NATIONAL RENEWABLE ENERGY LABORATORY

Streamlining and Standardizing Due Diligence to Ensure Quality of PV Power Plants

Technical Monitor: Sarah Kurtz

Solar Power International
September 10-13, 2017
Las Vegas, Nevada

NREL/PR-5J00-70270

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Solar Power International Workshop
Sunday, Sept. 10, 2017, 12:30-4:30 pm
Las Vegas, Nevada

Streamlining and Standardizing Due Diligence to Ensure Quality of PV Power Plants

Organized by the National Renewable Energy Laboratory

Those investing in PV power plants would like to have confidence that the plants will provide the anticipated return on investment. While due diligence is capably performed by independent engineers today, as PV systems mature, there will be benefit in standardization and streamlining of this process. The IECRE has defined technical information that is needed as a basis for each transaction step such as approving a design to begin construction, documenting readiness to operate, quantifying performance after a year of operation, and assessing the health of the plant in preparation for sale of the plant. The technical requirements have been defined by IEC Technical Committee 82 and have been designed to be both effective and efficient in completing the assessments. This workshop will describe these new tools that are now available to the community and will include a panel/audience discussion about how and when they can be most effectively used.

12:30 Welcome and Introduction: Sarah Kurtz (NREL)

12:45 Panel Discussion: Overview and value proposition of international standards to streamline the process of assessing quality of PV power plants
Moderator: Ingrid Repins
Greg Ball, Tesla
Jon Previtali, Wells Fargo
Edward Hsi, Swiss RE

2:15 Break

Introduction to break out sessions

2:30 Break out #1 Component testing (Ingrid Repins and Jon Previtali)

2:40 Break out #2 Design, installation, commissioning issues (Jim Rand and Greg Ball)

2:50 Break out #3 Assessment in preparation for asset transfer including annual performance test (Eric Daniels, Sarah Kurtz and Edward Hsi)

3:00 Break out sessions: More detailed information will be shared in each group, questions answered and feedback collected

4:15 Closing and next steps (Sarah Kurtz)

4:30 Adjourn

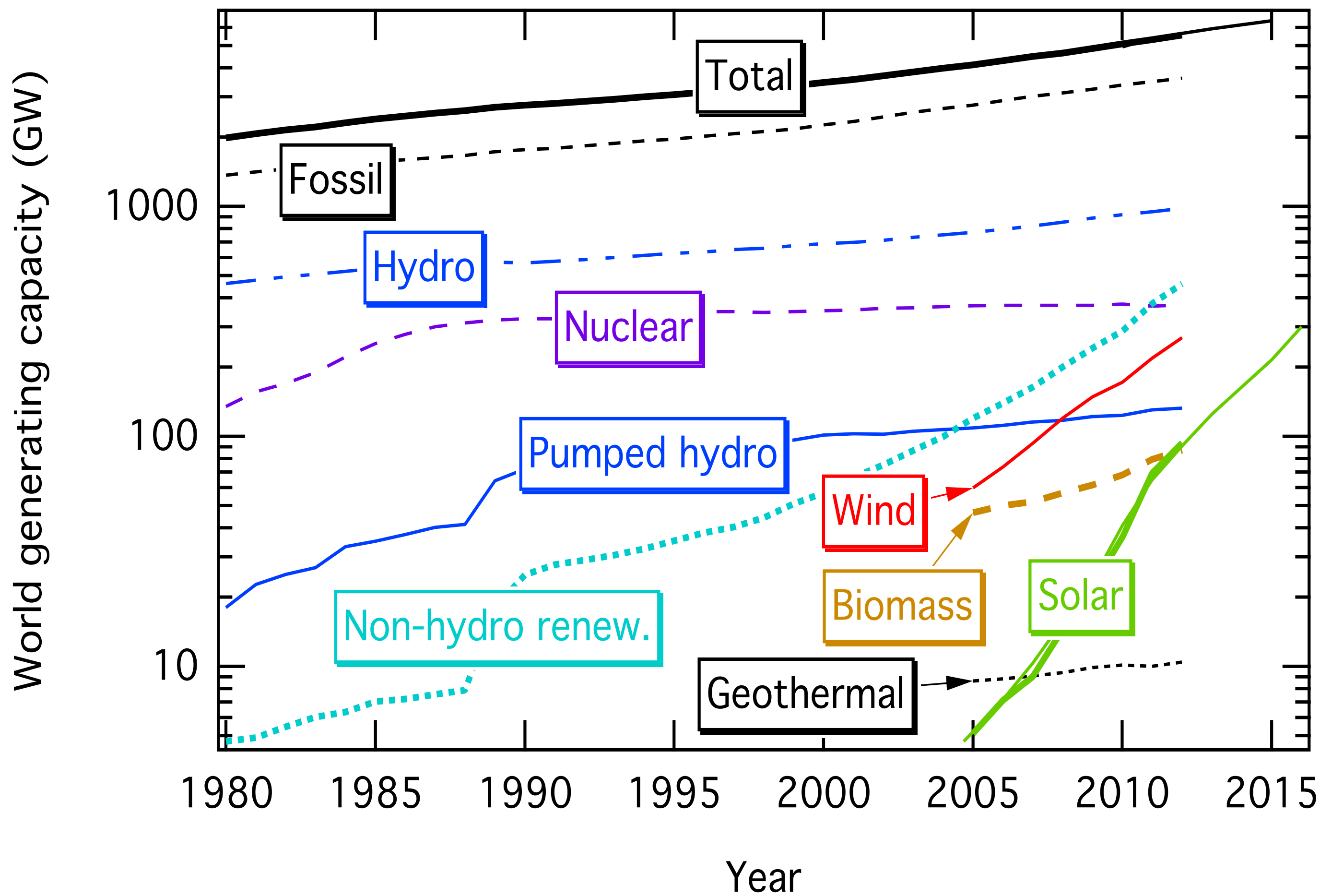
NATIONAL RENEWABLE ENERGY LABORATORY

Streamlining and Standardizing Due Diligence to Ensure Quality of PV Power Plants

Sarah Kurtz

September 10, 2017
Solar Power International Workshop

Motivation: the solar industry is maturing!



The solar industry has now "grown up" to the size of the nuclear industry
We should be thinking of how this "adolescent industry" may grow to maturity

Establishing bankability – need was identified years ago

- Due diligence process supports business decisions
- Standardization
  - Can *reduce cost* by not needing to revise your business processes for each new customer
  - Can *leverage the learning experience* in the community to *improve the due diligence process*
- Solar is growing internationally – an *international* platform is beneficial

Survey results

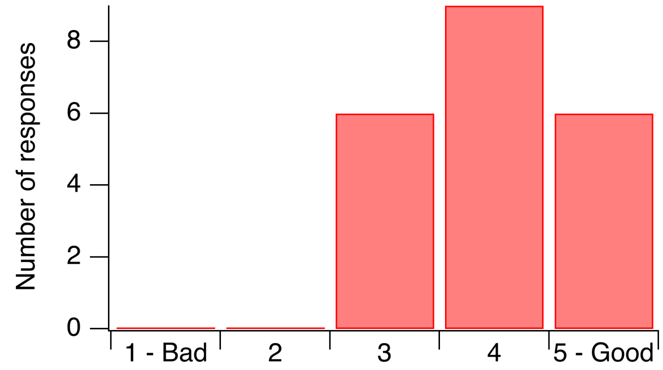
- Total of 22 responses

- 15 Engineering
- 8 System Owner
- 7 Procurement
- 5 Construction
- 3 Finance
- 2 Insurance
- 1 Policy

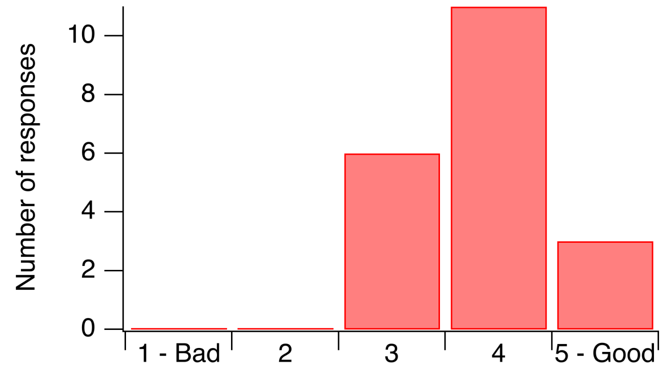
Survey results – what are you worried about?

How would you rate:

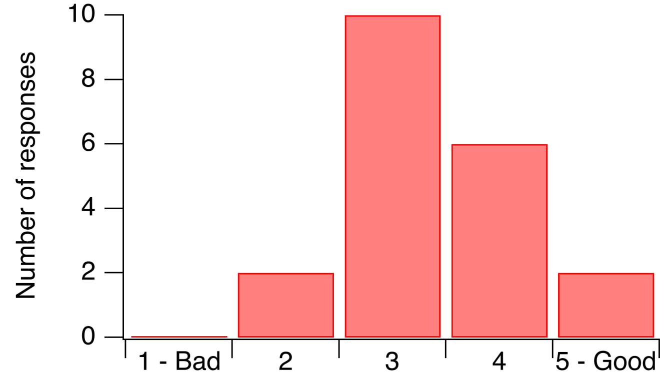
- The quality and reliability of your independent engineering reports?



- long-term reliability of your PV modules as manufactured?



- long-term reliability of your PV modules as installed?



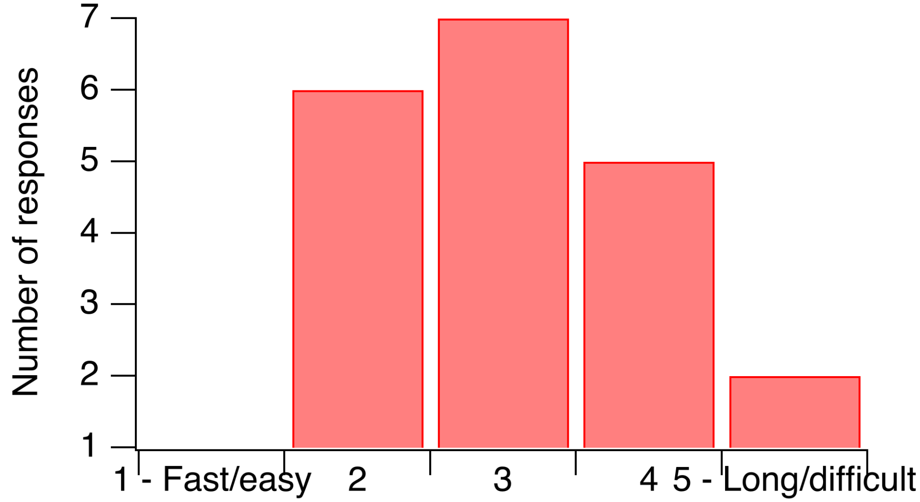
Comments

- I wish independent engineering **reports were more detailed in explaining their test procedures**
- Module quality and more importantly the QMS employed by major manufacturers are maturing and thus less of a concern for long term project financial performance. **Installation quality and lack of uniform QMS at EPC/installer is an ongoing threat** to long term financial performance of PV assets.
- **Installation can be weakness**

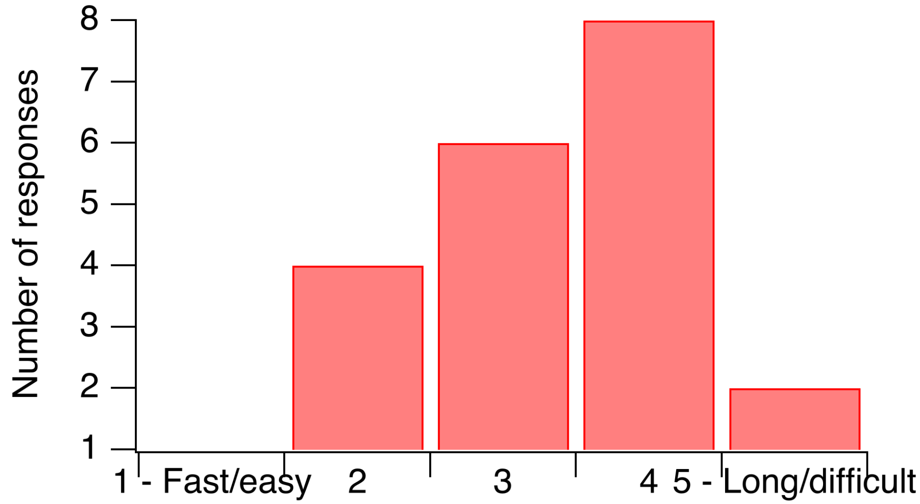
Survey results – what are you worried about?

How would you rate your ability to get:

- the quality of project engineering reviews you desire?



- the quality of module reliability testing you desire?



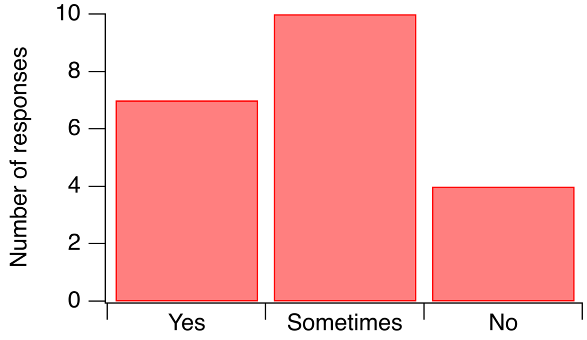
Comments

- Long term reliability studies of modules seem to be hard to come by
- The cost and time of module reliability testing is challenging for project economics
- Getting the module flash test data can be a pain for our EPC partners and can take forever

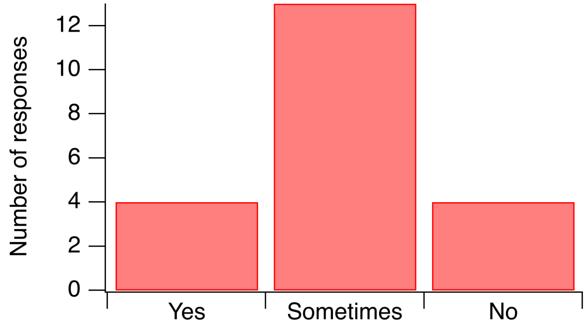
Survey results – what are you worried about?

Do you require:

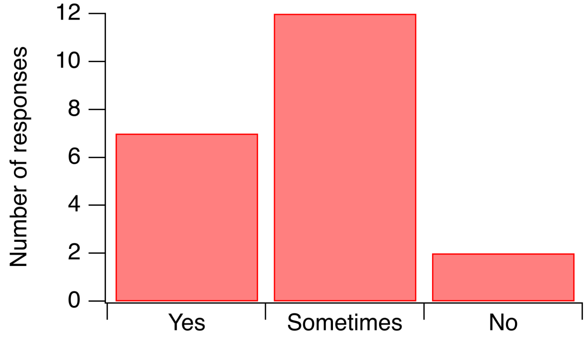
- any independent reliability testing of PV modules?



- any independent factory inspection of PV module manufacturers?



- any reliability testing or factory inspection of other equipment manufacturers, e.g. inverters?



What are key issues?

Could be addressed by standards?

- Module handling standards
- Performance testing
- QMS at the EPC/installer level
- Thermal defects measurement

Areas of due diligence and acceptance testing

- Thermal inspections
- Module degradation
- QMS standardization at the EPC/Installer level

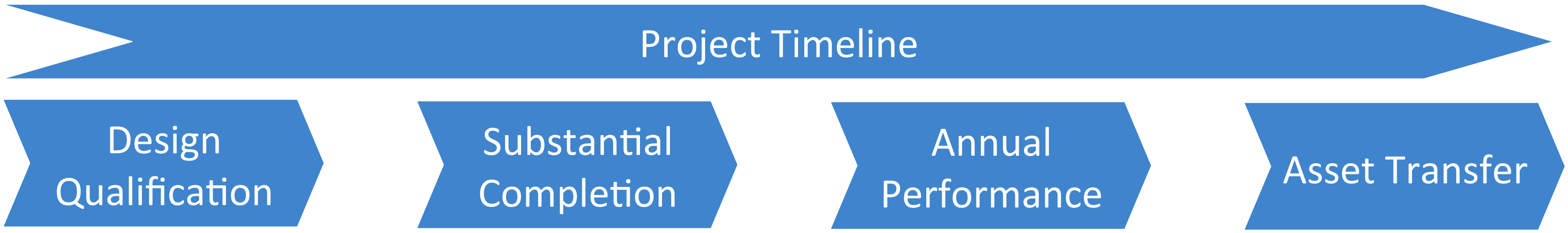
IECRE – International platform for PV standards

- IECRE was created in 2014 to fill this need:
  - Operates a single, global certification system
  - Builds on technical standards written under IEC and other standards organizations
  - Works harmoniously with local codes
- Key elements of IECRE are now in place – motivating today's workshop

IECRE.org

IEC → Technical standards → IECRE → Certificates for system

PV System Timeline and Certificates



- Need confidence that *each step* during a project is completed correctly
- For example:
  - Design qualification (ready to proceed with construction)
  - Substantial completion (ready to operate)
  - Annual performance (final completion, or annual check up)
  - Asset transfer (define health of plant as basis for acquisition)

PV System Timeline and Certificates

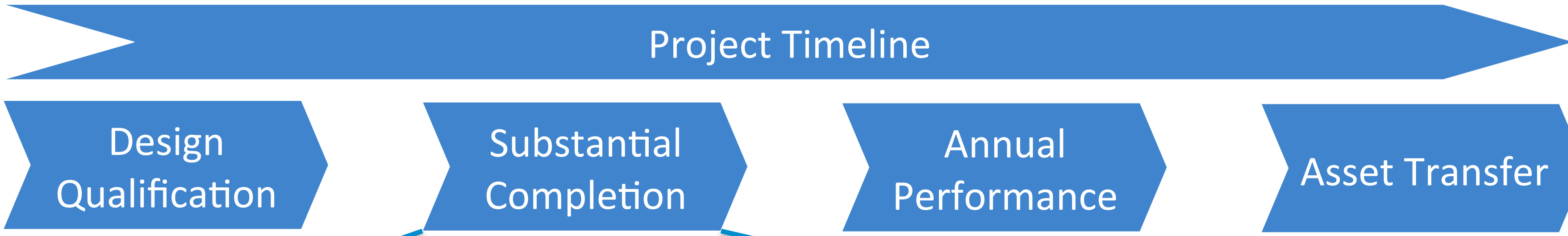
Project Timeline

Design Qualification → Substantial Completion → Annual Performance → Asset Transfer

Example considerations

- Local code requirements met
- **Component selection**
  - **Qualified for application**
  - **Quality control during manufacturing**
- Safety:
  - Restricted access if appropriate
  - Continuously monitored
  - Overcurrent protection
- Good design
  - Shading considered
  - Trenching

PV System Timeline and Certificates



Example considerations

- Local code requirements met
- Commissioning completed
- **Component quality verified**
- **Quality management during installation**
    - **Workers trained with oversight**
    - **Any design changes reviewed**
    - **Continuous improvement**
- **Performance check**
    - **Does power output match the design?**

PV System Timeline and Certificates

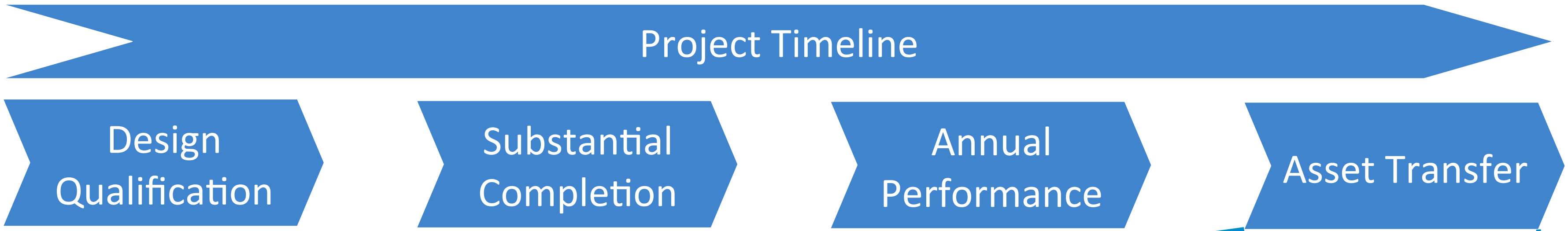
Project Timeline

Design Qualification → Substantial Completion → Annual Performance → Asset Transfer

Example considerations

- **Based on measured weather and original model, does plant perform as expected?**
  - **Energy availability** (e.g. if inverters break, the plant could be "off line" and unavailable)
  - **Performance index** (measured performance divided by expected performance based on measured weather)
- **O&M costs**
  - Relative to planned cost, how much did it cost to keep the plant running?

PV System Timeline and Certificates



Example considerations

- Has plant output been consistent with original model?
- Have O&M costs been consistent with original model?
- Is there evidence of problems to come? (Cracked cells, weeds growing through the modules, hot spots)

Today's workshop – Part 1

- Panel Discussion
  - Greg Ball will describe philosophy of IEC/IECRE standards development – how these have been designed to be useful to the community
  - Jon Previtali (Wells Fargo) will describe the benefit he sees from standardization from a banker's perspective
  - Edward Hsi (Swiss RE) will describe the benefit he sees from standardization from an insurer's perspective
  - Panel and audience discussion:
    - Are we agreed upon the benefit of standardization?
    - Are we agreed that IECRE is the right standard to adopt?
    - How do we move toward standardization?

Some sticky issues to discuss

- What about the companies that have differentiated themselves by giving a higher level of service? Is standardization in their best interest?

- Who should drive the adoption?

- Practically, what would it mean? How do we do it?

Today's workshop – Part 2

- Breakout sessions – start with introductions then break into smaller groups
  - Component testing and quality control
  - Design, installation, commissioning
  - Asset transfer assessment
  - Rating system
- Things to think about:
  - To use IECRE's approach, what would I change from what I'm doing now? (just simplified contract, or change in procedures?)
  - How could IECRE be made to be more useful and speed its adoption?

