Statement of Qualifications

Engineering Advisory Services

Leaders in technical due diligence for solar and energy storage

Revision Date: October 1, 2026

VDE AMERICAS

Executive Summary

VDE Americas is your trusted partner for utility-scale solar and energy storage transaction support, technical due diligence, and hail risk-mitigation services.

VDE Americas is a wholly-owned subsidiary of the VDE Association for Electrical, Electronic, and Information Technologies, one of the largest technology organizations in Europe. Our goal is to advance the deployment of clean energy projects that are financeable and insurable. To support this goal, our team **provides technical due diligence and engineering advisory services for large-scale photovoltaic (PV) and battery energy storage system (BESS) projects** in the Americas. We provide value for our customers by maximizing quality and performance while reducing technical risks at both the system and equipment levels. In 2023, we celebrated ten years of solar and energy storage project transaction support in the Americas.

The **VDE** Association for Electrical, Electronic, and Information Technologies **is the largest technology organization in the world to combine science, standardization, testing, certification, and engineering advisory services** under a single umbrella. Co-founded by Werner von Siemens in 1893 as a society for electrotechnologists, the VDE name has been associated with technical progress and innovation for more than 130 years. For more than 100 years, the VDE mark has been synonymous with the highest standards of product safety and consumer protection. Today, more than 200,000 types of products worldwide carry VDE certification marks.

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Figure 1. Download our tech memo for highly actionable, widely applicable, and product-agnostic recommendations and best practices for hail alert and defensive stow protocols for single-axis tracker-mounted solar power projects.

1 About Our Company

1.1 VDE Americas

Founded in 2013, VDE Americas provides **technical advisory and risk mitigation services** to equipment manufacturers and those who develop, finance, construct, own, operate, and insure large-scale solar power generation and energy storage facilities. Our consulting and digital services have facilitated the financing of **over $15 billion in operating renewable energy assets**. VDE Americas is the **world's leading expert in solar project hail risk intelligence and loss prevention**.

VDE Americas' goal is to **support the global energy transition by advancing the deployment of clean energy projects that are bankable, investable, and insurable.** To support this goal, we offer technical advisory services tailored to the renewable energy industry. Our services for solar and energy storage projects include independent engineering reports and certificates, performance engineering, construction monitoring, system commissioning, equipment reviews, technology reviews, testing services, and owner's engineering. Additionally, we specialize in hail risk analysis for utility-scale solar projects.

Figure 2. Timeline showing highlights from VDE Americas' first decade (2013–2023).

1.1.1 Organizational Structure

VDE Americas is a **wholly-owned subsidiary of the VDE Association for Electrical, Electronic, and Information Technologies** (see profile in Section 1.2). Headquartered in Germany, the VDE group employs more than 2,000 people in over 60 locations worldwide. The group's standards-making network and technical societies include roughly 100,000 subject matter experts and members, making VDE **one of the largest technology organizations in Europe.** As shown in Figure 3, VDE's operations include two North American business units, RETC (Renewable Energy Test Center) and VDE Americas. Both RETC (see profile in Section 1.3) and VDE Americas are headquartered in the San Francisco Bay Area.

To manage customer accounts and projects, VDE Americas maintains a core team of salaried technology experts and business professionals, which we augment on an as-needed basis with a deep bench of consulting engineers. Our organizational structure allows our knowledgeable and experienced in-house resources to collaborate with subject matter experts from the VDE network's other business units, technical societies, and professional associations. This approach allows us to leverage a distributed, global network of talented and trustworthy resources with diverse backgrounds and experience, including preeminent technology leaders from academia and industry.

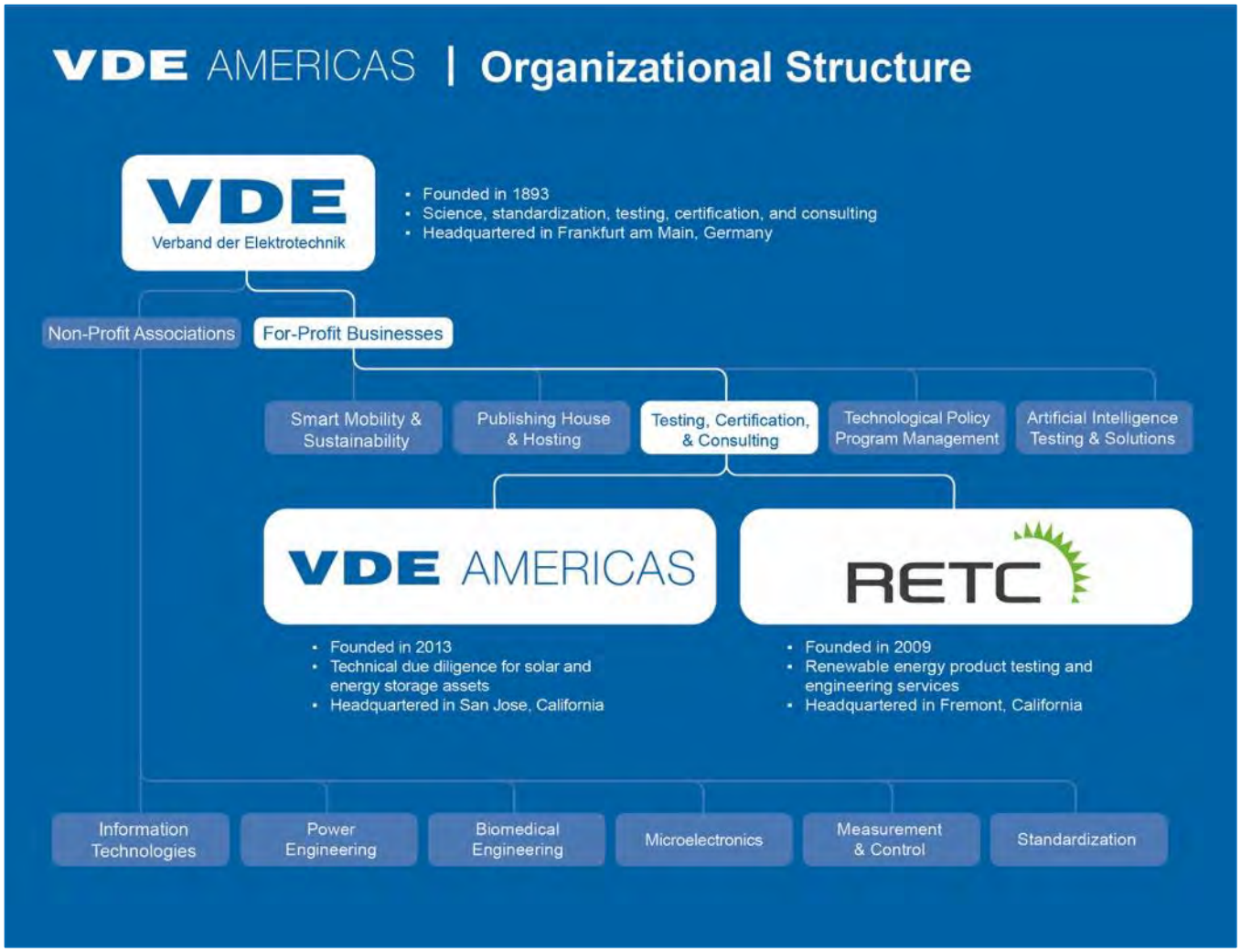

Figure 3. VDE's testing, certification, and consulting business units include VDE Americas and RETC, part of the VDE Group.

1.1.2 Core Values and Operational Approach

Our operational approach is to listen to, learn from, and partner with our customers—not only to acknowledge their requirements but also to recognize, consider, and respond to those factors that drive their success. This approach is rooted in the key principles described below in Table 1 and is applicable to all our products and services.

Principle	Description
Subject matter expertise	We maintain a core team of salaried technology experts and professionals to manage customer accounts and projects while also relying on a deep bench of contributing subject matter experts, using personal and professional connections and members of the VDE Association. This approach has enabled us to establish a distributed network of talented and trustworthy resources across the world with diverse backgrounds and experience while keeping administrative costs down.
Customer commitment	We are passionately committed to customer satisfaction. The success and sustainability of our business depends on customer trust and loyalty. We empathize with customers and are relentlessly committed to value creation. We understand that every customer has unique needs and requirements. We customize our products as needed to meet customer needs and requirements.
Accountability	Accountability means taking responsibility for our actions, commitments, and obligations. We pride ourselves on our responsiveness and ability to deliver against committed project schedules. We endeavor to get it right, on time, every time with integrity and transparency. Details matter. When we do not get it right the first time, we own it, and we make it right.
Continuous improvement	We are inclusive, open-minded, and forward-thinking professionals dedicated to the pursuit of continuous learning and improvement. Every project is a learning opportunity. Every project is an opportunity to exceed customer expectations. We have the courage to be candid, creative, and independent, and the willingness to fail as needed to succeed. A commitment to excellence is vital to all we do.

Table 1. VDE Americas' core values and operating principles.

