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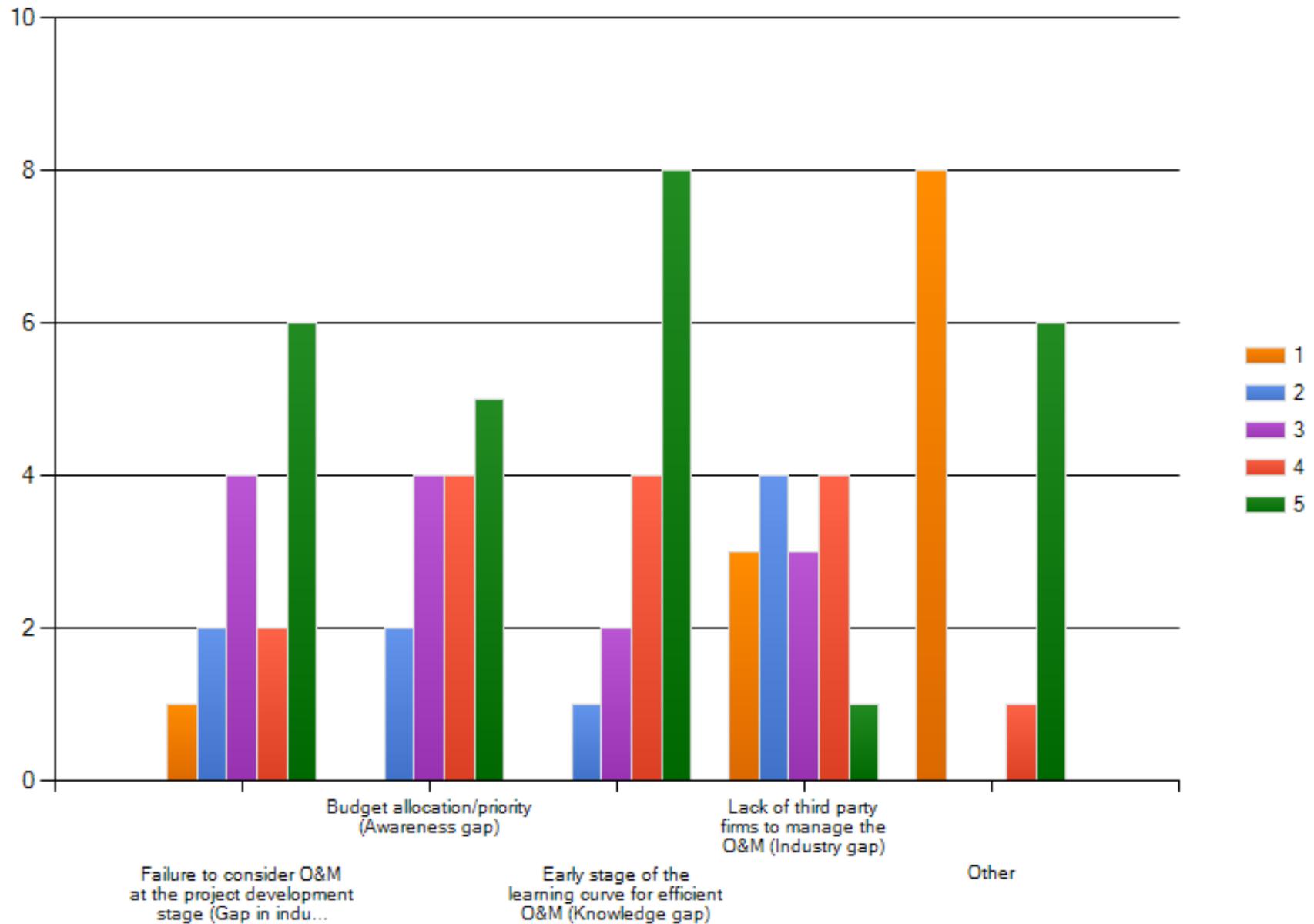
2013 O&M Workshop Survey Results

April 29, 2013



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Rank the most pressing PV reliability and O&M challenges (1: low, 5 high)

