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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Utility/Lab Workshop on PV Technology and Systems

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PV O&M Best Practices

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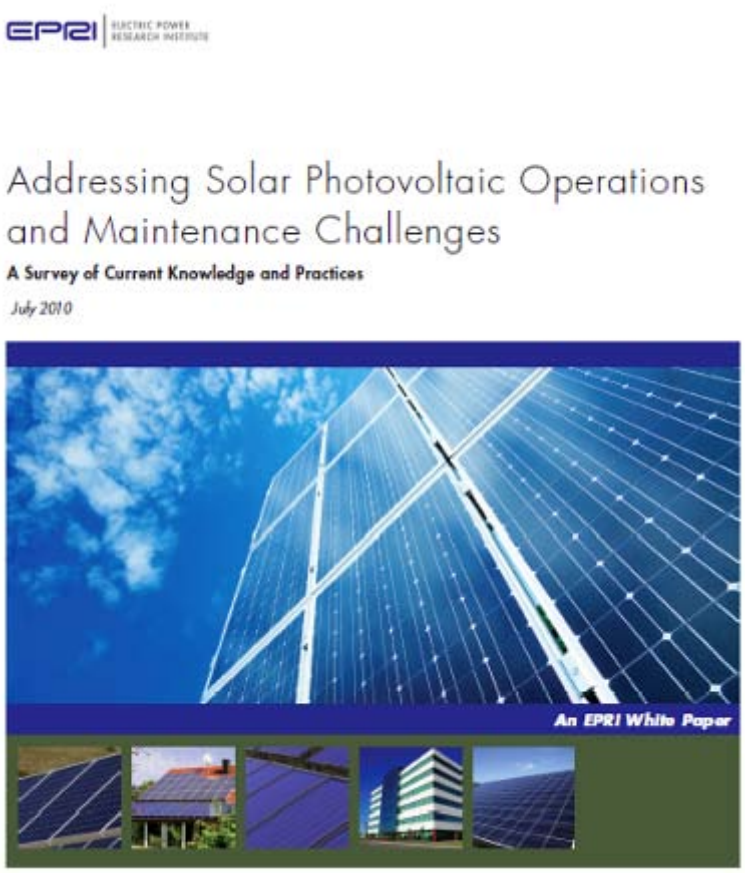
EPRI Survey-Driven White Paper on PV O&M Best Practices



Survey Sample and Respondent Profile:

