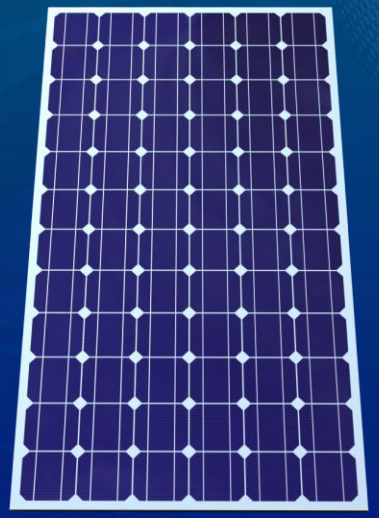
Photovoltaics: Safety & Efficiency Codes, Standards and Labelling, (Non)Regulation, and Certification Efforts

Brian Dougherty
Energy and Environment Division
Engineering Laboratory
National Institute of Standards and Technology
U.S. Department of Commerce

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Outline

- Solar Photovoltaic (Industry) Highlights
- Questions for You
- Solar PV Industry Priorities
  - Safety first
  - A hierarchy of standards and codes efforts
  - Product Testing and Labelling
- Government Regulations Besides Codes: Financial Incentives
- Certification Efforts



Solar PV Industry Highlights (1 of 3)

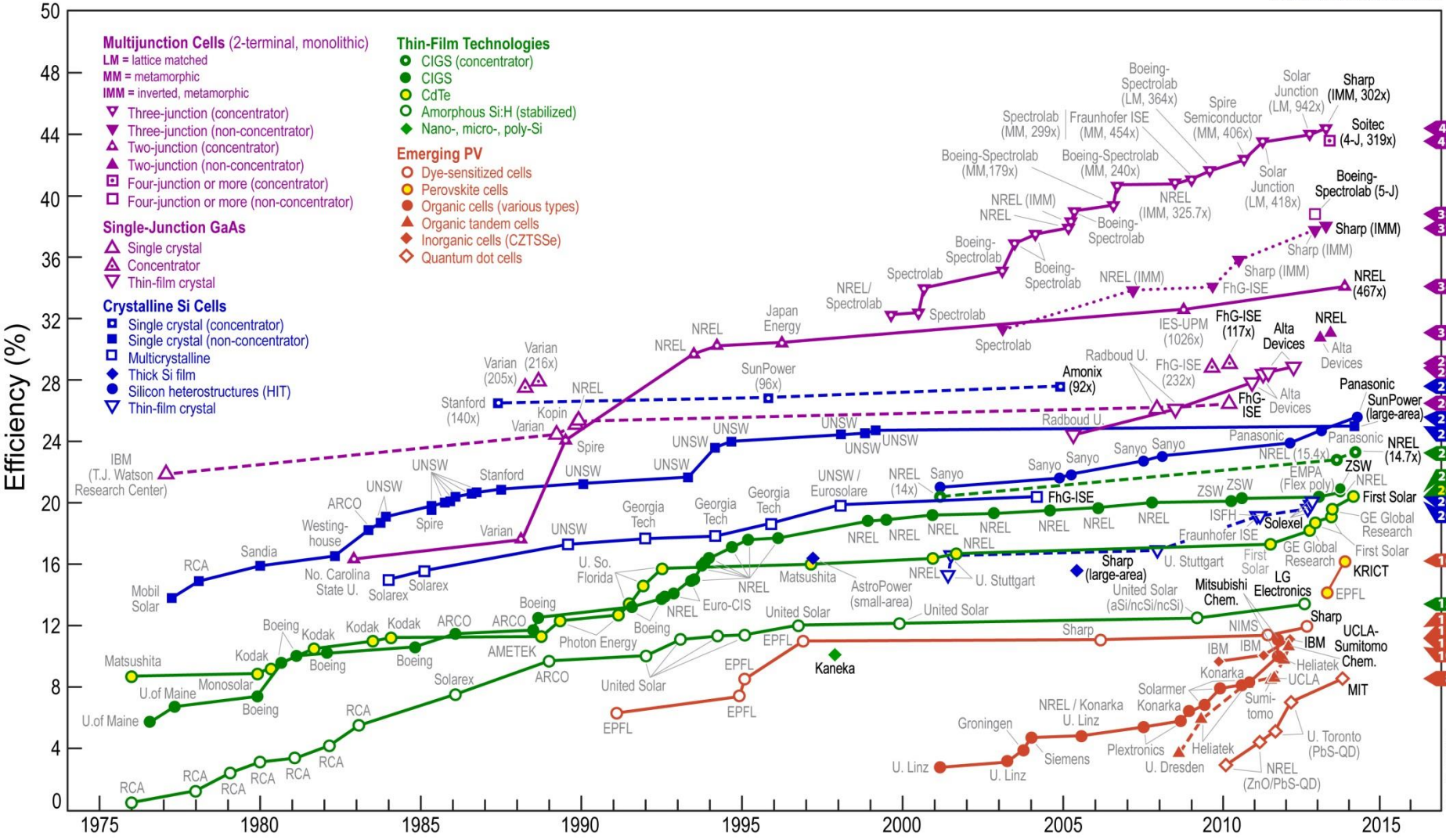
- Most solar modules are made using silicon crystalline cells
- The majority of solar cell/modules are manufactured in China
- Over the last 10 years, many companies have entered and left the solar module manufacturing market
- Manufacturers (typically) warranty their solar modules (10 – 30 yrs) and inverters (5 – 15 yrs)
- New and improved modules and inverters are continually introduced; usually a specific product model/line on market for 2 to 4 years

