CALL FOR PAPERS

THE 49th IEEE PHOTOVOLTAIC SPECIALISTS CONFERENCE

June 5-10, 2022
Philadelphia, Pennsylvania, USA

Abstract deadline: January 17, 2022

Call for Papers

On behalf of the Technical Program Committee, I am honored to invite you to submit an abstract on your latest achievements in photovoltaic (PV) research, development, applications, and impact to the 49th IEEE Photovoltaic Specialists Conference (PVSC-49). The PVSC-49 endeavors to cover the full spectrum of PV knowledge and innovation, from the basic science and engineering of materials, devices, and systems, to the examination of policy and markets and critical issues of social impact. PVSC aims to be a highly interactive and inclusive venue for everyone, from seasoned PV experts to entry-level professionals to students alike. The conference provides a unique opportunity to meet, share, and discuss PV-related developments in a timely and influential forum. Please contribute to the PVSC's tradition as the premier international conference on PV science and technology and help usher in a solar-powered world.

New this year: Publication of a conference proceeding will be optional. Full papers are encouraged but short abstracts will otherwise be used as the publication of record. Authors will have the option of submitting their evaluation abstract or a longer conference proceeding by the May 31, 2022, publication deadline. Exceptional submissions will be recommended for expedited review and publication in the IEEE Journal of Photovoltaics.

New this year: We have merged former Technical Areas on III-V and on space in new Technical Area 3 on III-V, Space and Concentrator Photovoltaics. PVSC-49 includes 11 Technical Areas, along with a slate of compelling Keynote and Plenary Speakers to be announced. The conference will also include several exciting cross-cutting themes and joint areas such as “Advanced Resource Management for 100% Renewable Electricity”, “Hybrid Tandem/Multijunction Solar Cells” and “Challenges and opportunities on grid and microgrid integration of PV systems”. When submitting an abstract in response to these and similar topics, select the Technical Area that best fits the nature of the work described in your abstract or select the specific Joint Area that is noted within the Area Descriptions (if applicable).

To have your paper considered for presentation at the PVSC-49, submit:

1. An evaluation abstract (3 pages maximum for technical committee review);
2. A short abstract of 300 words or less for display on the PVSC-49 website and default publication in the PVSC proceedings.

Abstract submission is via the PVSC-49 website where templates are provided. Detailed technical evaluation abstracts will be thoroughly reviewed. **The deadline for abstract submission is January 17, 2022,** at midnight Pacific Standard Time (UTC - 8 hours). Contributing authors will be notified of the acceptance status of their papers around March 15, 2022, after which they must confirm their ability to present their work at the conference. Invitation letters for visa applications are issued after registration to the conference upon request.

I look forward to welcoming you at the 49th IEEE Photovoltaic Specialists Conference in Philadelphia, Pennsylvania!

Karin Hinzer
Technical Program Chair
2022 49th IEEE PVSC

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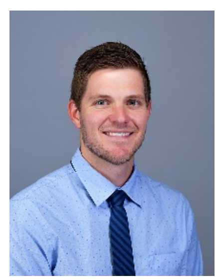

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Hope College
USA

Area 7 Chair
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Northwestern Polytechnical University
China

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Germany

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Ian Marius Peters
Forschungs Zentrum Jülich
Germany

Area 11 Chair
Brittany Smith
National Renewable Energy Lab
USA

Area 1: Fundamentals and New Concepts for Future Technologies

Area Chair: Elisa Antolín, Universidad Politécnica de Madrid, Spain
Co-Chairs: Vivian Ferry, University of Minnesota, USA
Rebecca Saive, University of Twente, The Netherlands

Sub-Area 1.1: Fundamental Conversion Mechanisms
Sub-Area 1.2: Unconventional Contact and Absorber Materials; Novel Deposition Techniques
Sub-Area 1.3: Unconventional Material & Device Architectures
Sub-Area 1.4: Advanced Light Management and Spectral Shaping

Area Description

Paradigm shifts in solar cell technology are invariably preceded by breakthroughs arising from basic scientific research. Area 1 comprises fundamental research and novel device concepts that will provide a platform for the development of future photovoltaic technologies. Papers are sought describing research in basic physical, chemical and optical phenomena, in addition to studies of new materials and innovative device designs, as well as photon management methods. Subjects of particular interest include, but are not limited to, new materials for all parts of the photovoltaic device, advances in the understanding of basic phenomena, nanostructures, advanced optical management approaches, new synthesis processes, and unconventional conversion mechanisms.

Sub-Area 1.1: Fundamental Conversion Mechanisms

Sub-Area Chair(s): Wen Hui (Sophia) Cheng, National Cheng Kung University, Taiwan

Sub-Area 1.1 captures both experimental and theoretical work exploring new paradigms for solar energy conversion. Papers submitted to this Sub-area would explore the fundamental physics or present initial experimental demonstrations related to novel energy conversion mechanisms. Papers on modeling and simulation of new device architectures to enable these conversion mechanisms are also encouraged. Areas of interest include, but are not limited to, non-conventional PV conversion processes based on quantum confined or nanostructured systems, engineered band alignments, intermediate band concepts, multiple exciton generation (MEG), transistor solar cells, thermophotonics, thermophotovoltaics, hot-carrier effects, or thermoradiative concepts. Also of interest are concepts and demonstrations of new materials and material science related to these concepts. Finally, crosscutting scientific approaches involving novel physics, photovoltaics for solar fuel generation, alternative solar energy storage mechanisms, and innovative device structures, are solicited.

Sub-Area 1.2: Unconventional Contact and Absorber Materials; Novel Deposition Techniques

Sub-Area 1.2 covers progress on the development of novel contact and absorber materials as well as processing techniques for improving the performance, functionality, reliability, and scalability of PV devices. Topics of interest include new materials for PV, including Earth-abundant absorber materials, new contact materials including carrier selective contacts, p-type transparent conducting materials, and transparent conducting oxides. Design and selection of new materials can enable applications in single crystalline, thin film, multijunction, and nanostructured PV devices, or may enable an entirely new device class on their own. Papers are sought that describe theoretical and/or experimental development of perovskite-inspired materials as well, including but not limited to absorber layers, coatings, electrode and carrier transport materials, and transparent conductive materials. Advances in growth, synthesis, thin film deposition, material printing, doping and passivation schemes are also solicited. Also of interest are innovative strategies to reduce the cost of more established technologies, such as novel substrates and re-use processes. Ultimately, such advances may enable cleaner and more sustainable PV deployment.

Sub-Area 1.3: Unconventional Material & Device Architectures: Nano, Quantum and Beyond

Sub-Area Chair(s): Magnus Borgström, University of Lund, Sweden

Modifications to the geometry of materials and devices can be used to realize advances in performance as well as relax material quality constraints. Sub-area 1.3 covers new material or device geometries, from nanowire devices and quantum dot materials to 2D structures. These unconventional architectures have the potential to improve the performance of known PV materials or to supplant them entirely, and they also open new routes to low-cost fabrication. Submissions including novel designs, new material morphologies such as nanostructures, implementation of new uses of quantum confinement, and the exploitation of varying dimensionality of confinement are encouraged. Developments in the field of graphene, or materials that form in 2D or layered structures are of interest in this Sub-area. Ideal submissions will range from studies of fundamental properties and materials to examples of working devices.

Sub-Area 1.4: Advanced Light Management and Spectral Shaping

Sub-Area Chair(s): Louise Hirst, University of Cambridge, United Kingdom

To achieve high power conversion efficiency, a solar cell must effectively utilize most of the incoming photons. This process involves the efficient coupling of the incident light into the solar cell with minimum loss, and effective use of the energy imparted by each photon. This Sub-area will focus on novel concepts, including advanced anti-reflection coatings, spectrum splitting, textured light trapping surfaces from front and/or rear surface, luminescent and fluorescent systems, micro- and nano-scale concentrator systems, and advanced photonic and plasmonic structures. With respect to plasmonics, both light trapping and hot carrier effects will be considered. It will also include photon recycling, angular restriction techniques for achieving improved open-circuit voltages and strategies to implement ultra-thin devices. In addition, ways to modify the spectrum of the incident sunlight using techniques such as up or down conversion either in planar layers or in waveguide structures will be considered. Papers submitted to this Sub-area should address one or more of these themes and may be theoretical or experimental in nature.

Area 2: Chalcogenide Thin Film Solar Cells

Area Chair: Mirjam Theelen, TNO partner in Solliance, The Netherlands
Co-Chairs: Shubhra Bansal, University of Las Vegas, USA
Amit Munshi, Colorado State University/Toledo Solar Inc.