IECRE – Streamlining & Standardizing Due Diligence

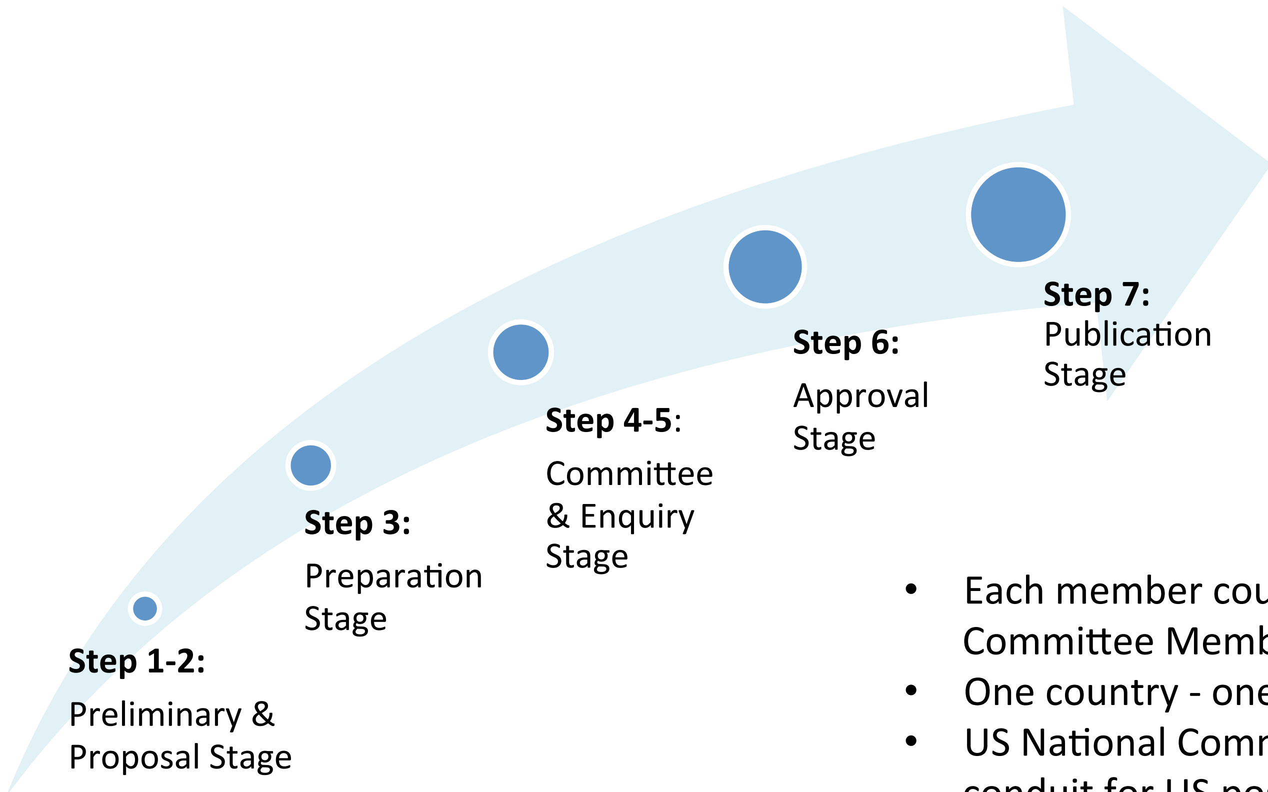
IECRE

Overview of International Standards for Assessing PV Power Plant Quality

Greg Ball, Tesla Energy
Co-Convenor, IEC TC 82 Working Group 6

SPI 2017 – Las Vegas, Nevada
September 10, 2017

International Electrotechnical Commission (IEC) Standards Development Process



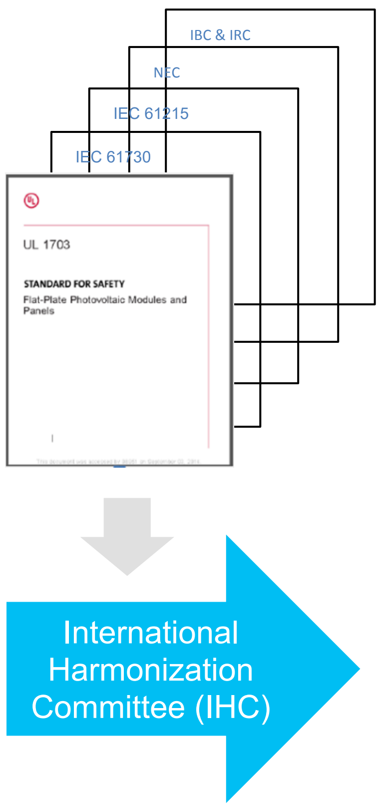
IEC 61730
IEC 61215

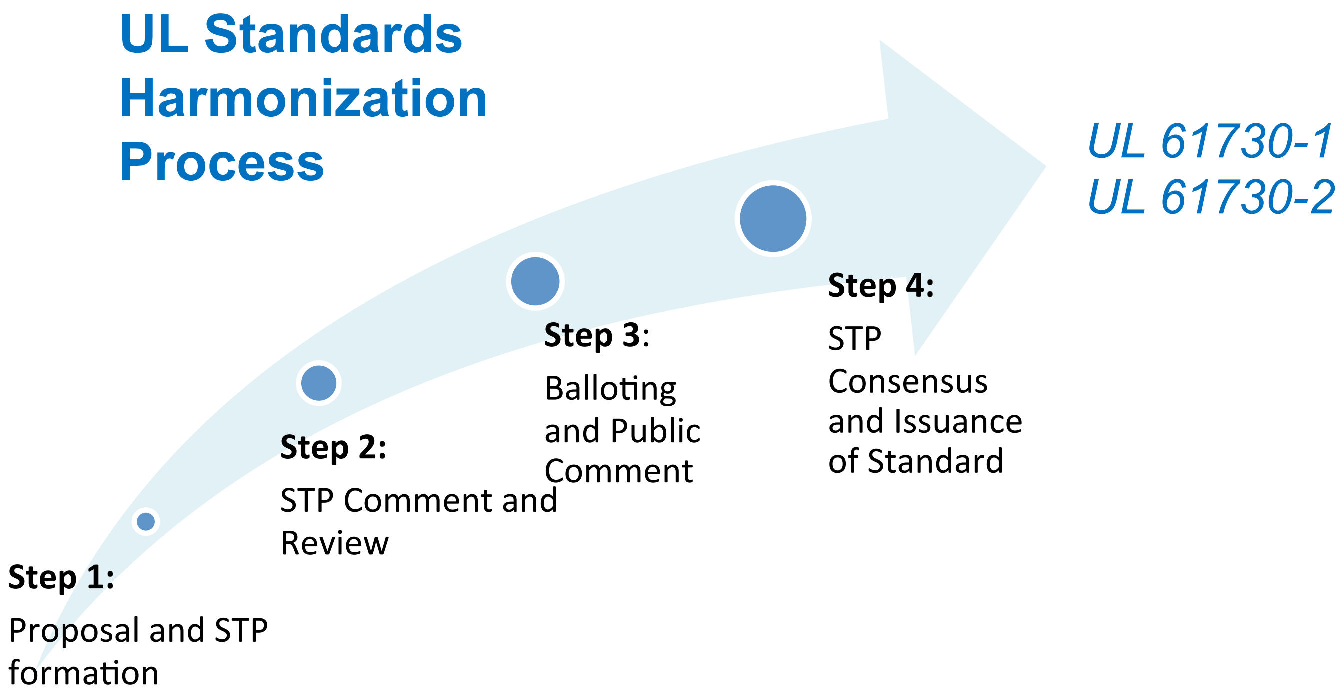
(50+ PV related)

- Each member country has a National Committee Member
- One country - one vote
- US National Committee serves as conduit for US positions

IECRE – Streamlining & Standardizing Due Diligence

Standards Harmonization Process





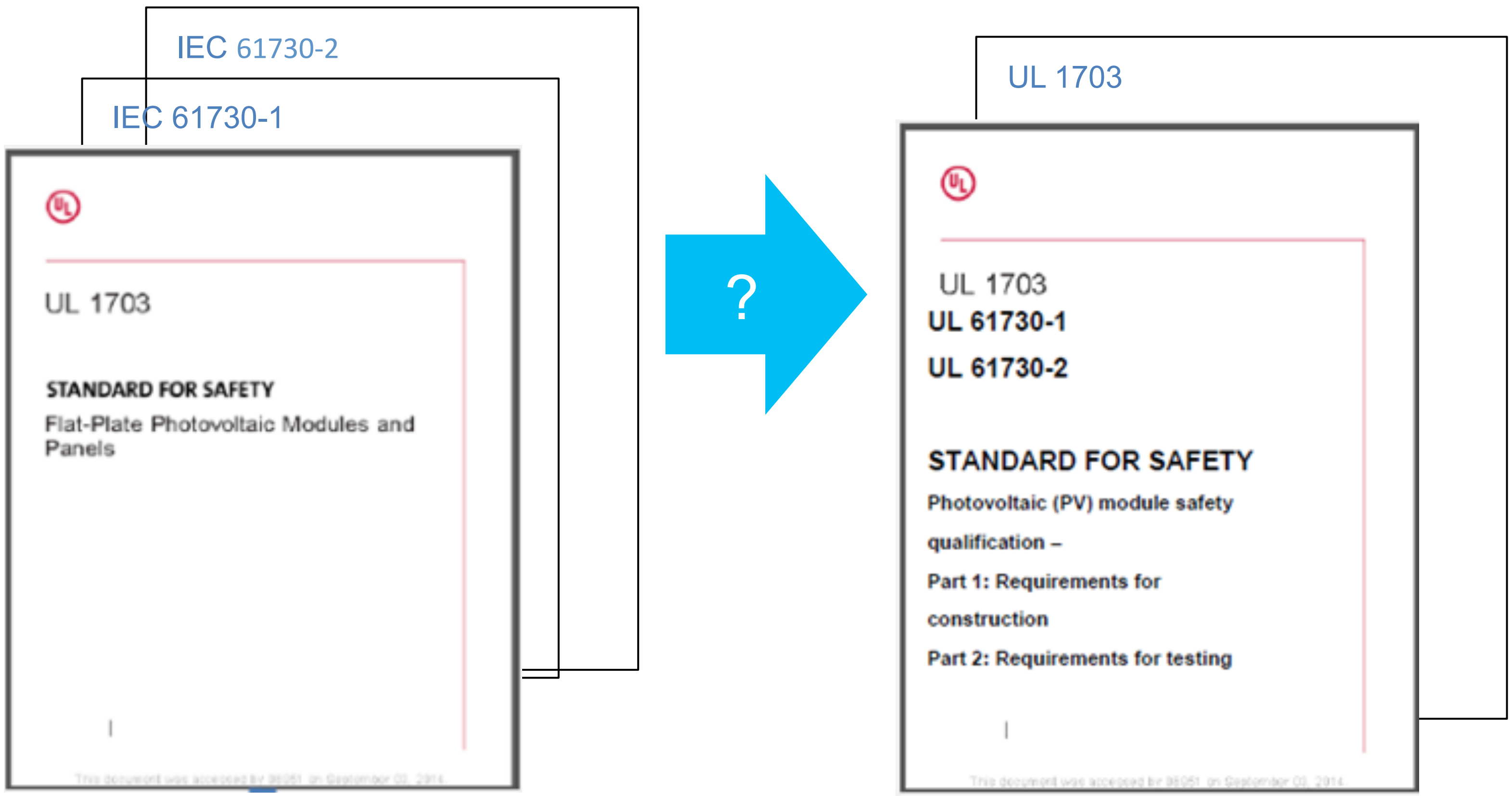
Considerations:

- Codes
- Component requirements
- Normative references
- Technical issues
- Permissions
- Other

*STP - Standards Technical Panel

IECRE – Streamlining & Standardizing Due Diligence

Harmonization and National Differences



In the Queue….

Standard	Title	ANSI / UL
IEC 61215-1	**PV modules - Design qualification and type approval - Part 1: Test requirements**	**YES**
IEC 61215-1-1	**Part 1-1: Special requirements for testing of crystalline silicon PV modules**	**YES**
IEC 61215-1-2	Part 1-2: Special requirements for testing of thin-film Cadmium Telluride (CdTe) based PV modules	
IEC 61215-1-3	Part 1-3: Special requirements for testing of thin-film amorphous silicon based PV modules	
IEC 61215-1-4	Part 1-4: Special requirements for testing of thin-film Cu(In,GA)(S,Se) based PV modules	
IEC 61215-1-5	Part 1-5: Special requirements for testing of flexible (non-glass superstrate) PV modules	
IEC 61215-2	**PV modules - Design qualification and type approval - Part 2: Test procedures**	**YES**
IEC 61724-1	PV system performance - Part 1: Monitoring	
IEC TS 61724-2	PV system performance - Part 2: Capacity evaluation method	
IEC TS 61724-3	PV system performance - Part 3: Energy evaluation method	
IEC TS 61724-4	PV system performance - Part 4: Degradation rate evaluation method	
IEC 61730-1	PV module safety qualification - Part 1: Requirements for construction	
IEC 61730-2	PV module safety qualification - Part 2: Requirements for testing	
IEC 62093	**Balance-of-system components for PV systems - Design qualification natural environments**	**YES**
IEC 62108:2016	Concentrator PV (CPV) modules and assemblies - Design qualification and type approval	
IEC 62109-1:2010	**Safety of power converters for use in PV power systems - Part 1: General requirements**	**YES**
IEC 62109-2:2011	Safety of power converters for use in PV power systems - Part 2: Particular requirements for inverters	
IEC 62109-3	Safety of power converters for use in PV power systems - Part 3: Particular requirements for electronic devices in combination with PV elements	
IEC 62446-1	PV systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection	
IEC 62446-2	PV systems - Requirements for testing, documentation and maintenance - Part 2: Grid connected systems - Maintenance of PV systems	
IEC TS 62446-3	PV systems - Requirements for testing, documentation and maintenance - Part 3: Outdoor infrared thermography of PV modules and plants	
IEC TS 62738	Design guidelines and recommendations for ground-mounted PV power plants	

IECRE – Streamlining & Standardizing Due Diligence

Site Selection (Project Development)	• Site assessment – soils or other structural evaluation • Utility interconnect and access hurdles • Energy prediction – preliminary design
Component Certifications (OD 401)	• Module standards IEC 61730, 61215, etc. • Inverter standards IEC 62109, 62093, 62891, 62920, etc. • Tracker and other BOS Standards – IEC 63104, 62817, etc.
Project Execution (OD 401)	• Design – IEC 62548, 62738 • Performance and Monitoring - 61724 series • Commissioning and maintenance – 62446 series
Quality Assurance Guidelines (OD 405)	• Module Design Qual & Type Approval – IEC 62941 • PV System Installation IEC 63049 • Power Conversion Equip (New Project TS 82-1278)

IECRE – Streamlining & Standardizing Due Diligence

IEC 61730-1

Edition 2.0 2016-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Photovoltaic (PV) module safety qualification –
Part 1: Requirements for construction

IEC 61730

- Module safety standard
- Shock, damage, fire…
- Similar to UL 1703, in the U.S.

IEC 61215-1

Edition 1.0 2016-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Terrestrial photovoltaic (PV) modules – Design qualification and type approval –
Part 1: Test requirements

IEC 61215

- Module design qualification
- Durability, performance
- Widely required

Component Safety – OD 401 and OD 405

IEC 62109-1, -2

- Inverter safety standard
- Similar to U.S. UL 1741
- Widely used internationally
- UL 62109-1 already adopted
- UL 62109-2 in adoption process
  - Forum for much improved ground fault protection


IEC 62109-1

Edition 1.0 2010-04

INTERNATIONAL STANDARD

colour inside

Safety of power converters for use in photovoltaic power systems –
Part 1: General requirements

Safety of power converters for use in PV power systems Part 1: General requirements

Part 2: Particular requirements for inverters

Component Safety – OD 401

IEC 62548

- PV system design
- Many similarities to NEC Art. 690
  - Additional design considerations
  - More information
- For US IECRE implementation supplemental to NEC compliance
- Largely harmonized with IEC 60364-7-712


IEC 62548

Edition 1.0 2016-09

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Photovoltaic (PV) arrays – Design requirements

Groupes photovoltaïques (PV) – Exigences de conception

Photovoltaic (PV) arrays – Design requirements

Design & Installation - OD 401

Design & Installation - OD 401

IEC TS 62738

- Large scale power plant design and installation
- Exceptions to IEC 62548, focusing on differences from resi and commercial PV.
- Sites restricted from public access
- Detailed guidelines relevant to large ground-mount installations

Voting Result APPROVED

Document 82/1291/DTS

Project : IEC TS 62738 ED1

IEC TS 62738 ED1: Design guidelines and recommendations for ground-mounted photovoltaic power plants

Reference	Circulation date	Closing date	Downloads
82/1291/DTS	2017-06-02	2017-08-25	
Compilation of Comments			
CC file			

Vote for P-Members

P-Members Voting	P-Members In favour	In favour %	Criteria	Result
22	22	100	>=66.7%	APPROVED

Design guidelines and recommendations for ground-mounted PV power plants

IEC 62446-1

- Original 62446 released in 2009
- One of highest selling PV standards
- Not a performance standard
- Inspection criteria
- Functional testing
- Faults/failures
- Optional test regimes

Not widely used in the US yet, partly due to the references to IEC standards rather than to UL standards and the NEC.


IEC 62446-1

Edition 1.0 2016-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance –
Part 1: Grid connected systems – Documentation, commissioning tests and inspection

PV systems - Requirements for testing, documentation and maintenance

Part 1: Grid connected systems – Documentation, commissioning tests and inspection

Commissioning - OD 401, 404

A Standardized Approach to Technical Due Diligence Using IECRE

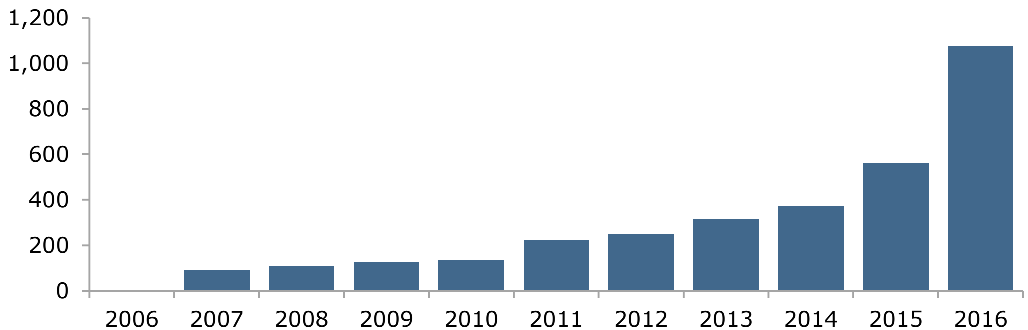
Jon Previtali, Director of Technology & Technical Services
SPI, September 2017

Together we'll go far

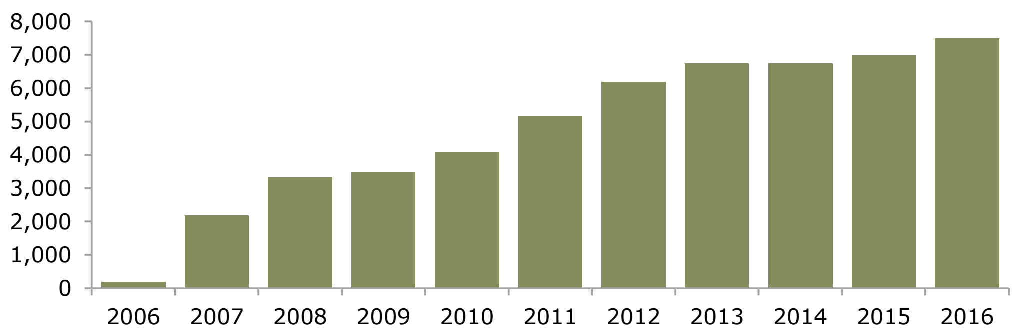
Wells Fargo Renewable Energy & Environmental Finance (REEF)

- Established in 2006 to **provide *tax equity* capital for the renewable energy industry.**
- Today, the group has **28 professionals with decades of combined experience in renewable energy.**
- Collaboration with **Wells Fargo CleanTech Banking** which offers traditional banking services & relationship management.