1.1.3 Thought Leadership

VDE Americas is an influential organization. To improve the quality and safety of PV and BESS products and fielded projects, we participate in national and international code- and standards-making panels and working groups. Where other organizations react to change and innovation, we actively shape the future and the things to come. We collaborate with other learning organizations and institutions to share best practices that promote safety and quality. Our integrity is not for sale. As an unbiased, independent third party, our perspective is product-, technology-, and manufacturer-agnostic. We are protecting critical energy assets to ensure a worthwhile future.

Technical Memorandum

Title	Best Practices for Hail Stow of Single Axis Tracker-Mounted Solar Projects
Author(s)	Dr. Peter Bostock, VDE Americas | Ken Elser, Wells Fargo Renewable Energy & Environmental Finance | Jon Previtali, VDE Americas
Published	February 14, 2024
Document	TM240214
Revision	A

Background

Figure 4. "Best Practices for Hail Stow of Single-Axis Tracker-Mounted Solar Projects" tech memo by Wells Fargo and VDE Americas.

1.2 VDE

VDE is the world's largest technology organization to combine science, standardization, testing, certification, and advisory services.

For more than 130 years, the VDE name has been associated with innovation and technological progress. In 1893, the VDE was officially founded in Berlin under its original name, "Verein Deutscher Elektrotechniker" (Society of German Electrotechnologists). When the organization relocated its headquarters to Frankfurt am Main in 1949, VDE rebranded itself as the "Verband Deutscher Elektrotechniker" (Association of German Electrotechnologists). Five decades later, the group realigned its name to better reflect its expanded membership and mission. Since 1998, VDE has stood for the "**V**erband **d**er **E**lektrotechnik, Elektronik, und Informationstechnik" (Association for Electrical, Electronic, and Information Technologies).

Today, VDE is the largest technology organization in the world to combine science, standardization, testing, certification, and engineering advisory services all under one umbrella. Since introducing the VDE certification mark (see Figure 5) in 1920, VDE has been synonymous with the highest standards of safety and consumer protection. Though best known for its work creating and maintaining electrical product safety standards, **VDE's core mission is to advance and promote the development of new technology, future generations of engineers and technologists, and lifelong learning.** We accomplish this as a professional association with roughly 100,000 subject matter experts and members, 1,500 member companies, and more than 2,000 full-time employees in 60-plus locations worldwide. Collectively, we are all dedicated to ensuring a future worth living.

Figure 5. In 2020, VDE celebrated the 100th anniversary of the VDE mark (1920–2020).

1.2.1 Mission & Guiding Principles

VDE's mission is to **ensure a worthwhile future**. Our guiding principles facilitate this goal:

- We stand for innovation, safety, and quality.
- We are regionally well-positioned based on a strong international network.
- We are independent.
- We provide a neutral working platform.
- We share our knowledge.
- We shape and interconnect education, research, and application.
- We promote and train.
- We develop mutual perspectives together.
- We are the platform for the next generation.
- We set standards.

1.2.2 History and Milestones

The history of VDE parallels the triumphs of modern technologies. Table 2 summarizes major VDE group milestones. For more than 130 years, VDE has been a pioneer in technological progress and innovation.

Year	Description
2023	130th anniversary of VDE and 10th anniversary of VDE Americas
2021	VDE acquires a majority stake in RETC (Renewable Energy Test Center)
2020	100th anniversary of the VDE mark
2018	VDE receives the German brand award and celebrates its 125th anniversary
2017	VDE signals its commitment to the future with a new slogan: "VDE—for a worthwhile future"
2013	VDE establishes VDE Americas
2003	VDE establishes VDE Global Services
1998	VDE rebrands as the "VDE Association for Electrical, Electronic and Information Technologies"
1993	100th anniversary of VDE
1991	VDE test center is renamed the "VDE Testing and Certification Institute" (aka the "VDE Institute)
1970	VDE and the German Institute for Standardization (DIN) jointly establish the German Electrotechnical Commission (DKE), which represents German interests in international standards
1954	VDE founds the first of its professional technology societies
1949	VDE relocates to Frankfurt am Main and rebrands as the "Association of German Electrotechnologists"
1935	VDE regulations are recognized as "rules of technology" under the Energy Industry Act
1920	VDE establishes its first testing center and registers the "VDE mark"
1906	VDE participates in the founding of the International Electrotechnical Commission (IEC)
1904	VDE publishes its first "book of standards", a 183-page document covering 17 provisions
1895	VDE passes its first electrical safety standard (VDE 0100)
1893	VDE is founded in Berlin as the "Society of Electrotechnologists"

Table 2. Summary of key VDE group milestones.

1.3 RETC (Renewable Energy Test Center)

A member of the VDE group, RETC played a key role in the development of the first consensus reliability and durability test standard for PV modules.

Founded in 2009 and headquartered in Fremont, California, RETC provides **engineering services and certification testing for renewable energy products**. RETC evaluates a wide range of cleantech products at its highly accredited laboratories, including **PV modules, mounting systems and trackers, power electronics, and BESS components**. In 2021, the VDE Group acquired a majority stake in RETC. Today, RETC is a wholly-owned subsidiary of VDE.

RETC's qualification and beyond-qualification test data support **bankability assessments, market-entry activities, and research and development.** The company's best-in-class testing and engineering due diligence **mitigate project-level risks related to product durability and asset performance.** Benefits of this work accrue at the portfolio level, ensuring investment returns for project sponsors and insurers, as well as an unimpeded flow of investment capital. By facilitating continued solar market growth, RETC's work is foundational to efforts to promote energy security and effective decarbonization.

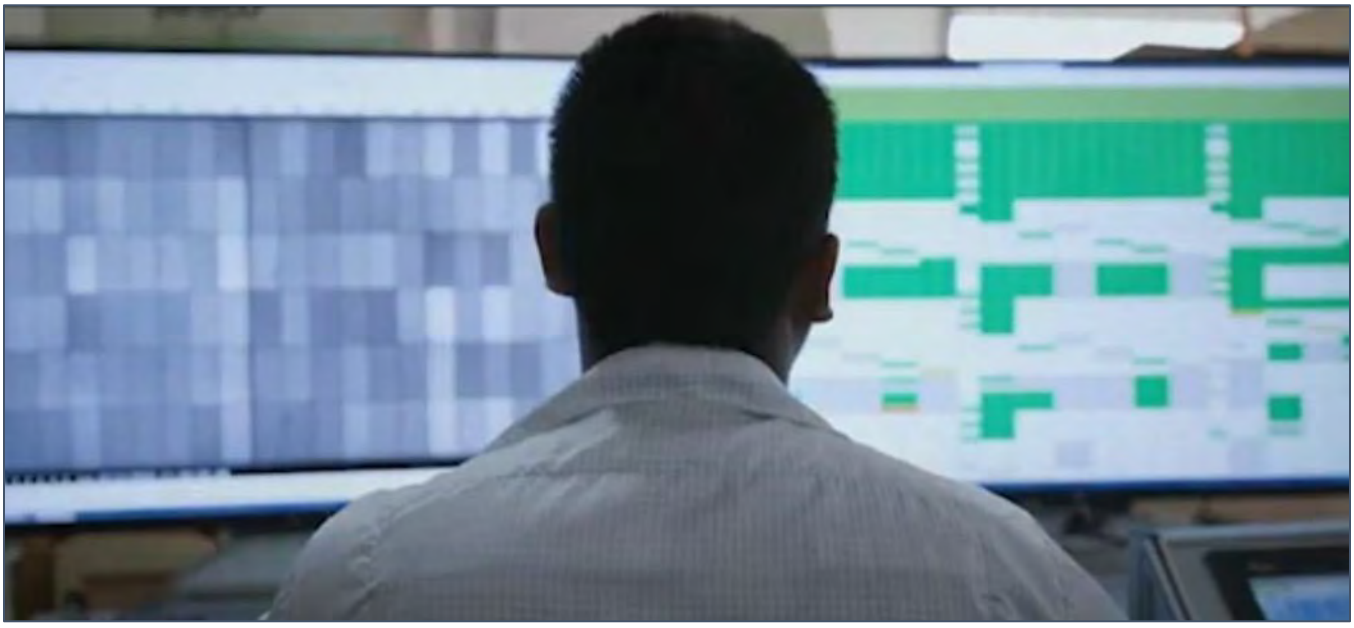

Figure 6. PV module characterization at RETC's state-of-the-art testing laboratory in Fremont, CA.

1.3.1 Thresher Test

Reliable in-field operation over a 25- or 40-year warranty period is a testament to rigorous manufacturing quality and product testing programs. Expanding on pioneering work conducted by the Jet Propulsion Laboratory, the Thresher Test was **developed by and for solar industry stakeholders**. Named after a type of farm equipment used to separate seed and grain (high-quality materials) from straw and chaff (low-quality materials), **the Thresher Test has been separating higher-quality solar modules and bill of materials from lower-quality products and product designs since 2011**.