Sub-Area 2.1: Absorber Preparation and Material Properties
Sub-Area 2.2: Contacts, Windows, Buffers, Substrates and Superstrates, Monolithic Integration, and Interfaces
Sub-Area 2.3: Cell and Module Characterization, Analysis, Theory, and Modelling
Sub-Area 2.4/7.7/8.8: Chalcogenide PV beyond the Factory: Applications, Reliability, Performance and Yield
Sub-Area 2.5/3.3/4.3/6.7: Hybrid Tandem/Multijunction Solar Cells (Joint Area)

Area Description
In recent years, thin film chalcogenide solar cells based on CIGSe and CdTe have achieved remarkable progress in terms of record conversion efficiencies >22% and manufacturing at the multi gigawatts-per-year scale. Over 40 GW of thin film modules have been produced and are operating reliably in the field, helping to bring the cost of PV electricity below most other sources and to open the way for a wide range of new applications. These exciting developments have been enabled by decades of work by the worldwide community of dedicated research, development, and manufacturing professionals working on their science and technology.

Area 2 brings this community together yearly to present and discuss contributions on solar cells based on $Cu(In,Ga)(S,Se)_2$, CdTe, $Cu_2ZnSn(S,Se)_4$, and other related materials. The aims of Area 2 are to provide a platform for presenting recent and on-going research leading to improved understanding of materials and devices, exploring new directions for more efficient production, and narrowing the gap between champion cell and module efficiencies. Topics range from insights into basic materials science, to analysis of device properties and new device structures, to discussions of the progress in deposition methods and growth control, and to long-term performance and reliability. We look forward to an exciting, cutting-edge conference that helps advance the science and technology of these fascinating and technologically important solar cells. In all subareas, industry contributions are encouraged.

Sub-Area 2.1: Absorber Preparation and Material Properties
Sub-Area Chair(s): Shogo Ishizuka, AIST, Japan
Sub-area 2.1 addresses progress in understanding thin film formation and the influence of processing on basic material properties and device performance. Examples of relevant topics include both experimental and theoretical aspects of: morphology, phase coexistence, microstructure, extended and point/bulk defects and their characterization, optoelectronic and transport properties, influence of substrates, compositional gradients and homogeneity, effects of material purity and contaminants, interrelation of properties and cell and module fabrication processes, in-situ, ex-situ and in-line methods of characterization, and impacts on short- and long-term performance.

Sub-Area 2.2: Contacts, Windows, Buffers, Substrates and Superstrates, Monolithic Integration, and Interfaces

Sub-Area Chair(s): Raquel Caballero, Universidad Autonoma de Madrid, Spain

The processing and properties of all layers in the thin film device stack as well as their integration into monolithically-integrated modules ultimately determine the cell and module performance. Sub-area 2.2 focuses on the functions, effects and properties of substrates/superstrates, contacts, buffer and window layers, and interfaces. Submissions describing advances in understanding these aspects and their effects on short-and long-term performance are welcome. Papers on progress in the cross-cutting areas of transparent conductors, moisture barriers, new or improved substrates, established and novel methods of cell scribing and interconnection in modules, and novel topics not listed are also encouraged.

Sub-Area 2.3: Cell and Module Characterization, Analysis, Theory, and Modeling

Sub-Area Chair(s): Alexandra Bothwell, NREL, USA

Continued progress in chalcogenide photovoltaics relies on continuing to gain insight into the origins of efficiency loss and concepts for overcoming them. Whereas Sub-areas 2.1 and 2.2 focus on the physical properties and processing of the layers making up cells and modules, Sub-area 2.3 addresses their net effects at the device and module level through measurement, analysis, theory, and modelling. These aspects enable feedback to continue improving cells and modules. Contributions are solicited in the areas of novel and established characterization methods, device analysis that yields insight into internal operation, one-, two- and three- dimensional modelling to understand current devices and guide progress, characterization of defects and recombination, and novel related topics not listed.

Sub-Area 2.4/7.7/8.8: Chalcogenide PV beyond the Factory: Applications, Reliability, Performance and Yield

Sub-Area Chair(s): Jessica de Wild, IMEC, Belgium & Lauren Doherty, Toledo Solar Inc. USA

The focus of chalcogenide thin film photovoltaics is widening from R&D into large-scale deployment. This joint Sub-Area solicits contributions addressing field deployment as well as reliability research. Contributions are solicited in areas related to metastability, degradation mechanisms, reliability data, field performance, performance ratios and novel applications, as well as deployment related issues that are not listed.

Sub-Area 2.5/3.3/4.3/6.7: Hybrid Tandem/Multijunction Solar Cells (Joint Area)

Sub-Area Chair(s): Frank Dimroth, Fraunhofer ISE, Germany & Rohit Prasanna, Swift Solar, USA

This wide-reaching Sub-Area solicits papers regarding materials, structures, and devices based on combinations of different materials (III-Vs, silicon, chalcogenides, organics, perovskites, etc.) toward the production and characterization of "hybrid" multi-junction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy and deposition, wafer/layer bonding, and mechanical stacking, as well as the characterization of these materials, structures, and devices, from the atomic scale to the device level (and beyond), as related to their hybrid nature. Abstracts on the theory and modeling of such devices are welcome, as is work related to new module and system architectures optimized for such hybrid cells. This is a Joint Sub-Area between Areas 2, 3, 4, and 6, and will host the popular "Battle Royal Session" of previous years.

Area 3: III-V, Space, and Concentrator Photovoltaics

Area Chair: Kenneth Schmieder, U.S. Naval Research Laboratory, USA
Co-Chairs: Stephanie Essig, University of Stuttgart, Germany
Mitsuru Imaizumi, JAXA, Japan

Sub-Area 3.1: III-V Photovoltaic Cells
Sub-Area 3.2: III-V Cost Reduction Strategies & Opportunities
Sub-Area 2.5/3.3/4.3/6.7: Hybrid Tandem/Multijunction Solar Cells
Sub-Area 3.4: Terrestrial III-V Photovoltaic Applications and Systems
Sub-Area 3.5: Space Photovoltaic Modules, Systems, and Flight Experience
Sub-Area 3.6/6.8: Perovskites for the Space Environment

Area Description

III-V solar cells offer unparalleled photovoltaic conversion efficiency, an expansive palette of material properties, high absorption coefficients, resilience in extreme environments, as well as compatibility with a wide-range of growth and fabrication strategies. These attributes make III-V's well-suited for a multitude of applications, including concentrator photovoltaics (CPV) and space power systems, along with a range of emerging technologies, such as autonomous vehicle power, commercial solar electric vehicles, thermophotovoltaics (TPV), laser power beaming receivers, dismounted soldier power, consumer electronics, and biomedical energy harvesters. Area 3 addresses all aspects of III-V photovoltaic device design, development, and systems. Thus, papers are encouraged on any of these subjects: methods to improve size, weight, power, and cost (SWaP-C) for any applications—land, sea, air, and space—as well as investigations of III-V system-level demonstrations.

Sub-Area 3.1 will deal with all device-level development of III-V photovoltaics for space and terrestrial applications, with the exception of low-cost strategies as well as hybrid integration of III-V's with other photovoltaic technologies (see Sub-Areas 3.2 and 3.3 for these technologies). Sub-Area 3.2 considers all aspects of cost reduction strategies for III-V photovoltaics. Joint Sub-Area 3.3 will involve the hybrid integration of III-Vs with other photovoltaic technologies, such as silicon, perovskites, or chalcogenide materials. Sub-Area 3.4 includes all terrestrial applications and demonstrations of photovoltaics at the module-to-system level. Sub-Area 3.5 comprises all space applications, demonstrations, and flight experience of photovoltaics at the module-to-system level. And lastly, Joint Sub-Area 3.6 concerns perovskites as an emerging material for space photovoltaics.

Sub-Area 3.1: III-V Photovoltaic Cells

Sub-Area Chair(s): Pilar Espinet-Gonzalez, CalTech, USA

This Sub-Area seeks to address all development up to the device-level for III-V photovoltaics, with the exception of low-cost strategies as well as hybrid tandem/multijunctions of III-Vs with other photovoltaic materials. Herein, abstracts of interest include but are not limited to: epitaxial growth, materials design and development, device-level theoretical modeling, novel processing strategies, unique photovoltaic architectures, single and multijunction devices, device-level photon management, ultra-thin photovoltaics, III-V wafer bonding (excluding bonding with non-III-V devices), materials/device-level characterization, III-V device reliability, environmental effects testing at the materials-to-device level, and device-level laser power beaming receivers.

Sub-Area 3.2: III-V Cost Reduction Strategies & Opportunities
Sub-Area Chair(s): Kevin Schulte, NREL, USA
Topics of interest in this Sub-Area concern all aspects of cost reduction strategies for III-V photovoltaics at the materials, device, or module level. This includes (but is not limited to) direct monolithic growth of III-Vs on low-cost templates, so long as the template is not an active photovoltaic subcell (in which case, consider submitting to Joint Sub-Area 3.3); substrate re-use as well as other substrate cost mitigation strategies; high-throughput epitaxial growth; increased growth precursor utilization efficiency; low-cost device fabrication strategies; low-cost array- and module-level assembly; and automation of manufacturing steps. "New Space" approaches to lower cost for space applications are also encouraged in this Sub-Area.