Solar PV Industry Highlights (2 of 3)

- The performance of solar photovoltaic modules are affected by:
  - Solar irradiance level
  - Angle of Incidence
  - PV cell operating temperatures
  - Solar spectrum

- Must minimize shading of the modules – a relatively small amount of shading can have a huge impact on reducing power production
- Sun-to-DC power conversion efficiencies for single-junction solar modules as high as 20%; higher for multi-junction, bi-facial, and concentrating
- NREL maintains world-record cell listing by type

Best Research-Cell Efficiencies

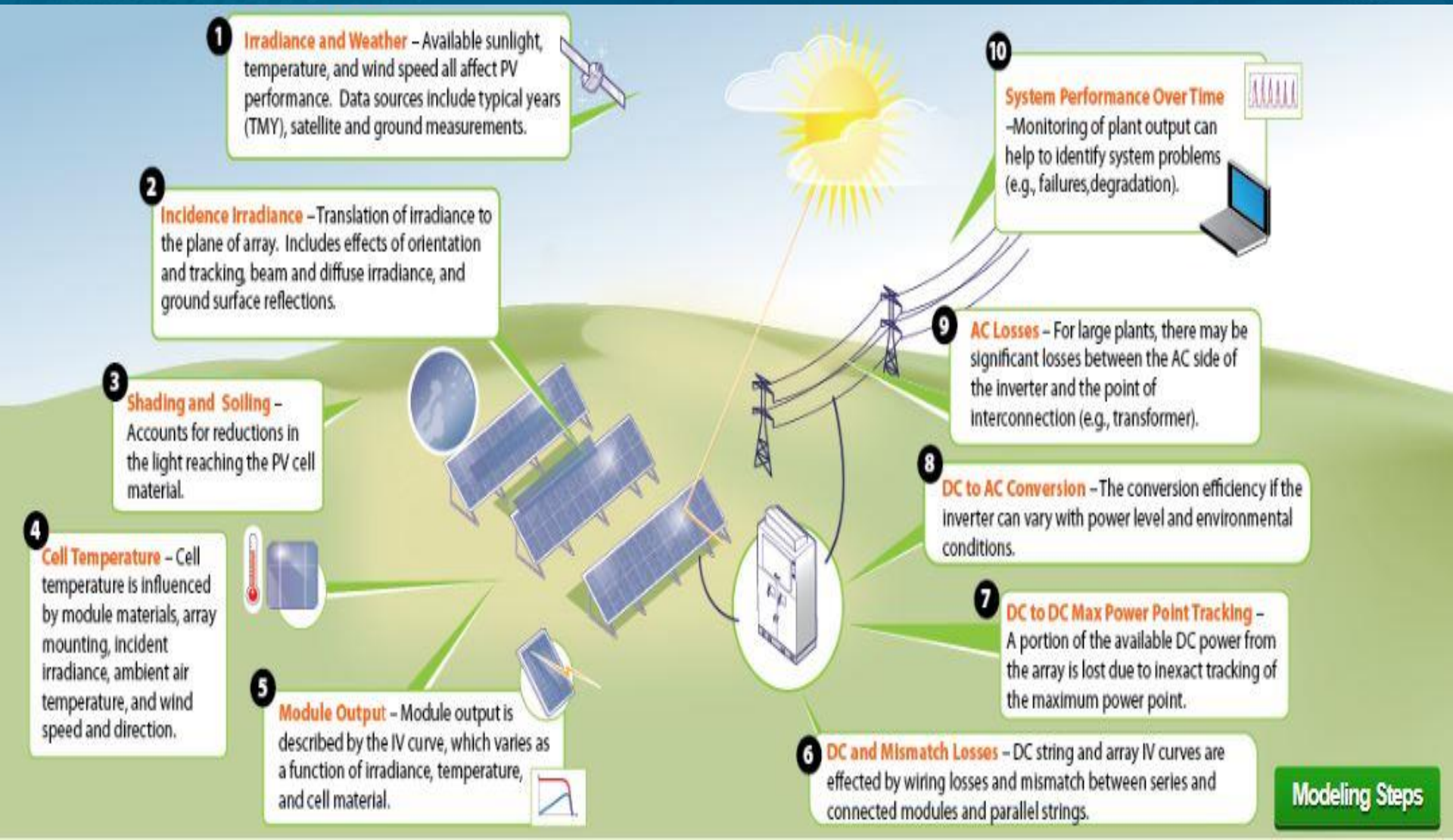


Solar PV Industry Highlights (3 of 3)

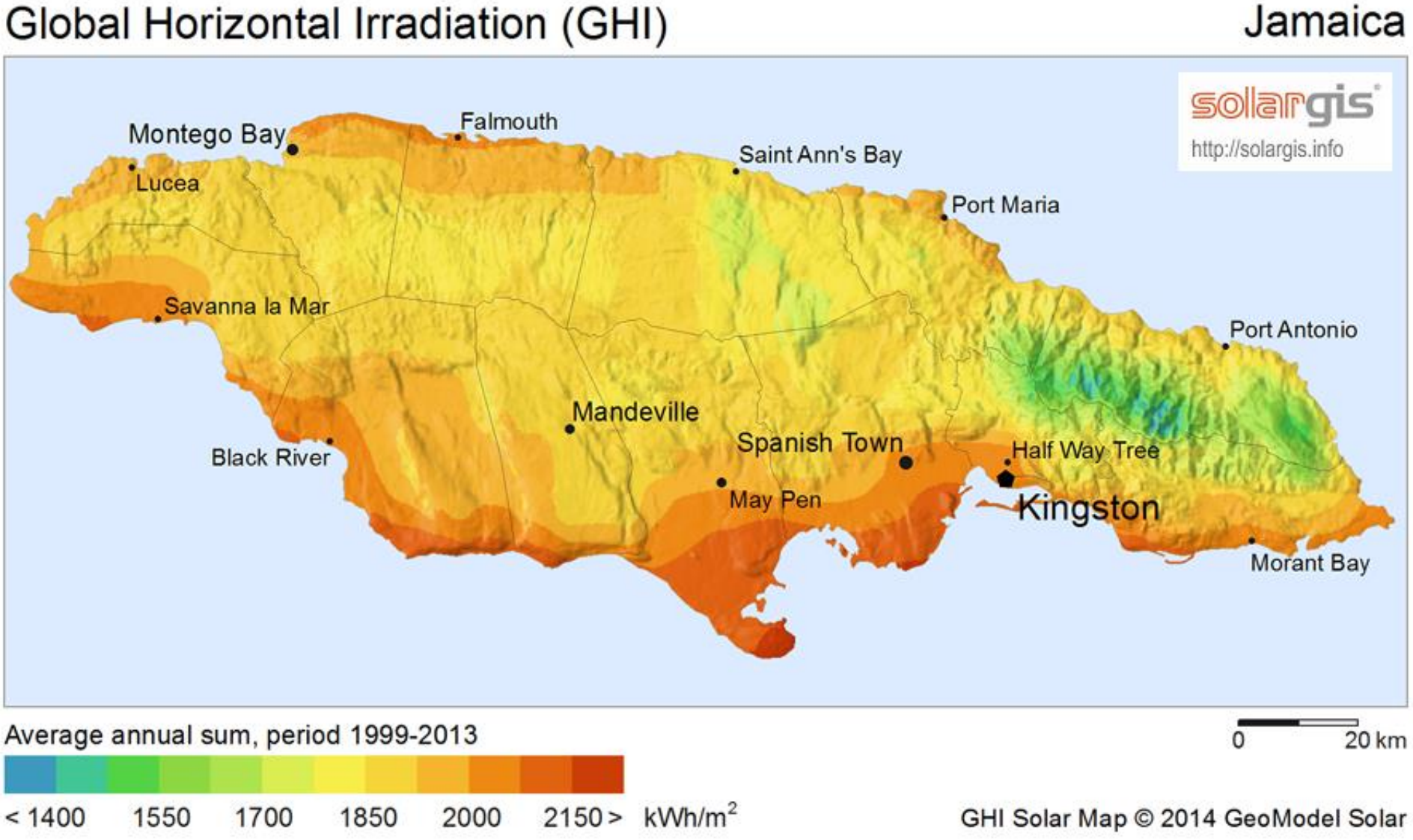
- Many companies and on-line tools exist to help with:
  - Evaluating the local solar resource
  - Modelling and designing a solar PV system
  - Evaluating the feasibility of a solar PV system
  - Providing 3rd party testing of modules
  - Conducting an on-site evaluation of an installed system
  - Troubleshooting an installed system and helping with processing a warranty claim