RETC played a critical role in developing the industry's first consensus reliability and durability test standard for PV modules. Module companies were understandably reluctant to share their internal testing protocols with competitors. As a workaround, the manufacturers agreed to share testing program details with RETC under a nondisclosure agreement. As the program coordinator, RETC could then review these testing protocols against an NREL database of failure modes observed in fielded PV power plants or during product certification testing. This analysis allowed the working group to isolate the test sequences that most effectively identified known failure modes. **RETC served as the Thresher Test program coordinator and was the first independent testing laboratory to offer the Thresher Test**.

1.3.2 PV Module Index Report

Since 2018, RETC has published an annual *PV Module Index Report*. This report compiles the **results of bankability and beyond-qualification tests conducted at RETC's accredited laboratories over a 12-month period.** The report generally catalogs test sequences and data according to three interrelated manufacturing disciplines: module quality, performance, and reliability.

The goal of the *PV Module Index Report* is **to empower solar project stakeholders to identify, quantify, and mitigate technical risks** on an application-specific basis. Project stakeholders can use these comparative test results to identify products or project designs best suited to a particular environment, location, or portfolio.

Publishing comparative test results is not intended to disparage or favor specific technologies, products, or manufacturers. Rather, successful solar project deployment demands differentiated products and design approaches. Comparative test data can inform strategic design adaptations to ensure that fielded projects can withstand site-specific risks while optimizing investor returns.

Products that perform well in tests simulating high wind speeds may not perform well in tests simulating high humidity. PV module designs that are resilient to severe hail or snow may not be cost-effective in large utility-scale applications in California's Central Valley, which rarely experiences such perils.

The goal of a data-driven approach to project development is not to eliminate every risk at any cost, but rather to **balance risk mitigation through a holistic cost-benefit analysis**. The bankability testing that underlies RETC's *PV Module Index Report* is foundational to a science- and engineering-based approach to technical risk mitigation.

Figure 7. Cover of an RETC *PV Module Index Report*

2 Technical Advisory Services

VDE Americas' advisory services support and de-risk the development and financing of large-scale solar, storage, and solar-plus-storage projects.

The increasing market adoption of renewable energy poses novel challenges to independent power producers, utilities, and grid operators alike—with widespread implications for virtually all wholesale and retail electricity customers. Sound design and construction in compliance with interconnection requirements are important prerequisites for ensuring the stability and performance of electricity grids. These are the types of challenges that VDE is uniquely well-positioned to address. Having been a key participant in the development of international technical standards addressing the safety, reliability, performance, and cybersecurity of electrical systems and equipment—including solar, wind, and battery energy storage system (BESS) applications—VDE has the knowledge, experience, and ability to be your trusted quality partner in the world of clean energy and smart living.

2.1 Independent Engineering

When engaged as an independent engineer (IE), we work with key solar and energy storage stakeholders to ensure that large-scale PV and BESS assets are designed, constructed, commissioned, and operated in accordance with applicable standards and best practices. We do so by providing unbiased, expert assessments of the project's design, construction, commissioning, and operation. As a third-party organization with in-depth subject-matter expertise, VDE Americas is uniquely qualified to verify that PV and BESS deployments meet energy production estimates and deliver expected financial returns.

We understand that every customer and project has unique requirements. To maintain our focus on adding value, VDE Americas can customize the scope of its technical due diligence and quality assurance services to best serve customer and stakeholder needs. Our experts can validate PV and BESS power plant engineering and performance or evaluate components, construction, and commissioning. Working with VDE Americas, customers benefit from in-depth subject matter expertise and ensure the timely completion of critical project milestones.

Figure 8. A high-level overview of VDE Americas' PV and BESS independent engineering advisory services.

2.2 Owner's Engineering

When engaged as an owner's engineer (OE), we work with investors and lenders to ensure the long-term success of a clean energy venture by reviewing and validating technical feasibility, regulatory compliance, and project execution. We do so by acting as a concierge-style extension of our client's deal teams to provide on-demand critical engineering analysis, oversight, and support. We specialize in transaction-level due diligence to de-risk financial transactions for solar, energy storage, and solar-plus-storage assets. We understand that every customer has unique needs, and we can customize our scope of work to deliver maximum customer value.

Typically, our due diligence scope of work involves reviewing confidential information memos (CIMs) to help clients make go/no-go decisions, providing term sheet negotiation support, and working directly with project development and IE staff to ensure the project meets client expectations. Our comprehensive technical due diligence survey significantly expedites this process. This work covers the provision of reports, certificates, and other supporting materials as required for financing purposes. We pride ourselves on our responsiveness and ability to deliver against project commitments and schedules.

Figure 9. A high-level overview of VDE Americas' PV and BESS owner's engineering advisory services.

2.3 Other Technical Advisory Services

In addition to serving project developers, sponsors, and the financial institutions they partner with, we also work directly with system designers, equipment manufacturers, power sales offtakers, utilities, and operators to evaluate technologies and identify and mitigate technical risks. These services include:

- Site feasibility studies
- Ground adaptation of satellite-based meteorological data ("MCP" reports)
- Technology reviews (aka "bankability" reports)
- Technical document review
- PV system commissioning oversight
- PV capacity test administration
- Failure and root cause analysis
- Performance engineering/analysis for operating projects
- Production estimate recasting
- Subject matter training and/or consulting
- Site inspections for construction quality and monitoring, damage assessment, or troubleshooting

2.4 Featured Projects

Whether as an independent engineer or an owner's engineer, we have advised clients on over 10 GW of constructed solar PV projects and more than 5 GW of BESS capacity (not including our catastrophic risk assessment services discussed in Section 3). A selection of the projects is presented in Table 3.

Project Name	Location	MW_{AC}	Year	Scope of Work Comments
Navisun Portfolio	Throughout US	95	2025	Portfolio review of 41 operating solar and BESS projects
Cider	Genesee County, NY	562	2025	Full Owner's Engineer (OE) scope of work; largest solar project in the Northeastern US
Kelso I+II	Scott County, MO	349	2025	OE for tax equity investor
Quail Ranch	Bernalillo County, NM	300	2025	Single-axis tracking PV project with 100 MW / 400 MWh AC-coupled BESS
Ridgely	Lake County, TN	177	2025	First Solar Series 7 project featuring automated Terrafab™ constructed block
White Wing Ranch	Yuma County, AZ	202	2024	First constructed utility-scale project with First Solar Series 7 PV modules
Mt. Laurel Portfolio	Various locations	43	2024	Full Independent Engineer (IE) scope of work for three projects located in PJM territory
Victory Pass Arica	Riverside County, CA	463	2024	Two similarly designed projects in close proximity with approximately 200 MW / 800 MWh capacity of AC-coupled BESS and complex offtake arrangements
Dairyland Portfolio	Throughout Wisconsin	23	2024	IE for portfolio of similarly designed solar projects serving rural cooperative utilities
Oxbow	Pointe Coupee Parish, LA	315	2024	Largest solar PV project constructed in Louisiana
Neptune	Pueblo County, CO	325	2023	Full OE scope of work on these projects with similarly designed AC-coupled BESS
Thunderwolf		250		
Big Oak Horizon	Throughout US	500	2023	Portfolio of three projects featuring First Solar Series 6+ modules
McFarland	Yuma County, AZ	580	2023	Two co-located PV projects featuring over 250 MW of BESS, including both AC- and DC-coupled systems, with portions of energy sold into merchant power markets
Arroyo	McKinley County, NM	300	2023	Full OE scope of work from design through construction on behalf of tax equity investors. Both projects include similarly designed 150 MW / 600 MWh AC-coupled BESS
Eland	Kern County, CA	310	2023	
Fall River	Fall River County, SD	86	2022	IE for similar designed utility-scale single-axis tracking PV projects w/PURPA interconnection/offtake agreements
Montana Sun	Yellowstone County, MT	86	2022	
Wheatridge	Morrow County, OR	50	2022	Scope included performance modeling of 30 MW / 120 MWh BESS
Golden Compass	Pinal County, AZ	200	2021	OE for tax equity investors
Rawhide Prairie	Larimer County, CO	22	2021	Scope of work included evaluation of 2 MWh BESS
Muscle Shoals	Colbert County, AL	227	2021	Largest solar plant in Alabama at the time of construction
Hunter	Emery County, UT	100	2020	Advisor to tax equity from term sheet through funding
Hillcrest	Brown County, OH	242	2020	Included detailed analysis of ground-adapted resource file
Rambler	Tom Green County, TX	200	2020	Aggressive technical diligence schedule for "sign and fund"
Highlander	Spotsylvania County, VA	485	2020	Complete technical advisory from term sheet through funding
Assembly	Shiawassee County, MI	160	2019	Two projects with a shared substation, multiple offtake agreements
Cove Mountain	Iron County, UT	180	2019	Included analysis of comprehensive network upgrades
Milford	Beaver County, UT	99	2019	Provided additional technical support through Project sale
Springbok 3	Kern County, CA	90	2019	Work included evaluation of test block and 1.5 MWh pilot BESS
Willow Springs	Kern County, CA	100	2018	One of the first projects to feature First Solar Series 6
Twiggs	Twiggs County, GA	200	2018	Included close oversight of construction due to Contractor exit
Phoebe	Winkler County, FL	250	2018	Scope of work also included sub-hourly production downside analysis
Mount Signal 2+3	Imperial County, CA	395	2018	Complex network of shared facilities to point of interconnection
Buckthorn	Pecos County, TX	150	2017	Came in after Initial Funding to provide support to tax equity
Great Valley	Fresno County, CA	200	2017	Multiple phases each having offtake agreements and POIs
Kern HS District	Kern County, CA	22	2017	IE for portfolio of mostly carport installations across 27 school sites
Luz Del Norte	Atacama Desert, Chile	141	2015	Provided certification of workmanship quality to EPC Contractor

Table 3. Featured projects from more than a decade of VDE Americas' technical advisory project work.