Sub-Area 2.5/3.3/4.3/6.7: Hybrid Tandem/Multijunction Solar Cells (Joint Area)
Sub-Area Chair(s): Frank Dimroth, Fraunhofer ISE, Germany & Rohit Prasanna, Swift Solar, USA
This Sub-Area solicits papers regarding materials, structures, and devices based on combinations of different materials (e.g. III-Vs, silicon, perovskites, chalcogenides, organics, etc) toward the production of hybrid multi-junction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy and deposition, wafer/layer bonding, and mechanical stacking, as well as the characterization of these materials, structures, and devices, from the atomic scale to the device level (and beyond), as related to their hybrid nature. Abstracts on the theory and modeling of such devices are welcome, as is work related to new module and system architectures optimized for such hybrid cells. This is a Joint Sub-Area between Areas 2, 3, 4, and 6, and will host the popular "Battle Royal Session" of previous years

Sub-Area 3.4: Terrestrial III-V Photovoltaic Applications and Systems
Sub-Area Chair(s): Kenji Araki, Miyazaki University, Japan
Abstracts for Sub-Area 3.4 involve all module- and systems-level III-V photovoltaics for terrestrial applications. This includes conventional CPV and (terrestrial) micro-CPV, but more broadly includes all terrestrial applications and systems that involve III-V photovoltaics. These emerging opportunities include, but are not limited to, photovoltaics for transportation applications; commercial-scale thermophotovoltaics (TPV); laser power beaming; underwater photovoltaics; unmanned aerial vehicles; and miscellaneous operational energy demonstrations.

Sub-Area 3.5: Space Photovoltaic Modules, Systems, and Flight Experience
Proposed Sub-Area Chair: Roberta Campesato (CEA-LETI)
Sub-Area 3.5 seeks abstracts concerning all module- and systems-level III-V photovoltaic development for space applications, as well as on-orbit reliability and performance. At the panel and array level, this includes the integration of space solar cells onto backplanes of interest—rigid or flexible blankets—as well as technologies required for electrostatic discharge control, stabilization against ionizing radiation (e.g., UV, particles), and interactions with electric propulsion subsystems. Papers dealing with all aspects of micro-CPV module development—optics integration, array-level performance, thermal management solutions, novel architectures—for the space environment are encouraged. In addition, papers dealing with all aspects of flight experience and reliability are of high interest. This Sub-Area also seeks strategies to improve AM0 calibration of solar cells and panels. Module- and system-level laser power beaming for the space environment is furthermore applicable. Additionally, while III-V multijunction

architectures dominate space photovoltaics, this sub-area is not limited to III-Vs and thus encourages space photovoltaic submissions—at all levels of development—related to alternative material systems (perovskites, however, should be submitted to Sub-Area 3.6).

Sub-Area 3.6/6.8: Perovskites for the Space Environment

This Sub-Area solicits papers regarding all aspects of perovskite development for the space environment. This may include (but is not limited to) novel AM0 perovskite cell and module designs, materials design of interlayers and interfaces for enhanced stability, environmental effects, reliability, testing standards, and performance reports.

Area 4: Silicon Photovoltaic Materials and Devices

Area Chair: Nazir Kherani, University of Toronto, Canada
Co-Chairs: Kaining Ding, Forschungs Zentrum Jülich, Germany
Andre Augusto, Arizona State University, USA
Udo Römer, University of New South Wales, Australia

Sub-Area 4.1: Silicon Feedstock & Wafering, Thin Silicon & Advanced Light Management
Sub-Area 4.2: Passivated, Carrier-Selective, and Heterojunction Contacts
Sub-Area 2.5/3.3/4.3/6.7: Hybrid Tandem/Multijunction Solar Cells (Joint Session)
Sub-Area 4.4: Metallization, Interconnection, Module Integration, and Recycling/Sustainability and Novel PV Integrations
Sub-Area 4.5: Device Physics, Modelling, New/Enhanced Characterization Techniques

Area Description
Silicon has been the dominant photovoltaic technology for decades with market share exceeding 90% while technologically continuing to develop and scientifically entering the realm of innovative integrations . Commercial cell efficiencies exceeding 22%-23% are becoming routine as manufacturers transition to PERC structures and high-quality monocrystalline wafers. Module costs have fallen below $0.3/W and are now commonly a small fraction of an installed system's cost, and the emergence of, for example, bifacial and shingled cells has broadened the module flavors now available, while the advent of vehicle integrated photovoltaics is expected to bring forth heretofore unforeseen innovation, and the dawn of silicon based tandems and multi-junctions are anticipated to yield an era of 30% plus efficiencies as the new norm.

In this environment of rapid innovation, Area 4 invites contributions that define, apprehend, and shape the future of silicon photovoltaic science and technology in all its stand-alone and integrated permutations and combinations. Topics of interest span the breadth of the silicon solar photovoltaic field, ranging from silicon purity to thin-film deposition, from electronic transport through new contact structures to high-efficiency devices, from light management to loss analysis, and from interconnection to module field degradation caused by cell deterioration. We also invite abstracts from industry addressing translation from lab to fab, challenges associated with manufacturing processes, recycling and sustainability, market trends and emergence of novel PV integrations, industry roadmaps, and challenges and opportunities the industry faces given the ever increasing focus on renewable energy. Area 4 is also accepting abstracts for a Joint Sub-Area on silicon-based tandem and multijunction devices in collaboration with Areas 2, 3 and 6.

Sub-Area 4.1: Silicon Feedstock & Wafering; Thin Silicon & Advanced Light Management
This Sub-Area focuses on silicon and thin silicon with obvious overlaps. Silicon customarily includes silicon feedstock purification and production through crystallization and wafering, including high-performance multicrystalline silicon wafers, improved Czochralski growth, novel silicon growth techniques, kerf-less slicing technologies, and alternative methods to produce silicon wafers such as direct wafering or epitaxy. Thin silicon—including those of amorphous silicon, microcrystalline silicon, epitaxial silicon, related alloys and thin flexible silicon wafers—pertain to thin silicon materials properties, deposition/growth methods including top-down and bottom-up approaches, flexible silicon handling, cell design and performance, and degradation. Further, advanced light management in relation to thin silicon is clearly essential and

encompasses surface engineering of silicon to increase photon absorption by classical, diffractive, Mie scattering, photonic techniques and plasmonic mechanisms, as well as approaches to reduce front-surface reflectance, reduce parasitic absorption, and reject sub-bandgap infrared light. Additionally, relevant areas include mechanical and electrical characteristics of the resulting wafers/foils and their impact on device performance; material changes during subsequent processing and defect engineering steps; and application opportunities and challenges ushered by the flexible form factor of thin silicon.

Sub-Area 4.2: Passivated, Carrier-Selective, and Heterojunction Contacts
Sub-Area Chair(s): Josua Stuckelberger, Australian National University, Australia & Ujjwal Das, University of Delaware, USA
This Sub-Area focuses on contacts formed on silicon absorbers, and specifically those layers that passivate the absorber surface (maintain high quasi-Fermi-level splitting and thus high implied open-circuit voltage) or selectively extract electrons or holes (minimize the quasi-Fermi-level drop across the contact) as well as hot carrier device physics. This also includes passivation of patterned/textured surfaces including high aspect ratio patterns. Additional topics pertain to device physics and characterization of contacts, the properties of new contact materials, and the performance of cells with contact layers such as amorphous silicon, tunnel oxides and polysilicon, metal oxides. Abstracts concerning the deposition methods used to form these contacts are also welcome.

Sub-Area 2.5/3.3/4.3/6.7: Hybrid Tandem/Multijunction Solar Cells (Joint Area)
Sub-Area Chair(s): *Frank Dimroth, Fraunhofer ISE, Germany & Rohit Prasanna, Swift Solar, USA*
This wide-reaching Sub-Area solicits papers regarding materials, structures, and devices based on combinations of different materials (III-Vs, silicon, chalcogenides, organics, perovskites, etc.) toward the production and characterization of "hybrid" tandem/multi-junction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy and deposition, wafer/layer bonding, and mechanical stacking, as well as the characterization of these materials, structures, and devices, from the atomic scale to the device level (and beyond), as related to their hybrid nature. Abstracts on the theory and modeling of such devices are welcome, as is work related to new module and system architectures optimized for such hybrid cells. This is a Joint Sub-Area between Areas 2, 3, 4, and 6, and will host the popular "Battle Royale Session" of previous years.