Cumulative Solar Projects Financed by Wells Fargo (MWDC)

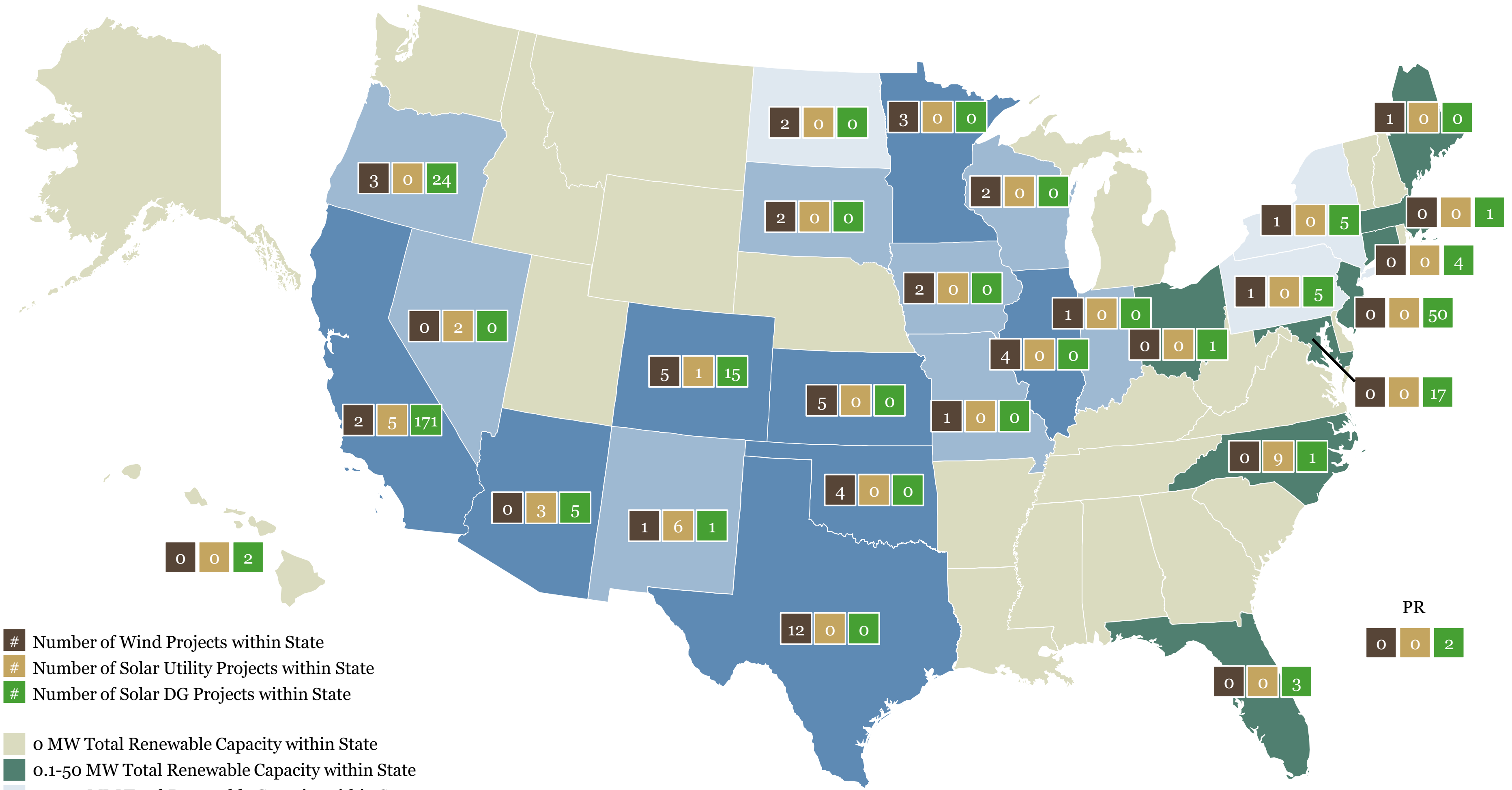


Cumulative Wind Projects Financed by Wells Fargo (MWAC)



Wells Fargo Renewable Energy & Environmental Finance (REEF)

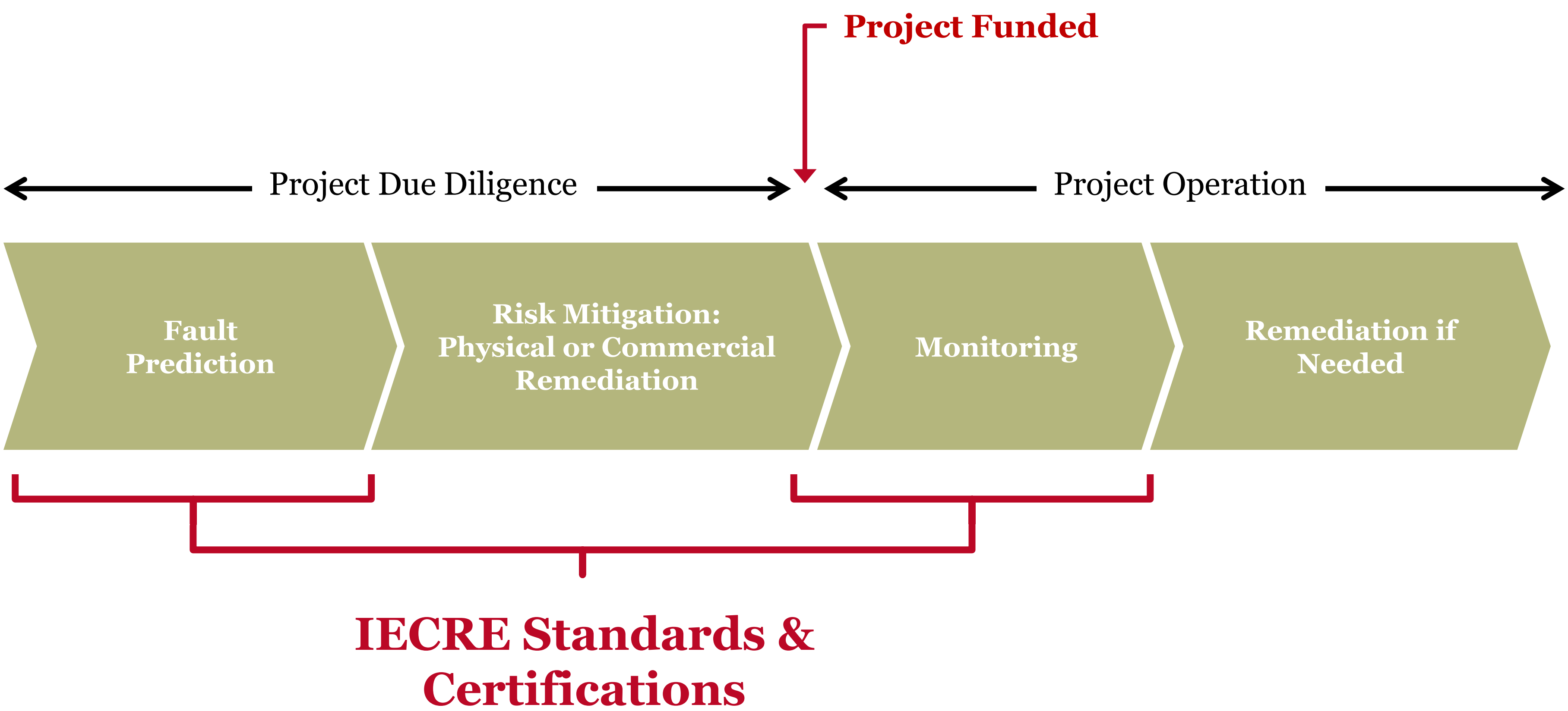
8+GW portfolio comprised of 50+ Wind projects and 300+ Solar projects



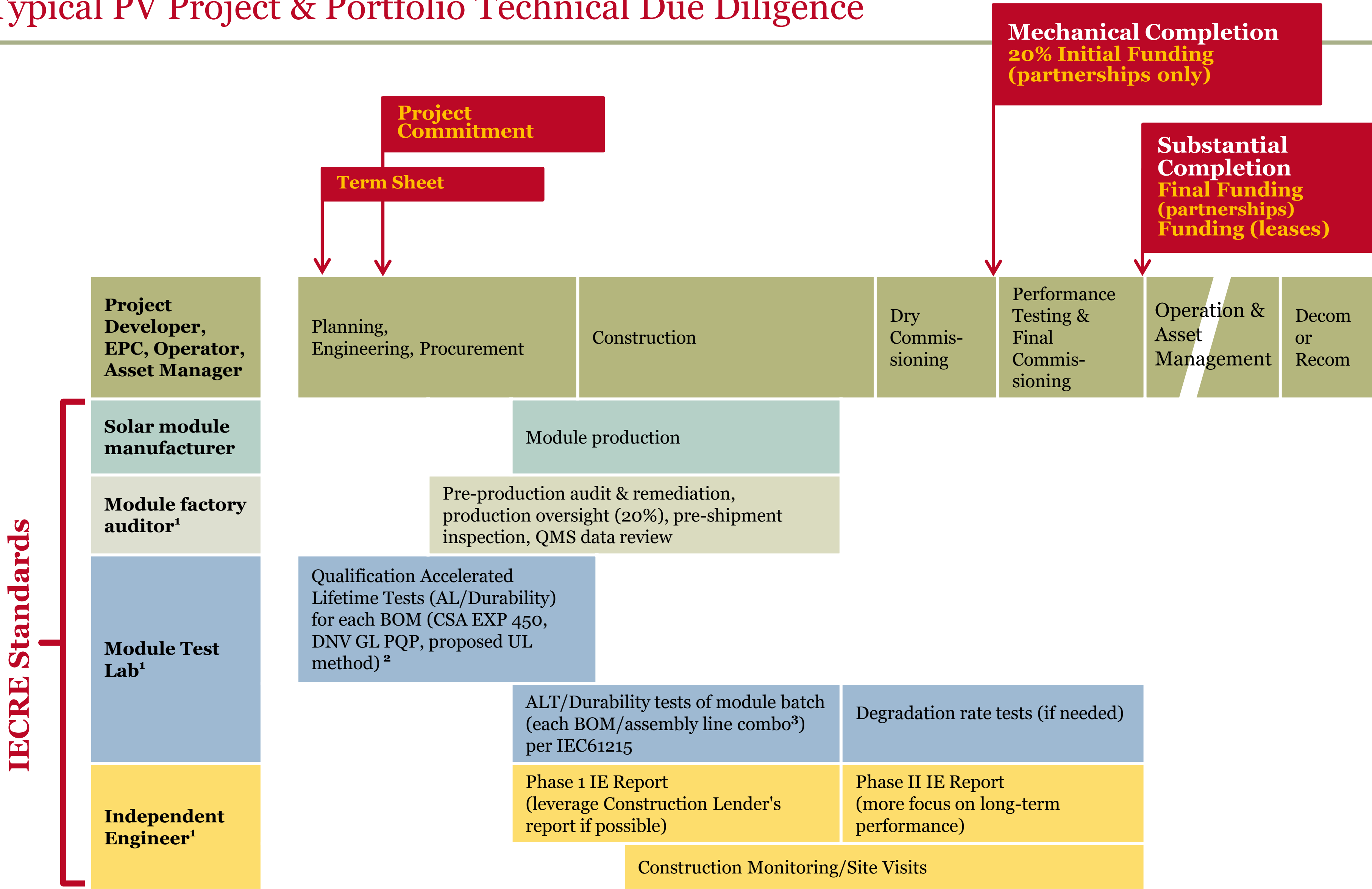
- # Number of Wind Projects within State
- # Number of Solar Utility Projects within State
- # Number of Solar DG Projects within State

- 0 MW Total Renewable Capacity within State
- 0.1-50 MW Total Renewable Capacity within State
- 51-150 MW Total Renewable Capacity within State
- 151-300 MW Total Renewable Capacity within State
- > 300 MW Total Renewable Capacity within State

Project Technical Due Diligence Goal: Predict and Mitigate Faults



Typical PV Project & Portfolio Technical Due Diligence



1 Sampling techniques and expert judgement based on record can be used to reduce cost
2 Ideally done in advance of module production, but could be done at start of production
3 Unless factory auditor confirms consistency between assembly lines

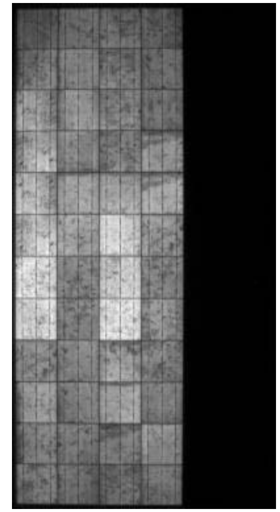
Thank you!

Jonathan.m.previtali@wellsfargo.com
(415) 947-1980

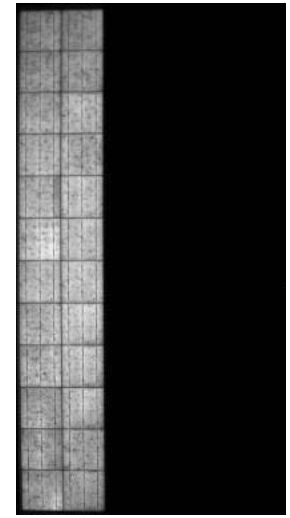
Appendix 1: Module Fault Detection & Remediation Examples

Example 1: Diode Failures

1) Fault Prediction: IEC 61215 + extended testing

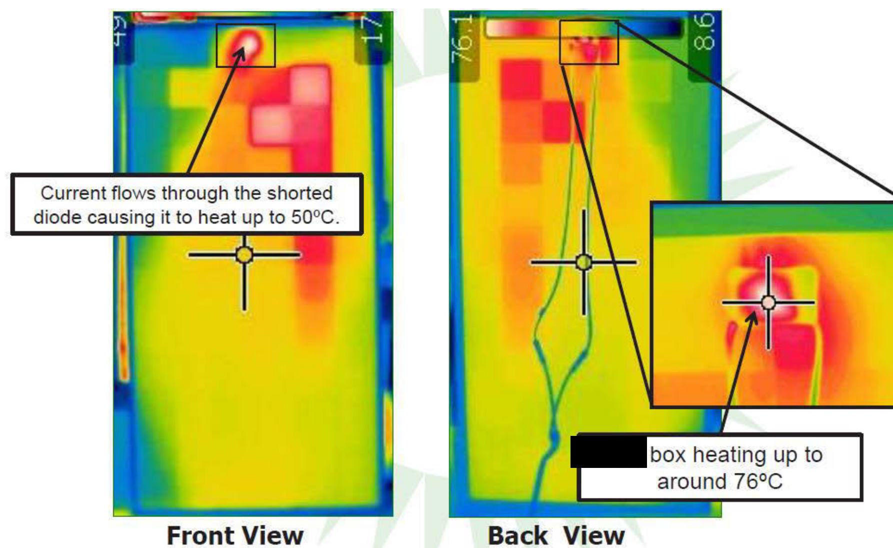


Diode failure at TC400



2-diodes fail at TC600

2) Fault Risk Mitigation: RCA, estimate of yield impact, yearly IR scans, extended warranty including serial defect protection

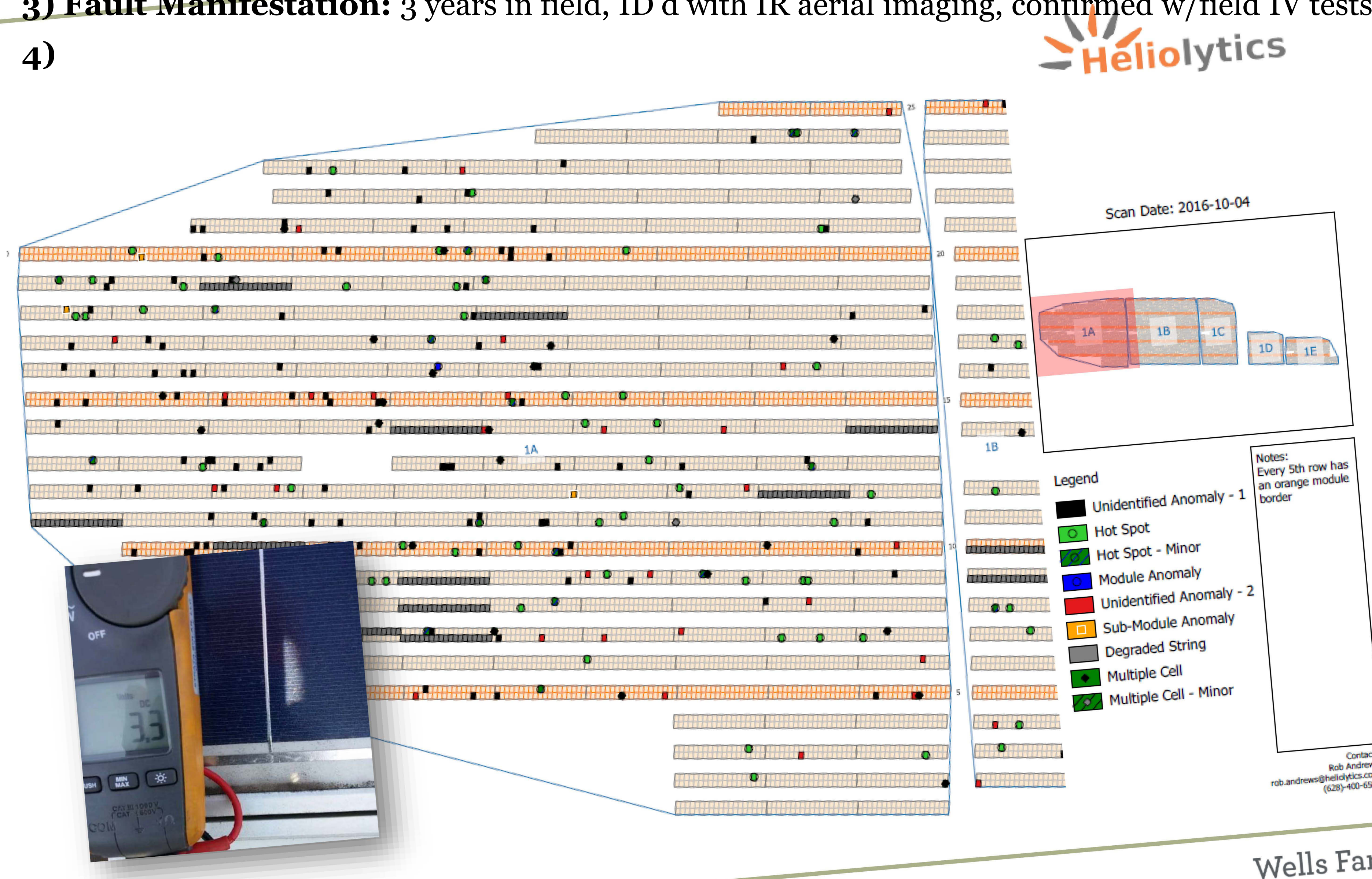


Failed diodes at lab under sun used to inform field technicians doing IR scans

Example 1: Diode Failures

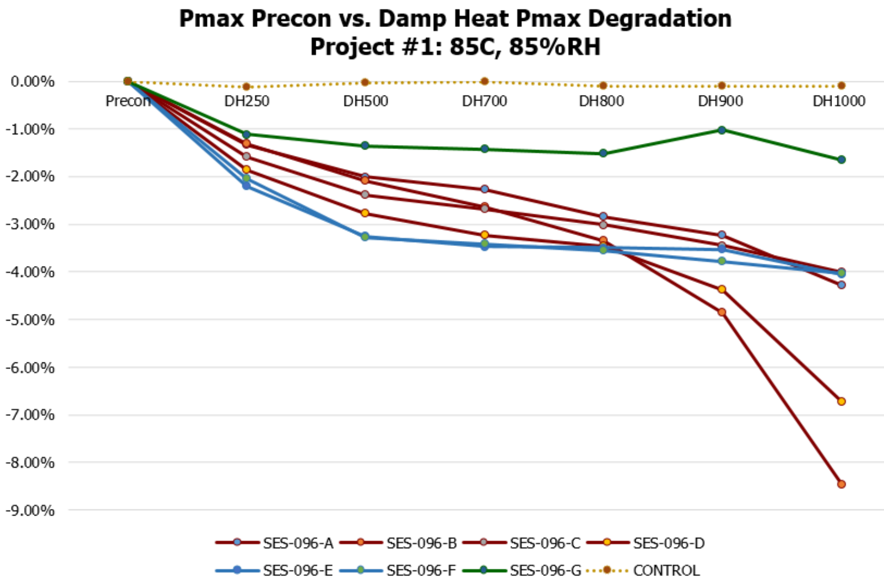
3) Fault Manifestation: 3 years in field, ID'd with IR aerial imaging, confirmed w/field IV tests

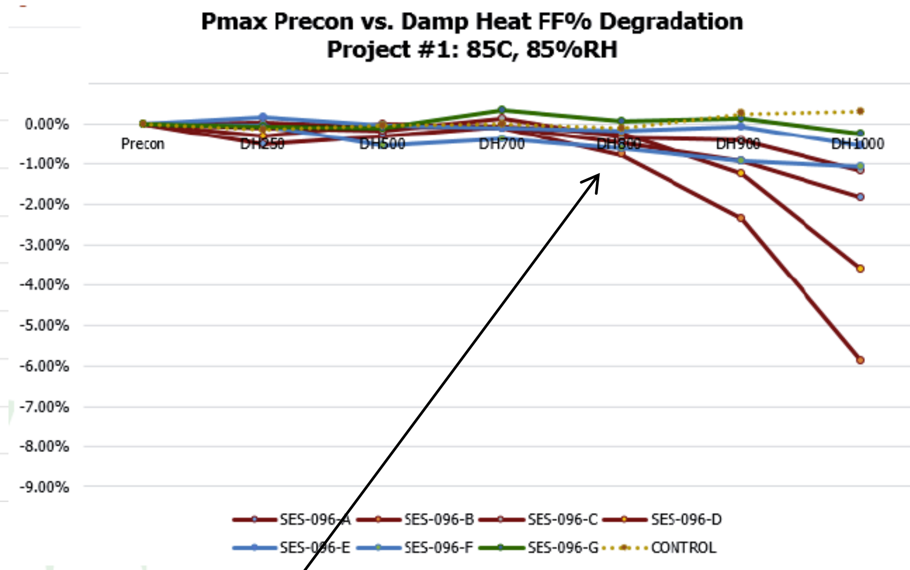
4)

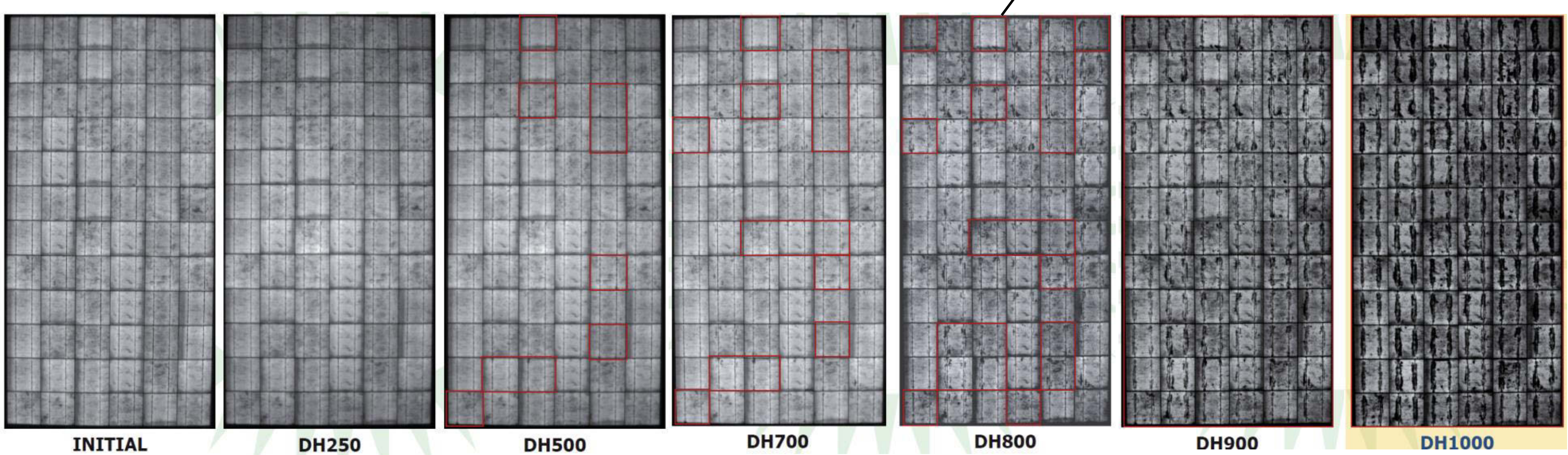


Example 2: Possible PV Cell Corrosion

1) Fault Prediction: IEC 61215 + extended testing + degradation rate testing (as part of mitigation), EL darkening correlating with fill factor loss starting at DH800







2) Fault Risk Mitigation: RCA, estimate of yield impact via degradation rate test & location-specific modeling, extended warranty, letter of credit, periodic IV test of instrumented sub-array, periodic PR test of project, cash trapped to replace modules if high degradation rate observed.