2.5 Featured Financing Parties

Our independent engineer reports and work products have been accepted and are trusted by leading institutions that provide financing for renewable energy projects, including, but not limited to, those shown in Figure 10.

Figure 10. Selection of banks who have provided financing to projects reviewed by VDE.

2.6 Battery Energy Storage System Experience

Our project experience reviewing BESS technology has grown in recent years, commensurate with the maturation of deployments throughout the United States and worldwide. A selection of these projects is discussed in Table 3 above. VDE team members have prior experience leading development, engineering, and asset management teams for top-tier energy storage developers and manufacturers with assets spanning dozens of sites throughout California and the Northeast, based on a variety of BESS technology providers. Our team members also sit on multiple technical panels for product safety standards related to renewable energy and energy storage, as developed by various standards bodies, including IEC, Underwriters Laboratories, and VDE/DKE.

Additionally, we have been working with leading financial institutions to help them understand and address the unique technical risks that BESS technologies may pose, particularly in safety and reliability. These efforts are informed in part by the comprehensive knowledge and experience of the BESS TestLab facility in Offenbach, Germany. In addition to providing subject-matter training, we have helped clients incorporate BESS requirements into their transaction documentation and develop tools to identify technical risks and model various downside scenarios across a range of use cases.

Within the VDE group, our colleagues around the world possess similar solar and BESS project experience, having provided technical advisory services—reviewing various technologies, applications, and capacity ratings >1 GW—throughout Europe, Asia, and the Middle East.

2.6.1 Battery Equipment Testing and Certification

VDE is an internationally active certification body that conducts hundreds of thousands of component tests per year. In the solar photovoltaics sector, we work with leading international manufacturers of PV modules, inverters, mounting systems, and balance-of-system (BOS) products to certify compliance with a range of IEC, UL, VDE, and other standards.

Through our ongoing engagement of key stakeholders in the renewable energy industry—particularly financial institutions and insurance firms—we recognize that existing standards requirements, although important, are insufficient to achieve bankability, investability, and insurability for all projects and major equipment. These standards must be extended with additional criteria, as illustrated in Figure 11. An important goal of VDE's Pyramid of Quality approach is to achieve a significant reduction of operational risks, which is paramount to project valuation.

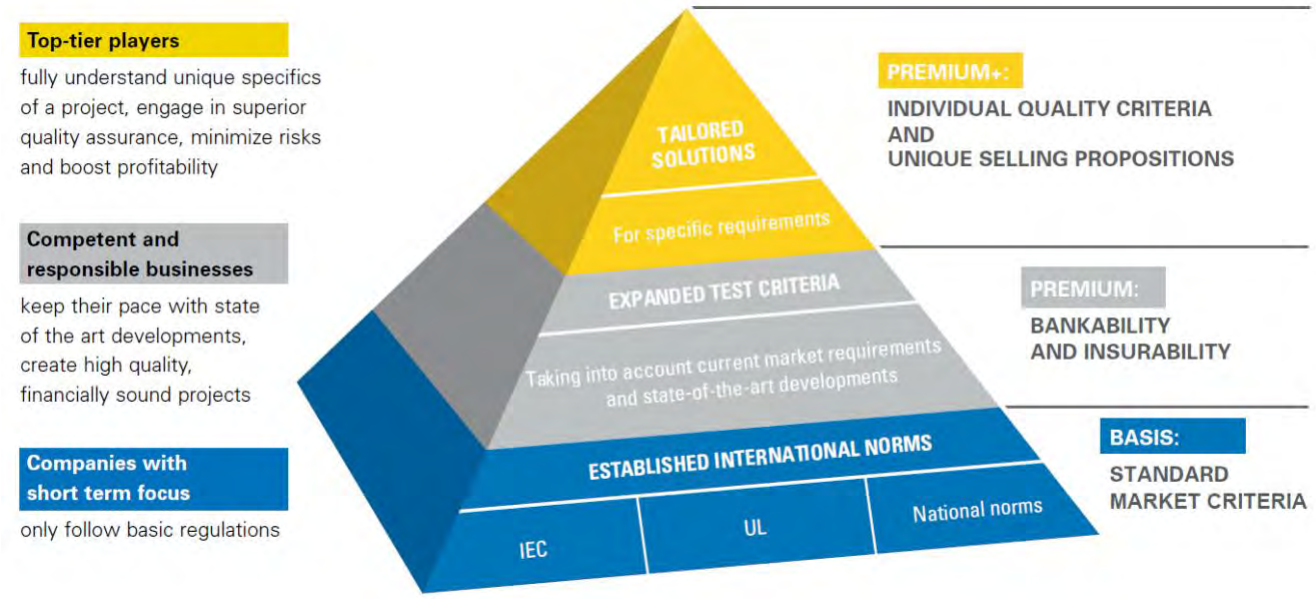

Figure 10. Project stakeholders can reduce risk by leveling up on VDE's Pyramid of Quality.

VDE offers state-of-the-art solar component testing capabilities in the United States, Europe, and Asia. The VDE group's facilities include RETC (Renewable Energy Test Center) in Fremont, California; an outdoor PV test laboratory in Phoenix, Arizona; a world-class BESS test lab in Offenbach, Germany; and facilities in Singapore and China. In addition to conducting component testing ourselves, VDE also partners with regionally established independent testing laboratories, effectively providing customers with a global network.

Figure 11. VDE's BESS TestLab in Ofenbach, Germany.

2.6.2 Battery Forensics and Accident Investigations

Many battery and energy storage accidents have occurred in recent years. This trend will continue as battery adoption and market growth expand further across stationary power supply and mobility applications. Battery accidents often result in lost revenue, system replacement costs, litigation, penalty payments to aggrieved parties, and potential fines.

We leverage our testing capabilities and large network of partner labs with the knowledge of our battery experts to conduct forensic investigations or accident investigations into cells or battery systems, either stand-alone or in collaboration with other established surveyors (e.g., in the marine business) and relevant authorities.

Our services in this field include:

- Inspection of accident sites in the field and at production facilities
- Catastrophic loss event survey
- Document reviews (i.e., quality assurance procedures and logs, shipping documentation, etc.)
- Inspection of product packaging and conformity to regulations
- Electrochemical analysis of samples (i.e., dismantling accident-adjacent but intact samples, new samples, and, where possible, damaged samples) to check for lithium-plating, contaminations, or other abnormalities
- Sample testing and retesting to confirm safety, determine accident root cause, or to independently verify conformance with UN 38.3 or SoC requirements (e.g., for air transport)
- BMS HIL testing to reconstruct incident conditions (where applicable)
- Evidence storage in dedicated battery storage units

2.6.3 Other Battery Technology Advisory Services

We leverage the knowledge and experience of our dedicated team and an extended network of contributing subject matter experts to customize and deliver technical advisory services tailored to the specific needs of our customers. In addition to serving project developers, sponsors, and the financial institutions they partner with, we also work with system designers, equipment manufacturers, power sales offtakers, utilities, and operators to evaluate technology and identify and mitigate technical risk.

These battery technology advisory services include: site feasibility assessment; technical document review; equipment manufacturer technology review (e.g., IE report); company due diligence (i.e., IP holdings, capabilities, market share, QA processes, product quality and USPs, supply chain management, competitive analysis); factory inspections; and subject matter consulting and training (e.g., basics of lithium-ion technology, correct handling, storage and disposal, transport regulations, HV battery systems, BMS basics and master class, etc.).

3 Catastrophic Risk Assessment

VDE Americas' natural catastrophe models help prevent catastrophic losses. We are the world's leading hail risk assessment expert for solar projects.

3.1 VDE Hail Risk Intelligence

VDE Americas provides solar project hail risk assessments **based on site-specific meteorological data and product-specific technical details**. We developed our award-winning hail risk assessment capabilities together with Central Michigan University's Dr. John Allen, a leading expert in severe convective storm meteorology.[1] Our science- and engineering-based hail risk reports provide project stakeholders with **financial loss and risk exposure estimates** based on latitude-longitude coordinates and fielded PV module and tracker technologies.

Solar project stakeholders can use VDE Americas' hail risk assessment data and engineering reports to **guide equipment specification, insurance terms, and risk exposure beyond insurance coverage.** Beneficiaries of our innovative hail risk advisory products and services include developers, owners, tax equity investors, lenders, insurers, asset operators, tracker manufacturers, and module companies.