Sub-Area 4.4: Metallization, Interconnection, Module Integration, and Recycling/Sustainability and Novel PV Integrations
Sub-Area Chair(s): Henning Schulte-Huxel, Institute for Solar Energy Research in Hamelin, Germany
This Sub-Area covers techniques for electrode formation, including printed metallization, plating, evaporation, dispensing or other transfer techniques, conductive adhesives, soldering, laser and thermal alloying of metals, transparent electrodes, selective doping, and contact opening for metallization. Electrodes also comprise the interface to subsequent module integration, and thus the Sub-Area also welcomes abstracts on mechanical adhesion, multi-wire technologies, and the interconnection of advanced cell structures like back-contact cells and silicon-based tandems. Abstracts area also welcome on sustainability and recycling issues vis-à-vis silicon solar cells and the natural/built environments; novel module constructs and novel PV integrations (more than a

PV module).

Sub-Area 4.5: Device Physics, Modelling, New/Enhanced Characterization Techniques
This Sub-Area focuses on understanding, quantifying, and modelling phenomena in silicon solar cells, including new interpretations of device physics, multi-dimensional models, numerical analysis of novel cell concepts, power loss measurement and mitigation strategies, computational simulations, and associated means of validation. Abstracts are also welcome on the development of new device characterization techniques, which may be based on, e.g., photoluminescence or capacitance measurements.

Area 5: Characterization Methods

Area-Chair: Paul Ndione, National Renewable Energy Laboratory, USA
Co-Chair: Govindasamy (Mani) Tamizhmani, Arizona State University, USA

Sub-Area 5.1: New Instruments, Methods and Data Analysis
Sub-Area 5.2: Advances in Optoelectronic Characterization Techniques
Sub-Area 5.3: Advances in In-Situ and In-Line Characterization
Sub-Area 5.4: Advanced Characterization of Photovoltaic Materials and Devices
Sub-Area 5.5/7.6: Advanced Characterization of Photovoltaic Modules and Systems (Joint Area)
Sub-Area 5.6: Performance Testing and Standards
Sub-Area 5.7/8.4: PV Module and System Reliability Characterizations: Lab and Field Inspection Techniques (Joint Area)

Area Description

The photovoltaic (PV) industry has grown exponentially in recent years. A sustainable development and expansion of the solar market, depends on both the development of new PV-relevant technologies and a better understanding of PV components and their properties from the materials level to the system level. In return, these rely on advanced characterization techniques that are necessary to ensure the bankability and reliability of PV modules and systems.

Sub-Area 5.1: New Instruments, Methods and Data Analysis

Sub-Area Chair(s): Kyumin Lee, ARRAY, USA

This sub-area focuses on the latest development of characterization tools, measurement techniques and analysis methods for photovoltaic applications. Papers should present technical novelty, describe the work done on the development of the tool or method, demonstrate its capabilities and limitations and compare it to existing tools and methods in term of limitations. Papers should not advertise a commercially available equipment but can refer it.

Sub-Area 5.2: Advances in Optoelectronic Characterization Techniques

Sub-Area Chair(s): Jason Baxter, Drexel University, USA

This Sub-Area aims to focus on measurement techniques that should elucidate the optoelectronic properties of PV materials and devices (PV cells and modules). Topics of interest may include methods based on interferometry, spectroscopy, microscopy, imaging, luminescence, absorption, etc. For this Sub-Area, papers focusing on the technique rather than the material aspects are preferred.

Sub-Area 5.3: Advances in In-Situ and In-Line Characterization

Sub-Area Chair(s): Laura Shelhas, NREL, USA

This area targets laboratory and synchrotron based in-situ techniques as well as in-line high-throughput measurement techniques. This includes equipment and method for monitoring the growth or deposition of PV materials under different environmental and operating conditions. Papers should aim at elucidating changes in materials properties that should predict performance during device operation or provide manufacturing-related benefit.

Sub-Area 5.4: Advanced Characterization of Photovoltaic Materials and Devices
Sub-Area Chair(s): Jessica Yajie Jiang, University of New South Wales, Australia
This Sub-Area is on novel methods to study photovoltaic materials, their structure, properties, and how these relate to processing and performance, with a focus on both materials and devices (PV cells). For materials, examples of topics that would fit into this area include novel scanning probe techniques, such as variants of atomic force microscopy, scanning microwave microscopy, Kelvin probes, and advanced X-ray or photoemission methods, among others. For devices, papers should address the challenge of characterizing devices broadly. Examples include but are not limited to capacitance methods, study of device transients, methods to understand instability in device performance, degradation of device performance, ageing etc. Development of operando measurements are also welcome in this Sub-Area. Papers focusing on the characterizations of emerging PV materials and devices (single junctions and tandem) are welcome in this Sub-Area. Any paper related to optoelectronic characterizations should be submitted to Sub-area 5.2.

Sub-Area 5.5/7.6: Advanced Characterization of Photovoltaic Modules and Systems (Joint Area)
Sub-Area Chair(s): Mengjie Li, University of Central Florida, USA & Masahiro Yoshita, AIST, Japan
Papers focusing on characterization of complete modules and systems where the nature of the device is dominated by the ensemble of microscopic behaviors distributed throughout a large area rather than the understanding of individual microscopic behaviors should be submitted in this Sub-Area. For example, papers in this Sub-Area could focus on methods such as LBIC, photoluminescence or electroluminescence specifically as applied to understanding module performance rather than the same methods applied to small areas of device. Machine learning methods corelating those microscopic behaviors in materials and devices to PV module performance are also welcomed. Other examples of papers relevant to this area include adaptation of existing methods to characterize modules from emerging technologies such as perovskites.

Sub-Area 5.6: Performance Testing and Standards
Sub-Area Chair(s): Werner Herrmann, TUV, Germany
A key component of characterization, especially of cells, modules and systems, is testing of the performance and efficiency. Papers related to such characterization methods are welcome in this Sub-Area. In addition, this Sub-Area is intended for submissions related to standardization approaches to characterization. For example, standards for light flux measurement, calibration methods for simulators, testing temperatures, and other fundamental parameters of characterization that also might potentially be incorporated into future standards can be submitted here.

Sub-Area 5.7/8.4: PV Module and System Reliability Characterization: Lab and Field Inspection Techniques (Joint Area)
Sub-Area Chair(s): Gabriele Eder, OFI, Austria
Photovoltaic module and systems are likely to degrade during transportation, installation, and operation over time. Detection of fault and failures as well as understanding of degradation mechanisms on PV modules and system largely rely on advances in both field and laboratory (destructive and non-destructive) characterization techniques to improve the bankability and reliability of PV modules and systems. This Sub-Area calls for papers reporting characterization

techniques and methods on the reliability of PV modules and system both in the Lab and on the field. The papers should focus on presenting novel techniques, progress on deploying and monitoring, as well as improved data acquisition and analysis and best practice that allow a better understanding of degradation and failure modes, and potentially enables more efficient characterization of PV modules and PV systems. Areas of interest include field characterization techniques (I-V tracing, infrared imaging, electroluminescence imaging, UV fluorescence, etc. or a combination of these). Further to these, laboratory test/inspection methods tailored for fault detection in-situ characterization methods, sensors in correlation with accelerated reliability studies are relevant. Papers studying innovations in the fields of inspection data analytics and diagnostic algorithms, remote failure detection and wide-area inspections for PV systems are also of interest for contributions in this Sub-Area.

Area 6: Perovskite and Organic Materials and Solar Cells

Area-Chair: Jeffrey Christians, Hope College, USA
Co-Chairs: Lyndsey McMillon-Brown, NASA
Emilie Planès, Université de Savoie, France

Sub-Area 6.1: High Efficiency Perovskite Solar Cells and Tandems
Sub-Area 6.2/8.7: Performance, Reliability and Yield for Organic and Perovskite PV (Joint Area)
Sub-Area 6.3: Scale-Up and Scalable Processing of Perovskite Solar Cells
Sub-Area 6.4: Organic and Dye-Sensitized Solar Cells
Sub-Area 6.5: Advances in Perovskite Solar Cell Development
Sub-Area 6.6: Alternative Halide Perovskite Materials and Solar Cells
Sub-Area 2.5/3.3/4.3/6.7: Hybrid Tandem/Multijunction Solar Cells (Joint Area)
Sub-Area 3.6/6.8: Perovskites for the Space Environment

Area Description

Halide perovskite materials are rising stars for solar cell and optoelectronic applications. Based on abundant materials and scalable coating technologies, these emerging PV technologies show potential for low-cost, lightweight, and flexible solar power generation. Perovskite solar cells have certified power conversion efficiency of 25.5% in single junction devices and 29.5% as tandem solar cells with silicon. Performance continues to improve as new device architectures arise and materials are improved, but these promising materials still must show their viability in the market by combining performance, stability, and low toxicity at scale. Beyond halide perovskites, continued promise exists in organic photovoltaics and quantum dot solar cells, which have both surpassed certified efficiencies of 18%, and dye-sensitized solar cells. Together, these alternative materials and device designs unlock new opportunities for the photovoltaics of the future.