3) Fault Manifestation: None observed after two years

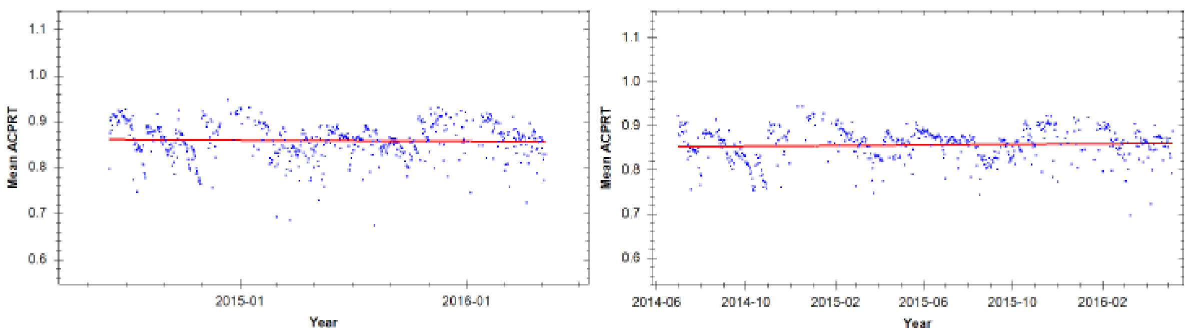
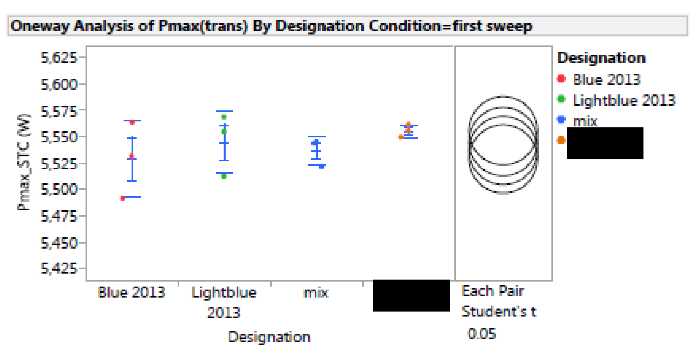


Figure 2. System performance using the ACPRT metric for the [redacted] projects [redacted]he blue points represent daily mean ACPRT values, and the red lines represent linear regression fits to the daily data.

In addition, string-level IV curves were collected to evaluate the performance of the module categories. The data were collected on 2016-03-16 using a Solmetric PVA1000 measurement tool and adjusted to standard test conditions of 1000 W/m^2 irradiance and 25 °C temperature. The performance differences between the groups were found to be less than 0.5%, confirming that accelerated degradation has not been observed.



Example 3: Junction Box Lid Failure

1) Fault Prediction: IEC 61215 + extended testing on two utility scale projects show PPE (polyphenylene ether) junction box lid failure **AFTER** many untested modules are deployed on DG projects…

Lid fails after DH1000

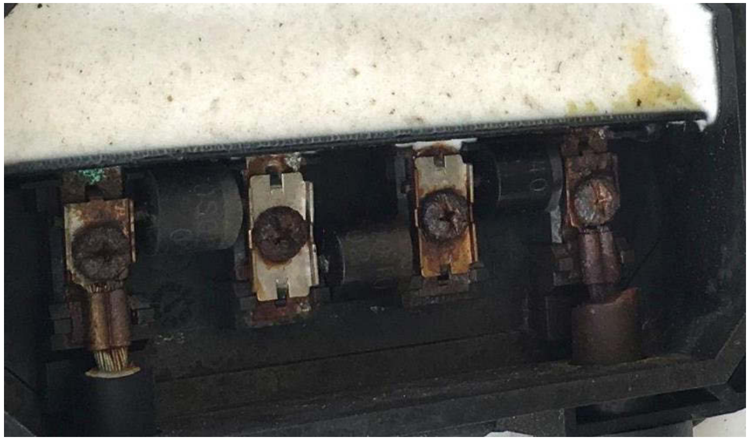
2) Fault Risk Mitigation: RCA, extended warranty, letter of credit, FEA (table below), IE review, lid redesign & replacement, field inspections, *no reliability testing…which proved to be a mistake.*

Finite Element Analysis (FEA) results

Pin Material Strength, kg	27.72
Measured old pin force, kg	17.82
Measured new pin force, kg	5.74
Safety Factor, Old Design @ 25C	1.56
Safety Factor, Old Design at 100C	1.38
Safety Factor, New design at 25C	4.83
Safety Factor, New design at 100C	3.45

Example 3: Junction Box Lid Failure

3) Fault Manifestation: Many failed lids observed in original *and* replacement lid



Corrosion probably due to loss of replacement lid.
3-year old rooftop project near CA coast.

4) Fault Remediation: Lid redesign with new material, ALT testing (table below), additional lid redesign & replacement, field inspections: ***module replacement for a small portion of total modules with severe corrosion.***

Lid Type	Stress	Amount	N	Failure Rate	
1	DH	1000	23	52%	2014 testing
2	DH	1000	145	2%	2014 testing
2	DH	2000	23	4%	2014 testing
2	HF	20/40	12	0%	RETC
2	HF	60	12	8%	RETC
2	HF	80	12	17%	RETC
2	HF	100	12	25%	RETC
2	TC / HF	50 / 20	20	10%	2014 + RETC
2	TC / HF	100 / 40	10	0%	RETC
4	DH	1000	24	0%	RETC
4	DH	2000	22	0%	RETC
4	HF	20/40/60/80	36	0%	RETC
4	HF	100	10	0%	RETC
4	TC / HF	50 / 20	34	0%	RETC
4	TC / HF	100 / 40	30	0%	RETC

Accelerated Lifetime Testing (ALT) results

Appendix 2: IE Scopes of Work

PV & Wind Projects, PV-ESS Projects and Module Accelerated Lifetime Testing (ALT)*

* Module Factory Audit SOWs available from Factory Auditors

PV Project Technical Due Diligence Scope of Work (updated 9/2017 and now includes wind, construction loans)

Solar, Wind IE Report SOW, Scorecard and Q/A Log

DG Portfolio Solar	Utility Scale Solar	Utility Scale Wind	Engineering (or other) Service if applicable	Solar Standard	Construction Loan: Ideally Pre-Construction, or Early Construction	Commitment to Fund: Ideally Pre-Construction, or Early Construction	Periodic Throughout Construction	Initial Funding for Partnership (upon Mechanical Completion)	Final Funding for Partnership (upon Substantial or Final Completion)	Post-Funding
								Final Funding for Sale Leaseback (at Substantial or Final Completion)		
x	x		***PV Project Certificate***	IECRE OD-401				x		
x	x		***Module Factory Audits***	OD-405-1 to 3						
x	x		Pre-production audit and remediation as-needed		x	x				
x	x		Production oversight and remediation as-needed (20% of assembly time)		x	x				
x	x		Pre-shipment inspection (visual, EL, flash test of random sample)		x	x				
x	x		QMS (quality management system) data review		x	x				
x	x		***Module Reliability Testing (if needed based on audit)***							
x	x		Module Pre-Qualification Tests (IEC and Extended Testing)	See Module ALT tab	x	x				
x	x		Statistical Module Batch Tests (each BOM/factory combo)	See Module ALT tab	x	x				
x	x		Degradation Rate Characterization Tests	See Module ALT tab	x	x				
x	x	x	***Equipment Review***							
		x	Wind Turbines, components, safe harbor status, storage records		x	x				
		x	Wind turbine suitability to site							
x	x		PV modules		x	x				
x	x		Inverters		x	x				
x	x		Racking, Tracker or Parking Structure		x	x				
x	x		Medium Voltage Transformers		x	x				
	x	x	Generation Step-up Transformers		x	x				
x	x		Data Acquisition System/Meters		x	x				
	x	x	SCADA System/Meters		x	x				
x	x	x	Communication Infrastructure		x	x				
x	x	x	Meteorological Station		x	x				
x	x		Other material equipment if any		x	x				

DG Portfolio Solar	Utility Scale Solar	Utility Scale Wind	Engineering (or other) Service if applicable	Solar Standard	Construction Loan: Ideally Pre-Construction, or Early Construction	Commitment to Fund: Ideally Pre-Construction, or Early Construction	Periodic Throughout Construction	Initial Funding for Partnership (upon Mechanical Completion)	Final Funding for Partnership (upon Substantial or Final Completion)	Post-Funding
x	x	x	***Contracts Review (technical only, but including review and gap analysis of various guarantees, tests, operating requirements)***							
x	x	x	PPA		x	x				
	x	x	Merchant Revenue, hedge contract, etc.							
x	x	x	EPC including substation(s)		x	x				
x	x	x	EPC schedule		x	x				
	x	x	EPC site access		x	x				
x	x	x	O&M - Preventative Maintenance		x	x				
x	x	x	O&M - Corrective Maintenance		x	x				
x	x	x	O&M - Time & Materials or Other Work		x	x				
x	x		Washing Plan		x	x				
x	x	x	Asset Management		x	x				
x	x	x	Monitoring Service Provider		x	x				
x	x	x	Spare Parts List						x	
	x	x	Shared Facilities & Cotenancy Agreements							
x	x	x	Decommissioning		x	x				
x	x	x	Site Lease		x	x				
		x	Buildout Agreement		x	x				
x	x	x	Others if needed		x	x				
x	x	x	***Contractors Review***							
x	x	x	EPC, high voltage (if applicable) and any other main subs		x	x				
x	x	x	O&M and main subs		x	x				
x	x	x	Asset Management including infrastructure (ticketing, billing system, etc.)		x	x				
x	x	x	Monitoring Service Provider		x	x				
x	x	x	Others if needed, Scheduling Coordinator		x	x				

PV Project Technical Due Diligence Scope of Work

DG Portfolio Solar	Utility Scale Solar	Utility Scale Wind	Engineering (or other) Service if applicable	Solar Standard	Construction Loan: Ideally Pre-Construction, or Early Construction	Commitment to Fund: Ideally Pre-Construction, or Early Construction	Periodic Throughout Construction	Initial Funding for Partnership (upon Mechanical Completion)	Final Funding for Partnership (upon Substantial or Final Completion)	Post-Funding
x	x	x	***Design Review (50% sample with PE stamp review for Solar DG)***	IECRE OD-403 (pending)	Draft Drawings	Final Drawings				
	x	x	Geotech report		x	x				
	x	x	Civil including foundations, earthwork, drainage		x	x				
x	x	x	Electrical including substation(s) and gen-tie line.		x	x				
x	x	x	Structural including wind loading (for both ground and roof), structural roof integrity and post pull-out test results for ground (if needed)		x	x				
x	x	x	Mechanical		x	x				
	x	x	Architectural (for on-site buildings only)		x	x				
x	x	x	***Site Review***		x	x				
x	x	x	Site plan including access, transmission and substation(s)		x	x				
	x	x	System impact, facility or interconnection study		x	x				
	x	x	Archeological, cultural and local community impact		x	x				
x	x	x	Equator Principals (outside US only)							
	x	x	Hazardous waste on-site		x	x				
	x	x	Off-site contamination		x	x				
	x	x	Endangered species		x	x				
x			Roof condition		x	x				
	x	x	Land condition including flood plane		x	x				
x	x	x	***Operational Budget Review (including reserve accounts, confirm rates are "market")***		x	x				
x	x	x	O&M		x	x			x	
x	x	x	Spare Parts List		x	x				
x	x	x	Asset Management, reconciled with Managing Partner responsibilities		x	x				
x	x	x	Monitoring Service Provider		x	x				
x	x	x	Decommissioning		x	x				
x	x	x	Others if needed		x	x				

PV Project Technical Due Diligence Scope of Work

DG Portfolio Solar	Utility Scale Solar	Utility Scale Wind	Engineering (or other) Service if applicable	Solar Standard	Construction Loan: Ideally Pre-Construction, or Early Construction	Commitment to Fund: Ideally Pre-Construction, or Early Construction	Periodic Throughout Construction	Initial Funding for Partnership (upon Mechanical Completion)	Final Funding for Partnership (upon Substantial or Final Completion)	Post-Funding
x	x	x	***Financial Model Review (pro forma) review***		x	x				
x	x	x	Revenue including TOD if applicable							
x	x	x	Other sources of revenue such as PBI, SRECs.		x	x				
x	x	x	Expenses		x	x				
	x	x	Review of Curtailment Study (may be performed by third-party)		x	x				
x	x	x	***Energy Production Estimate***		x	x				
		x	Wind Resource Assessment/Report		x	x				
x	x		Solar Resource Assessment		x	x				
x	x		PAN file creation or confirmation of validation (module)		x	x				
x	x		OND file creation or conformation and validation (inverter)		x	x				
		x	Turbine power curve review/validation		x	x				
x	x		Loss estimation (curtailment, shading, soiling, snow, etc.)		x	x				
x	x		Load study for non-export systems and loss estimation		x	x				
x	x	x	Independent simulation including Inter-Annual Variability and P50, P75, P90, P99 for 1 and 10 years		x	x				
	x	x	***Transmission and Curtailment Report***							
	x	x	Historical Analysis		x	x				
	x	x	Forward Looking Analysis if curtailment is not compensated.		x	x				
	x	x	Review of network status, upgrades, timeline, budget for adequacy requirement, etc.		x	x				
	x	x	Tracking account estimate (for projects settling on LMP market)		x	x				

PV Project Technical Due Diligence Scope of Work

DG Portfolio Solar	Utility Scale Solar	Utility Scale Wind	Engineering (or other) Service if applicable	Solar Standard	Construction Loan: Ideally Pre-Construction, or Early Construction	Commitment to Fund: Ideally Pre-Construction, or Early Construction	Periodic Throughout Construction	Initial Funding for Partnership (upon Mechanical Completion)	Final Funding for Partnership (upon Substantial or Final Completion)	Post-Funding
x	x	x	***Site Inspections (on-site or remote)***							
			Small DG Photographic (desktop)/Remote Inspection						x	
	x	x	Utility Scale Monthly Physical/On-Site Inspection				x			
x	x	x	Physical/On-Site Inspection at Mechanical Completion (50% sample for DG)					x		
x	x	x	Photographic (desktop)/Remote Inspection at Final Completion						x	
x	x	x	***Mechanical Completion Review***							
x	x	x	Confirmation all major equipment has been installed per plan including substation(s)					x		
x	x	x	Commissioning tests outlined in EPC	IECRE OD-401				x		
x	x		String polarity (if not already covered in short circuit current testing)					x		
x	x		Open circuit voltage and short circuit current testing or the equivalent such as a full coverage IV curve tracer kit or module or system-level infrared imaging audit (if interconnected)					x		
x	x		Grounding continuity					x		
x	x		Megger testing					x		
x	x	x	***Substantial or Final Completion Review***							
x	x	x	Confirmation all construction is complete and equipment commissioned per plan						x	
x	x		Performance Test (at least 5 days for DG, 15 days for utility scale at sufficient solar irradiance), e.g. Energy Yield Tests, Performance Ratio Tests or Capacity Test with energy validation	IECRE OD-401					x	

PV Project Technical Due Diligence Scope of Work

DG Portfolio Solar	Utility Scale Solar	Utility Scale Wind	Engineering (or other) Service if applicable	Solar Standard	Construction Loan: Ideally Pre-Construction, or Early Construction	Commitment to Fund: Ideally Pre-Construction, or Early Construction	Periodic Throughout Construction	Initial Funding for Partnership (upon Mechanical Completion)	Final Funding for Partnership (upon Substantial or Final Completion)	Post-Funding
x	x		Functional, aka Availability Test (continuous, autonomous operation, at least 5 days for DG, 15 days for US at sufficient solar irradiance)						x	
		x	Power Curve Test Plan review							
	x	x	Confirmation of remote SCADA system functionality at operator's facility via screen sharing with operator.						x	
	x		Confirmation of VPN connection to SCADA system at back-up operator's facility via email from investor's back-up operator						x	
x	x		Confirmation of investor's parallel monitoring feed functionality via email from investor's parallel monitoring service, Industrial Evolution.						x	
x	x		Confirmation that required Continuity of Operations Program (COP) documentation has been uploaded to investor share drive.						x	
x	x	x	O&M Manual Review						x	
x	x	x	Punch List Review to confirm no material risk to project operation or pro forma						x	
x	x	x	***Review Supplemental Reports (and reference in IE reports)***						x	
x	x	x	Construction monitoring reports				x	x	x	
x	x		Module lab testing reports					x		
x	x		Module factory audit reports					x		
	x	x	Transmission/Curtailment study					x		
x	x	x	Insurance review					x		
x	x	x	Local tax review					x		
x	x	x	Others if needed					x		

PV Project Technical Due Diligence Scope of Work

DG Portfolio Solar	Utility Scale Solar	Utility Scale Wind	Engineering (or other) Service if applicable	Solar Standard	Construction Loan: Ideally Pre-Construction, or Early Construction	Commitment to Fund: Ideally Pre-Construction, or Early Construction	Periodic Throughout Construction	Initial Funding for Partnership (upon Mechanical Completion)	Final Funding for Partnership (upon Substantial or Final Completion)	Post-Funding
x	x	x	***Reporting***							
x	x	x	IE Reports		x	x				
x	x	x	Supplemental IE Reports (bring-downs)					x	x	
x	x	x	IE Mechanical Completion Certificate	IECRE OD-401				x		
x	x	x	IE Substantial Completion Certificate	IECRE OD-401					x	
x	x	x	IE Opinion Letter (sale leaseback only)						x	
x	x	x	Project Scorecard (this file)				x			
x	x	x	Project Description (as requested by attorneys, leases only)					x		
x	x	x	List of documents relied open for IE opinion (if required by attorneys)					x	x	
x	x	x	***Meetings and Dialogue***							
x	x	x	Kick-off		x	x				
x	x	x	Periodic meetings (semi-monthly or weekly if needed)				x			
x	x	x	Discussion and feedback				x			
x	x	x	Q/A log		x	x	x	x	x	
x	x	x	***Project Administration and Management***							
x	x	x	Data Collection (per Project)		x	x	x			
x	x	x	Project administration (per Project)		x	x				
x	x	x	Project management (per Project)		x	x	x	x	x	
x	x	x	***Post-Funding Activity***							
x	x	x	Confirmation of closing punch list items							x
x	x		Annual PV plant performance certificate	IECRE OD-402						x
		x	Power Curve Test review							x

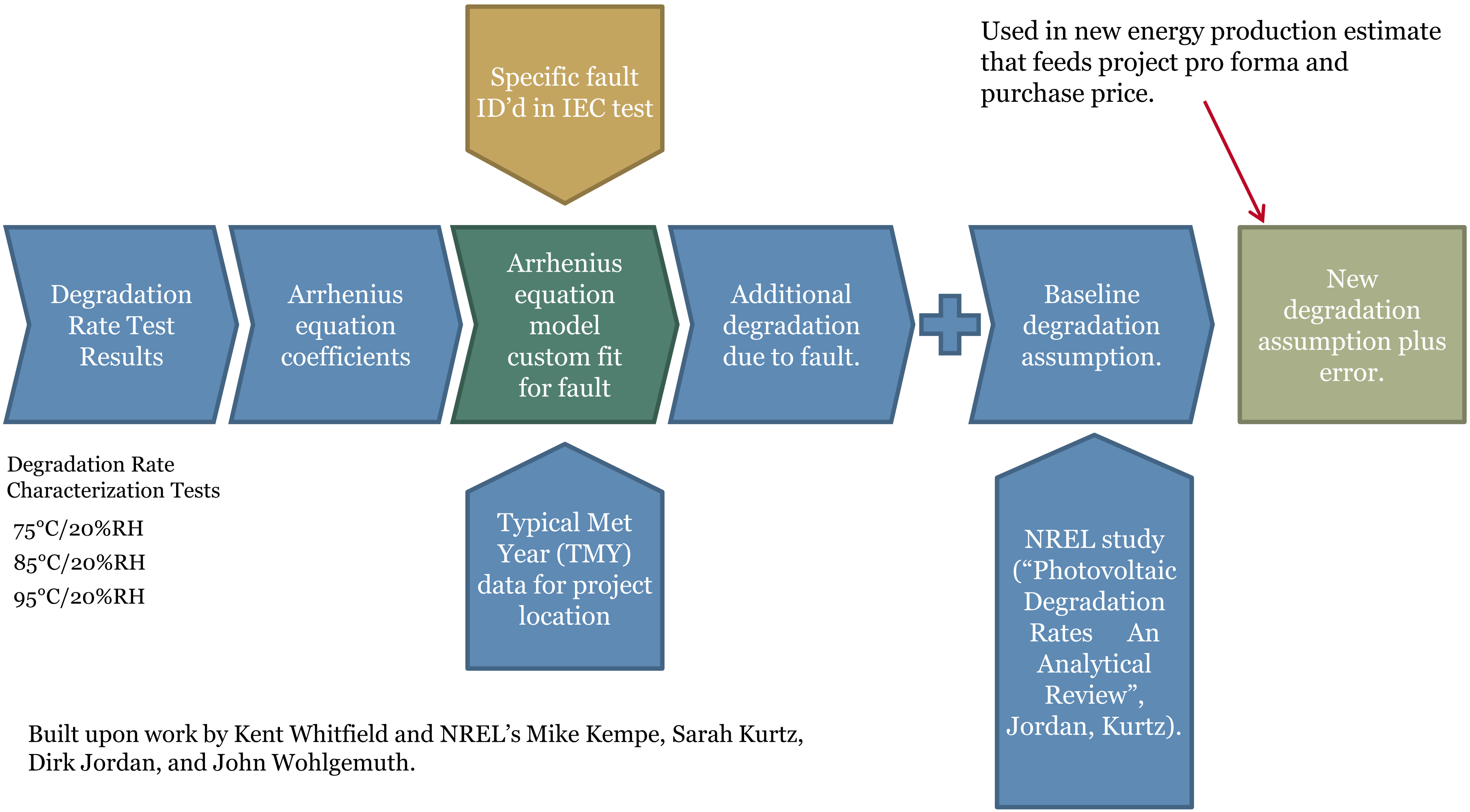
Example of PV Module Accelerated Lifetime Testing (ALT) Scope of Work

	Standard or Source	Test Module Count or Component Sample Count															
Weeks:			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Days at Lab:				7	14	21	28	35	42	49	56	63	70	77	84	91	98
Air Shipment			x														
Sample prep, outdoor preconditioning (Clause 5 61215)				x													
Visual, EL, IV, Flash Test, Wet Leakage (when required)				x	x	x		x	x	x	x			x			x
Module Qualification Tests (IEC and Extended Testing)																	
TC (Thermal Cycling)	NREL Qualification Plus	varies				200		500		800							
DH (Damp Heat)	NREL Qualification Plus							500			1000			1500			2000
DML/TC50/HF30	NREL Qualification Plus					x											
PID (Potential Induced Degradation)	NREL Qualification Plus					192											
Statistical Module Batch Tests (each BOM/factory combo)																	
TC (Thermal Cycling)	IEC 61215	30 (6 per test) for 95% confidence level that 90% of modules will be defect free				200											
DH (Damp Heat)	IEC 61215							500			1000						2000
TC50/HF10 (Thermal Cycling/Humidity Freeze)	IEC 61215				x												
PID (Potential Induced Degradation)	IEC 61215				96												
DML (Dynamic Mechanical Load)	IEC 61215								x								
LID (Light Induced Degradation)	IEC 61215	20 of existing sample set						x									
PAN file validation/creation (for PVSyst)	IEC 61853-1	3 of existing sample set						x									
IAM (Incident Angle Modifier) loss validation	IEC 61853-2			x													
Bypass Diode Test	IEC 61215	All of sample set		x													
Degradation Rate Characterization Tests*																	
75°C/20%RH	NREL special for Wells Fargo	6 (1 with defect + 1 control with no defect per test)						500			1000			1500			2000
85°C/20%RH	NREL special for Wells Fargo							500			1000			1500			2000
95°C/20%RH	NREL special for Wells Fargo							500			1000			1500			2000
Other tests**																	
Modules:																	
Hot Spot Test	NREL Qualification Plus/ASTM E2481-06	5			x												
Components:																	
UV Exposure of Junction Box	NREL Qualification Plus	5						500									
Bypass Diode and Junction Box Thermal Test	NREL Qualification Plus	5			96												
UV Exposure for Encapsulants	NREL Qualification Plus	5															~4000 hours>>
UV Exposure for Backsheets	NREL Qualification Plus	12															~4000 hours>>
UV Exposure for Cables and Connectors	NREL Qualification Plus	3															~4000 hours>>
Result checks/Reports				Initial Check	Check 1	Check 2		Check 3	Check 4	Check 5	IEC 61215 Report, Stop deg rate char tests if no fault found						Extended Test Report, Degradation Rate Characterization (if needed)

*Initiated for each BOM/factory combo, but stopped if no fault found in IEC baseline

**Performed if there is a reason for concern, e.g. historical defect, known issue, significantly new component, material or design, etc.

