicated with **red** titles.

The letter indicates the **SESSION**, the first number indicates the **FLOOR**, and the second number indicates the **TABLE**.

**D.1.1** **Matthew Muller** and **Michael Deceglie**, [PV soiling losses: measurements, modeling, and mitigation strategies](#)

**D.1.2** **Bing Guo**, [Soiling loss quantification using photographs of a checkered pattern](#)

**D.1.3** **Kirsten Perry** and **Matthew Muller**, [Automated shift detection in sensor-based PV power and irradiance time series](#)

**D.1.4** **Ali Dionigi** and **Haley DiGiovanni**, [Climate change performance losses...are you accurately predicting wildfire losses on your solar project?](#)

**D.1.5** **Jessica Forbess**, **Teff Reed**, **Rhonda Bailey**, [Daily soiling rates and recovery correlated with air quality and precipitation in Oakland, CA](#)

**D.1.6** **Dirk C Jordan** and **Cliff Hansen**, [Clearsky detection for plane-of-array irradiance time series data at different data frequencies](#)

**D.1.7** **Dan Berger** and **Hamid Gerami**, IE OE - how are owners evaluating

**D.1.8** **Hubert Seigneur**, **Brandon Silva**, **Paul Lunis**, **Marios Theristis**, **Manjunath Matam**, **Cecile Molto**, **Mengjie Li**, **Ryan Smith**, [PV reliability performance model \(PVRPM\) in SAM using Python](#)

**D.1.9** **Xin Chen**, **Anubhav Jain**, **Todd Karin**, **Clifford Hansen**, **Michael Deceglie**, **Bennet Meyers**, **Laura Schelhas**, **Bruce King**, **Dirk C Jordan**, [PVPRO: a software tool and analysis method to extract degradation mechanisms from production data](#)

**D.1.10** **Kevin S Anderson** and **William B Hobbs**, [Improved CdTe PLR estimates: spectral mismatch and self-shading](#)

**D.1.11** **Adam Hoffman**, **Laurie Burnham**, **Bruce H King**, **Daniel Riley**, [Variance and uncertainty in high-quality PV field performance test results](#)

**D.1.12** **Mark A Mikofski**, **Abhishek Parikh**, **William F Holmgren**, **Jeffrey Newmiller**, **Rounak Kharait**, [Effect of sampling rate on hourly modeling errors](#)

**D.2.1** **William C Oltjen**, **Yangxin Fan**, **Jiqi Liu**, **Liangyi Huang**, **Mengjie Li**, **Hubert Seigneur**, **Xusheng Xiao**, **Kristopher O Davis**, **Laura S Bruckman**, **Yinghui Wu**, **Roger H French**, [Automated framework for the quality assessment of spatiotemporal photovoltaic data](#)

**D.2.2** **William B Hobbs**, **Mason Reed**, **James Rand**, [Assessment of tornado-related damage to a utility scale solar plant](#)

**D.2.3** **Scott Sheppard**, **Daniel Fregosi**, **Christopher Perullo**, **Michael Bolen**, [Preliminary results in detecting PV underperformance in real time using existing plant instrumentation](#)

**D.2.4** **Nate Croft**, **Alex Kapetanovic**, **Bobby Gruenstern**, **Jackson Siff**, **Jeff Organ**, [Quantifying the impact DC capacity degradation has on long-term sub-hourly losses](#)

**D.2.5** **Veronica Anderson**, **Victor Garcia**, **Ben Browne**, **Adam Shinn**, [Quantifying the impact of first-year performance losses on utility and commercial scale PV plants](#)

**D.2.6** No Poster

**D.2.7** **Leonardo Micheli**, **Marios Theristis**, **Diego L Talavera**, **Gustavo Nofuentes**, **Joshua S Stein**, **Florencia Almonacid**, **Eduardo F Fernandez**, [Revenue variability in electricity spot markets: an incentive for future PV loss mitigation?](#)

**D.2.8** **Brittany Smith**, **Jarett Zuboy**, **Michael Woodhouse**, [Techno-economic analysis \(TEA\) support to DuraMAT: cost models, LCOE results, and market trends](#)

**D.2.9** **Richa Khosla**, **Leah Holton**, **Alex Berlinsky**, [Impacts of undulating terrain on production estimates](#)

**D.2.10** **Justin Roelant**, [Using NREL's RdTools to validate reduced module degradation rates for thin-film CdTe modules](#)

**D.2.11**

## AGENDA – Friday, 25 February 2022

### 8:00am **Session 9: Performance and Service Life of High Energy Yield Modules**

- [Network models of active degradation mechanisms and pathways for service life prediction of indoor and outdoor PV modules](#) – Roger H. French, SDLE Research Center
- [Comprehensive approach to prepare large format modules for extreme weather conditions](#) – Hongbin Fang, LONGi
- Early-life performance degradation analysis of recent photovoltaic module technologies: anonymous analysis – Marios Theristis, Sandia National Laboratories
- [DuraMAT's roadmap towards a holistic reliability assessment of PV modules based on interacting predictive modeling tools](#)– Martin Springer, NREL
- Live question and answer period