Area 6 presents itself as an ideal forum for researchers in the field to present their progress in halide perovskite and organic materials for photovoltaics. This Area aims to highlight the rapid progress throughout these technologies, and provide a platform that facilitates the continued pursuit of widespread commercialization of these technologies. Topics range from device architectures, fabrication methods, long-term performance, and reliability, to novel applications, fundamental materials insights, and the development of alternative materials. The rapid development of organic and perovskite materials and devices marks a strong foundation for this Area, and we aim to facilitate a comprehensive discussion on the broad scope of these exciting solar cells.

Sub-Area 6.1: High Efficiency Perovskite Solar Cells and Tandems

Sub-Area Chair(s): Juan-Pablo Correa-Baena, Georgia Tech, USA & Nakita Noel, Princeton, USA

Sub-Area 6.1 covers progress on the development higher efficiency perovskite solar cells. Unlocking power conversion efficiencies beyond the detailed balance limit for single junction solar cells requires high efficiency single junction halide perovskite photovoltaics as well as tandem and multijunction architectures. The focus of this Sub-Area is on concepts relating to material design, solar cell fabrication, and module implementation that enable high efficiency.

Contributions are welcome which feature experimental and theoretical work on proof-of-concepts, materials design for multijunction devices, device design and implementation, and the interplay between the various absorber films and interlayers in the cell layout.

Sub-Area 6.2/8.7: Performance, Reliability and Yield for Organic and Perovskite PV (Joint Area)

Sub-Area Chair(s): Nikoleta Kyranaki, CEA-LITEN INES, France & Erin Sanehira, Cubic PV, USA

Reaching a high level of reliability and durability is key to deployment of perovskite and organic solar cells at scale. Hence, this sub-Area is dedicated to the progress of stability in the context of individual devices and device components, as well as the wide range of efforts to determine reliability and yield in real-world settings. Discussed topics thus include intrinsic and extrinsic degradation mechanisms, efficiency loss issues in perovskite and organic photovoltaics and modules, and long-term durability testing.

Sub-Area 6.3: Scale-Up and Scalable Processing of Perovskite Solar Cells

Sub-Area Chair(s): Annalisa Bruno, ENEA, Italy

With the growing push for utility scale implementation of perovskite solar cell modules, sub-Area 6.3 focuses on developments related to scale-up, large-area fabrication and processing, high-throughput, as well as environmentally friendly and green manufacturing methods for perovskite solar cells. This sub-Area also includes perovskite module design, module testing, fabrication techniques, process chain evaluation, and life cycle assessment.

Sub-Area 6.4: Organic and Dye-Sensitized Solar Cells

Sub-Area 6.4 covers progress on the development of pure organic solar cells and dye-sensitized solar cells, including material optimization, the use of fullerene and non-fullerene based molecules, new charge transport materials and device designs. The Sub-Area will feature fundamental studies, as well as solar cell fabrication and testing. Hence, we welcome a broad range of submissions from first principles design and synthesis of new donor and acceptor materials, over methods of controlling and characterizing their microstructure in thin films, to finally device optimization, stability and scalability.

Sub-Area 6.5: Advances in Perovskite Solar Cell Development

Sub-Area Chair(s): Lukas Wagner, Fraunhofer ISES, Germany

Sub-Area 6.5 covers the latest developments in organic-inorganic hybrid and fully inorganic halide perovskite-based solar cells. The optoelectronic properties of the materials are highly tunable, making them attractive for a range of applications including building-integrated PV and tandem solar cells. This sub-Area focuses especially on the tunability offered by substitution of elemental and molecular components in the perovskite structure, which may enable better performance, new device architectures, design of interfaces in the layer stack, advances in fabrication routes, and novel processing steps. We invite contributions from the broad range of topics relating to halide perovskite-based PV.

Sub-Area 6.6: Alternative Halide Perovskite Materials and Solar Cells

Sub-Area Chair(s): Sofia Masi, Universitat Jaume, Spain

Challenges faced by typical halide perovskite materials, combined with the performance of the class of materials, has led to a range of studies focused on related alternative materials. In Sub-

Area 6.6 we are looking forward to receiving contributions on the development of lead-free perovskite solar cells, low-dimensional absorbers such as Ruddlesden-Popper and Dion-Jacobson phases, and other halide perovskite-inspired materials. Featured studies could include either theoretical or experimental work focused around this diverse group of absorber materials.

Sub-Area 2.5/3.3/4.3/6.7: Hybrid Tandem/Multijunction Solar Cells (Joint Area)
Sub-Area Chair(s): Frank Dimroth, Fraunhofer ISE, Germany & Rohit Prasanna, Swift Solar, USA
This wide-reaching Sub-Area solicits papers regarding materials, structures, and devices based on combinations of different materials (III-Vs, silicon, chalcogenides, organics, perovskites, etc.) toward the production and characterization of "hybrid" multi-junction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy and deposition, wafer/layer bonding, and mechanical stacking, as well as the characterization of these materials, structures, and devices, from the atomic scale to the device level (and beyond), as related to their hybrid nature. Abstracts on the theory and modeling of such devices are welcome, as is work related to new module and system architectures optimized for such hybrid cells. This is a Joint Sub-Area between Areas 2, 3, 4, and 6, and will host the popular "Battle Royal Session" of previous years.

Sub-Area 3.6/6.8: Perovskites for the Space Environment
This Sub-Area solicits papers regarding all aspects of perovskite development for the space environment. This may include (but is not limited to) novel AM0 perovskite cell and module designs, materials design of interlayers and interfaces for enhanced stability, environmental effects, reliability, testing standards, and performance reports.

Area 7: PV Modules, Manufacturing, Systems and Applications

Area Chair: Zhe Liu ("Chris"), Northwestern Polytechnical University, China
Co-Chairs: Natasha Hjerrild, GAF Energy, USA.
Nicholas Rolston, Arizona State University, USA

Sub-Area 7.1: Module Materials, Design, and Manufacturing
Sub-Area 7.2: System Design, Optimization and Performance
Sub-Area 7.3: Modelling and Predicting Energy Yield
Sub-Area 7.4: Strategies for Performance Monitoring and Rating
Sub-Area 7.5: Novel Applications and Integration of PV
Sub-Area 5.5/7.6: Characterization Techniques for PV Modules and Systems (Joint Area)
Sub-Area 2.4/7.7/8.8: Chalcogenide PV beyond the factory: applications, reliability, performance and yield (Joint Area)

Area Description

The PV module is the mechanical support and electrical connection of the cells. It offers both electrical protection and protection from the environment. It is the primary product around which a PV system is based and it can be modified and optimized for locations, environments, and applications. As such, the PV module represents the cornerstone product of the PV industry. Recently, innovations in module construction have been largely responsible for significant increases in efficiency, annual yield, and the corresponding decreases in the levelized cost of energy (LCOE) for photovoltaic electricity generation. New materials, assembly technologies, and structures are being developed for PV modules and will further reduce costs and increase performance. For example, bifacial modules are becoming an increasingly attractive way to reduce cost via increased energy yield. Additionally, customers and operators are seeking and utilizing energy yield prediction methods to reduce investment risk. Improved energy yield estimates will reduce some of the soft costs in financing and thus further reducing the LCOE. Area 8 is seeking papers describing significant advances in module technology, PV module design and manufacturing, methods for forecasting and modelling energy yield and performance, innovative PV deployment and new applications, as well as testing and system monitoring.

A detailed description of each Sub-Area is provided below. For each Sub-Area, papers reporting completed work, accompanied by validation from the field, laboratory testing, or comprehensive modelling are encouraged and welcome.

Sub-Area 7.1: Module Materials, Design, and Manufacturing

In Sub-Area 7.1, abstracts are invited that describe new materials and methods for module production with particular interest on: new materials for backsheets, encapsulants, glass, or interconnects; new techniques for module assembly to reduce cost, increase efficiency or enhance reliability; new designs for bifacial applications; module adjustments and optimization for extreme environments; and novel module electrical configurations. In coordination with Area 8, we particularly welcome submissions describing state-of-art or new methods to improve module manufacturing quality, including quality assurance of module materials and subcomponents; statistical analysis tools for process control; automation of module assembly; and artificial intelligence methods for process monitoring.

Sub-Area 7.2: System Design, Optimization, and Performance
In Sub-Area 7.2, abstracts are invited that describe new concepts for complete photovoltaic systems, methods of system optimization, field results, full life-cycle analysis of system components and system performance analysis. System optimization could be for energy yield, LCOE, self-consumption, LCA and end of life considerations or other aspects important for a specific application or environment. In particular, we welcome submissions describing system design and optimizations for bifacial modules, trackers in PV systems, floating PV, grid-connected or off-grid systems and performance comparisons with the system performance models. Note that the papers related to forecasting and solar resource should be submitted under Area 10 and power electronics methods for optimization in Sub-Area 8.4 or Area 9.