PV Module Degradation Rate Characterization Analysis Method



Built upon work by Kent Whitfield and NREL's Mike Kempe, Sarah Kurtz, Dirk Jordan, and John Wohlgemuth.

Technology Review

ESS (Energy Storage System)

- Equipment
  - Battery Modules
  - Enclosure
  - Power Conversion System
  - Cooling system,
  - BMS (confirm operation within warranty limits)
  - BOS
- Integration/installation staff
  - Qualifications
  - Track-record
- Manufacturing process
  - Factory testing
  - Quality Management/Manufacturing Execution System
  - Workplace Safety & Living Wage
  - Recycling/Disposal
- Estimated Useful Life (EUL) Estimate
  - demonstrated through lifecycle testing
- Fire protection
- Code compliance
- LOTO
- Sound, heat and other environmental factors
- Toxicity & other health risks
- Recycling and/or decommissioning
- Warranty terms
- Spare parts strategy (unique v. off-the-shelf)

EMS (Energy Management System)

- Equipment
  - Meters
  - ESS gateway
- Control system
  - Forecasting data
  - Utility rate data
  - Software/firmware updates
- Integration/installation staff
  - Qualifications
  - Track-record

Integrated ESS/EMS

- System track record in application planned
- **System Characterization Testing** (in IE or supplier's lab)
  - Validate expected performance model over the range of expected operating conditions
    - ESS response time
    - Energy & power capacity
    - Degradation rate
  - Confirm operations within warranty limits
- Compliance with ITC requirements
- Commissioning & performance test procedures
- Isolation of PV system from ESS interference
- Continuity of Operations Program (COP)
  - Parallel monitoring system
  - EMS & ESS Service replacement plan

Proposed ESS Technical Due Diligence Scope of Work

PV-ESS Portfolio Review

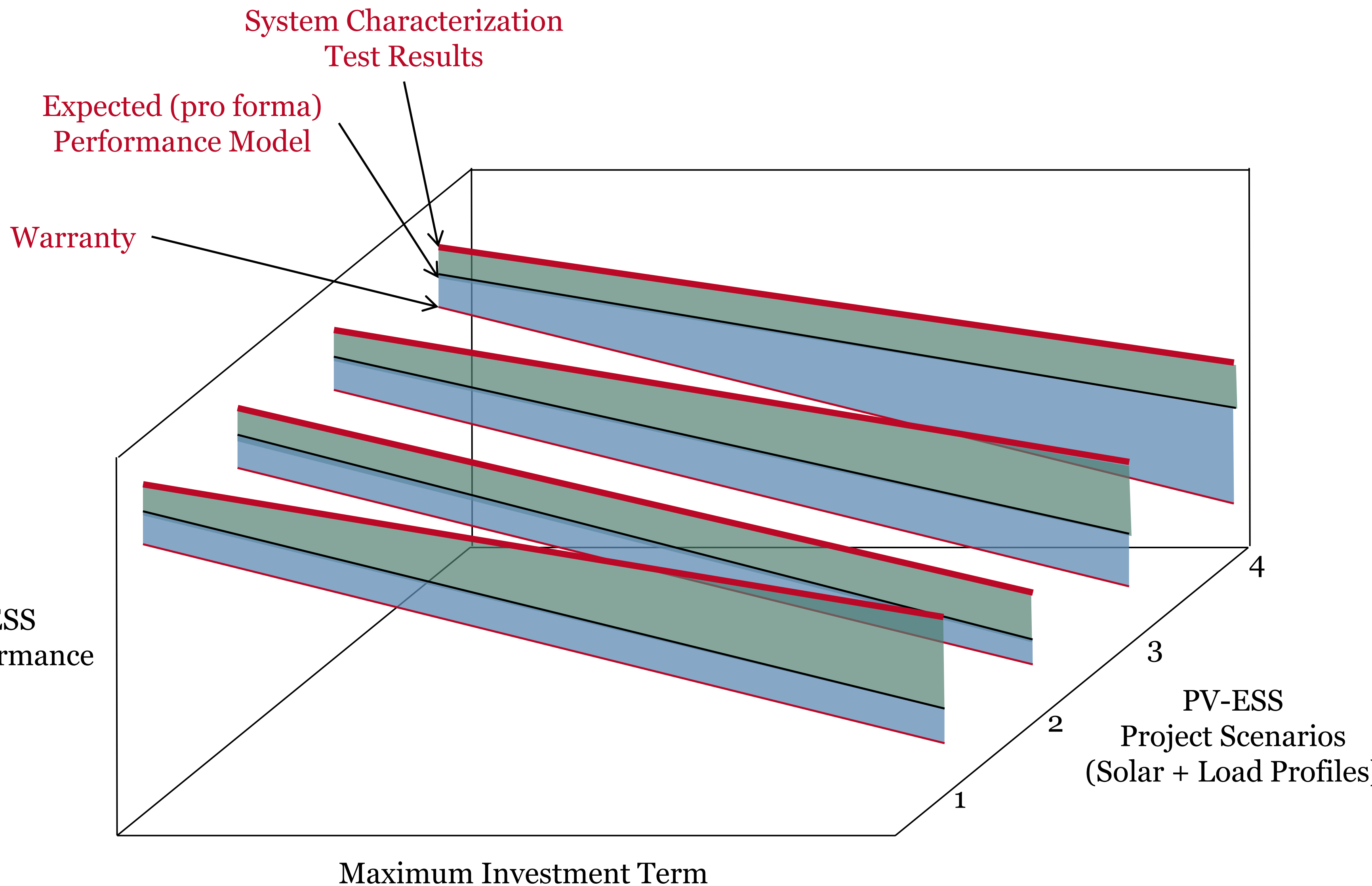
- Contractors
  - EPC
  - O&M
  - Asset Management
- Continuity of Operations Program
  - Equipment
  - Software
  - Operations
  - Asset Management

Project Review (ESS Portion*)

- Expected performance model
  - **Validated using System Characterization Test results**
  - Performance risks
  - Long-term predictability of load
  - Uncertainty
- Electrical Design
  - *including EMS communications infrastructure*
- Civil/mechanical
- O&M and Asset Management (AM) Plan
  - spare parts list/availability
  - reliability of parts suppliers
  - preventative maintenance
  - corrective/unexpected maintenance
  - budget (O&M and AM)
- Decommissioning Plan
- Commissioning & performance test data review
  - confirmation of passing results
- Site inspections (on site and/or remote photographic)
- PE Stamps
- Permits
- Other material documents

** See Appendix 4 for Project Review of PV Portion*

Expected ESS Performance Model Validated Using System Test Results



(not to scale)

Appendix 3:

Technical/O&M/AM Due Diligence for Prospective Project Sponsors

Technical/O&M/AM Due Diligence for Prospective Project Sponsors

General

- Experience with technology contemplated for funding, customers, MW developed in US and abroad, time in business in US and abroad.
- Experience in various ISOs
- Staffing, e.g. number of staff and make up (field staff, ops center, etc.) vs. subcontractors, qualification of subcontractors, locations, safety record
- General project development strategy, e.g. greenfield, brownfield, acquisition

Project Development/Construction

- MW constructed, locations
- Aspects of EPC performed as prime
- Use and qualifications of EPCs, subcontractors and preferred EPCs, and subcontractors
- Use and qualification of equipment, e.g. module accelerated lifetime testing, IE reports, and preferred equipment
- Supply agreements and relationships w/OEMs, e.g. spare parts, training, troubleshooting, access to IP in case OEM exits the business
- Project commissioning and performance testing methods
- Preferred independent engineers and willingness to have WF contract them directly
- Engagement with local community
- EPC warranties

O&M and Asset Management

- Assets under management, owned and third party, concentrations by state
- Performance metrics, e.g. production v. pro forma, ideally by state
- Areas outsourced/subcontracted, use and qualifications of subcontractors and preferred subcontractors
- Operations center, e.g. performance monitoring, plant control, work flow management/ticketing system
- NERC/FERC CIP qualifications, e.g., physical and IT security
- Energy forecasting and settlement capabilities
- Preventative and corrective maintenance, use of major maintenance budgets/reserve account
- Spare parts management strategy, e.g. inventory, IP in escrow, ordering as-needed
- Failure/root cause analysis and remediation procedures
- Sponsor's Continuity of Operations Program (COP), confirmation of market rate O&M/AM budget for back-up service providers
- Reporting, e.g., Monthly Operating Reports, portal
- Warranty claims experience and warranty work management
- Insurance policy management
- Billing method
- REC accounting, e.g. via WREGIS
- O&M and performance guarantees
- Other services available

Appendix 4:
Tax-Equity Financing Structures Available for PV, Wind PV-ESS Projects

Sale-Leaseback Tax Equity Structure

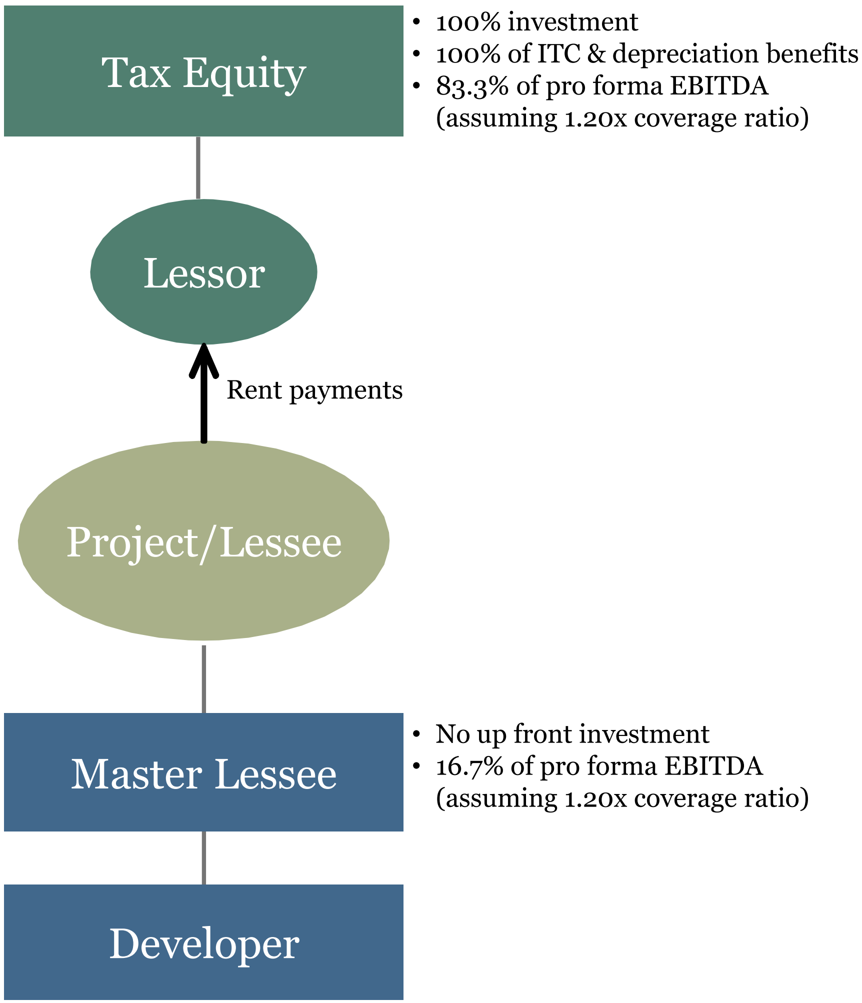
Sale Leaseback Structure Overview

- Developer sells project to TE Investor, who leases it back to Developer
- 1.20x coverage ratio is applied to project EBITDA to derive lease payments
- 100% of tax benefits transferred to the TE Investor:
  - ITC
  - MACRS Depreciation
- Typically lease and PPA are coterminous
- Purchase price can be greater than cost to build, giving rise to Developer margin
- Multiple projects can be cross-collateralized and cross-defaulted
- Partial Lessee rent prepayment
- 90/110 tax rent allocation with 467 loan

Advantages of the Sale Leaseback Structure

- Financing 100% of the project fair market value
- Tax Equity Investor takes 100% of tax benefits
- Tax risks similar to equipment leasing market
- Developer's cash returned at sale (day one): current tax gain, but accounting income realized over time
- Structure is relatively simple/mechanical compared to Partnership Flip
- Tax Equity Investor typically manages advisors (appraiser, engineers, legal, etc.)

Sale Leaseback Structure



[1] Rent allocation schedules must be within 90% to 110% of the average annualized rents of the lease, not counting an allowable three-month initial rent holiday

Partnership Flip Tax Equity Structure

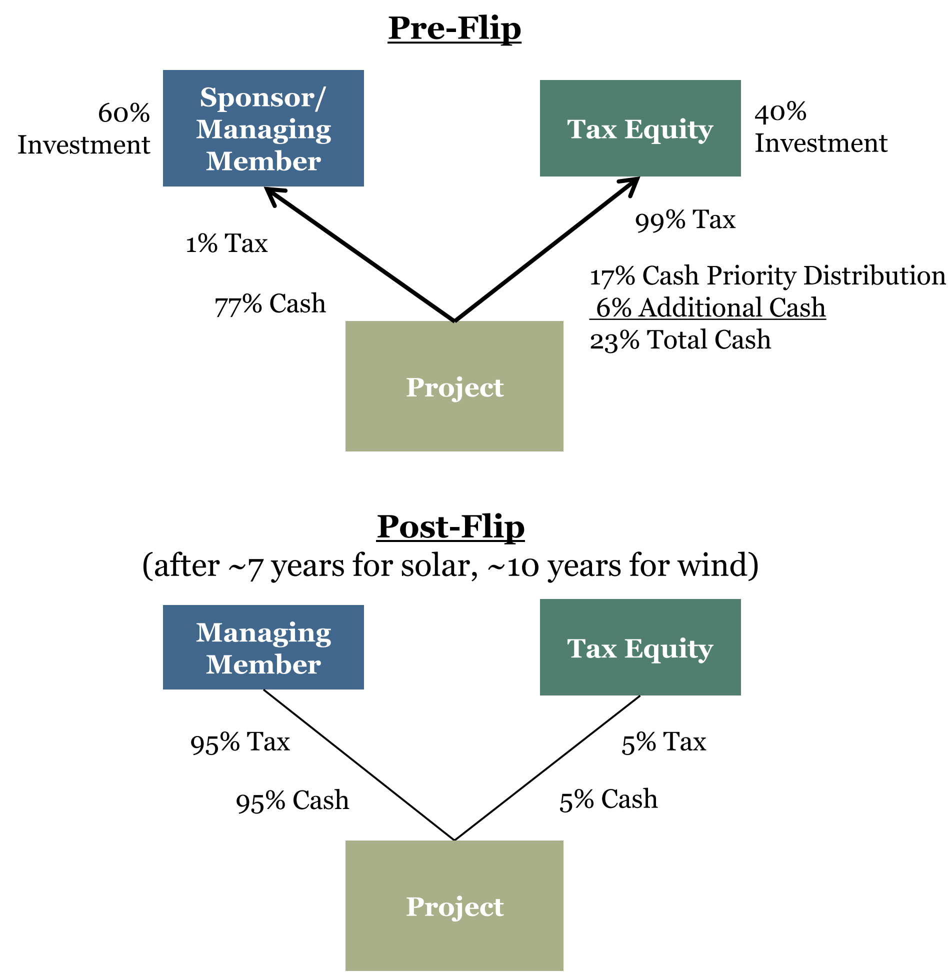
Partnership Flip Structure Overview

- Created to monetize tax credits and provide Sponsor a steady cash flow stream
- TE contributes ~40-75% of total capital; Sponsor contributes the remainder
- TE takes relatively low cash percentage (~5-30%) and high portion of tax benefits (up to 99%)
- Minimum 2% cash on cash return over full term to retain profit motive other than tax
- Yield-based flip: once TE Investor realizes its IRR, share of cash and tax flips down (typically to around 5%)
- TE does not typically permit debt at the project level, but can accommodate back leverage
- Structural mitigations to prevent excessive flip tenor extension can include: Preferred Return, Springing Cash Allocations, or Paygo structures

Advantages of the Partnership Flip Structure

- TE's total share of cash is much lower than in the SLB, and the term of the financing is shorter (7-10 years vs. 20 years)
- Sponsor retains most of the residual economic upside/downside
- TE can be flexible about how we approach structuring as long as we stay within our internal guidelines for flip extension in downside cases. If Sponsor has a pre-flip cash target, we can fix the cash and solve to the investment percentage. Similarly, if Sponsor has a tax-equity investment % target, we can solve for cash allocation.
- Allows TE Investor to disproportionately allocate cash and tax benefits. Allows for steady cash distribution and back leverage.
- If deal has unique features, like merchant RECs, they can be specially allocated to the Sponsor.

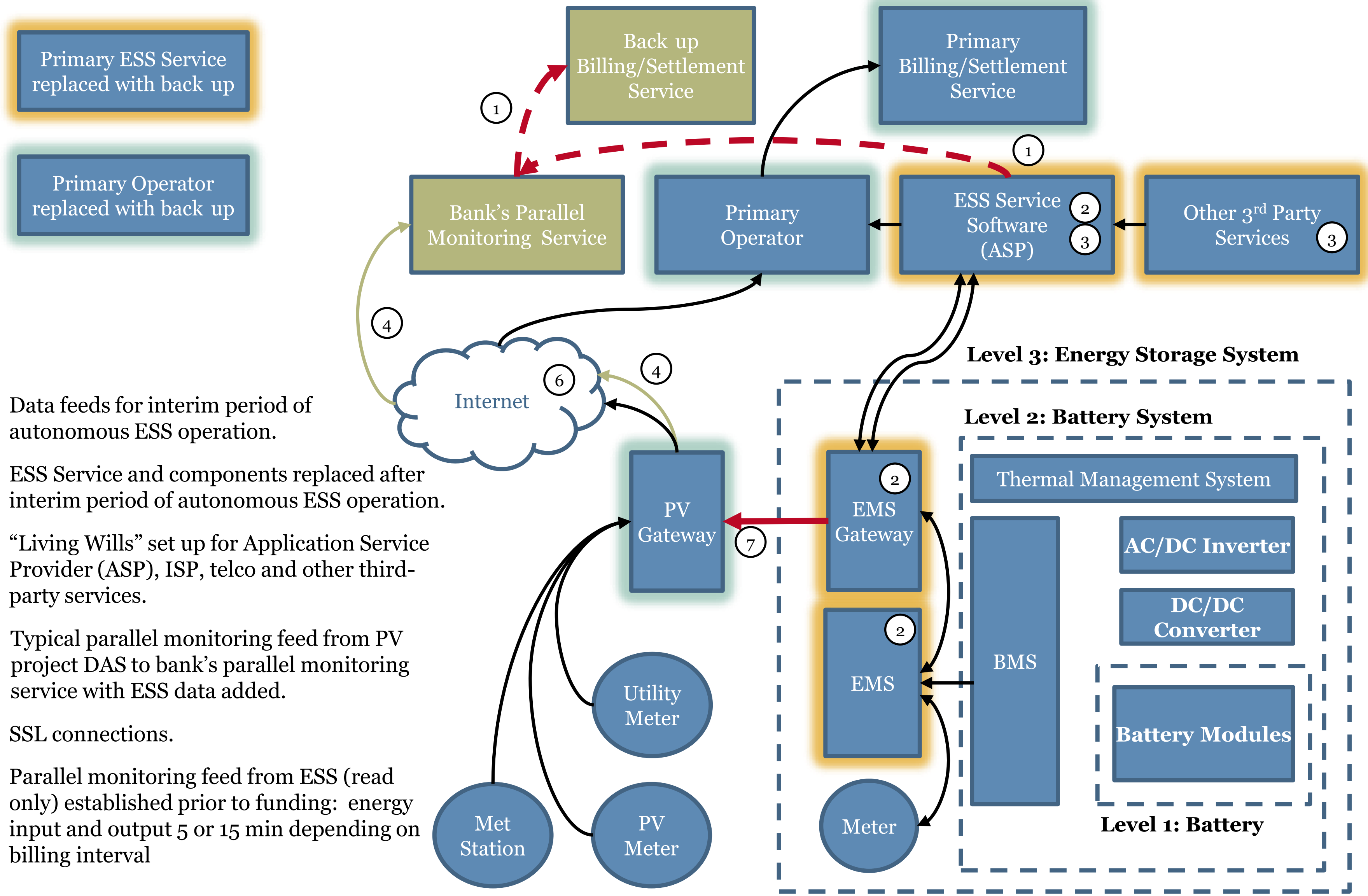
Partnership Flip Structure



Note: *Values shown are indicative and vary for Wind vs Solar, among other factors.*