- In most countries (still), the continued growth in solar PV installation is fueled by favorable government-created financial incentives

Example: PV Modeling Guidance



Example: Solar Resource Mapping



Questions for You

- Will your country offer financial incentives to promote the installation of solar energy?
  - First cost of an installed system is (still) substantial.
- Will the solar arrays be connected to a central electrical grid?
- If yes, will your electric utilities offer favorable energy storage options for the solar energy?
  - Yes: electric utilities serve as the storage for excess solar energy
  - No: solar energy owner has to provide energy storage
- Will your country offer financial incentives to promote the manufacturing of solar energy modules and/or inverters?

Solar PV Industry Priorities

1. ***Electrical, Mechanical & Fire SAFETY***
   - All components (modules, inverters, combiner boxes)
   - Installed systems
   - Consider only new components / new installed systems

Primary Focus

2. Solar Module Model Pass-Fail Qualification
3. Single-Point, New Module Electrical Rating

Secondary Focus

4. Module/System Performance over time
5. Multiple-Point Electrical Rating for New Modules
6. Audit/Confirmation Testing and Inspection

Least focus up until recently

Electrical, Mechanical & Fire Safety (1 of 3)

- In the USA, the **National Electric Code** (NEC) contains sections that specifically cover solar-energy and distributed power generation systems
  - Provides specifications on equipment, installation methods, and design protocols
  - Extensive, detailed document on safe electrical practices
  - Revised/updated every 3 years through a rigorous review process.
- The International Residential Code (IRC) and the International Energy Conservation Code (IECC) reference related standards that apply if installing, respectively, a residential or commercial PV system
- The International Fire Code (IFC) establishes solar provisions relating to fire access and fire safety.

Electrical, Mechanical & Fire Safety (2 of 3)

- Primary source of PV safety standards in the USA:
  - Underwriters Laboratory (UL)
  - Institute of Electrical Engineering and Electronics (IEEE)
- PV modules and inverters models are independently tested and labelled for safety performance: UL, Intertek, TUV
- Secondary source of PV standards in the USA: ASTM International
- Both IEC and ASTM Intl publish numerous PV standards; many are very similar and so redundant.

Electrical, Mechanical & Fire Safety (3 of 3)

- New Resource from the International Electrotechnical Commission (IEC): International Solar Energy Provisions (ISEP)
- The ISEP is:
  - a collection of recommendations from various building and electrical codes on both solar thermal and PV
  - all safety related
  - just being published

Solar Module Model Pass-Fail Qualification (1 of 2)

- A series of pass-fail torture tests designed to identify near term failures in the new model of PV module
- The specific series of test are specified in standards of the IEC
  - IEC Standard 61215 (modules with silicon crystalline cells)
  - IEC Standard 61646 (modules with thin-film cells)
- These two IEC standards reference several other related IEC standards