Sub-Area 7.3: Modelling and Predicting Energy Yield
Sub-Area 7.3 focuses on PV methods of module modelling and the prediction of produced energy. Abstracts relating to mechanical, thermal and electrical modelling of PV modules and systems including methods for determining parameters for these models are also welcome. Abstracts of particular interest are those describing: methods for determining model parameters from laboratory and/or outdoor characterization for different modules and installation types; models for the effect of solar spectrum on module output; and methods for estimating system losses, e.g. shading losses, or temperature variations, BOS related losses, etc. We also welcome the energy yield analysis for novel PV concepts, such as, tandem PV modules.

Sub-Area 7.4: Strategies for Performance Monitoring and Rating
Sub-Area 7.4 welcomes abstracts reporting novel methods and technologies for system or individual module monitoring during operation, improved techniques for system performance testing, and research describing novel analysis strategies to extract the information on system or module health and performance from available monitored data. We welcome abstracts describing: advances in or evaluations of methods for determination of plant performance metrics; procedures for conducting commissioning and acceptance tests. We particularly invite abstracts reporting efforts to compare and/or harmonize among the various standards for system testing and rating.

Sub-Area 7.5: Novel Applications and Integration of PV
Sub-Area 7.5 welcomes abstracts describing recent advances in building integrated PV systems (BIPV), off-grid PV systems, hybrid systems, mini/micro-grids, DC end-use systems, mobility and transportation systems, infrastructure-integrated PV, agri-PV, and other not-traditional PV applications. In particular, we welcome abstracts reporting new innovations, visions for future development, and advanced analyses of the cost reduction potential for building related PV applications, advances in building design tools with integrated PV modelling functionality, as well as reports of building power system performance. We are particularly interested in topics covering design and engineering advances, novel requirements, dual-use studies, and results from system simulations and field demonstration. In addition, we would like to emphasize papers that have a goal of leveraging the distributed nature of solar PV to enhance social equity. Note that papers related to floating PV or PV on water should be submitted in Sub-Areas 7.2, 7.3, or 7.4 where applicable.

Sub-Area 5.5/7.6: Advanced Characterization of Photovoltaic Modules and Systems (Joint Area)

Sub-Area Chair(s): Mengjie Li, University of Central Florida, USA & Masahiro Yoshita, AIST, Japan

Papers focusing on characterization of complete modules and systems where the nature of the device is dominated by the ensemble of microscopic behaviors distributed throughout a large area rather than the understanding of individual microscopic behaviors should be submitted in this Sub-Area. For example, papers in this Sub-Area could focus on methods such as LBIC, photoluminescence or electroluminescence specifically as applied to understanding module performance rather than the same methods applied to small areas of device. Machine learning methods corelating those microscopic behaviors in materials and devices to PV module performance are also welcomed. Other examples of papers relevant to this area include adaptation of existing methods to characterize modules from emerging technologies such as perovskites.

Sub-Area 2.4/7.7/8.8: Chalcogenide PV beyond the Factory: Applications, Reliability, Performance and Yield (Joint Area)

Sub-Area Chair(s): Jessica de Wild, IMEC, Belgium & Lauren Doherty, Toledo Solar Inc. USA

The focus of chalcogenide thin film photovoltaics is widening from R&D into large-scale deployment. This joint Sub-Area solicits contributions addressing field deployment as well as reliability research. Contributions are solicited in areas related to metastability, degradation mechanisms, reliability data, field performance, performance ratios and novel applications, as well as deployment related issues that are not listed.

Area 8: Module and System Reliability

Area Chair: Karl-Anders Weiß, Fraunhofer ISE, Germany
Co-Chairs: Roger French, Case Western Reserve University, USA

Sub-Area 8.1: PV Materials and Module Durability and Accelerated Testing Methods
Sub-Area 8.2/9.4: Reliability of Power Electronics and Storage and PV Effects on Grid Reliability (Joint Area)
Sub-Area 8.3: Field Experiences in PV Systems
Sub-Area 5.7/8.4: PV Module and System Reliability Characterizations: Lab and Field Inspection Techniques (Joint Area)
Sub-Area 8.5: Effects and Mitigation of Soiling on PV Systems
Sub-Area 8.6: Module and System Reliability in the Circular Economy
Sub-Area 6.2/8.7: Performance, Reliability and Yield of Perovskites and OPV (Joint Area)
Sub-Area 2.4/7.7/8.8: Chalcogenide PV beyond the factory: applications, reliability, performance and yield (Joint Area)

Area Description

Long-term durability, reliability of PV systems is critical for reliable, efficient, and sustainable energy production as the share of renewables – and especially PV - increases in our energy mix. Moreover, the systems delivering the expected return on investment for all players along the value chain provide the industrial driver for continued growth. PV system lifetimes are extending to 30-40 years and are often deployed in harsh weather conditions. The industry is both risk averse requiring all new technologies (from PV, cell through module materials, components, and systems elements) to prove their robustness in extensive testing before field deployment and rapidly adopting new technologies faster than they can be field tested. More systems are being deployed on areas subject to harsh weather including high winds, flooding, hail, lightening and fire, which requires additional diligence for resilient system design. Finally, long-lasting, and reliable PV systems are also the foundation for an ecologically sustainable PV system.

Within this context, Area 8 considers the reliability and resiliency of all types of PV systems and their components and technologies as well as impact of materials, processing, installation, and operations throughout the value chain. Inverter and BOS failures are frequently reported in the field and are of special interest in this Area. Taking the growing market of storage systems into account, Area 8 is now also encouraging papers on the reliability solar + energy storage systems and related components.

Topics especially critical to the success of the PV industry include comprehensive reporting of failures and degradation rates on the field, and in-depth understanding of physics/chemistry of degradation/failure modes for current and next generation PV materials and technologies. This work serves as a foundation for development of adapted accelerated tests, and the validation of those tests' ability to correlate with outcomes in the field. Discussion of best practices in Design-for-Reliability, Failure Mode and Effect Analysis, manufacturing Quality Assurance and Safety measures, and resiliency are within the interest of the Area; as well as the latest development of science-based standards, test protocols, and modelling approaches for all PV technologies, including BOS components and storage systems.

Submission of papers on detailed scientific research studies as well as visionary papers addressing the full range of these topics are invited. Area 8 has been divided into eight sub-areas, as presented below. This area may also host several joint sessions with other Areas since reliability is influencing and influenced by all steps along the value chain.

Sub-Area 8.1: PV Materials and Module Durability and Accelerated Testing Methods
Sub-Area Chair(s): Gernot Oreski, PCCL, Austria & Bill Gambogi, Comcast Corporation, USA
Module and module components are subject to high temperatures, thermal cycling, humidity, ultraviolet light, electrical, and mechanical stresses. These can result in a variety of failure mechanisms such as glass corrosion, encapsulant browning, EVA yellowing, backsheet cracking, bubbling and delamination, interconnect fatigue and corrosion, frame corrosion and fatigue, bypass diode failure, junction box failure, and cable and connector failure. Submissions are encouraged on experimental studies of the chemistry and physics of these or other module failure mechanisms, accelerated stress tests and method to extract acceleration factors, modelling of degradation and failure rates, interfacial and multi-scale module simulations. Reports linking failure modes to material, module manufacturing, process parameters and insights in critical controls are invited. Studies of degradation rates in recently developed high performance modules using high efficiency mono, bifacial and/or tandem cells (PERx, n-type, HIT, IBC, large wafers/cells), high density module designs (shingling, tiling, cut cells, close spacing, bifacial, large modules) and next generation module materials (AR-coatings, backsheets, encapsulants) are of interest, as are studies demonstrating field-relevant accelerated testing. Papers presenting detailed Failure Mode and Effect Analysis (FMEA) to assess the potential failure modes and development of adapted tests are also of interest. Studies presenting reliability of modules and materials for novel applications and conditions (lightweight, floating, tracked), and integrated PV solutions (BIPV, VIPV, IIPV) are of interest.

Sub-Area 8.2/9.4: Reliability of Power Electronics and Storage and PV Effects on Grid Reliability (Joint Area)
Sub-Area Chair(s): Saeed Peyghami, Aalborg University, Denmark & Alessandro Ciocia, Politecnico di Torino, Italy
As the penetration level of PV systems in the power grid increases, correctly assessing the reliability of power converters and the effects of PV systems on the reliability of power grids for system-level analysis becomes crucial. At the equipment level, recent experiences show that the converters are frequent failure sources in many applications such as wind and PV systems, as their reliability strongly depends on the operating and climate conditions. Additionally, the number of electrical storage systems connected to PV systems is increasing and so also reliability of these systems becomes relevant. At the system level, the availability of the PV system should be included in the power system reliability model. This Sub-Area addresses reliability evaluation approaches and reliability metrics at the equipment level – dedicated to the PV power converters and storages – and at the system level – devoted to the reliability of power systems with PV generation.