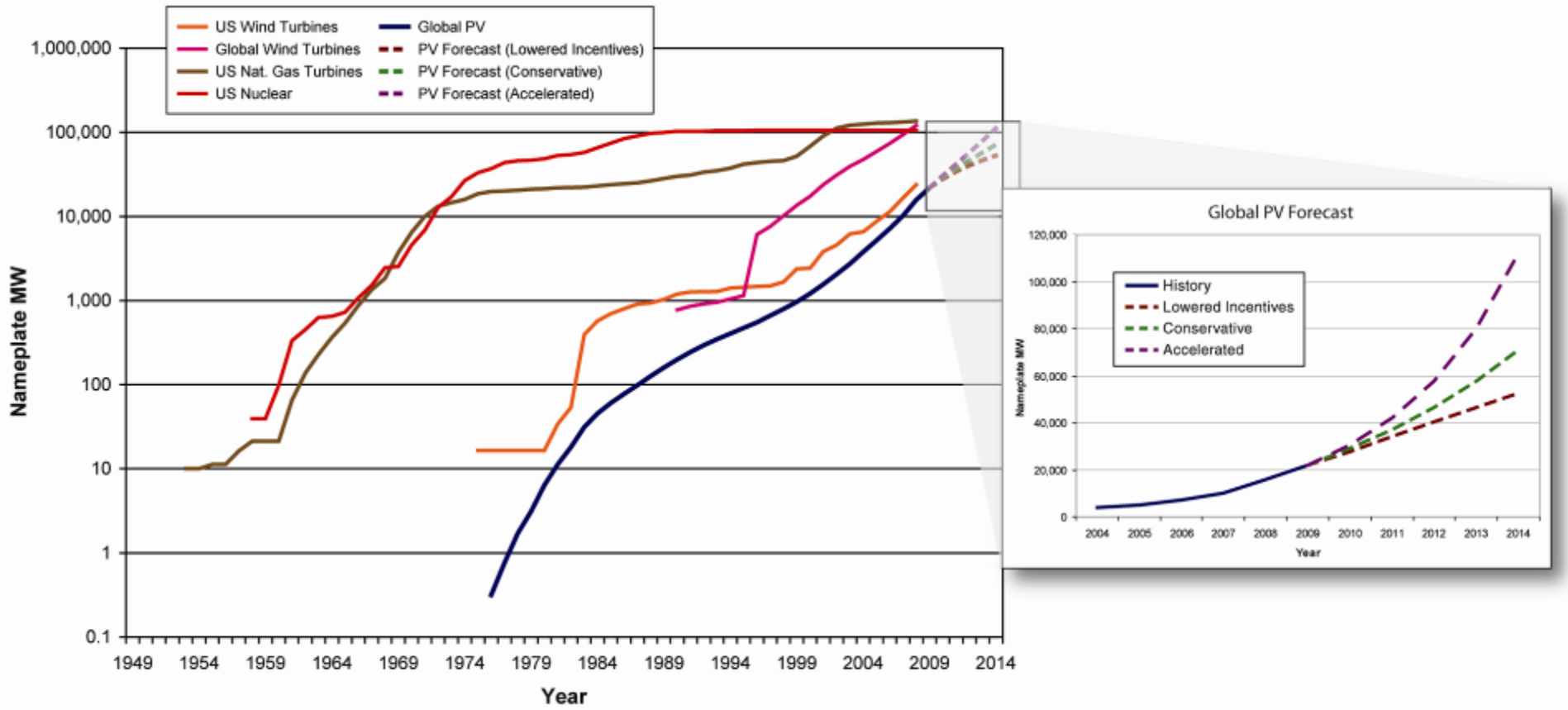
Utilities

- Arizona Public Service (APS)
- Austin Energy
- Detroit Edison
- Salt River Project (SRP)
- San Diego Gas & Electric (SDG&E)
- Southern California Edison (SCE)

Non-Utility Companies

- Draker Laboratories
- Florida Solar Energy Center
- Fat Spaniel Technologies
- Solar Power Partners
- Sun Edison
- SunPower Corp.

Cumulative Adoption Rates across Select Generation Technologies with Global PV Growth Forecast



Sources: EIA (U.S. Nuclear, Nat. Gas, and Wind), European Wind Energy Association (Global Wind), and Navigant Consulting PV Service (Global PV, Historic and Forecasted).

The relevance of PV O&M is growing!

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Select Utility Solar PV Ownership Initiatives

Utility	Investment ($M)	Initial Application Filing	Proposed Activity
Arizona Public Service	$14.7	5/11/2009	1 MW utility-owned PV installed on residential/commercial customer rooftops; 0.5 MW stand-alone on utility-owned or leased property.
Duke	$50.0	6/6/2008	8 MW utility-owned roof-mounted PV (reduced from originally requested 16 MW).
Los Angeles Dept. of Water & Power*	$1350.0	3/19/2009	400 MW of utility-owned PV to be installed on city-owned rooftops, reservoirs, and parking lots by 2014; Program status unclear.
National Grid	$31.1	4/23/2009	5 MW of PV to be installed on five company-owned, mostly brownfield sites in Massachusetts.
Northeast Utilities	$42.0	2/12/2009	6 MW to be installed on utility/customer property from 2009-12; targeting landfill, brownfield, commercial & government buildings.
Pacific Gas & Electric	$1,450.0	2/24/2009	250 MW utility-owned PV, plus 250 MW 3rd party-owned PV to be developed over five years starting in 2010.
Public Service Electric & Gas	$773.0	2/10/2009	120 MW utility-owned PV to be deployed on utility poles/street lights, public schools, municipal and county-owned buildings, utility facilities/ land.
San Diego Gas & Electric	$250.0	7/11/2008	50 MW utility-owned tracking and thin-film PV, 27 MW 3rd party-owned to be installed in five years.
Southern California Edison	$875.0	3/27/2008	250 MW utility-owned ground- and rooftop-mounted PV to be installed in five years starting in 2008, plus 250 MW 3rd party-owned PV developed.
Totals	**$4,835.8**		~1.1 GW of utility-owned PV to be installed ~527 MW of 3rd party-owned PV to be installed for utility PV programs

Notes:

*Estimated range in LADWP program cost is $1.1 to $1.6 billion without tax benefits; Program proposed as Measure B amendment on the municipal ballot was defeated 50.5% to 49.5% on 3/19/2009; Program status unclear.