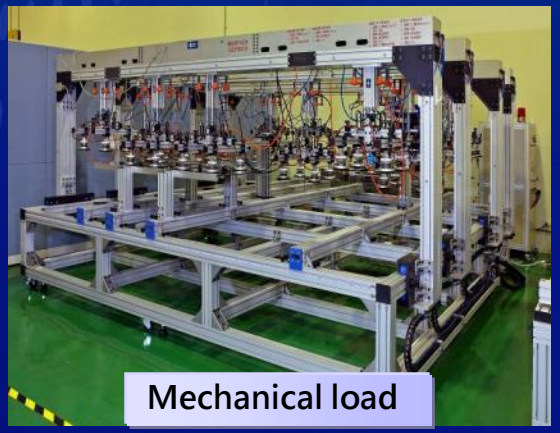

NOCT/outdoor test


UV test

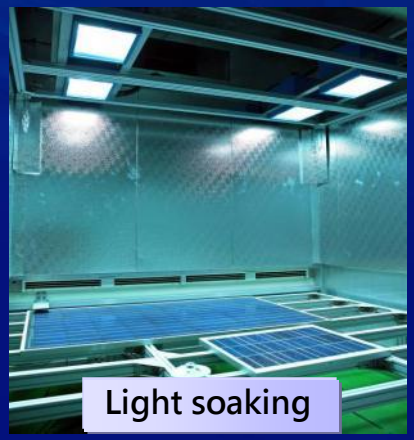

Damp heat/Thermal cycle/HF test

Solar Module Model Pass-Fail Qualification (2 of 2)

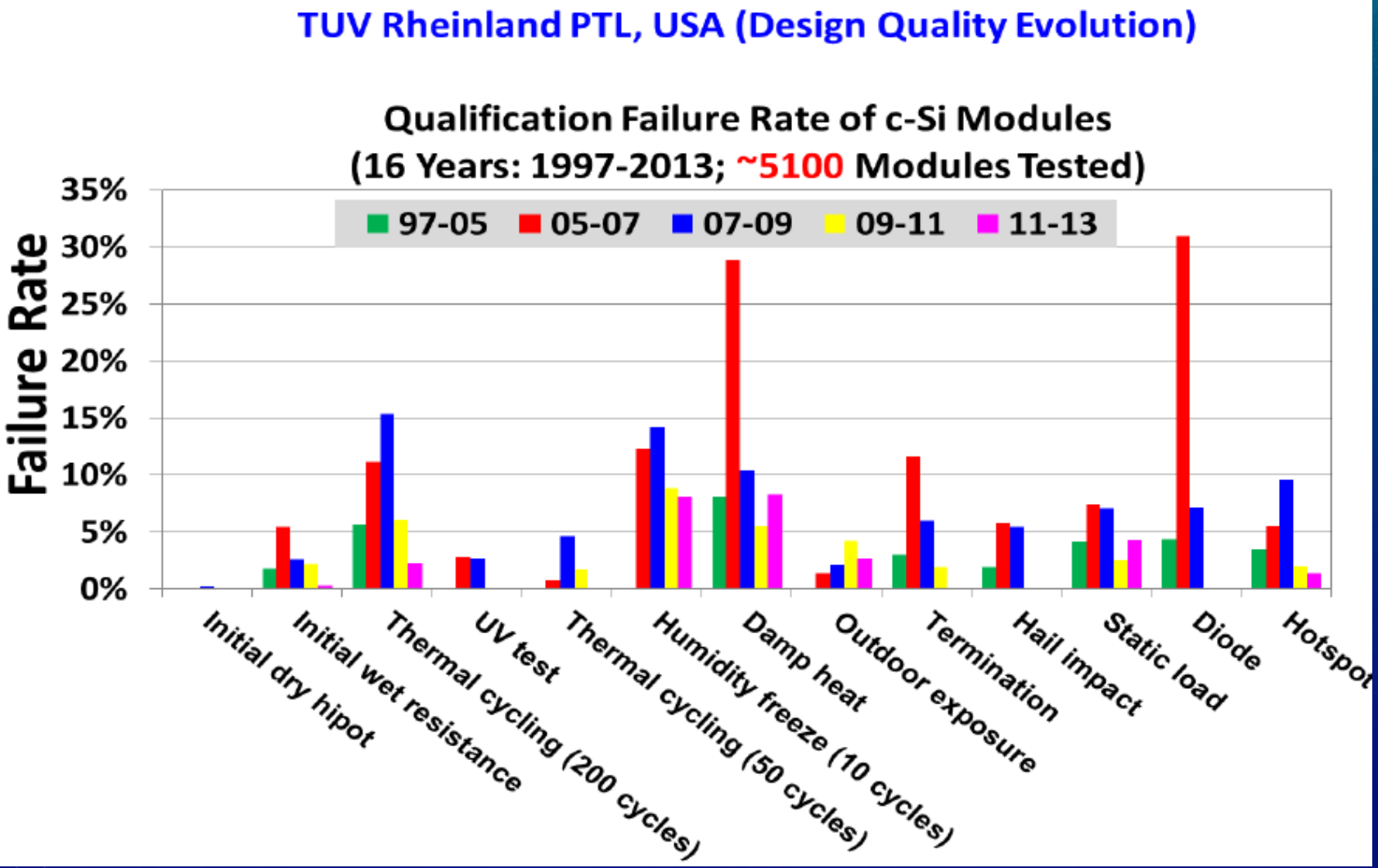
- PV module manufacturers voluntarily conduct these series of tests (in order to better compete)
- Testing only conducted on new modules
- Modules are labeled to confirm passing the applicable suite of IEC qualification tests
- Although sometimes used to infer module lifetime, not designed to do so; alternative ways being developed to perform accelerated aging testing