Appendix 5:
Proposed Continuity of Operations Plan for PV-ESS Projects

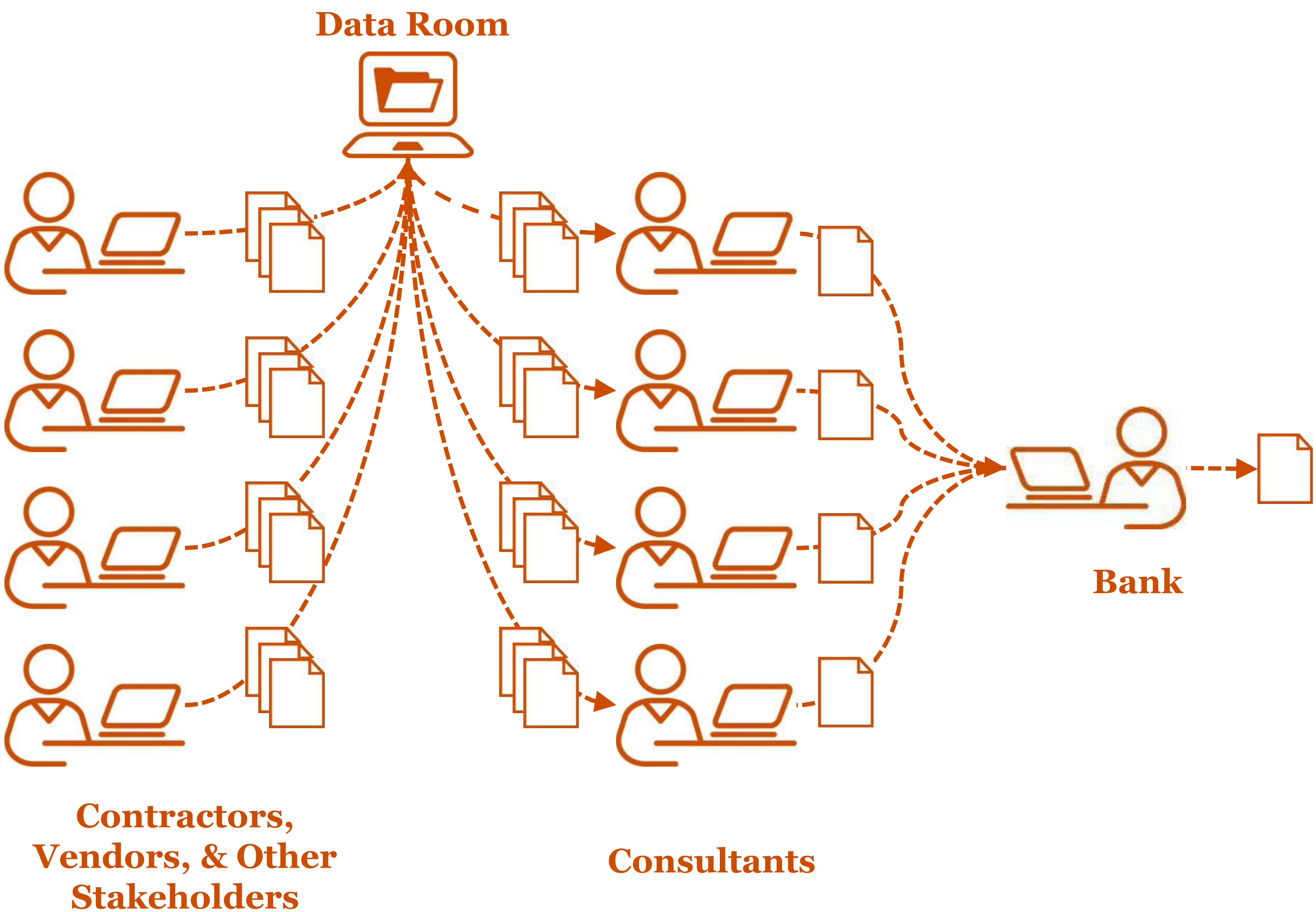
Proposed Continuity of Operations Program (COP) for PV-ESS



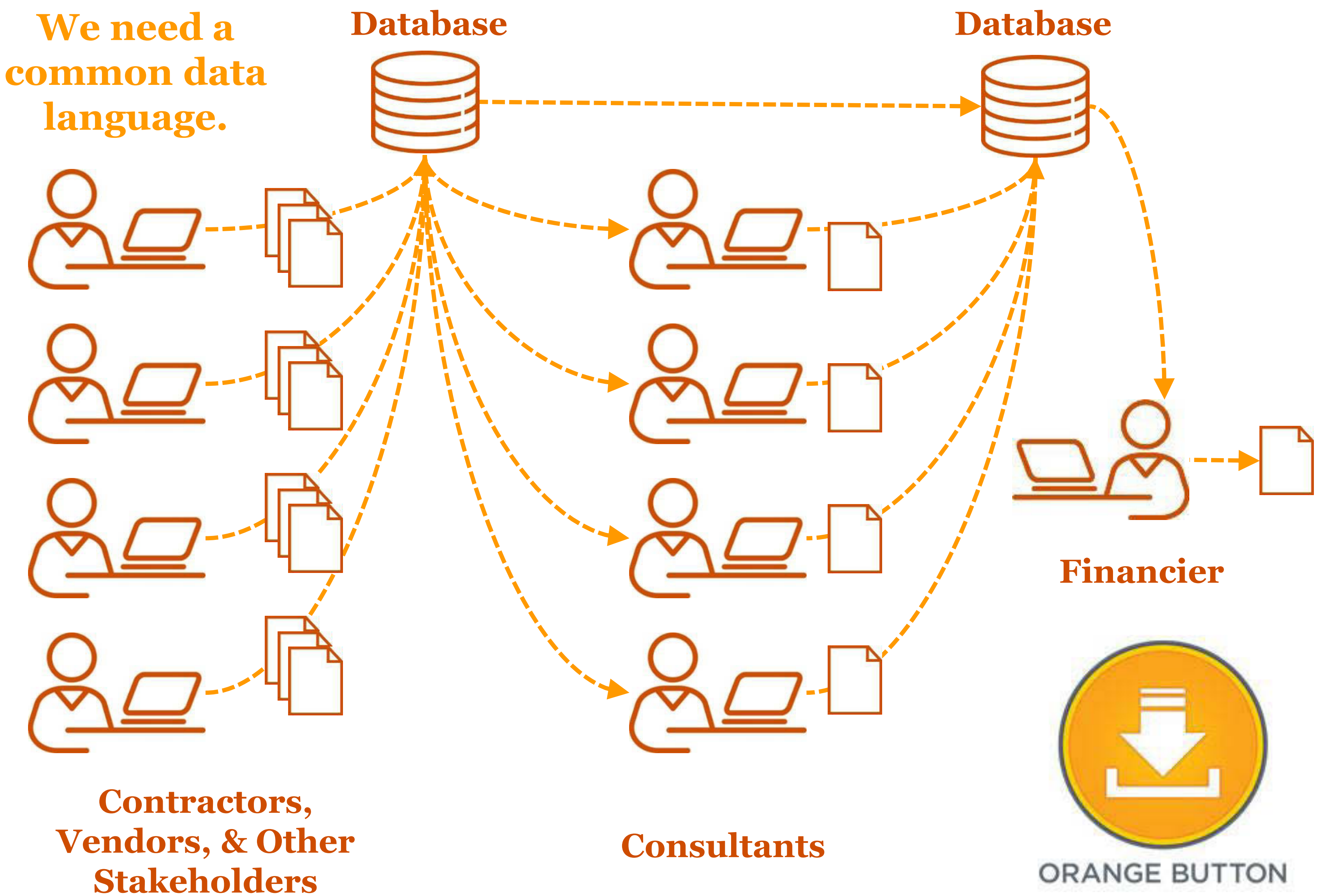
1. Data feeds for interim period of autonomous ESS operation.
2. ESS Service and components replaced after interim period of autonomous ESS operation.
3. "Living Wills" set up for Application Service Provider (ASP), ISP, telco and other third-party services.
4. Typical parallel monitoring feed from PV project DAS to bank's parallel monitoring service with ESS data added.
6. SSL connections.
7. Parallel monitoring feed from ESS (read only) established prior to funding: energy input and output 5 or 15 min depending on billing interval

Appendix 5:
Streamlining Data Management with the Orange Button

Information Flow with Documents, "The Old Way"



Information Flow with Data **in Documents**, "The Modern Way"



NATIONAL RENEWABLE ENERGY LABORATORY

Introduction to "Component Testing" Breakout Session

Ingrid Repins, National Renewable Energy Laboratory

Jon Previtali, Wells Fargo

September 10, 2017

Solar Power International Workshop

“Component testing” in IECRE

The operational documents (OD’s) and standards that IECRE is based on might tell you:

- What to do

9 PV System Performance Test Results

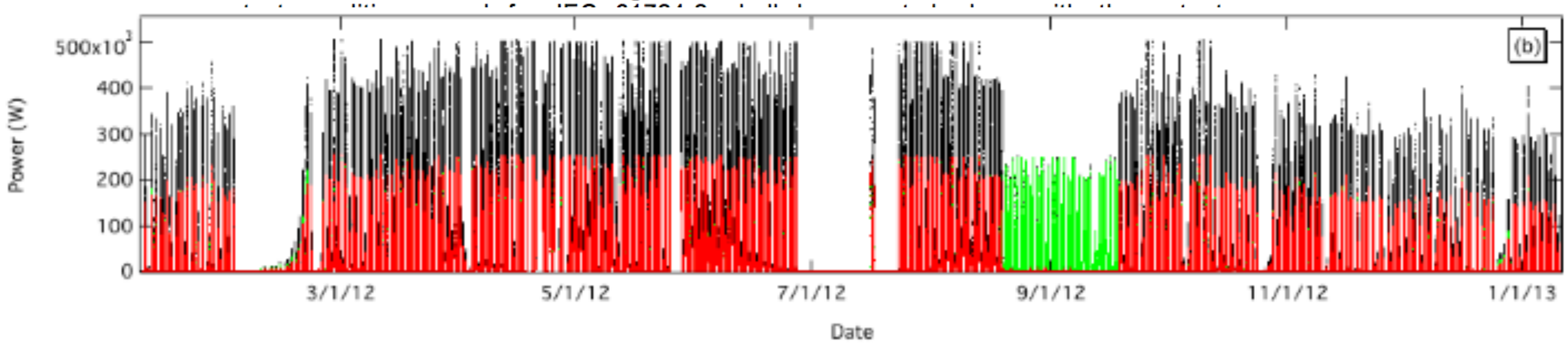
This evaluation shall be performed by the RECB based in the report of the REIB.

The system performance shall be recorded according to Table 2 and with guidance described below.

9.1 Output power measurement

The AC output power, P_{out}, as defined in Table 3 and section 7.6 of IEC 61724-1 is measured for reference test conditions using the method described in IEC 61724-2[10]. The reference

Example from OD 401 “Conditional PV Project Certificate”



“Component testing” in IECRE

The operational documents (OD’s) and standards that IECRE is based on might tell you:

- What to do
- How to do it

Example from 61724-1, “PV System Performance Monitoring,” called in OD 401

7.3.4.3 Calibration

a) Choose a reference condition of irradiance and PV device temperature, e.g. STC.

b) Determine a calibration value for the short-circuit current of the clean device at the designated reference condition. It is sufficient to use the manufacturer’s datasheet values.

c) Using the clean device to measure irradiance, determine calibration values for the max

“Component testing” in IECRE

The operational documents (OD’s) and standards that IECRE is based on might tell you:

- What to do
- How to do it
- Requirements for components

Example from OD 401

5 Documentation of Equipment Certificates and Oversight of Quality Management

This evaluation shall be performed by the RECB.

PV modules shall be certified according to IEC 61215 and IEC 61730, including any special tests defined in the relevant part of the IEC 61215 series (for example, IEC 61215-1-1 for crystalline silicon modules). This certification shall be completed by a certification body accredited to ISO/IEC 17065 using ISO/IEC Scheme type 5 according to ISO/IEC 17067.

“Component testing”

Portion of a product datasheet

QUARTECH MODULE | NEW TECHNOLOGY

- Reduces cell series resistance
- Reduces stress between cell interconnectors
- Improves module conversion efficiency
- Improves product reliability

PRODUCT & MANAGEMENT SYSTEM | CERTIFICATES*

IEC 61215 / IEC 61730: VDE / MCS/CE/JET/KEMCO/SII/CEC AU/INMETRO/CQC
UL 1703 / IEC 61215 performance: CEC listed (US) / FSEC (US Florida)
UL 1703: CSA | IEC 61701 ED2: VDE | IEC 62716: TUV | IEC60068-2-68: SGS
PV CYCLE (EU) | UNI9177 Reaction to Fire: Class 1

ISO9001: 2008	I Quality management system
ISOTS16949:2009	I The automotive industry quality management system
ISO14001:2004	I Standards for environmental management system
QC080000:2012	I The certificate for hazardous substances process management
OHSAS18001:2007	I International standards for occupational health and safety

Component testing in IECRE

There has been a lot of recent work in developing component test standards on the module and the inverter, since these are among the most complex, expensive, and rapidly-evolving PV system components.

- IEC 61215 for module design qualification published in 2016. Amendment with additional environmental stresses (dynamic mechanical load and PID tests) in progress.
- International harmonization of UL 1703 and IEC 61730 for module safety nearing conclusion.
- IEC 62109-3 for module integrated power electronics in progress.
- Revision of IEC 62093 to provide focused design qualification testing for modern power electronics, is underway.

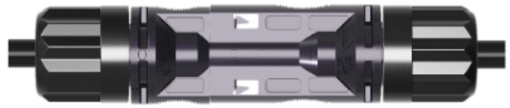
Component testing across the PV system in IECRE

However, all system components must be durable and safe.

Required component testing:

CERTIFICATIONS

IEC 62852: TÜV-Rheinland / CE
UL 6703: CSA
Compliance with RoHS, REACH and NEC
(no locking sleeve required)



Component	Subject	IEC Standard	Called In
Module	Safety	61730-1,2	OD401 and OD403
Module	Design qualification	61215-x	OD401 and OD403
Inverter	Safety	62109-1	OD401 and OD403
Tracker	Design qualification	62817	OD401 and OD403
Plugs and connectors	Safety	62852	OD401 and OD403, via 62548
Switch and controlgear	Rules and requirements	60947-1,-3	OD401 and OD403, via 62548
Fuses	Requirements	60269-6	OD401 and OD403, via 62548
Circuit breakers	Requirements	60898-1,-2 or 60947-2	OD401 and OD403, via 62548
Combiner boxes	Degree of protection	60529	OD401 and OD403, via 62548
Surge Protection	Performance requirements	61643-21	OD401 and OD403, via 62548
HV switch and controlgear	Specifications and requirements	62271-1,-100,-102, -103,-200	OD401 and OD403, via 62738
Power cables	Requirements	60502-1,-2	OD401 and OD403, via 62738
Mechanical connectors	Requirements	61238-1	OD401 and OD403, via 62738

Discussion Points for Component Testing Breakout

A product with IEC certification via component tests
- matches important datasheet or label specifications
- is likely to avoids the most commonly-observed safety and durability failures

Component testing does not ensure that
- that the product will meet its warranty period
- every part the manufacturer produces is the same

Printed copy of the relevant component testing standards that you can look through.

Terminology in standards: requirements ("must," "shall") vs. recommendations ("may," "should," "recommended," "guided by.")

Your feedback and questions.

IECRE

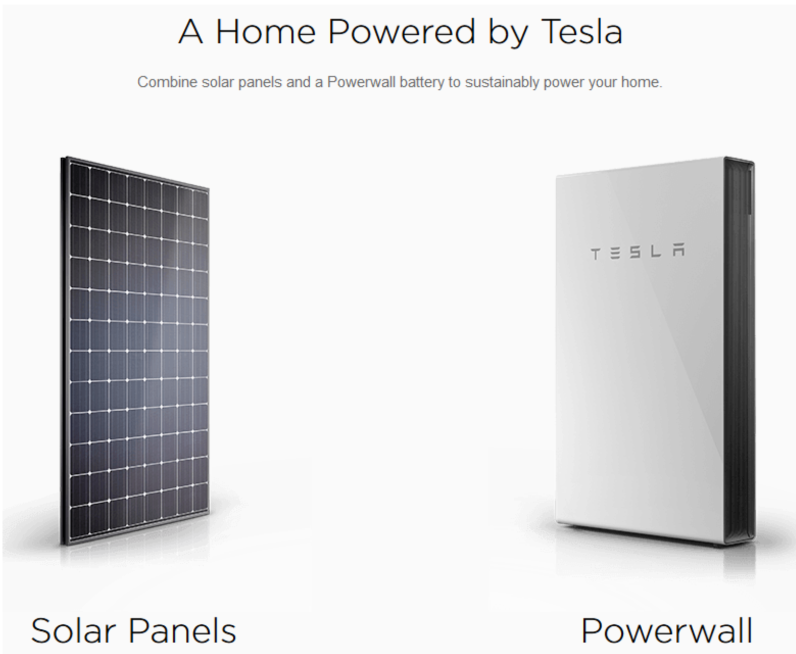
Break out #2

Design, Installation, Commissioning Issues

Dr. Jim Rand, Core Energy Works
Greg Ball, Tesla Energy

SPI 2017 – Las Vegas, Nevada
September 10, 2017

Tesla Energy

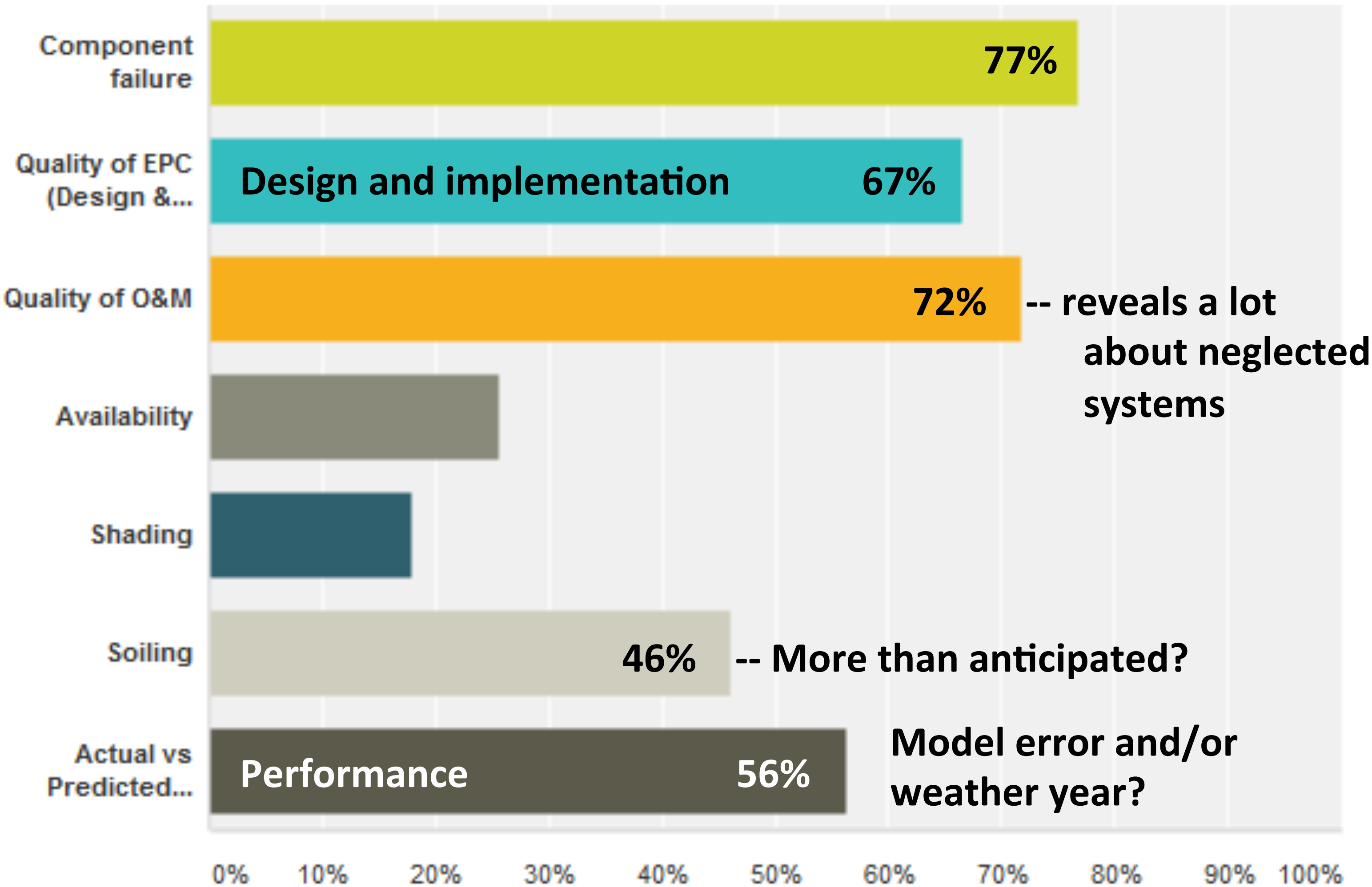


Break Out Discussion

- Feedback on design, installation and commissioning issues
- Review of OD documents and questionnaires (handouts)
- Questions and discussions on the standards
- Comments and feedback on process

IECRE – Streamlining & Standardizing Due Diligence

Results from 2015 Survey – Items with large impact on plant financial performance:



IECRE – Streamlining & Standardizing Due Diligence

What are you most concerned about or what is it that you have the least confidence in?

Module Issues

- Module degradation
- Module design faults not well covered by standards, like cell cracks
- High accuracy models for long-term product durability or accelerated testing methods.
- Direct replacements for older failing modules
- Polymers, reliability due to extreme weather & earthquakes.

BOS Durability and Reliability

- BOS suppliers' quality, reliability and maturity. Lack of standardization, accountability of performance measures across industry.
- High accuracy models for long-term product durability or accelerated testing methods.
- I have the least confidence in the long term reliability of the plant
- Good standard development is hampered by the fact that manufacturers and distributors/dealers would likely prefer to deal with quality and reliability as a proprietary matter rather than helping less-experienced competitors gain more market share.

IECRE – Streamlining & Standardizing Due Diligence

What are you most concerned about or what is it that you have the least confidence in?

System Level Design and Engineering

- While there are individual standards for each component, the optimal interaction between system components at the prevailing environmental conditions on site is often enough not fully understood by system integrators.

Project Execution and Commissioning

- Much damage can be done during transport and installation that will not show up for years after commissioning. Not therefore caught by "certification."
- Quality of workmanship.
- Skill of field techs
- Current commissioning standards do not go deep enough into the most critical items which affect PV system performance at the time of commissioning and in the future.