Major Elements of PV O&M

Preventative Maintenance (PM)

- Panel cleaning (~1-2x/year or as needed)
- Vegetation management (~1-3x/year)
- Wildlife prevention (variable)
- Water drainage (variable)
- Retro-commissioning (1x/year)
- Upkeep of data acquisition and monitoring systems (e.g., electronics, sensors) (frequency: undetermined)
- Upkeep of power generation system (e.g., inverter servicing, BOS inspection, tracker maintenance (~1-2x/year)

PM's value measured in system efficiency and system/component lifespan.

Corrective maintenance

- On-site monitoring/mitigation
- Critical reactive repair
  - Address production losses
- Non-critical reactive repair
  - Address production degradation
- Warranty enforcement (as needed)

Condition-based maintenance

- Active monitoring—remote and on-site options
- Warranty enforcement (planned)
- Equipment replacement (planned)

Major variables influencing extent and cost of PV O&M

- Site characteristics and environment
  - Systems size, type (e.g., roof mount, ground mount, tracker) and location
  - Number of distinct arrays, meters, inverters and ease of access
  - Availability of water
- Scope of O&M service and scale economies
- Desired level of monitoring capability
- Warranty terms and extent of equipment standardization
- On-site vs. off-site management
  - Can affect labor costs by 2-3x

Caption: FPL's 10 MW Cape Kennedy PV Plant

European O&M costs 50-100% higher than US, given greater embrace and scope of O&M activities

Utility-Scale PV Power Plant O&M Cost Estimates: Typically ~1-2% of System Lifetime

System Size	$/kW	% of O&M Relative to "All In" Cost
1 MW and Less	$6/kW - $27/kW	<1% to 5%

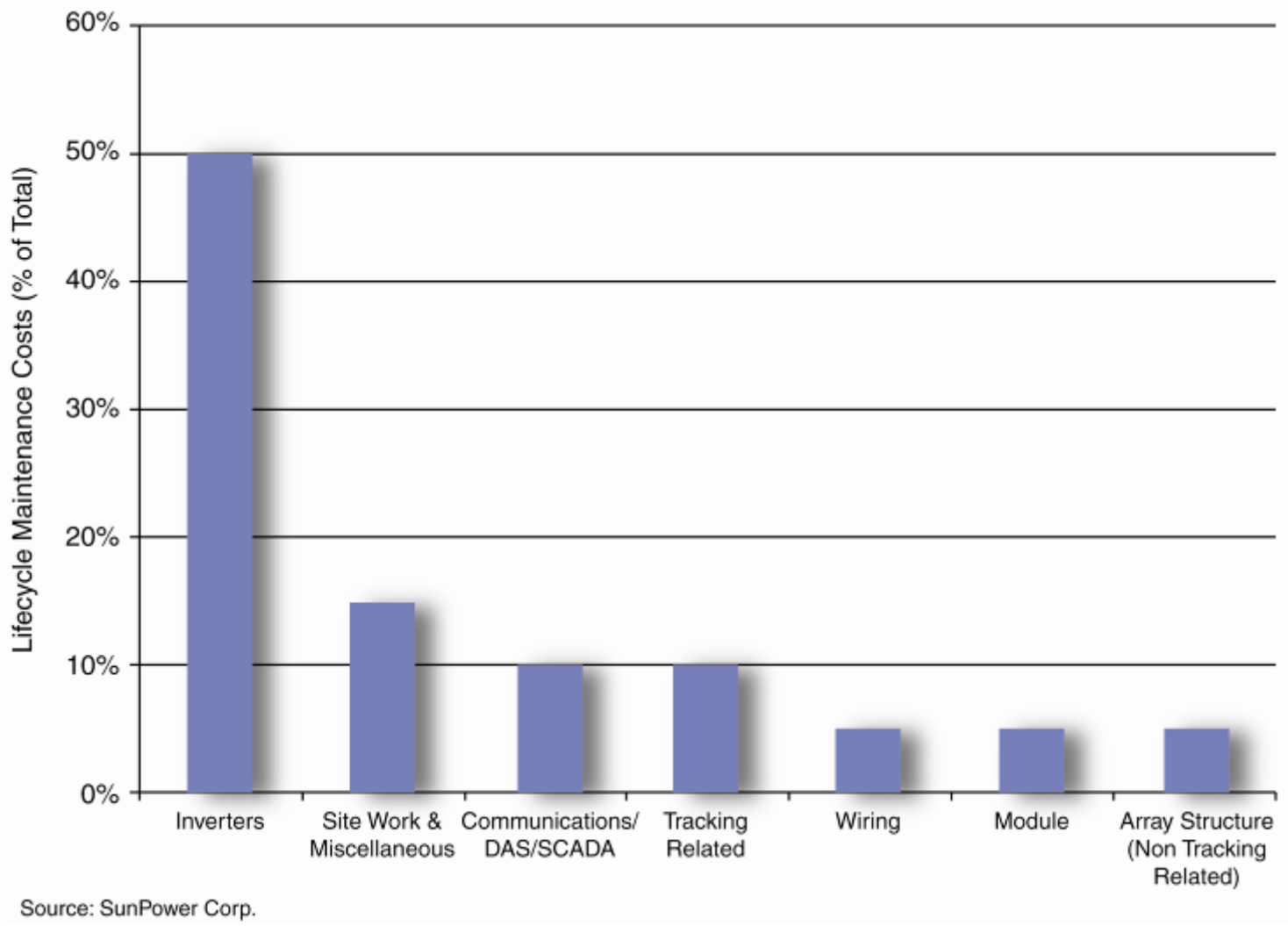
Notes:
Figures represent a range of anecdotal data and comprise costs for handling O&M of distributed PV assets via utility in-house and outsourced approaches. Data largely indicates direct O&M costs and doesn't include variables such as roof leases and utility management oversight of labor.