Sub-Area 8.3: Field Experiences in PV Systems
Sub-Area Chair(s): David Moser, EURAC, Italy
This Sub-Area focuses on statistics of types of failures, data analysis techniques for field data for large-scale and small-scale systems, analysis of mechanisms of observed degradation and

failures, electrical and mechanical impacts of failures, degradation rates models, safety and operational failures from large PV systems, expected vs. actual field performance, and long-term operation models of PV plants. Submissions may include, but are not limited to, analysis of field observations from deployments of all PV technologies, methods of analysis of such data, experimental approach and energy yield predictions, best practices and technical/economic insights into operations and maintenance, and models or reviews. Papers studying PV system-level availability, in diverse climatic and site conditions, reliability related to extreme environmental events, mounting methods, and interactive effects are encouraged. Innovations in the field of system data analytics and remote failure detection are also of interest. This area encourages submissions of field experiences with inverter or BOS failure, repowering, field repair, energy storage, varying DC/AC ratios, and bifacial field performance.

Sub-Area 5.7/8.4: PV Module and System Reliability Characterization: Lab and Field Inspection Techniques (Joint Area)

Sub-Area Chair(s): Gabriele Eder, OFI, Austria

Early detection and diagnosis of PV failure modes and degradation mechanisms largely rely on advances in both field and laboratory (destructive and non-destructive) characterization techniques. This Sub-Area explicitly calls for papers presenting novel techniques, progress on deploying, as well as improved analysis and best practice, acquisition and interpretation of inspection data/measurements from existing and emerging field characterization techniques such as I-V tracing, infrared imaging, electroluminescence imaging, UV fluorescence, or a combination of these. Further to these, laboratory test/inspection methods tailored for fault detection in-situ characterization methods, sensors in correlation with accelerated reliability studies are relevant. Papers studying innovations in the fields of inspection data analytics and diagnostic algorithms, remote failure detection and wide-area inspections for PV systems are also of interest for contributions in this Sub-Area.

Sub-Area 8.5: Effects and Mitigation of Soiling on PV Systems

Sub-Area Chair(s): Elisabeth Klimm, Hochschule Anhalt, Germany & Leonardo Micheli, Universidad de Jaén, Spain

Soiling can be a major factor affecting both the performance and profitability of PV. This Sub-Area focuses on studies related to various aspects of soiling: monitoring, estimation and both ground- and satellite-based forecasting of soiling losses and rates, cleaning solutions and cleaning frequency optimization, materials, and tests for anti-soiling coatings, both artificial soiling to test functionality and abrasion testing to test for durability. The Sub-Area welcomes as well technical and/or economic studies on both corrective and preventive soiling mitigation measures, such as cleaning and anti-soiling retrofit solutions, as well as case studies presenting their implementation in operating PV plants. Also, methods to map the soiling losses for different climate conditions and site characteristics are of interest in this Sub-Area, along with studies on the fundamental physics of soiling deposition and removal mechanisms and their modelling.

Sub-Area 8.6/11.5: Module and System Reliability in the Circular Economy (Joint Area)

Developing a circular economy for PV modules, components, and systems becomes increasingly important as deployments continue to grow. One of the biggest challenges for a circular economy is defining and quantifying what we mean by "circularity". This area welcomes papers on how to define, quantify, and measure circularity for PV systems and components. Maximizing component and system useful life is one way to make PV more circular. This sub area encourages papers on how system reliability and resiliency affect circularity, and approaches to extending the useful life such as optimized O&M, repair, refurbishing, repowering, and reuse/resale. Safety and performance testing of repaired or re-sold components and systems are critical and of strong interest. Developing circular supply chains reduces waste at end of life, and it may have significant benefits for a more resilient and diverse supply chain at all stages from initial manufacturing through operations. submissions on reducing the amount of virgin feedstocks, repairable systems/components, use of recycled feedstocks or materials, supply chain resiliency, and backwards compatibility or spare parts are encouraged. End of life management issues including recycling, material recovery, and system reuse.

Sub Area 6.2/8.7: Performance, Reliability and Yield of Perovskites and OPV (Joint Area)
Sub-Area Chair(s): Nikoleta Kyranaki, CEA-LITEN INES, France & Erin Sanehira, Cubic PV, USA
Reaching a high level of reliability and durability is key to deployment of perovskite and organic solar cells at scale. Hence, this sub-Area is dedicated to the progress of stability in the context of individual devices and device components, as well as the wide range of efforts to determine reliability and yield in real-world settings. Discussed topics thus include intrinsic and extrinsic degradation mechanisms, efficiency loss issues in perovskite and organic photovoltaics and modules, and long-term durability testing.

Sub Area 2.4/7.7/8.8: Chalcogenide PV beyond the Factory: Applications, Reliability, Performance and Yield (Joint Area)
Sub-Area Chair(s): Jessica de Wild, IMEC, Belgium & Lauren Doherty, Toledo Solar Inc. USA
The focus of chalcogenide thin film photovoltaics is widening from R&D into large-scale deployment. This joint Sub-Area solicits contributions addressing field deployment as well as reliability research. Contributions are solicited in areas related to metastability, degradation mechanisms, reliability data, field performance, performance ratios and novel applications, as well as deployment related issues that are not listed.

Area 9: Power Electronics and Grid Integration

Area Chair: Fernanda Trindade, University of Campinas, Brazil
Co-Chairs: Sara Eftekharnejad, Syracuse University, USA
Pedro Pablo Vergara, Delft University of Technology, Netherlands

Sub-Area 9.1: Power Converter Design, Modelling, and Control
Sub-Area 9.2: Ancillary Services and Grid Support Functionalities
Sub-Area 9.3: Microgrids and Distribution System Operation and Control
Sub-Area 9.4/8.2: Reliability of Power Electronics and PV Effects on Grid Reliability (Joint Area)
Sub-Area 9.5/10.3/11.4: Advanced Resource Management – Towards 100% Renewable Electricity (Joint Area)

Area Description

As PV installations become more widespread, the demands on the power electronic converters designed to interface solar panels to the grid will continue to increase. Likewise, the rapid integration of massive levels of distributed PV penetrations motivates new challenges to managing grid operations. At the component level, advanced inverter functionality and energy storage will enhance grid stability to manage fast-changing phenomenon by using rapid response to control and stabilize the grid. Further, advanced topologies and controls will continue to improve power converter performance and reduce system cost. At the system level, the optimization and management of distributed PVs and other grid resources will continue to support the integration of large penetrations of renewables and enable more advanced grid services and support functionalities. The increasingly active nature of the power distribution systems will motivate new methods for microgrids and distribution grid operations requiring proactive management of the variables generation resources.

The power electronics and power systems community are encouraged to submit contributions addressing the full range of scientific and technical contributions to the field of PV integration into the grid. Of particular interest is a special Joint Session with Areas 8 and 9 inviting publications on topics related to the "reliability of power electronics and PV effects on grid reliability," representing new opportunities for publication at the PVSC.

Sub-Area 9.1: Power Converter Design, Modelling, and Control

Sub-Area Chair(s): Dr. Aleksandra Lekic, Assistant Professor, TU Delft, Netherlands

New converter designs for DC-DC and inverter applications for PV energy conversion promise higher efficiency, improved power density, increased switching frequencies, and higher voltage operation. Emphasis is placed on novel circuit designs, magnetics, wide-bandgap semiconductor materials, and other innovations in component-level converter design. In addition, advanced power electronics controls at the individual converter level, multi-converter-based microgrids, and large PV power plants are crucial to accommodate fast dynamics, nonlinearities, and complex system interactions. This Sub-Area invites contributions on any facet of design, modelling and control of power electronics for PV converters, microgrids, and power systems. Results with circuit analysis, experimental validation, and field testing will be featured.

Sub-Area 9.2: Microgrids and Distribution System Operation and Control
Sub-Area Chair(s): Dr. Alvaro Furlani Bastos, SANDIA, USA
Wide integration of distributed PV generation and fast-acting power converters introduce unprecedented variability and unpredictability on microgrids and distribution system operation. Also, microgrids offer an effective way of combining and controlling renewable energy sources, such as solar PVs, allowing operation in both islanded and grid-connected modes. However, to extract full advantages of integrating PV generators into these systems, adequate control techniques are required. This Sub-Area seeks papers that address problems arising from the integration of PV into distribution systems, including voltage and frequency regulation, Volt-var optimization, power quality, stability, protection, PV sizing and placement, and other pertinent issues.