Mechanical load


Hail test


Light soaking

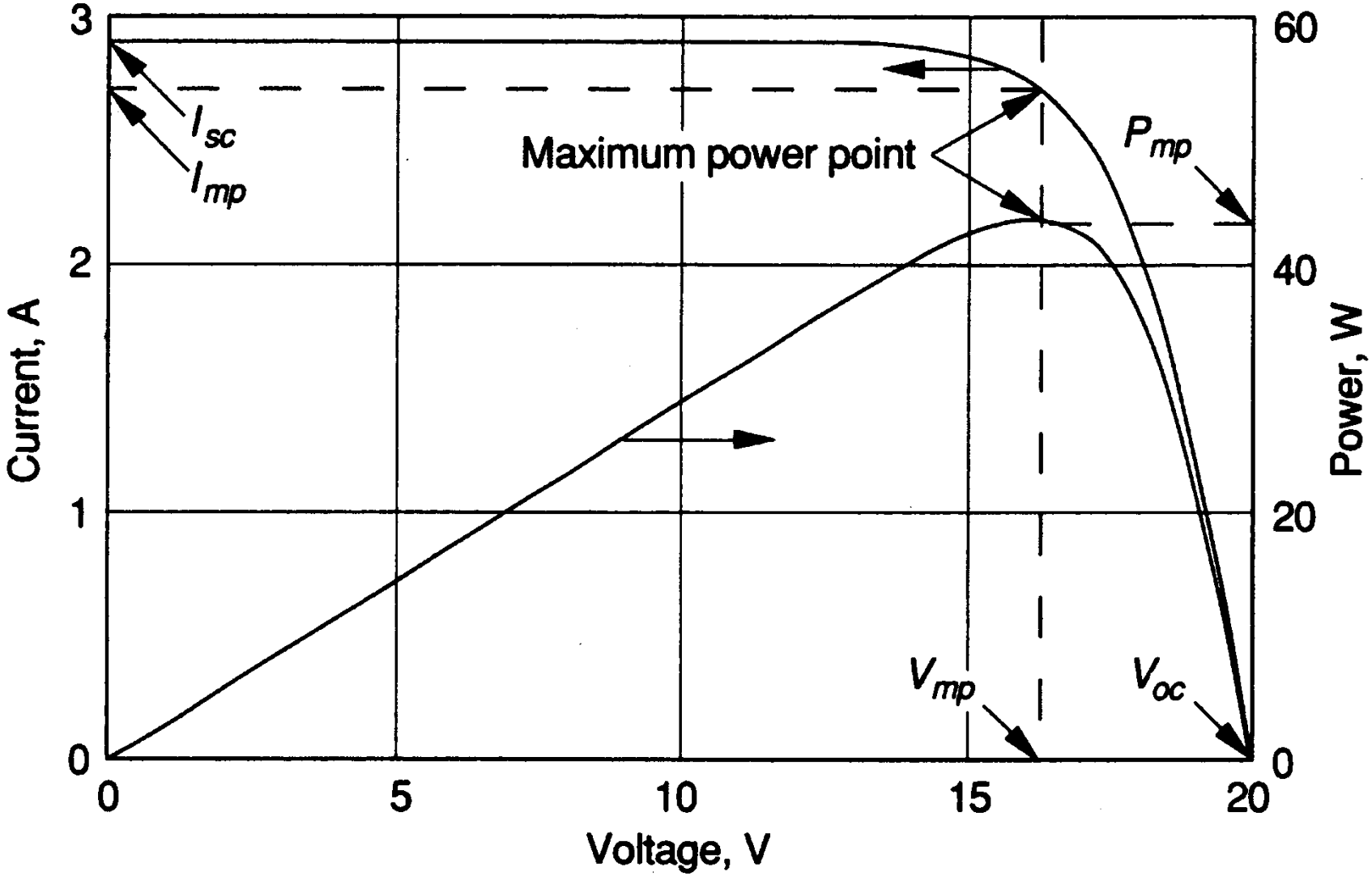
Failure Rate for Qualification



Ref: 2014 IEEE PVSEC ,TUV Rheinland

Single-Point, New Module Electrical Rating

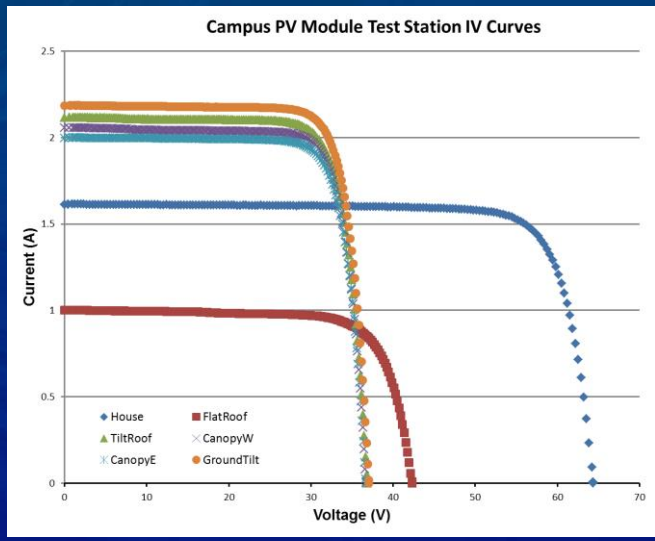
- A single test that is used for rating PV modules
- Favorable test conditions that correspond to the modules peak DC electrical output
  - used in sizing a PV system: maximum current, voltage, and power
  - Most times based on STC; California requires a slight de-rate by requiring PVUSA test conditions
- Modules typically tested indoor using a flash solar simulator
- IEC and ASTM standards cover the testing steps/requirements
  - Tests and requirements of the solar simulator and reference cell or module
- A very small sample of modules are independently tested to confirm the manufacturers' published ratings



Typical *I-V* and *P-V* curves for a PV module

Module Electrical Performance

- Independent measurements available from a few sources
- California Energy Commission: Go Solar California
  - List modules that have past their requirements for allowing a solar PV installation to be eligible for financial incentives
  - www.gosolarca.com
- Photon International Magazine
  - Has a outdoor monitoring facility
  - Report on changes in performance over time
  - Must subscribe to the magazine for access
- TUV Rheinland
  - Combination of laboratory and field testing to characterize modules
  - Fee based
  - Program just being introducted



Government Regulation

- Besides codes, government impact on the solar industry in the USA comes mainly via economic incentives
- Otherwise, participation at the U.S. federal government level is limited to offering fee-based calibration services for manufacturers and independent testing laboratories; *nothing comparable to DOE appliance performance regulations*
- A few States in the USA do have performance requirements
  - California (big impact)
  - Florida (little impact)
- Many States offer financial incentives or enact laws that aid the installation/ownership of PV
  - Net metering laws and adopting interconnection & permitting standards
  - Renewable Portfolio Standards (leads to renewable energy certificates/credits)
  - Tax breaks, grants, rebates, loans, and some feed-in tariffs

Certification Efforts

- Currently limited to 3rd party testing of new modules and inverters
  - IEC Qualification Tests
  - Single-Point Power Rating In Certain Cases
    - Required as part of the buyers contract
    - Required by the government (e.g., State of California)
  - Selection of tested units often decided by the manufacturer
- At least in the USA, nothing comparable to the audit testing conducted on appliances
- Past efforts to create a voluntary audit/certification program have never got traction (e.g, PowerMark)
- But, IEC now developing a testing and certification program for renewable energy equipment (IECRE)