PV O&M budgeting: an inherent compromise between the costs and benefits of maintaining asset availability and performance.

O&M Costs ($/kW-yr)	Fixed-Tilt c-Si	Fixed-Tilt CdTe	Fixed-Tilt a-Si	Tilted Single-Axis Tracking c-Si	Single-Axis Tracking c-Si
Scheduled Maintenance/Cleaning	$20	$25	$25	$30	$30
Unscheduled Maintenance	$2	$2	$2	$5	$5
Inverter Replacement Reserve	$10	$10	$10	$10	$10
Subtotal O&M	$32	$37	$37	$45	$45
Insurance, Property Taxes, Owner's Costs	$15	$15	$15	$15	$15
Total O&M	$47	$52	$52	$60	$60

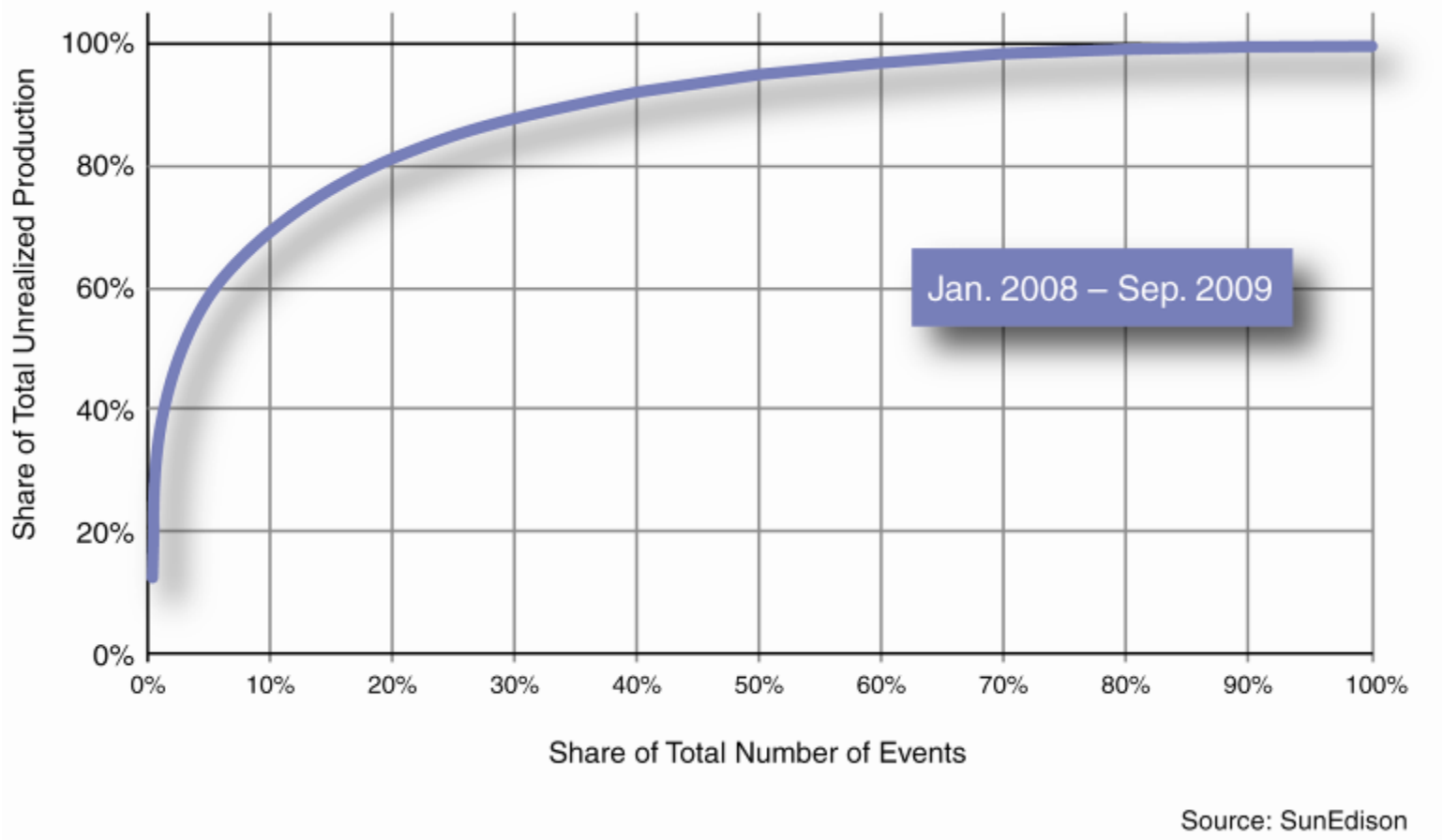
Notes:
Fixed-Tilt c-Si defined as polycrystalline modules mounted at a fixed 30 degree tilt facing south. Fixed-Tilt CdTe defined as cadmium telluride modules mounted at a fixed 30 degree tilt facing south. Fixed-Tilt a-Si defined as amorphous silicon modules mounted at a fixed 30 degree tilt facing south. Tilted Axis Tracking c-Si defined as monocrystalline modules on a north-south axis tracker tilted south at 20 degrees with backtracking. Single Axis Tracking c-Si defined as monocrystalline modules on a north-south axis tracker with backtracking.