### Poster Session E

### 10:15am **Session 10: Emerging Materials: Tandems and Perovskites**

- Reliability engineering for emerging PV technologies: lessons from CdTe – Dirk Weiss, First Solar
- Emerging materials technology – Andrew Dawson, US Department of Energy
- Emerging materials discussion panel – moderator Timothy Silverman, NREL, panel: Andrew Dawson, US Department of Energy, Dirk Weiss, First Solar, Laura Schelhas, NREL, Michael Owen-Bellini, NREL, Brian Habersberger, DOW
- Live question and answer period

### Poster Session E Awards

## Poster Session E – Friday, 25 February 2022

**Notes:** **DuraMAT** posters are indicated with **red** titles.

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**E.1.1 Abigail R Meyer, P Craig Taylor, Vincenzo LaSalvia, Xue Wang, William Nemeth, Matthew Page, David L Young, Sumit Agarwal, Paul Stradins, [Atomic structure of defect responsible for light-induced efficiency-loss in monocrystalline silicon solar cells in warmer climate regions](#)**

**E.1.2 Christine Bordonaro and James Vance, [2021 performance review of a community solar plus storage project](#)**

**E.1.3 Benjamin Figgis, Giovanni Scabbia, Brahim Aissa, [Investigation of yield differences of PV technologies in desert climate](#)**

**E.1.4 James Elsworth and Frank Oudheusden, [The nuts and bolts of PV: maturing solar PV racking and module mounting critical bolted joint technologies for LCOE reductions and increased reliability](#)**

**E.1.5 Mohamed Adawi and Robert A. Fleming, [Accelerated soiling and cementation testing for PV cover glass materials](#)**

**E.1.6 Jon D Ness, Chris Needham, Frank Oudheusden, [Classifying solar PV joints](#)**

**E.1.7 Nancy Trejo and Giles Eperon, [Packaging flexible perovskite solar cells to withstand accelerated stress testing](#)**

**E.1.8 Hao Song, Dawei Ren, Yangdong Ni, Jing Tang, Jean-Nicolas Jaubert, [Vibration effect on large-format PV modules](#)**

**E.1.9 Buck Brown, Zheyu Zhang, Johan Enslin, Shuangshuang Jin, Ramtin Hadidi, Jin Tan, Peter Hacke, Ramanathan Thiagarajan, Shuan Dong, Xiaonan Lu, Miles Russell, Matt Ursino, Joe Hodges, Brendan Ford, Daniel Clemens, [Failure mode and effects analysis for a photovoltaic inverter](#)**

**E.1.10 Joseph McCabe, [High DC/AC-ratio vertical bifacial PV with behind-the-inverter storage](#)**

**E.1.11 James Hartley, [An integrated multi-physics, multi-scale modeling capability for PV stressors and failures](#)**

**E.1.12 Manjunath Matam, [Filtering unreliable data in the PV plant performance and diagnostic analysis](#)**

**E.2.1 Andre Chavez, Brian Rummel, April Jeffries, Sang M Han, Nick Bosco, Brian Rounsaville, Ajeet Rohatgi, [Carbon-nanotube-reinforced composite gridlines towards commercialization](#)**

**E.2.2 Jeff Wang, [Deep dive in cross-mating](#)**

**E.2.3 Linkesh Diwan, [Use-and-throw has got to go: looking at module repairability and recyclability scenarios from a cost and risk perspective](#)**

**E.2.4 Hiroshi Kanno, Junpei Irikawa, Yuya Nakamura, Haruhisa Hashimoto, Mikio Taguchi, [Key technologies for achieving high reliability and cost effectiveness in HJT modules](#)**

**E.2.5 Eric Helfer, Petra Christöfl, Gernot Oreski, Julia Petro, Mario Gschwandl, Dominik Graf, Philipp Rechberger, [Long-term and degradation behavior of polymeric inverter casings](#)**

**E.2.6 Asim Bisayee, Gowri Ganesh, Tanmay Joyashi, [A comprehensive analysis of electroluminescence \(EL\) & IR imaging on photovoltaic modules parameters through artificial intelligence and image processing techniques](#)**

**E.2.7 Nathan Roosloot, Dag Lindholm, Mike Dallaway, Guillaume Kegelart, Bjørn Riise, Josefine H. Selj, Gaute Otnes, [Evaluation of moisture ingress through edge sealants for floating PV applications](#)**

**E.2.8 Leander Van Cappellen, Martijn Deckers, Omid Alavi, Fereshteh Poormohammadi, Michaël Danen, Johan Driesen, [Real-time temperature sensitive electrical parameters and model-based condition monitoring for PV inverter applications](#)**

**E.2.9 Dylan Colvin, Nafis Iqbal, Max Liggett, Jannatul Ferdous Mousumi, Balaashwin Babu, Craig Neal, Sudipta Seal, Dana B Sulas-Kern, Dirk C Jordan, Kristopher O Davis, [Multiscale characterization of degraded silicon heterojunction modules installed in a hot-humid climate](#)**

**E.2.10 Todd Karin, David Penalva, James Nagel, [Catastrophic PV connector failures and advanced inspection techniques](#)**

**E.2.11 Heather Mirlletz, Silvana Oviatt, Teresa Barnes, [Short-lived modules need to be efficient, lightweight and circular for the energy transition](#)**