Figure 12. Storm chaser footage from Andrews County, TX of a severe hailstorm in March 2022.

[1] In December 2022, a VDE Americas-led team won $50,000 to support ongoing hail risk assessment product development activities in Round 6 of the U.S. Department of Energy's American-Made Solar Prize.

3.1.1 Probable Maximum Loss Reports

Given that solar projects are a relatively new asset class and market segment, the insurance industry lacks a reliable way to assess the hail vulnerability of PV power plants. VDE Americas' **probable maximum loss (PML) and average annual loss (AAL) reports** address this gap by providing insurance loss estimates based on project location and technical system design details.

Our PML assessments characterize the return interval of naturally occurring hail at the local scale of a solar asset. Informed by these site-specific meteorological data, we estimate probabilistic financial loss based on comparative project-specific resiliency characteristics, defensive stow capabilities, emergency response protocols, and business interruption. Insurers, reinsurers, and insurance consultants typically use our PML and AAL results to **set appropriate convective storm premiums and sublimits**. Moreover, solar project insurance customers can use location- and technology-specific AAL estimates to right-size severe convective storm deductibles.

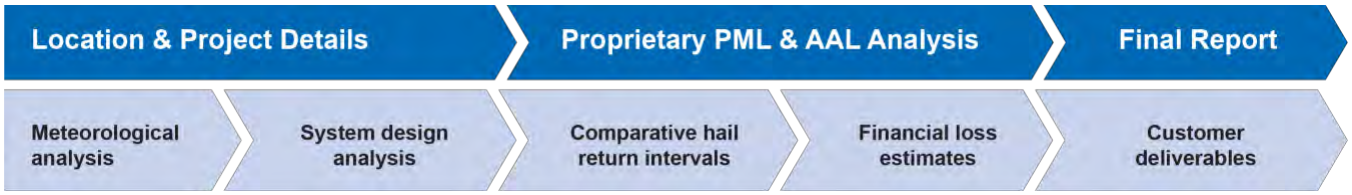

Figure 13. VDE Americas' probable maximum and average annual loss estimates can inform insurance terms and conditions.

3.1.2 Pro-Forma Risk Exposure Reports

While insurers often base coverage terms on a 500-year event, real-world investment and lending periods are measured in decades, not centuries. VDE Americas' **Pro-forma risk exposure (PRE**) reports address this gap by providing **cumulative financial loss estimates over customer-specified hold periods**, such as 10 years for tax-equity investors or 40 years for long-term owners. A Poisson distribution is a discrete probability distribution, named after a French mathematician, used in probability theory and statistics to show how many times an event is likely to occur over a specific period.

Our PRE analyses employ more than 10,000 Monte Carlo iterations to characterize discrete event probability over specific financial hold periods. Informed by probabilistic distribution results and naturally occurring hail return interval data, we estimate cumulative financial loss based on the number of events associated with specific hail size ranges, project-specific resiliency characteristics, defensive stow capabilities, and emergency response protocols.

As the solar insurance market has hardened, project stakeholders often must pay more money for less insurance coverage. In this context, VDE Americas' PRE report results provide owners and developers with a means to understand their financial risk exposure beyond insurance. These report data are also useful for evaluating the value proposition associated with parametric insurance policies that index event payout amounts to naturally occurring hail diameter.

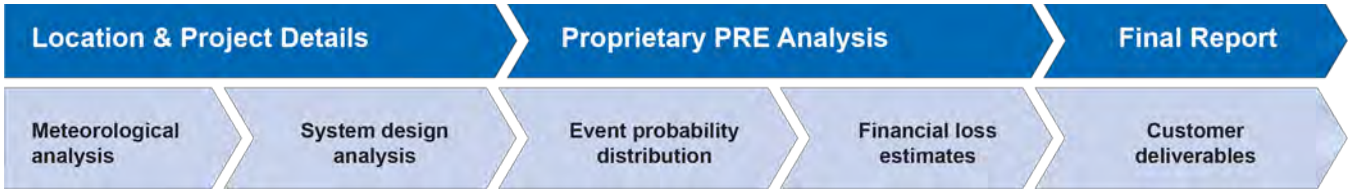

Figure 14. VDE Americas' Poisson risk exposure (PRE) reports provide loss estimates over typical financial hold periods.

3.1.3 VDE Hail Risk Atlas

VDE Americas' **subscription-based hail risk maps** allow project stakeholders to visually estimate solar project risk exposure without ordering full engineering reports. Our hail return interval maps characterize the probability of hailstones ranging in diameter from 25 mm to 95 mm. The technology-specific financial loss maps account for all major PV module construction types and tracker defensive stow angles, whether tilted into or out of the wind. Subscribers can access this data as layers in ArcGIS Online, a software platform many large-project developers already use for solar project prospecting. Hail return interval and financial exposure maps are ideal for identifying, quantifying, and mitigating hail risk during early-stage project development activities. Available via Esri's ArcGIS Marketplace, VDE's hail risk exposure maps help **inform site selection, equipment specification, and financial pro forma assumptions**.

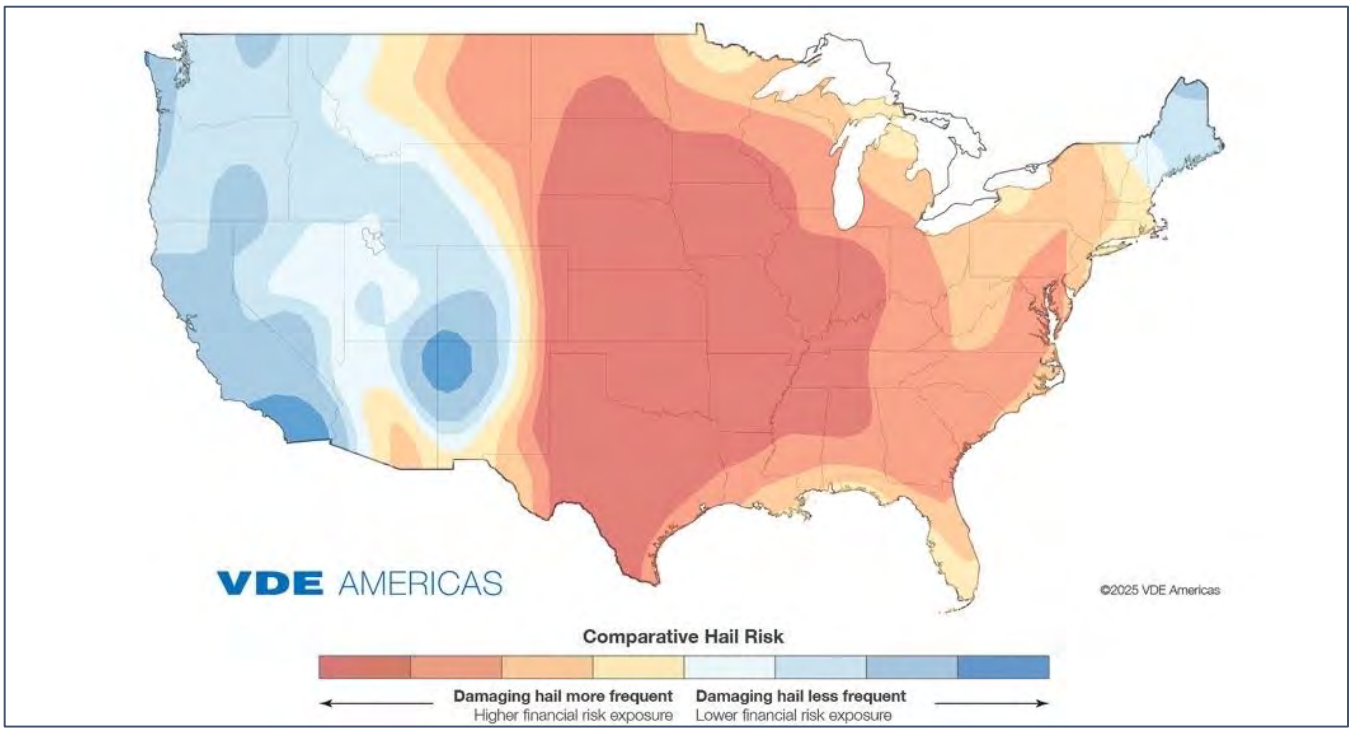

Figure 15. ArcGIS Online users can subscribe to VDE's Hail Risk Atlas to estimate meteorological or financial risk exposure.

3.1.4 Other Hail Products and Services

In addition to standard product offerings, VDE Americas offers data suitable for integration with enterprise-level software solutions or white-labeled partner reports. We also offer bespoke consulting services to assess portfolio- or product-level hail risk.

Product	Description
Remote operations center audits	Efficacy review of hail monitoring, alerting, and stow protocols
Hail event forensic investigations	Investigate root causes of and contributing factors to hail losses
Run radar hail event modeling	Map hail swath and intensity based on radar reflectivity data using latitude-longitude coordinates and event timestamp
Comparative hail risk assessments	Model financial value proposition for product designs, such as hail-hardened PV modules or defensive stow enhancements

Table 4. A partial list of VDE Americas' customizable hail risk advisory product and service options.