Solar PV Power Plant Maintenance Cost Breakdown

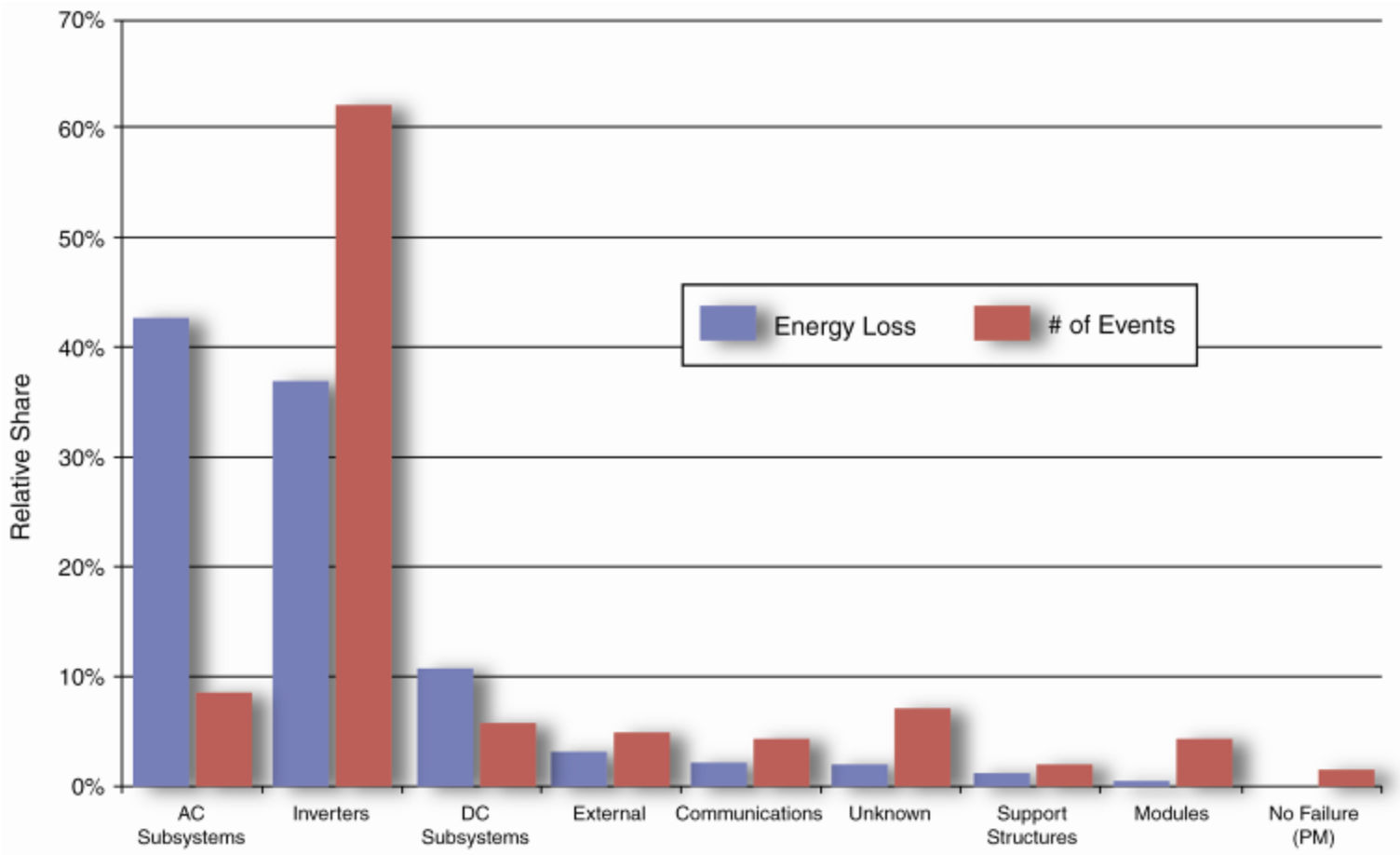


Source: SunPower Corp.

The 80/20 Rule: 80% of Unrealized