IECRE – Streamlining & Standardizing Due Diligence

What are you most concerned about or what is it that you have the least confidence in?

Performance

- Predictability of yield
- Inaccuracy of the system
- The definition and use of PV performance metrics have not been standardized.
- Grading of installed power plants for state-of-health based on numerically obtained results through field evaluation.

O&M

- Inverter parts availability;
- High quality O&M tech skill;
- Enough money in the O&M and asset management budgets.
- Bankruptcy of solar companies, not supporting warranties - need independent, inexpensive, means to validate

Core Energy Works

Dr. James Rand
Dr. Mason Reed

Experts in Silicon PV Modules
- Manufacturing
- Performance
- Testing

Recent Field Testing (IV, EL, IR)
- 78,126 Modules Evaluated in the Field
- 9 Sites
- 5 Manufacturers

Warranty Issues
- Provide Warranty Support for Manufacturers
- Evaluate Potential Warranty Issues for System Owners

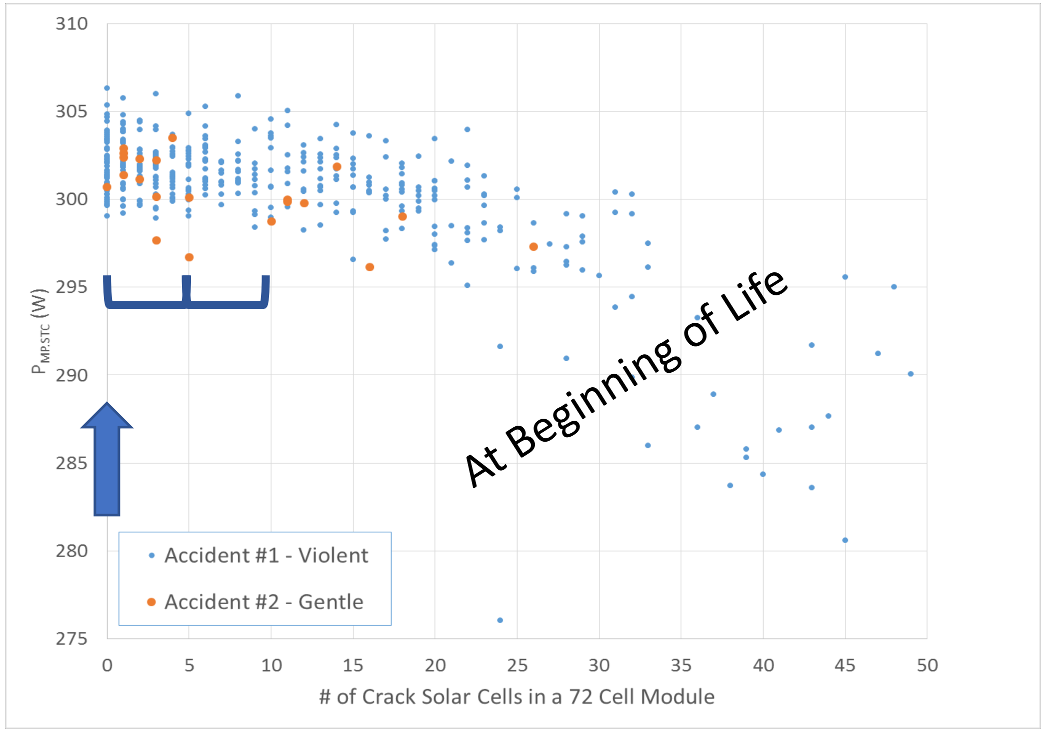
Laboratory Based "Rough Handling" Study
- Evaluated 6 different Technologies for Rough Handling
- Greatly Varying Results

1,000 Modules in inventory, 5 different Manufacturers

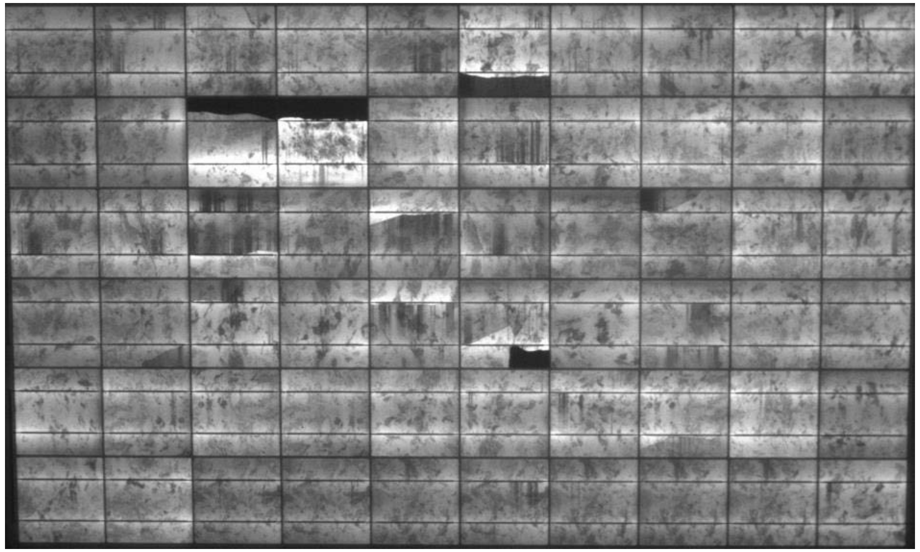
Laboratory Test Capabilities
- From Single Module STC testing to
- Full Containers Evaluating Transportation Damage

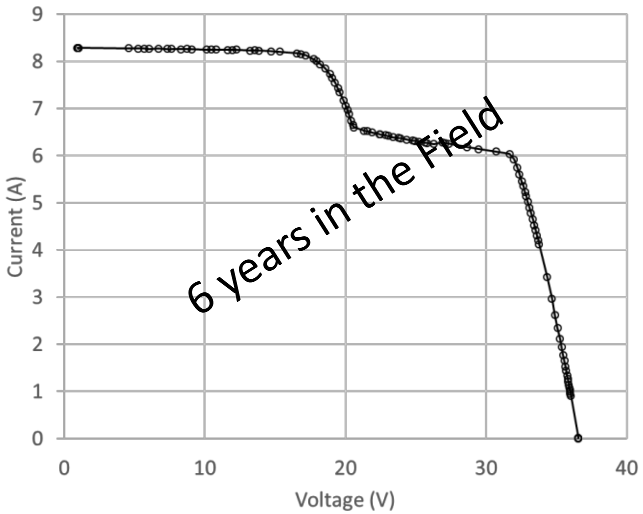
Cracked Solar Cells

Little or No Impact to Power at Beginning of Life



After Some Time in the Field…Well it Depends





Module History:

Warranty return from a commercial rooftop.

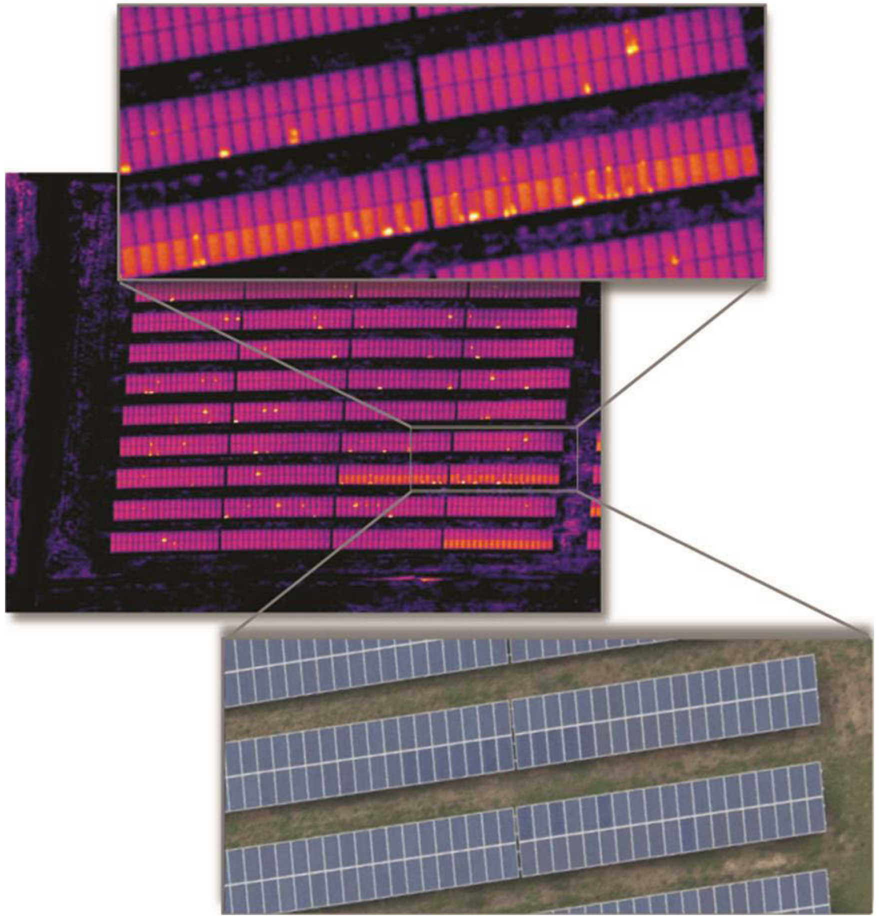
6 years in operation.

~20% Power loss at STC

Cracked Solar Cells – They Might Not be Bad, But They Can't be Good

Infrared Imaging – Powerful Diagnostic Tool

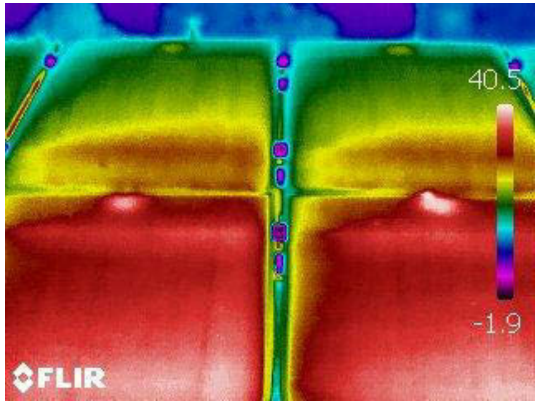
CORE ENERGY WORKS

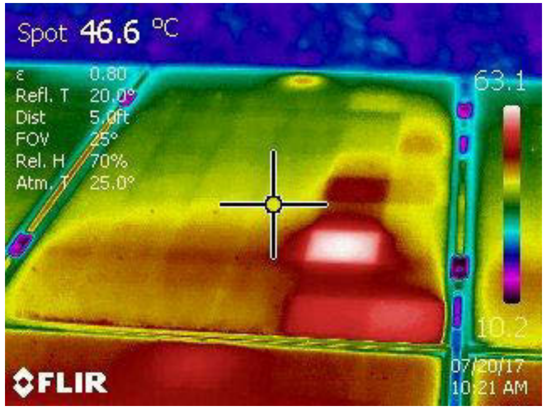


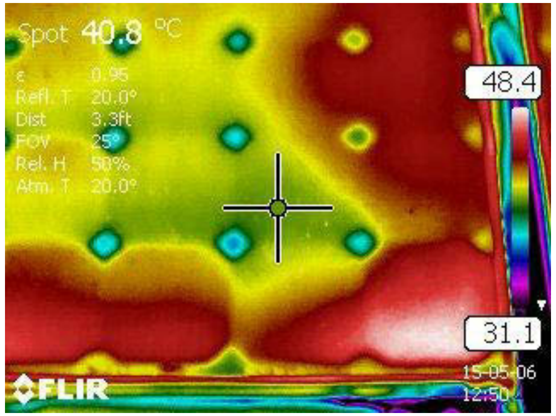
Aerial inspections that simultaneously capture both visible and IR imagery, as shown here, provide system operators with complementary data sets.

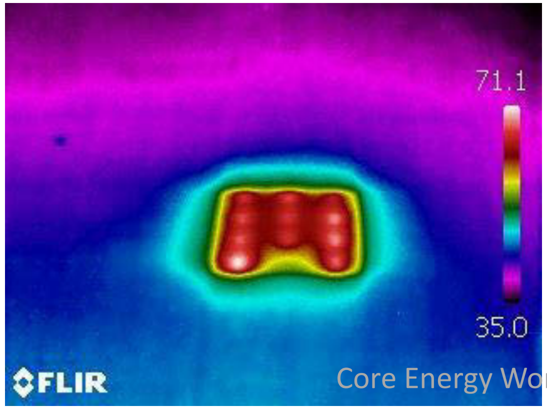
R. Andrews of Heliolytics, "Introduction to Aerial Inspections" SolarPro, Issue 10.1, Jan/Feb '17

IEC TS 62446-3
Photovoltaic (PV) Sytems – Requirements for testing documentation and maintenance
Part 3: Photovoltaic modules and plants- Outdoor infrared thermography.









NREL Quality of PV Power plants

OD-404 Assessment for Asset Acquisition or Sale

Suncycle USA, September 10, 2017

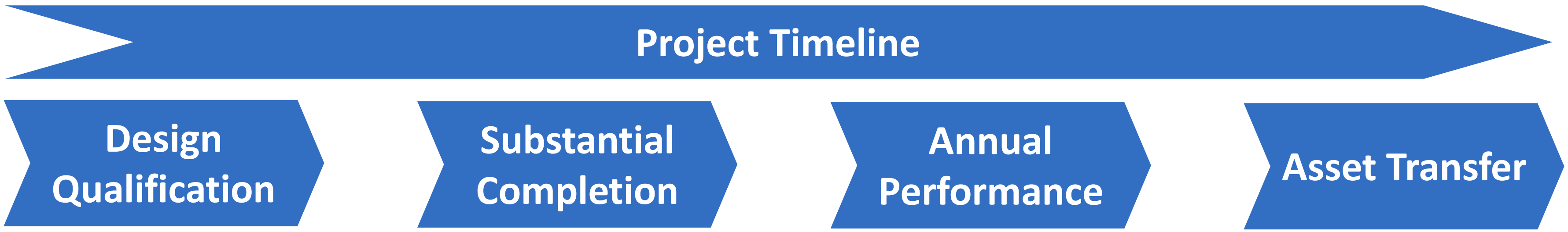
Eric Daniels, Sarah Kurtz NREL, Edward Hsi Swiss RE

suncycle solar services

Suncycle history

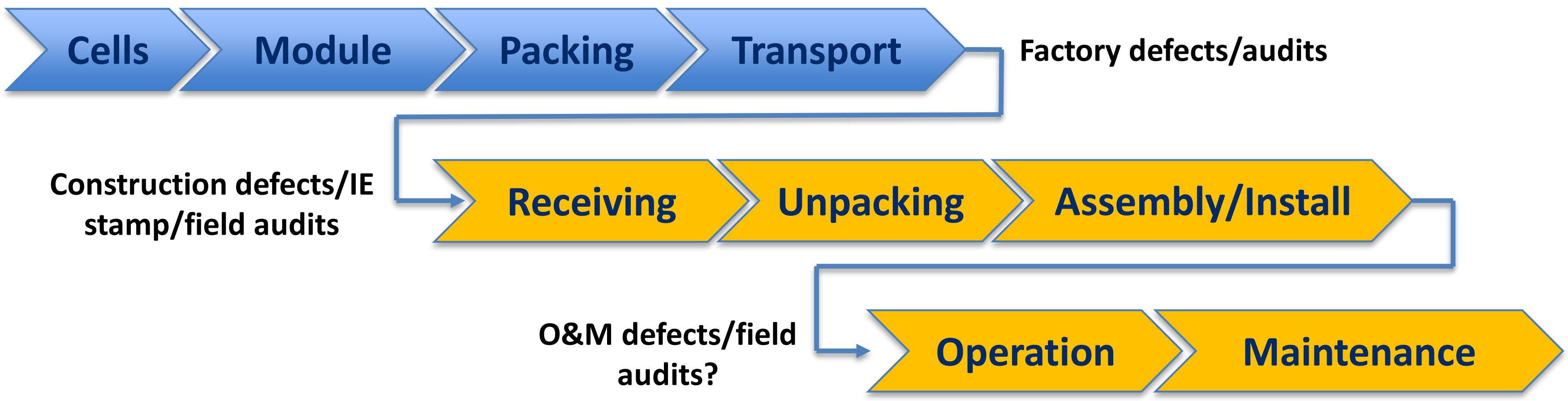
- Founded in 2007 to conduct field audits, diagnostics, failure and repair of solar assets
- Often called for warranty service and assessments for manufacturers, insurers, owners, EPCs and operators
- Over 3 million modules assessed
- In-field or lab, module quality audits, acceptance testing, IR, EL, UV and Pmp using mobile and mini labs

PV System Timeline and Certificates



- Need confidence that *each step* during a project is completed correctly
- For example:
  - Design qualification (ready to proceed with construction)
  - Substantial completion (ready to operate)
  - Annual performance (final completion, or annual check up) *optimization*
  - Asset transfer (define health of plant as basis for sale or acquisition)
  - Component testing, QC, design, commissioning and performance resolved/understood

Stages for defect origination

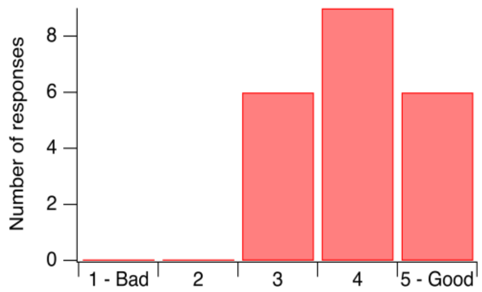


- Modules with severe failures typically do not leave the factory. However, this depends on the manufacturer's QA capability and criteria. Audits available.
- Defects and failures can be introduced during construction and by O&M. This handling may exacerbate minor factory defects.
- Insurers may cover factory warranty and performance degradation risk.
- Determination of asset health upon acquisition may establish subsequent liability when problems emerge.

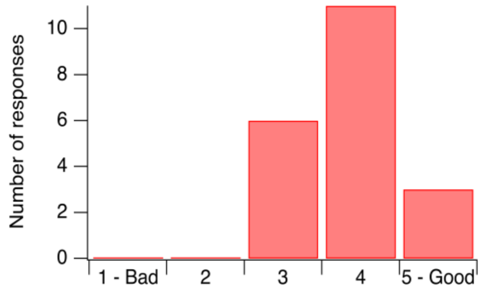
Survey results – what are you worried about?

How would you rate:

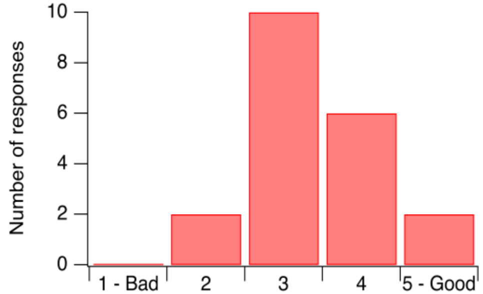
- The quality and reliability of your independent engineering reports?



- long-term reliability of your PV modules as manufactured?



- long-term reliability of your PV modules as installed?

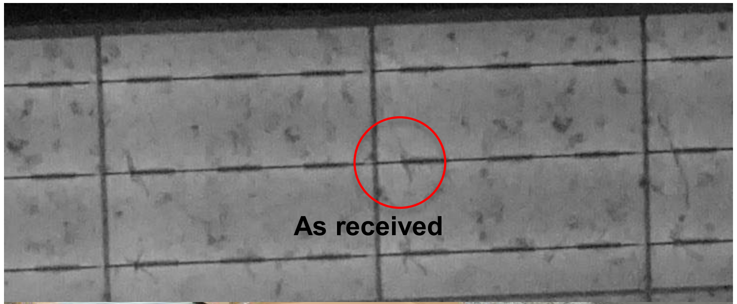


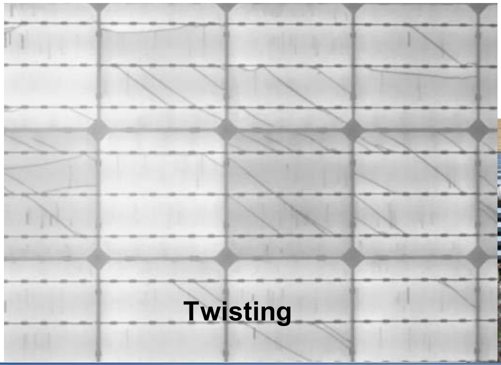
suncycle solar services

Field audit observations

- Field audits as received to confirm factory/transport damage
- Onsite handling related concerns
  - Transport of pallets
  - Handling of modules
  - Transport of panels

- Opportunities: Standards for transport, handling, assembly?