Sub-Area 9.3: Advanced Monitoring, Optimization, and Ancillary Services
Sub-Area Chair(s): Dr. Livia Raggi, Brazilian Electricity Regulatory Agency, Brazil
Advanced monitoring, optimization strategies, and the ancillary grid services that PV inverters can provide can play a key role in mitigating technical and economic challenges recently imposed on power grid operators. This Sub-Area solicits papers addressing aspects of grid integration related to advanced monitoring, optimization, inverter functionality possibly integrated with battery storage and other emergent technologies.

Sub-Area 8.2/9.4: Reliability of Power Electronics and PV Effects on Grid Reliability (Joint Area)
Sub-Area Chairs: Dr. Saeed Peyghami, Assistant Professor, Aalborg University, Denmark & Dr. Alessandro Ciocia, Adjunct Professor, Politecnico di Torino, Italy
As the penetration level of PV systems in the power grid increases, correctly assessing the reliability of power converters and the effects of PV systems on the reliability of power grids for system-level analysis becomes crucial. At the equipment level, recent experiences show that the converters are frequent failure sources in many applications such as wind and PV systems, as their reliability strongly depends on the operating and climate conditions. At the system level, the availability of the PV system should be included in the power system reliability model. This Sub-Area addresses reliability evaluation approaches and reliability metrics at the equipment level – dedicated to the PV power converters – and at the system level – devoted to the reliability of power systems with PV generation.

Sub-Area 9.5/10.3/11.4: Advanced Resource Management – Towards 100% Renewable Electricity (Joint Area)
Sub-Area Chair(s): Ian Marius Peters, Forschungszentrum Jülich, Germany
PV installations are on the rise. Estimates see a cumulative capacity of 770GW for 2020, and more than 1TW by 2022. Regions across the world are experiencing the impact of significant penetration from PV and wind in their electrical networks and markets. In this Sub-Area, we want to address what technologies, concepts and policies are most beneficial in addressing the challenges of the energy transition. For the next conference, we will focus on everything needed to allow annual PV capacity expansions of more than 1TW. We especially encourage contributions from students and aim to cover diverse regions and approaches.

Area 10: Solar Resource for PV and Forecasting

Area Chair: Ian Marius Peters, Forschungszentrum Jülich, Germany
Co-Chairs: Merlinde Kay, UNSW, Australia
Skip Dise, Clean Power Research, USA

Sub-Area 10.1: Solar Resource – Characterization, Assessment and Variability Modelling
Sub-Area 10.2: Forecasting – Solar Resource or PV Power Output from Minutes to Days Ahead
Sub-Area 9.5/10.3/11.4: Advanced Resource Management – Towards 100% Renewable Electricity (Joint Area)

Area Description

Solar resource measurement and forecasting are essential for evaluating technical and financial performance in PV applications, and uncertainties related to the solar resource contribute directly to uncertainties in economic viability. This research area covers technologies and methods to quantify and model solar irradiance with a particular focus on applications in the PV sector.

Sub-Area 10.1: Solar Resource – Characterization, Assessment and Variability Modelling

Sub-Area Chair(s): Merlinde Kay, UNSW, Australia

Understanding the available solar resource is essential for technical and economic planning of a PV system. Technological advancements in characterizing and analyzing the available solar resource, as well as other relevant environmental factors, allows for improved PV modelling techniques and system optimization. In this Sub-Area, innovations in methodology of solar resource assessment, characterization, and variability modelling are covered. The chief objective should be reducing PV efficiency loss and modelling uncertainty. We explicitly include analyses of all relevant factors for PV modelling, here – for example analyses of the solar spectrum, correlations between solar resource and temperature, impacts of humidity and aerosols, soiling rates, albedo measurement practices, as well as their impacts on PV system performance.

Sub-Area 10.2: Forecasting – Solar Resource or PV Power Output from Minutes to Days Ahead

Sub-Area Chair(s): Skip Dise, Clean Power Research, USA

As PV panels generate increasing amounts of the world's electricity, forecasting becomes ever more important. Highly accurate forecasting of the expected power output and its uncertainty is required for grid management and economic assessment. In this Sub-Area, all topics related to improvements in our ability to predict PV power output and solar resource are invited. We especially welcome contributions that highlight innovations in mathematical or artificial intelligence methodologies and studies that compare model uncertainties, uses of the probabilistic information, and skill scores.

Sub-Area 9.5/10.3/11.4: Advanced Resource Management – Towards 100% Renewable Electricity (Joint Area)

Sub-Area Chair(s): Ian Marius Peters, Forschungszentrum Jülich, Germany

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Area 11: PV Deployment, Policy and Sustainability

Area Chair: Brittany Smith, National Renewable Energy Laboratory, USA
Co-Chairs: Stephen Tay, National University of Singapore, Singapore

Sub-Area 11.1: Government, Policy, and Financing
Sub Area 11.2: Social, Economic, and Environmental Sustainability
Sub Area 11.3: Energy Justice, Workforce Development, and Outreach
Sub-Area 9.5/10.3/11.4: Advanced Resource Management – Towards 100% Renewable Electricity (Joint Area)
Sub-Area 8.6/11.5: Module and System Reliability in the Circular Economy (Joint Area)

Area Description

The PV Deployment, Policy and Sustainability area provides an opportunity to discuss aspects required to ensure the long-term success of the PV industry. It represents an extension of the traditional scope of the conference where current concerns and strategies to increase the adoption of PV as a major electricity source will be discussed. Area 11 also serves as the focus point for examining issues related to equity and social impact, both within the PV industry and its application throughout the world.

Two joint areas are planned: the first (between Areas 9, 10 and 11) will address challenges towards 100% Renewable Electricity; the second (between Areas 8 and 11) will address environmental impact of PV manufacturing and the circular economy.

Sub-Area 11.1: Policy, Markets, and Financing

This topic focuses on strategies to sustain or accelerate high PV growth rates and rapid cost reductions through policy, market, and financial models that are critical to expanding PV deployment and the ongoing success of PV installations. The installed costs of a PV system declined by more than 60% between 2010 and 2020 and PV power became the least cost energy source in many regions, yet certain market barriers continue to inhibit wide scale PV deployment. This Sub-Area solicits papers that will help conference participants better understand policy impacts, market drivers, and financial considerations that are paramount to overcoming these barriers. We encourage researchers to present international efforts and discuss potential areas for expanded collaboration in this sub-area.

Sub Area 11.2: Environmental and Economic Sustainability

This area seeks submissions with a broad, systems-level perspective on the sustainability of PV, throughout the life cycle. Life-cycle assessment (LCA) of current and future PV technologies is of particular interest. Other areas of interest include perspectives on material supply (e.g. improving efficiency of raw material extraction, concerns related to critical or scarce materials), manufacturing (e.g. dematerialization, efficiency gains), usage (e.g. influencing user behaviour, encouraging adoption) and end-of-life (e.g. recycling technologies, toxicity concerns, disposal pathways). Novel approaches and results regarding assessing the environmental impacts of PV are particularly encouraged.

Sub Area 11.3: Energy Justice, Workforce Development, and Outreach

This sub-area focuses on social sustainability topics, such as outreach and education on the benefits of solar power, energy access and equity for underserved communities, and workforce development. Examples of outreach could include fostering popular acceptance of PV power, or communicating the financial benefits of personal PV adoption. Energy justice and equity topics may address access and adoption rates in underserved communities, or upholding indigenous peoples' rights with regards to PV project development. Workforce education topics can include original education to prepare the workforce for jobs associated with various aspects of photovoltaic research, manufacturing, systems design and deployment, and grid integration. Innovative education methods can include but are not limited to interdisciplinary approaches in education, new teaching methods, online education, and hands-on learning. Papers regarding diversity throughout the PV workforce are strongly encouraged. Examples of diversity topics could include aspects such as recruitment practices, retention strategies, or assessment methods.

Sub-Area 9.5/10.3/11.4: Advanced Resource Management – Towards 100% Renewable Electricity (Joint Area)

Sub-Area Chair(s): Ian Marius Peters, Forschungszentrum Jülich, Germany

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Sub-Area 8.6/11.5: Module and System Reliability in the Circular Economy (Joint Area)

Developing a circular economy for PV modules, components, and systems becomes increasingly important as deployments continue to grow. One of the biggest challenges for a circular economy is defining and quantifying what we mean by "circularity". This area welcomes papers on how to define, quantify, and measure circularity for PV systems and components. Maximizing component and system useful life is one way to make PV more circular. This sub area encourages papers on how system reliability and resiliency affect circularity, and approaches to extending the useful life such as optimized O&M, repair, refurbishing, repowering, and reuse/resale. Safety and performance testing of repaired or re-sold components and systems are critical and of strong interest. Developing circular supply chains reduces waste at end of life, and it may have significant benefits for a more resilient and diverse supply chain at all stages from initial manufacturing through operations. submissions on reducing the amount of virgin feedstocks, repairable systems/components, use of recycled feedstocks or materials, supply chain resiliency, and backwards compatibility or spare parts are encouraged. End of life management issues including recycling, material recovery, and system reuse.