Production Due to 20% of Total Outage Events



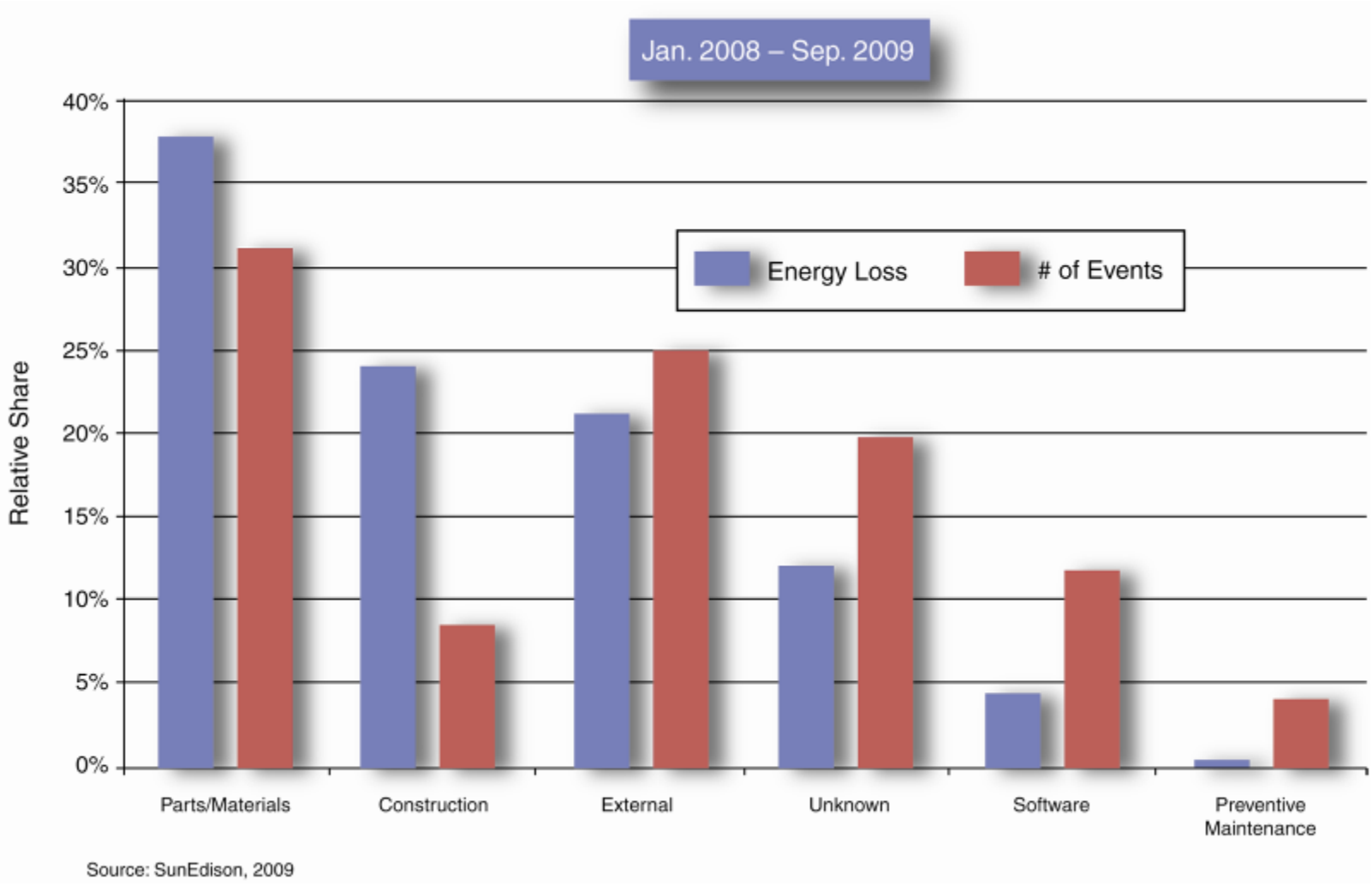
PV System Failure Areas and Relative Frequencies