3.2 Understanding Hail Risk

Hail has proven to be among the largest property damage risks for solar projects in hail-prone regions. According to insurance industry estimates, **hail accounts for less than 2% of solar project insurance claims volume—but more than 50% of total solar losses.** Although property insurance and warranties play a crucial role in mitigating these risks, they do not eliminate the perils associated with severe hailstorms. Insurance often does not cover all exposure, and warranties are subject to carve-outs, photovoltaic (PV) module design-standard limitations, and burden of proof. The scale of these hail losses has disrupted the renewable insurance market and, in some cases, hindered solar project development and financing in hail-prone regions.

3.2.1 Hailstorm Loss Events

Hail forms via accretion as convective storm updrafts carry water droplets into extremely cold areas of the atmosphere, where they freeze, grow, and increase in mass. Hail falls when the downward gravitational force exceeds the strength of the thunderstorm updraft. To meet the minimum ballistic-impact requirements in the IEC 61215-2 product qualification standard, PV module designs must withstand 11 impacts of a 25-mm freezer iceball at terminal velocity. As solar markets have proliferated in hail-exposed regions, so have reports of catastrophic damage consistent with naturally occurring hail larger than 25 mm.

Pecos County, Texas (2019). In May 2019, seasonal thunderstorms in West Texas produced damaging hail over the 182 MW-rated Midway Solar farm. According to insurance industry reports, severe hail damaged more than 400,000 solar modules at the 600-hectare site, resulting in insured losses of $70 million to $80 million. Hail damage included broken glass as well as modules with cracked cells. In response to the historic magnitude of these losses, insurance premiums increased by as much as 400%.

Fort Bend County, Texas (2024). In mid-March 2024, a series of very severe spring hailstorms occurred directly southwest of Houston. Three severe hail-producing storms occurred within a 12-hour period. All three of these hailstorms met >500-year event severity criteria. Four utility-scale solar projects were exposed to >500-year hail. Three solar farms that had implemented operational hail defense protocols withstood 1-in-500-year hail exposure. These results provide conclusive evidence that operationalized stow protocols are effective at preventing solar module glass breakage during a severe hail event.

Figure 16. Severe hail damage at a 5 MW Nebraska Public Power District solar project following a June 2023 storm.

3.2.2 Hail Risk Mitigation

The single most important thing we have learned via VDE Americas' catastrophic risk advisory work is that **hail losses are not an insurmountable barrier to solar project development and investment activities.** Though some locations will inevitably experience severe hail, large project losses are not inevitable. Collectively, the industry can prevent and mitigate hail risk by improving technical literacy, due diligence, and risk mitigation.

Identify and quantify severe hail risks. Early-stage design and due diligence activities should include an initial assessment of severe convective storm risk. The goal of this assessment is to characterize hail risk (low, moderate, high) at a location-specific level. In large utility applications, qualified technical advisors should quantify probabilistic loss levels over event recurrence intervals required by insurers (e.g., 500-year event) and typical investment hold periods (e.g., 10-, 20-, and 40-year hold). The goal of these loss studies is to provide comparative probable maximum loss (PML) and average annual loss (AAL) values based on site-specific meteorological characteristics (e.g., historical hail event severity and frequency) and project-specific technical considerations (e.g., PV module glass thickness and strengthening, tracker stow angle, and so forth).

Mitigate risks via strategic technical adaptations. Strategic design adaptations ensure that fielded projects can withstand site-specific risks while optimizing investor returns. For example, project stakeholders seeking to minimize hail risk should pay special attention to PV module selection, tracker stow characteristics, and remote operations center capabilities. Beyond-qualification testing has shown that module ballistic-impact resistance is a function of front glass thickness and heat strengthening; moreover, module tilt angle impacts hail resilience. In at-risk locations, project stakeholders can mitigate financial risk exposure by deploying hail-resistant modules and adhering to hail-stow best practices.

Where PV module hail resilience is insufficient on its own to reduce the risk of hail damage to acceptable levels, stowing single-axis tracker-mounted PV modules at a maximum tilt angle mitigates hail damage in two important ways: First, it can reduce the effective area of glass that is exposed to falling hail; second, it reduces the damage potential associated with hail impacts. Horizontally oriented PV modules (i.e., flat or 0° tilt) are subject to the normal element of kinetic energy associated with falling hail (i.e., direct impacts). Rotating PV modules to a tracker's maximum tilt angle (i.e., 50°–75°), generally results in glancing blows that reduce the normal element of kinetic energy associated with falling hail, significantly reducing hail-impact damage potential and expected project losses.

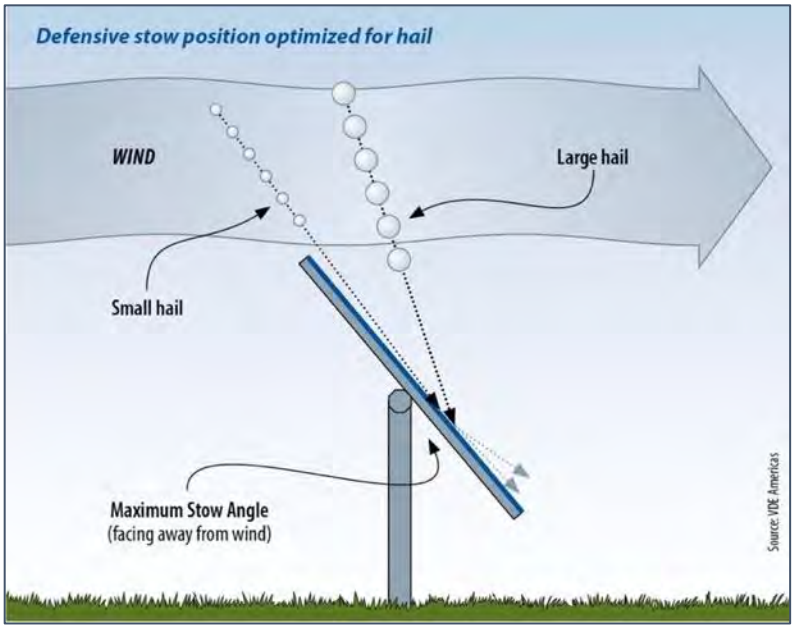

Figure 17. For hail defense, stow PV modules facing away from the wind at a maximum tilt angle ahead of approaching severe thunderstorms.

4 About Our Team

VDE Americas' deep bench of talent includes industry professionals who have dedicated their careers to advancing renewable energy. The team members below are regular contributors to project work.

4.1 Senior Leadership

4.1.1 Executive Team

Cherif Kedir
CEO and President, VDE Americas

Cherif Kedir is the CEO and president of VDE Americas, a leading provider of technical advisory and risk mitigation services for solar and energy storage assets, and its sister company VDE RETC, a pioneering testing laboratory for solar modules, inverters, racking products, and battery energy storage components. Unifying executive leadership across the VDE Group's two North American business units, Kedir strengthens their combined ability to identify and mitigate technical risks and help protect the bankability and insurability of critical energy assets. A solar industry veteran of more than two decades, Kedir joined VDE Americas with an extensive background in solar and semiconductor durability, reliability, and certification testing, as well as expertise in product research and development, failure analysis, and performance enhancement. Before joining RETC, which the VDE Group acquired in 2021, he held senior leadership positions at Solaria, a solar module company, and Xilinx, now part of AMD. Kedir holds an MBA from Santa Clara University.

Taylor Geer
COO, VDE Americas

Taylor Geer Taylor Geer is the COO at VDE Americas, implementing and overseeing the company's strategic plans and operations. Engaged in the renewable energy transition for over 25 years, he has global experience with solar, energy storage, and wind projects across all stages of development and operation. Prior to joining the VDE Group, Geer spent 5 years working in project development, including serving as vice president of engineering at Emeren US and vice president of technical analysis at Ørsted Americas. Previously, he held a variety of roles over a 17-year tenure at DNV, including leading the advisory firm's M&A due diligence team. Geer holds a BS in Mechanical Engineering and Materials Science Engineering from U.C. Berkeley, as well as a BA in Philosophy from U.C. Santa Cruz. He also earned an MS degree in Mechanical Engineering from the Renewable Energy Research Lab at the University of Massachusetts Amherst and an MBA at the University of Oregon.

4.1.2 Director-Level Team Leaders

Lisa Casey
Director, VDE Americas

Lisa Casey is director of technical advisory at VDE Americas with nearly 15 years of experience in engineering and project management. Leveraging her experience as a former U.S. Department of Energy (DOE) Loan Programs technical lead, Lisa supports stakeholders through project development, construction, financing, and operations, by evaluating project designs, major equipment, site conditions, performance assumptions, and long-term operational considerations to help clients make informed investment decisions. Prior to her work at the DOE's Loan Programs Office, Lisa spent over a decade at Clark Construction Group as an engineer and project manager. During her tenure at Clark Construction Group, she managed complex, high-value projects and developed company-wide risk management and training initiatives. She received her BS degree in Civil Engineering with a minor in Earth and Ocean Sciences from Duke University. Lisa holds a Certificate in Energy & the Environment from Duke University's Nicholas School of the Environment.