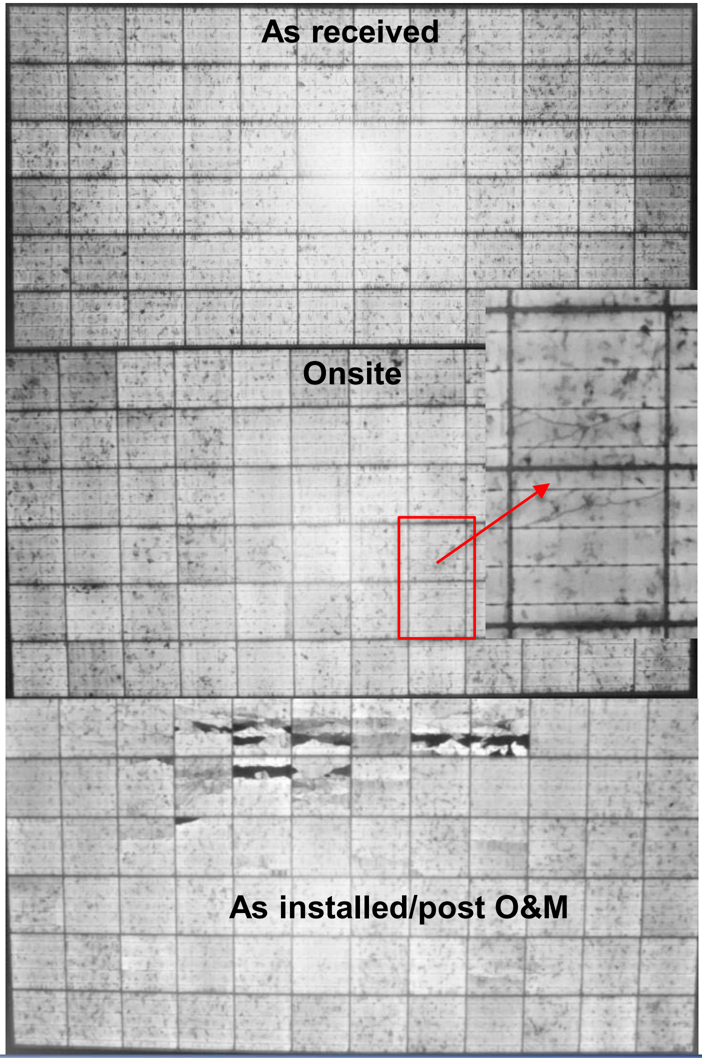




Examples of defects

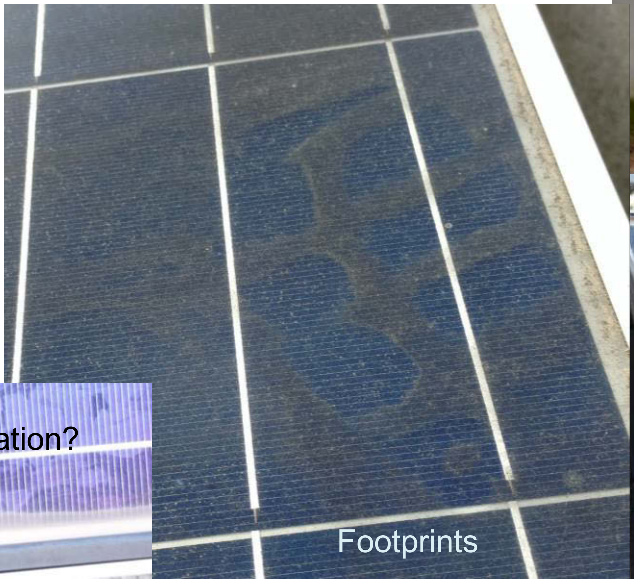
- Factory as received off truck, typically minor defects
- As delivered to installation point: increase in severity of defects
- As installed or post O&M: potential for significant defects

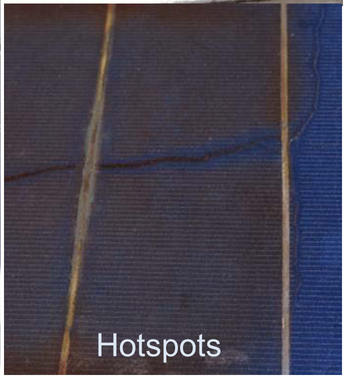
- *At substantial completion…*

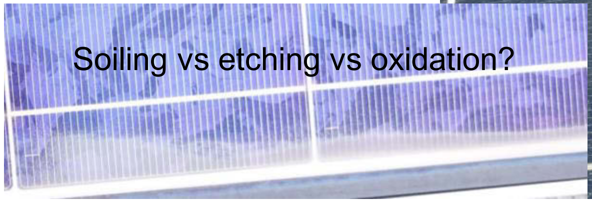


Potential longer term defects

- Debris from weeding collecting on frames & structure
  - Evidence of soil accumulation in weep-holes
  - Collecting along cable trays
- Stepping on modules
- Damaged spare module inventory
  - Pallet storage
  - Handling
- Soiling
- Hotspots







PV System Assessment

- Documentation of past performance (OD-402)
  - Consistent with original model?
  - Consideration of initial DC to AC ratio, predicted and actual degradation rates?
  - Weather and/or environmental factors?
- Review of maintenance performed (OD-404)
  - Are costs and schedule consistent with original model?
  - Verification of condition and method for rating (eg. minor vs severe)?
- Plant inspections and results
  - Evidence of deficiencies or corrective actions?
  - Are findings recent and relevant?
  - *What audit techniques are available and at what cost?*
- Documentation
  - Included as part of assessment, missing documents noted as deficiencies
  - History of alerts, outages, etc.

System Classifications

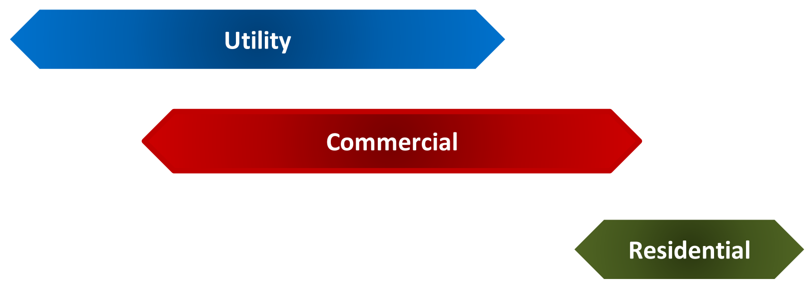
- Assessment criteria may be designed reflect system type

Class A
High Precision

Class B
Medium Precision

Class C
Basic Precision

Typically-targeted system size:



Specific requirements for each class

Parameter	Symbol	Units	Monitoring Purpose	Required? Class A High precision	Class B Med. precision	Class C Basic precision
PV array power (DC)	P_A	kW	Energy output, diagnostics and fault localization	√		
Output voltage (AC)	V_{out}	V	Energy output	√	√	
Output power (AC)	P_{out}	kW		√	√	√
Output energy	E_{out}	kWh		√	√	√

Plant Assessment discussion

- What should assessment reports include?
  - Alert history
  - SCADA data
  - O&M records
- Inspection requirements and to what level?
  - IV
  - IR
  - EL
  - UV
- Documents required?
  - As-built drawings
  - Commercial records: warranties, service agreements, others?
  - Plant records
  - Inspection, O&M and corrective actions
- Plant rating scheme? Pass/fail, R/Y/G, more detailed?
- Limits to time between inspection and certification?

Contact information

Thanks for your attention

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T +1 240 629 8302

PV power plant rating approach for technical and financial risk and performance assessments

IECRE

Las Vegas, NV, 10 September 2017

Agenda

EXXERGY
Focusing on the flow of energy

- EXXERGY
- Background of original initiative by EXXERGY
- Auditing and rating process

Who is EXXERGY ?

EXXERGY
Focusing on the flow of energy

- Well established consulting company
- Consultancy competencies: Technology, market intelligence, management, strategies
- Focus on: Companies in the energy and glass industries
  Renewable energy and energy efficiency
- Thorough understanding of the industry, it's cycles, business rules, trends (political, technological, demand, supply, …)
- Listening to and understanding our customers; tailor made approach and solutions
- Qualified and comprehensive solutions from one single source for all relevant strategic and operational areas
- Years of operational industry experience, extensive expertise and thorough understanding of critical business processes
- Experts in working out sustainable strategies
- Wide network of experienced consultants (app. 60) and specialized cooperating companies
- Alliance of competences ensures flexibility

EXXERGY covers business fields with competence

EXXERGY
Focusing on the flow of energy

MEMBER OF PVEXPERTS

Solar	Glass	Power Storage	Wind		
				Corporate Strategy	Sales and marketing Organizational development Mergers and acquisitions Value definition Balanced scorecard
				Markets	Market analysis Concept development New markets and market entry Product development Operational support
				Finance	Business planning Tailor-made financing structures Fund raising Performance warranty Insurance
				Human Resources	Leadership and HR -development Management assessment Recruitment
				Technology Processes	Technology transfer Innovation control Process optimization TQM Comprehensive manufacturer audits

Regional focus:

- China (Shanghai)
- Europe (Frankfurt)
- North America (New York)
- South America (São Paulo)

To improve project bankability, EXXERGY had designed a performance warranty insurance (2012)

EXXERGY	• QA Coordinator • Principle manufacturer's auditor
TÜV Rheinland	• Co-Auditor factory inspection • Product testing • Safety and performance relevant PV power plant inspection (incl. function check, measurements, detection and listing of defects) • PV power plant approval
HDI Gerling	• Insurer
Munich RE	• Re-Insurer
NEXXERGY	• Operational quality control • Procurement supervision • PV power plant approval (incl. design and construction supervision)

In 2014, IECRE was formed to streamline the bankability process using international standards

EXXERGY
Focusing on the flow of energy

Problem: PV systems are complex and may have many different problems.
- How does a customer/investor know that a PV system is "good"?
- How much more should a customer pay for a higher quality system?

Solution: International standards implemented consistently
- Improve confidence by capturing the collective wisdom of the global community
- Reduce costs by streamlining processes

IECRE provides certificates (based on IEC technical standards) for each step in the project timeline (only a subset is shown here)

IECRE

Project Timeline

Design Qualification

Example Considerations:
- Local code requirements met
- Component selection
  - Qualified for application
  - Quality control during manufacturing
- Safety:
  - Restricted access if appropriate
  - Continuously monitored
  - Overcurrent protection
- Good design
  - Shading considered
  - Trenching
  - Robust structure for use environment

Example Standards Referenced:
- Module selection
  - IEC 61215 – Design Qualification Test
  - IEC 61730 – Safety Test
  - Additional changes are in the works
  - IEC 62941 – Quality control during manufacturing
- PV plant design guidelines:
  - IEC 62548 – Small systems guidelines
  - IEC 62738 – Utility-scale systems guidelines – publish in 2017

Substantial Completion

Example Considerations:
- Local code requirements met
- Commissioning completed
- Component quality verified
- Quality management during installation:
  - Workers trained with oversight
  - Any design changes reviewed
  - Continuous improvement
- Performance check
  - Does power output match the design?

Example Standards Referenced:
- IEC 62446-1 – Commissioning
- IEC 63049 – Quality management for installation process
- IEC 61724-2 – Capacity test
- IECRE OD-401

Annual Performance

Example Considerations:
- Based on measured weather and original model, does plant perform as expected?
  - Energy availability (e.g. if inverters break, the plant could be "off line" and unavailable)
  - Performance index (measured performance divided by expected performance based on measured weather)
- O&M costs
  - Relative to planned cost, how much did it cost to keep the plant running?

Example Standards Referenced:
- IEC 61724-3 – Energy test
- IECRE OD-402

At end of year:
Performance index: 100%
Delivered 100% of expected energy
(calculated from model and measured weather)
Energy availability: 99%
Plant was functioning to deliver 99% of energy
O&M costs: 90% of planned costs

Asset Transfer

Example Considerations:
- Has plant output been consistent with original model?
- Have O&M costs been consistent with original model?
- Is there evidence of problems to come? (Cracked cells, weeds growing through the modules, hot spots)

Example Standards Referenced:
- IEC 61724-3 – Energy test
- IEC 63049 – Quality management of O&M service
- IEC 62446-2 – O&M guide
- IEC 62446-3 – Plant inspection
- IECRE OD-404

Realizing a comparable and potentially compatible approach has independently been made, EXXERGY got involved in IECRE efforts in 10/2016

The quality assurance philosophy is built on a solid foundation and 5 main pillars

EXXERGY
Focusing on the flow of energy

3. Technical project rating
➔ Risk classification ➔ Performance assessment

2. Project realization phase ratings

2.1. Manu-facturer production super-vision	2.2. Transport super-vision	2.3. Con-struction super-vision	2.4. Com-missioning protocol	2.5. O&M SOP protocol evaluation

1. Baseline ratings

1.1. Manufacturer audit
1.1.1. Modules 1.1.2. Inverters

1.2. EPC audit

1.3. O&M service provider audit

➔ The EXXERGY rating system can be used after commissioning as well as anytime thereafter, e. g. for annual review or asset transfer assessments provided that the initial rating has previously been established

The rating points are transformed into a risk exposure which may trigger the leverage financing or insurance premium conditions calculation

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Rating	Min. %-points	Max. %-points	Risk exposure	Leverage financing / insurance premium conditions
AAA	95	100	Undisclosed	Under discussion
AA	90	<95		
A	85	<90		
BBB	80	<85		
BB	75	<80		
B	70	<75		
C	65	<70		Unavailable
D		<65		

Attracts low risk investors

Attracts high risk investors

No certificate issued (report, only)

AAA	95,1	–	100,0	“Pass”	Risk low →
AA	90,1	–	95,0		
A	85,1	–	90,0		
BBB	80,1	–	85,0	“Pass”	Risk medium →
BB	75,1	–	80,0		
B	70,1	–	75,0		Risk high →
C	60,1	–	70,0	“Fail”	No acceptance
D	≤ 60,0				

Do the concept and approach of PV power plant rating make sense for IECRE?

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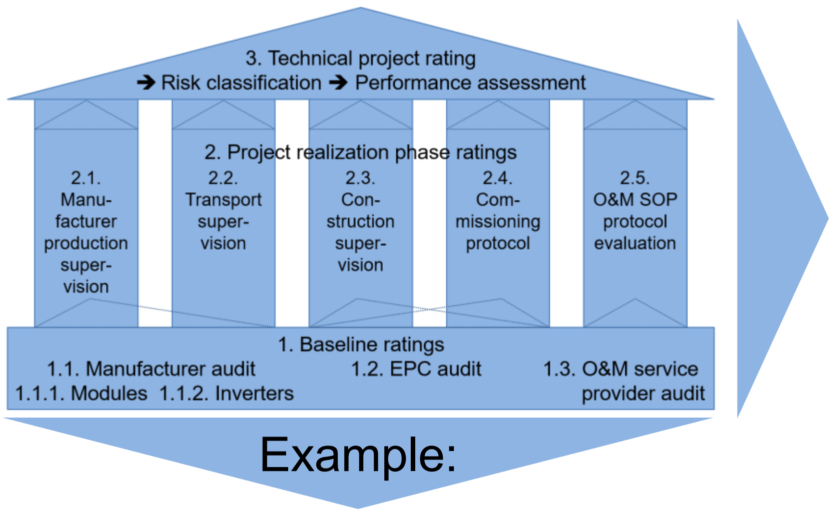

Questions to the audience:

- Do you support the concept of aligning the (to be modified) EXXERGY rating system into the IECRE system?
- What input can you provide to improve the rating system?
- Do you have any other comments?

Scoring => Topic	**Baseline**	**Realization**	Unweighted result	Weighting	**Weighted result**
Modules					
Inverters					
Transport					
EPC					
Commissioning					
O&M					
Totals					**89,1%**
PV power plant rating =>					**A**

Imprint

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IECRE Certificate

OD-401: Conditional PV project certificate (Commissioning)

http://iecre.org/documents/refdocs/

Objective of OD-401: The Conditional PV project certificate defines the IECRE process for successfully commissioning a well-built PV plant.

This document represents an outline of the current status

Element to check	How it is checked
Confirm that design follows best practices	Confirm design according to IEC 62548 or IEC 62738, (using OD-403, when approved)
The modules are designed to be safe and durable	Modules certified to IEC 61730 and 61215
The module manufacturer makes them the same (safe and durable) every time	Manufacturer quality management system (QMS) certified to IEC 62941
Power electronics are designed to be safe	Certified to IEC 62109
Trackers are designed to be durable	Certified to IEC 62817
There is Quality Assurance (QA) for installation and for Operations and Maintenance (O&M)	Certify to IEC TS 63049
System is complete, as designed	Use IEC 62446-1 to compare completed system with original design, including grounding, shock protection, fuse rating, etc.
System is complete and functioning	Confirm voltage and current from each string using IEC 62446-1
Capacity test is within designed range	Complete capacity test according to IEC 61724-2, reporting capacity and performance index

The IECRE documents are available (no cost) at:
http://iecre.org/documents/refdocs/

The IEC documents are available (for purchase) at:
https://webstore.iec.ch/

IEC standards referenced directly in the Conditional PV Project Certificate are listed and described briefly on the back of this sheet.

IEC 62548 *Photovoltaic (PV) arrays – Design requirements*

- Compliance with IEC 60364 “Low-voltage electrical installations”
- PV array system including the mechanical design
- Selection and erection of electrical equipment
- Marking and documentation

IEC/TS 62738 *Design guidelines and recommendations for photovoltaic power plants*

- Items similar to IEC 62548
- Communications systems

IEC 61215 Terrestrial photovoltaic (PV) modules - Design qualification and type approval

- Applies various stress tests that have been demonstrated to cause failures that have been observed in the field and confirms that 95% of name plate performance is retained
- Confirms accuracy of nameplate rating both before and after stress testing

IEC 61730 Photovoltaic (PV) module safety qualification

- Applies various stress tests that have been demonstrated to cause failures that have been observed in the field and confirms that safety is retained

IEC 62109 Safety of power converters for use in photovoltaic power systems

- Applies various stress tests that have been demonstrated to cause failures that have been observed in the field and confirms that safety is retained

IEC 62446-1 *Grid connected photovoltaic (PV) systems – Part 1: Minimum requirements for system documentation, commissioning tests and inspection*

- System documentation (designer/installer, wiring diagram, string layout, datasheets, mechanical design, emergency systems, O&M information, test results and commissioning data)
- Inspection and testing results (DC and AC systems including grounding, polarity, open-circuit and short-circuit measurements, insulation resistance and others)

IEC/TS 62446-2 *Grid connected photovoltaic (PV) systems – Part 2: Maintenance of PV systems*

IEC/TS 62941 *Guideline for increased confidence in PV module design qualification and type approval*

- Addresses design to match warranty, control of incoming materials and manufacturing process, continual improvement and corrective action programs, accuracy of power measurements, control of electrostatic discharge, documentation to enable traceability, etc.

IEC/TS 63049 *Guideline for increased confidence in PV system installation and operation*

- Addresses training of workers, oversight of work, collection and evaluation of performance of previously installed systems and addressing identified problems

IEC 61724-1 *Photovoltaic system performance – Part 1: Monitoring*

- Defines 3 accuracy classes (A, B, and C)
- Requirements for data sampling, data quality checks, and sensor maintenance.
- Defines power-related parameters to be calculated

IEC/TS 61724-2 *Photovoltaic system performance – Part 2: Capacity evaluation method*

- Corrects system power data to target reference environmental conditions using defined coefficients or model, then compares that result to the promised target value.

IECRE Certificate

OD-402: Annual PV plant performance certificate

http://iecre.org/documents/refdocs/

Objective of OD-402: Compare the performance of the PV plant relative to the original design/model.
This document represents an outline of the current status.

Element to check	**How it is checked**
Document predictions of plant performance based on design and historical data	Referencing original design
Compare the measured and the historical insolation data	IEC 61724-3
Compare expected (based on measured weather data) with measured energy	IEC 61724-3
Compare expected and measured energy during times of unavailability	IEC 61724-3
Compare predicted and actual O&M costs	OD-402
Compare predicted and measured capacity factor (optional)	IEC 61724-3
Compare predicted and measured performance ratio (optional)	IEC 61724-3
Compare predicted and measured availability (optional)	IEC 61724-3
Compare predicted and measured energy performance index (optional)	IEC 61724-3
Compare predicted and measured power performance index (optional)	IEC 61724-2
Documentation of significant events (greater than 0.1% of annual energy)	IEC 61724-3

The IECRE documents are available (no cost) at:
http://iecre.org/documents/refdocs/

The IEC documents are available (for purchase) at:
https://webstore.iec.ch/

IEC standards referenced directly in the Annual PV plant performance Certificate are listed and described briefly on the back of this sheet.

IEC 61724-1 *Photovoltaic system performance – Part 1: Monitoring*

- Defines 3 accuracy classes (A, B, and C)
- Requirements for data sampling, data quality checks, and sensor maintenance.
- Defines power- and energy-related parameters to be calculated

IEC/TS 61724-2 *Photovoltaic system performance – Part 2: Capacity evaluation method*

- Corrects measured system power data to target reference environmental conditions using defined coefficients or model, then compares that result to the promised target value.

IEC/TS 61724-3 *Photovoltaic system performance – Part 3: Energy evaluation method*

- Quantifies actual electricity production (energy), and compares with that predicted from the measured weather data.

IECRE Certificate

OD-404: PV plant assessment
http://iecre.org/documents/refdocs/

Objective of OD-404: Assess the condition of a PV plant to identify it is likely to perform as predicted in future years.

This document represents an outline of the current status

Element to check	How it is checked
Plant records are available (as-built drawings, interconnection agreement, warranties, O&M records, planned maintenance schedule/costs, other records)	OD-404 lists the elements required for each project type (U1, U2, U3, and U4)
Additionally, plant records should include description of model and the resulting predictions of plant performance based on design and historical data	Referencing original design; document using OD-402
Additionally, plant records should include performance checks (preferably for multiple years)	See OD-402 and IEC 61724-3
Documentation of O&M deficiencies and opportunities for improvement	IEC 62446-2
Deficiencies in plant condition including visual inspection, IR inspection, and EL inspection	IEC 62446

The IECRE documents are available (no cost) at:
http://iecre.org/documents/refdocs/

The IEC documents are available (for purchase) at:
https://webstore.iec.ch/

IEC standards referenced directly in the Conditional PV Project Certificate are listed and described briefly here:

IEC 61724-1 *Photovoltaic system performance – Part 1: Monitoring*

- Defines 3 accuracy classes (A, B, and C)
- Requirements for data sampling, data quality checks, and sensor maintenance.
- Defines power- and energy-related parameters to be calculated

IEC/TS 61724-2 *Photovoltaic system performance – Part 2: Capacity evaluation method*

- Corrects system power data to target reference environmental conditions using defined coefficients or model, then compares that result to the promised target value.

IEC/TS 61724-3 *Photovoltaic system performance – Part 3: Energy evaluation method*

- Quantifies actual electricity production (energy), and compares with that predicted from the measured weather data.

IEC 62446-1 *Grid connected photovoltaic (PV) systems – Part 1: Minimum requirements for system documentation, commissioning tests and inspection*

- System documentation (designer/installer, wiring diagram, string layout, datasheets, mechanical design, emergency systems, O&M information, test results and commissioning data)
- Inspection and testing results (DC and AC systems including grounding, polarity, open-circuit and short-circuit measurements, insulation resistance and others)

IEC/TS 62446-2 *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 2: Maintenance of PV systems*

- Describes different types of maintenance activities.

IEC/TS 62446-3 *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 3: Photovoltaic modules and plants – Outdoor infrared thermography*

- Describes how to take and interpret IR images.

IEC 60904-13 *Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules*

- Describes how to take and interpret EL images.

IECRE Certificate

OD-405: Requirements for certification of a quality system for PV module manufacturing

http://iecre.org/documents/refdocs/

Objective of OD-405: Provide confidence in the manufacturer's quality management system beyond that provided by an ISO 9001 certification.

This document represents an outline of the current status of OD-405 implementation of IEC/TS 62941.

The IECRE documents are available (no cost) at:
http://iecre.org/documents/refdocs/

The IEC documents are available (for purchase) at:
https://webstore.iec.ch/

Requirements of IEC 62941:

- Design reflects intended lifetime and use environment
- Purchasing process is controlled to meet needs of intended design implementation
- Production process is controlled to meet needs of intended design implementation
- Records are kept to enable traceability
- Monitoring and measurement equipment are kept in calibration, especially to enable accurate measurement of power output (I-V curves)
- Manufacturing conditions are controlled to avoid damage from electrostatic discharge
- An ongoing product monitoring program is maintained (including stress testing of sampled modules)
- Non-conforming product is controlled
- Continual improvement program is implemented in a systematic way
- Corrective and preventive actions are taken when appropriate