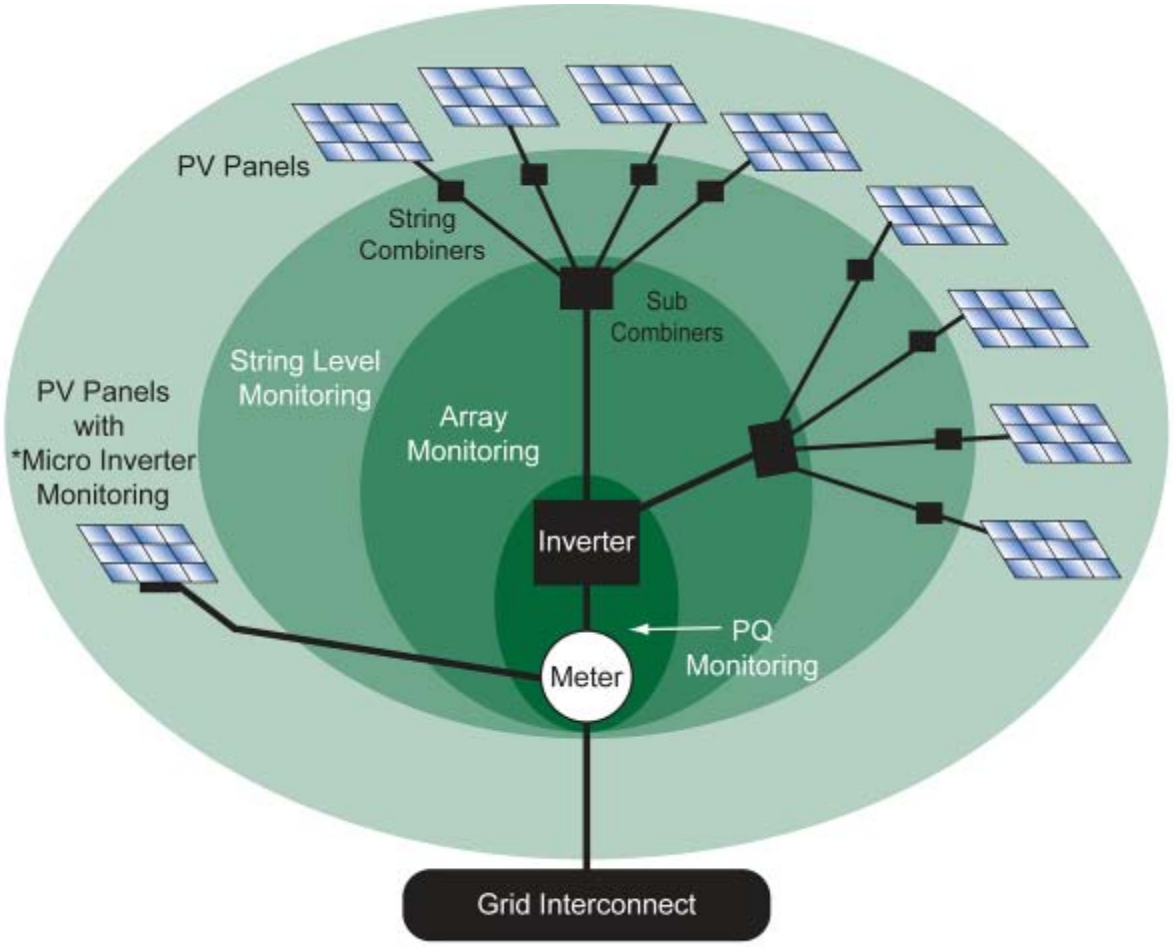
Note: The graph illustrates relative outage impacts and corresponding event frequency for SunEdison's PV fleet during January 2008 to September 2009