Dr. Jonathan Allen, PE
Director, VDE Americas

Dr. Jonathan Ostrom Allen, PE, is the director of hail risk at VDE Americas. With over 30 years of experience in data analytics and scientific research related to the electric utility industry, he contributes to the development and advancement of natural catastrophe modeling products and services, mitigates technical risks for customers, and oversees operational hail stow verification studies for equipment manufacturers and project owner-operators. Previously, Jon specialized in ambient air quality and air quality control research, with a focus on coal-fired power plants. For these studies he determined the effect of power plant operations on control efficiency, developed empirical process models, and recommended changes to improve mercury control. Jon has authored 30 peer-reviewed publications, 13 conference papers, and 55 technical reports. In addition to BS degrees in Chemical Engineering and Finance from University of Pennsylvania, Jon holds an MS and a PhD in Chemical Engineering from the Massachusetts Institute of Technology.

The VDE network includes 2,000 employees at over 60 locations worldwide, as well as an association with more than 100,000 honorary experts and 1,500 companies.

4.2 Subject Matter Experts

In alphabetical order, VDE Americas' in-house and in-group technical subject matter experts include:

Albert Chang is a performance engineer for VDE Americas with experience in solar, power systems, and BESS modeling. He began his professional career by developing capacity-expansion models for grid decarbonization research, which led to an interest in designing and deploying renewable energy technologies. Prior to joining VDEA, Albert interned at Smartville, where he developed the SV360, a second-life EV stationary energy storage system. He was responsible for building the hardware system, including low- and medium-voltage cabling, battery paralleling and combiner boxes, BMS controllers, sensors, and a microgrid for battery testing. Today, Albert leverages his modeling expertise to design software tools and functions for advancing the solar modeling industry. Albert received a BS in Mechanical Engineering from the University of California, San Diego, and an MS in Energy Science, Technology, and Policy from Carnegie Mellon University.

Manu Chandy is a project manager for PV modules and systems at VDE SIS. Combining technical expertise with client-focused project leadership, Chandy has built a strong track record in advancing product reliability, compliance, and process excellence across the renewable energy industries. He has over a decade of international experience in project management and engineering across Asia and Europe. Since early 2016, he has been driving testing, certification, and quality assurance projects for photovoltaic modules, initially based in Singapore before relocating to Germany in June 2025. He works closely with global certification bodies, factory inspections, IEC 62941 audits, and supports manufacturers in meeting and exceeding international quality and safety standards.

Kevin Crepps is a project engineering manager for VDE Americas. Kevin started his career in logistics working for MasTec, a leading construction firm, before joining the renewables industry in 2015 as an installation technician on SolarCity's C&I team. Kevin later leveraged his field experience to become a certified electrician in California, earning his certification while working as a project manager on solar and electrical infrastructure projects. Kevin joined UL Solutions in 2020 as a project manager for renewable energy advisory and due diligence services, where he managed independent engineering efforts for over 500MW of PV capacity. Before joining VDE, Kevin served as a technical due diligence manager at Greenbacker Capital, leading diligence on both solar and wind projects from development through construction. Kevin holds an AS degree in Natural Science from Sierra College and is a certified Project Management Professional (PMP).

Tyjal DeWolf-Moura is an engineer and applied scientist at VDE Americas focused on PV module technology and catastrophic risk analysis. Tyjal leverages his expertise in science, statistics, simulation, and programming to tackle unique challenges, advance research, and develop probabilistic tools for hail risk mitigation. He holds a BS degree in Physics with a minor in Mathematics from the New Mexico Institute of Mining and Technology, where he graduated with honors. Tyjal earned an MS degree in Physics from the Colorado School of Mines, where he wrote a thesis on the geometric phase of entangled photons in a Laguerre-Gaussian beam, which has potential applications in quantum computing. He also holds an MS degree in Materials Science and Engineering from the University of California, Merced, where he focused on renewable energy under the mentorship of Professor Sarah Kurtz, contributing to research on solar PV module efficiency.

Arne Grünewald is the project manager for energy solutions at VDE SIS. Arne studied applied physics at the University of Würzburg, Bavaria. After graduating, he led R&D projects focused on material circularity and the optimization of recycling processes. Since 2022, he has been a project manager at VDE Renewables, coordinating battery storage systems, technical due diligence projects, and system consultancy on sustainability and industrial feasibility. He also contributes his expertise to the DKE standardization body, including all relevant aspects of standardization mandated by the EU Battery Regulation and the EU Battery Passport. He is also a lecturer in strategic process management, quality, and project management at the TH Aschaffenburg, University of Applied Sciences, and has further expertise in setting up and auditing quality management systems as a strategic quality manager and auditor.

Dominik Hennefeld is the head of the laboratory for batteries and energy storage systems at the VDE Institute Battery Test Lab in Offenbach, Germany. He is an electrical engineer with more than 10 years of experience in lithium-ion energy storage systems and drive technology. He is an outstanding expert in parameter design for battery

management systems and in developing lithium-ion battery test cases for electrical, mechanical, and environmental testing. Dominik is particularly concerned with the behavior of lithium-ion batteries under abuse conditions and with failure mechanisms that could eventually lead to the development and propagation of fires within battery storage systems. He has an in-depth knowledge and advises our customers on battery design and construction. Dominick also manages testing and certification projects for VDE's clients in Germany and Europe.

Edward Ibe, PE, is a principal engineer for VDE Americas and a subject matter expert in power conversion technologies and battery energy storage systems (BESS). A licensed professional engineer in Texas, he has over 15 years of experience in power conversion equipment design and electrical engineering for utility-scale renewable energy applications. As senior power conversion engineering manager for Silicon Ranch, a major independent power producer, Edward was responsible for the design, construction, commissioning, and operational optimization of a renewable energy portfolio comprising over 160 sites. During a seven-year tenure with TMEIC, a leading inverter manufacturer, he built an engineering office from scratch, managed over 20 engineers globally, and helped scale the inverter business to $460M in annual sales. As TMEIC's chief design engineering manager, Edward led the development of certified PV inverters, variable frequency drives, uninterruptible power supplies, and switchgear. Edward received a BS in Electrical and Computer Engineering from the University of Ohio and an MS in Electrical Engineering from Wright State University.

Shivam Khosla is a project engineer II for VDE Americas. He began his professional career as an engineering intern at Sacramento Municipal Utility District (SMUD). In SMUD's Policy and Strategy Department, he researched and developed an electric vehicle subscription model, focusing on charging stations, electric vehicle operation, and nationwide charging subscription rates, while playing a crucial role in vehicle-to-grid demonstration projects. In the Research and Development Department, he contributed to SMUD's 2030 Zero Carbon Project by integrating smart inverters and exploring vendor-aggregator models to increase DER adoption. As a project engineer for VDE Americas, Shivam applies his critical thinking skills to large-scale solar and solar-plus-storage applications. Shivam holds a BS in Mechanical Engineering from the University of California, Davis, and earned an Associate of Science degree in Natural Science and Mathematics from Yuba College.

Jochen Mähliß is the head of the battery business at the VDE Institute Battery Test Lab in Offenbach, Germany. He has deep expertise in lithium-ion batteries. Working in various R&D positions focused on batteries, Jochen has been actively involved in developing testing standards for lithium-ion batteries. He has contributed to several publications on lithium battery fire safety and hazards, effective loss prevention, and firefighting procedures. Jochen is an active member of various working groups and standard-setting bodies. In 2011, he founded and led Batteryuniversity GmbH, a battery laboratory focused on testing large battery storage systems. Jochen organizes workshops and provides in-house training on lithium-ion battery technology. Jochen completed his studies and obtained his doctorate at the Johann Wolfgang Goethe University in Frankfurt, Germany.

Stipe Mandic is a senior project manager for batteries and energy storage systems at VDE SIS. He studied energy management at the University of Applied Sciences in Darmstadt. During his time at university, he worked for energy supply companies in testing and certification. After graduation, he worked as a standardization manager at DKE, the German standardization body. He later moved to VDE Renewables, bringing valuable experience in standardization and energy management. Currently, he is a project engineer for battery and energy storage systems, responsible for technical due diligence and system consulting. He stands for a sustainable economy in which batteries are indispensable.

Daniel Moghtader is a performance engineering manager at VDE Americas, specializing in advanced technical modeling of solar power systems. He develops cutting-edge methodologies for uncertainty quantification, module performance optimization, and statistically rigorous models for energy production forecasting. His work helps investors and developers make data-driven decisions for solar projects during and after the due-diligence period. As the technical lead for capacity testing programs, Daniel ensures strict compliance with ASTM E2848-13 standards while pioneering improved approaches to performance validation. Prior to joining VDE, Daniel leveraged his chemical background at NREL, where he contributed to innovative quality control systems for gigawatt-scale roll-to-roll electrolyzer manufacturing. Daniel holds a BS degree in Chemistry from Loyola Marymount University and an MS in Advanced Energy Systems Engineering from Colorado School of Mines.