Source: SunEdison, 2009

Root Causes of PV System Component Failure



PV Monitoring Options Across the System



Solar Power Partners, 2010, Redrawn by EPRI, 2010

In-Housing Versus Outsourcing PV O&M

Utility In-Housing

Pros

- Better visibility on personnel/equipment issues
  - Improved quality control
- Ability to leverage existing utility assets
- Workforce training
- Institutionalization of PV O&M process

Cons

- Upfront costs
- Work force knowledge/resource ramp up
  - Utility perspective: Adding payroll = long term financial concerns
- Increased risk

Turnkey/Third-Party Outsourcing

Pros

- Lower upfront costs and upfront risk
- Less drain on utility labor force
- Transitional O&M option
  - 3rd party trains and hands O&M responsibility to utility in negotiated timeframe

Cons

- Less control/understanding of O&M process
- Potential for higher back-end costs
  - Based upon equipment selection
- Dependence on outsourced contractors

No consensus on cost-benefit of in-house vs. outsource options, but tradeoffs apparent.

Warranty Coverage: An Essential O&M Ingredient

Typical Equipment/Service Warranties		
Modules	Inverters	EPC Wraps
10-20 years	10 years	< 5 years (1-3 years)

- System warranties clearly outline responsibility for system repairs, between plant owner, plant manager/EPC, and integrator, including:
  - Repair response requirements – “critical” vs. “non-critical”
  - System performance thresholds
- Primary warranty scenarios (from the utility perspective):
  - **PPA**: Warranty terms embedded in the PPA and are the integrator’s responsibility for the duration of plant lifetime
  - **Ownership (outsource):** Utility contracts out to EPC/turnkey provider who handles warranty enforcement (pass through) for negotiated time period
  - **Ownership (in-house)**: Utility responsible for warranty enforcement

Warranties are only as good as the companies that honor them!

Workforce Safety Protocols

Current workforce skill level mismatched w/reqts of successful PV asset O&M.

- Significant training of *utility and third-party personnel* is necessary to improve the labor pool while insuring its safety.

Third Party Services Providers

- At minimum, federal OSHA rules followed any time personnel are in the field
- Industrial safety courses and formal training and qualification offered
  - How to handle fault and voltage protection
  - Working rules around skylights and angled roofs
  - Adherence to stringent fire codes

Utilities

- SCE developing in-house O&M standards
  - Staff perform annual retro commissioning
- Austin Energy maintains/distributes list of qualified contractors that are NABCEP certified
- Utilities and municipalities host annual or semi-annual workshops
  - John Wiles of NMSU and Bill Brooks of Brooks Engineering offer classes on new product developments and associated handling

Lessons Learned & Best Practices

30 best practices/lessons learned gathered from EPRI interview sample along 3 broad categories:
1) Preventative Maintenance; 2) Monitoring; 3) Warranty

- *Focus on design, engineering and the initial build of the PV plant.*
- *Institute continuous commissioning and continuous stress testing*
- *Two overriding factors driving O&M decision-making are system*
- *size and site distance from personnel.*
- *Identify core factors that determine the economic tradeoffs of monitoring resolution.*
- *Consider creating boilerplate contracts to clearly articulate the insurance requirements to O&M third parties*

4th International Conference on Integration of Renewable and Distributed Energy Resources

6th – 10th December 2010

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