Bill Reaugh serves as principal engineer at VDE SIS and the company's head of power conversion technologies. Based in Offenbach, Germany, since August 2025, Bill has over 25 years of experience in electrical engineering and electronics, starting in 1997 as a repair technician for the US Marine Corps. Before joining VDE Americas as a principal engineer, Bill served as Blue Oak Energy's Director of Engineering. As a U.S. product manager for an inverter OEM, Bill helped develop Kaco's 1,500-volt central and string inverters. In 2002, while still finishing his first degree, Bill became the fourth hire at SMA America, where he spent 5 years building the technical training and customer service departments. Subsequently, Bill expanded his industry knowledge to include building-integrated solar. As the VP of project development at Draker, a SCADA and monitoring company, Bill helped grow a startup business into a multimillion-dollar acquisition target. Bill holds a Bachelor of Science degree in Computer Engineering from the University of California, Davis, and an MBA from Drexel University.

Chase Varner is a senior project engineer for VDE Americas with expertise in quality standards and knowledge-sharing systems for independent engineering and technical due diligence deliverables. A technical due diligence consultant specializing in large-scale energy transactions and project finance, he has advised or supported transactions for leading energy investors, developers, and infrastructure funds. Prior to joining the VDE Group, Chase served as a technical due diligence consultant for Black & Veatch, a global engineering, procurement, consulting, and construction company specializing in infrastructure development. Chase received a BS degree in Mechanical Engineering from the University of Michigan.

Dennis Weaver is a staff meteorologist for VDE Americas. Dennis began his meteorology studies at Central Michigan University, where he worked alongside Dr. John Allen researching the impact of reported damage descriptions on severe hail characteristics. While at Central Michigan, Dennis was selected as a NOAA Hollings Scholar and collaborated with researchers at the National Severe Storms Laboratory on the local economic impact of severe tornadoes. At Villanova University, Dennis produced a master's thesis on projected changes in climatological hail risk and exposure across the United States. At VDE Americas, Dennis applies his software development skills and meteorological knowledge to help de-risk large-scale solar assets. Dennis received a BS in Meteorology from Central Michigan University and an MS in Environmental Science from Villanova University.

Dr. Jason Weeks is a principal engineer at VDE Americas and a subject matter expert in lithium-ion battery technology and battery energy storage systems (BESS). He brings extensive experience in independent engineering, technical due diligence, and project finance, having supported the financing of more than 65 project portfolios with a cumulative capacity totaling 11.6 GW. These portfolios range in capacity from 5 MW to 2.3 GW and include some of the largest utility-scale BESS and solar-plus-storage projects in the United States. Dr. Weeks has served as a technical liaison for project financings valued at up to $4.1 billion, working with leading lenders and investors—including Wells Fargo, U.S. Bank, Bank of America, J.P. Morgan, SoftBank, and others. His experience spans nearly all major BESS manufacturers and key U.S. energy markets (i.e., CAISO, ERCOT, and PJM). Beyond his project advisory work, Dr. Weeks has led BESS training programs, hosted an internal lecture series, and developed a BESS augmentation optimization model to support long-term system planning and performance.

Dean Wen is the China country manager for the VDE Global Services. Dean is an electrical engineer with more than 20 years' experience in industrial electrical equipment and systems. His professional experience includes 5 years working with energy storage and lithium-ion battery technology, first at MCC Group in China, on several large-scale engineering projects of Baosteel Group. Dean has worked at VDE Global Services China since 2005. He is focused on onsite inspections for energy storage system installations and leads a team of factory inspections for critical components of BESS and system integration, as well as testing projects for VDE's clients.

Patrick Zank is the business development manager for VDE SIS. Patrick specializes in battery and energy storage systems and holds a degree in industrial engineering with a focus on materials science. Since joining VDE, he has led technical due diligence for BESS, supported system-level consulting projects, and published studies on battery technologies and alternative propulsion systems. He serves as an expert at DKE, contributing to international electrotechnical standardization, and is involved in the Battery Passport consortium, supporting the development of the Digital Product Passport under the EU Battery Regulation. Patrick acts as Key Account Manager for international partners across PV, BESS, and grid conformity, fostering strategic collaborations and aligning technical expertise with market needs. He is also a frequent speaker and trainer at international conferences and industry events on energy storage, quality assurance, regulation, and digital product data systems.

4.3 Consulting Engineers and Scientists

Dr. John Allen contributes to the development of VDE Americas catastrophic risk assessment capabilities. Originally from Sydney, Australia, John is a meteorologist and climate scientist. Work at the Allen Research Group spans a variety of topics but primarily focuses on severe convective storms around the globe, their characteristics, climatology and response to factors such as climate variability and change. In addition to his consulting work, John is a Professor of Meteorology in the Department of Earth and Atmospheric Sciences at Central Michigan University (CMU). He holds a Bachelor of Science and a doctorate degree in Earth Sciences (Meteorology and Applied Mathematics) from the University of Melbourne, Australia. In 2013, he began a postdoctoral appointment at the International Research Institute for Climate and Society at Columbia University and was later promoted to Associate Research Scientist. He joined CMU in the summer of 2016.

Dr. Ron Fritz is the founder of InSite Technologies, a statistical consulting firm that specializes in process improvement, sampling, and study design. His consulting work for VDE Americas includes contributions to the development of an improved hail impact characterization test protocol based on a Weibull test-to-failure methodology. For more than a decade, Ron served as a senior principal engineer and statistician for PepsiCo. He has also served as a senior process improvement engineer and scientist for W.L. Gore & Associates, a global materials science company. An expert in quality assurance and quality control, Mike is certified as a Six Sigma Black Belt by the American Society for Quality. He holds a BS in Manufacturing Engineering Technology from National University, an MS in Systems Management from University of Southern California, and a PhD in Industrial Engineering with a minor in Statistics from Clemson University.

Anastasios (Stas) Hionis, PE, brings more than 20 years of experience in engineering, energy modeling, fieldwork, and data analytics to provide technical due diligence and advisory services for renewable energy assets. He has experience in all stages of the project lifecycle, including design, energy production modeling, construction, commissioning, and acceptance. As a forensic engineer, Stas specializes in identifying the root causes of failures, developing methodologies for corrective actions, and advising clients on lessons learned. He also uses his detailed field knowledge to evaluate risks and opportunities in construction and operating assets. Stas serves as the CEO of PV AMPS, an independent engineering firm he founded in 2014, based in Sacramento, California. Stas received a BS in Mechanical Engineering from Cal Poly, San Luis Obispo, and is licensed in 38 states as a Mechanical and Electrical Engineer.

Neal Shah, PE, is a registered professional engineer in over 6 states. His firm, NS Structural Engineering, Inc., has over 45 years of combined structural engineering experience. Neil founded his practice on fundamental principles to deliver quality, competitive engineering services. The firm's areas of emphasis include educational, commercial, airports, healthcare, transportation, federal, and solar energy structural engineering. Neal has worked with VDE Americas since 2015 and has extensive experience designing and reviewing solar structural IFC (Issued for Construction) drawings. He is well versed in the California Department of State Architect's "pre-check" structures, including solar carports and canopy structures. Neal holds a MS degree in Structural Engineering and a BS degree in Civil Engineering from the University of California, Irvine.

JP Von Rahl has nearly two decades of solar industry experience, spanning construction to balance-of-system (BOS) component manufacturing. Starting his career in the field, he has worked through every aspect of PV project deployment; as a result, he brings a holistic approach to project planning, design, equipment selection, and acceptance for completion. JP has worked with leading mechanical and electrical BOS companies, giving him a critical perspective on the relationship between component selection and installation and the long-term health and viability of renewable assets. As the director of advisory services at PV Amps, JP assists clients with the launch, verification, and optimization of solar and energy storage projects. JP received a BS in construction technologies from the College of the Redwoods.

List of Acronyms

Acronym	Description
AAL	Average annual loss
BESS	Battery energy storage system
DIN	Deutsches Institut für Normung (German Institute for Standardization)
DKE	Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE (German Commission for Electrotechnical, Electronic & Information Technologies of DIN and VDE)
IE	Independent engineer
IEC	International Electrotechnical Commission
NOAA	National Oceanic and Atmospheric Association
OE	Owner's engineer
PML	Probable maximum loss
PRE	Poisson risk exposure
PV	Photovoltaic (solar)
ROC	Remote operations center
RETC	Renewable Energy Test Center
VDE	**V**erband **d**er **E**lektrotechnik, Elektronik, und Informationstechnik (Association for Electrical, Electronic, and Information Technologies)

VDE Americas provides technical advisory and risk mitigation services to renewable energy stakeholders—from project owners and financiers to equipment manufacturers and those who construct, operate, and insure large-scale power generation and energy storage facilities. A wholly owned subsidiary of the VDE Group, VDE Americas is recognized globally as the leading authority in solar project hail risk intelligence and loss prevention. The company's expertise and innovative solutions have facilitated billions of dollars of investment in renewable energy assets.

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