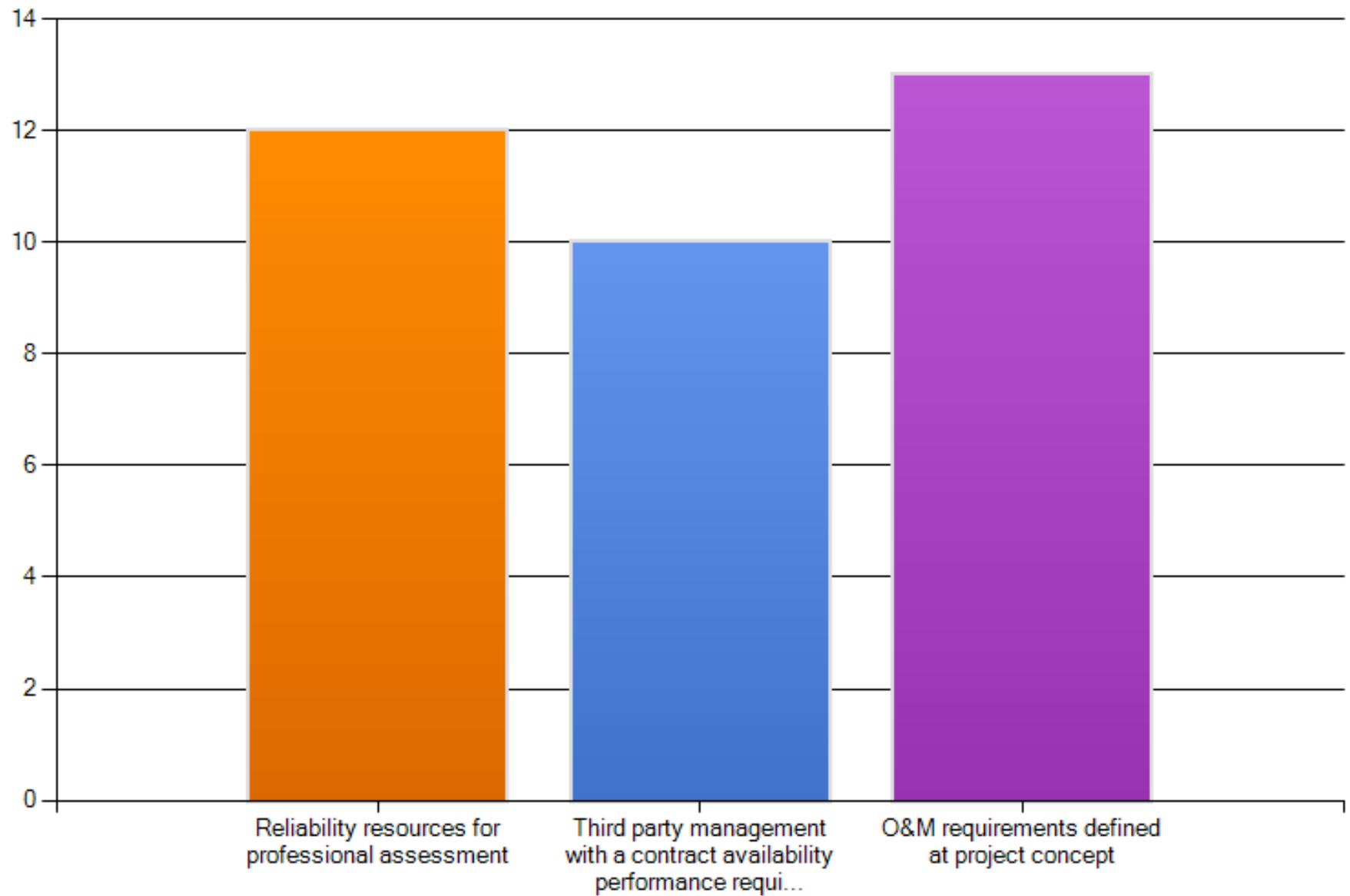


Most pressing reliability and O&M challenges

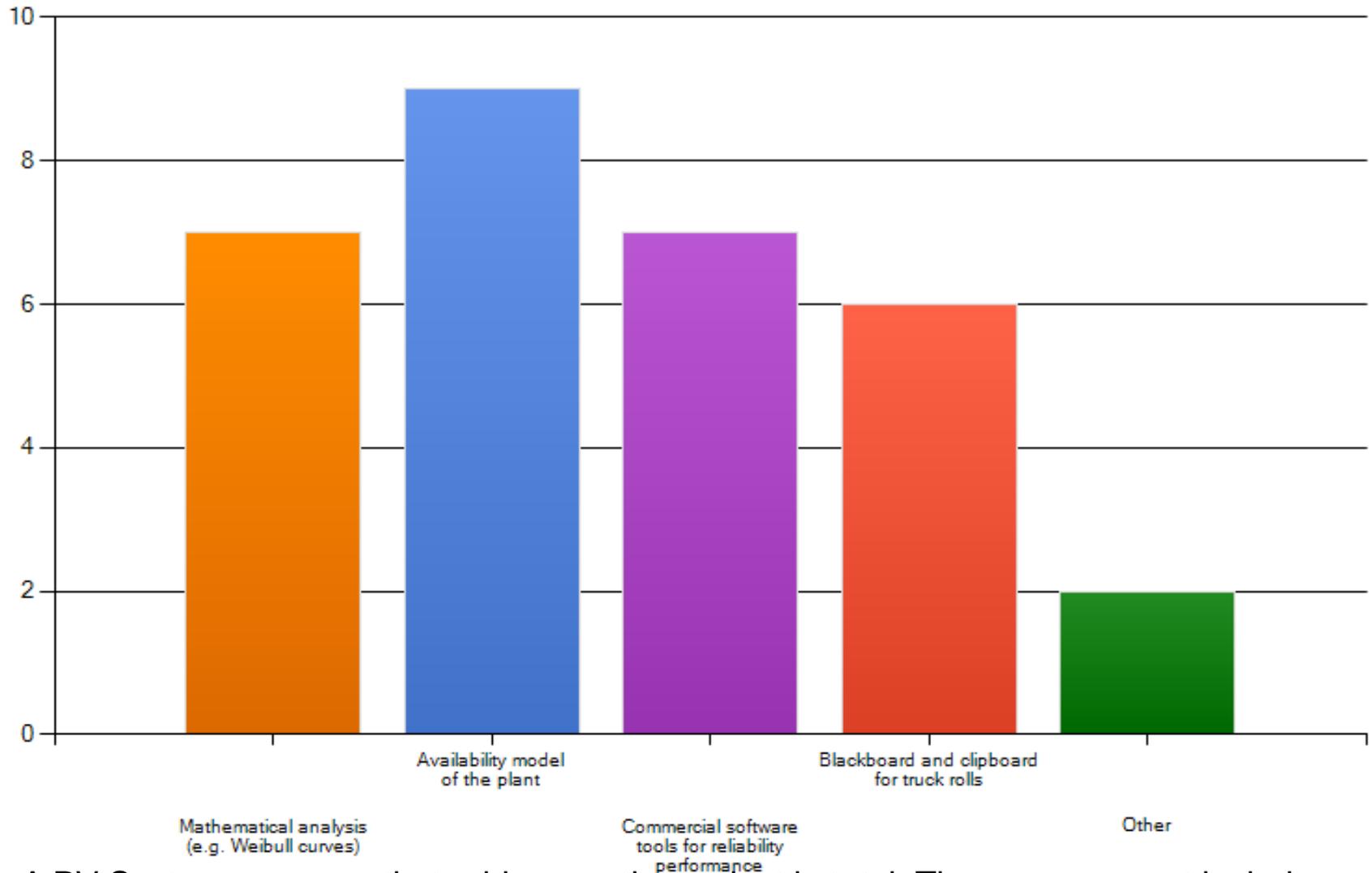
Other:

- SCADA/DAS optimized as an O&M tool
- A lack of O&M standards and accurate cost information. The apparent unwillingness or inability to deviate from existing poor reliability and O&M practices by not coming to terms with the impact of not delivering PV systems as complete systems and primarily addressing first cost as the most important component in existing business models.
- More standardized data
- Let's build... Who care about 20 years?
- Premature inverter failures, unplanned extended outages early in project

What is and can be done to realize plant performance and cost improvements? Choose all that apply.



**What predictive tools do you use for determining PV performance and reliability?
Choose all that apply.**

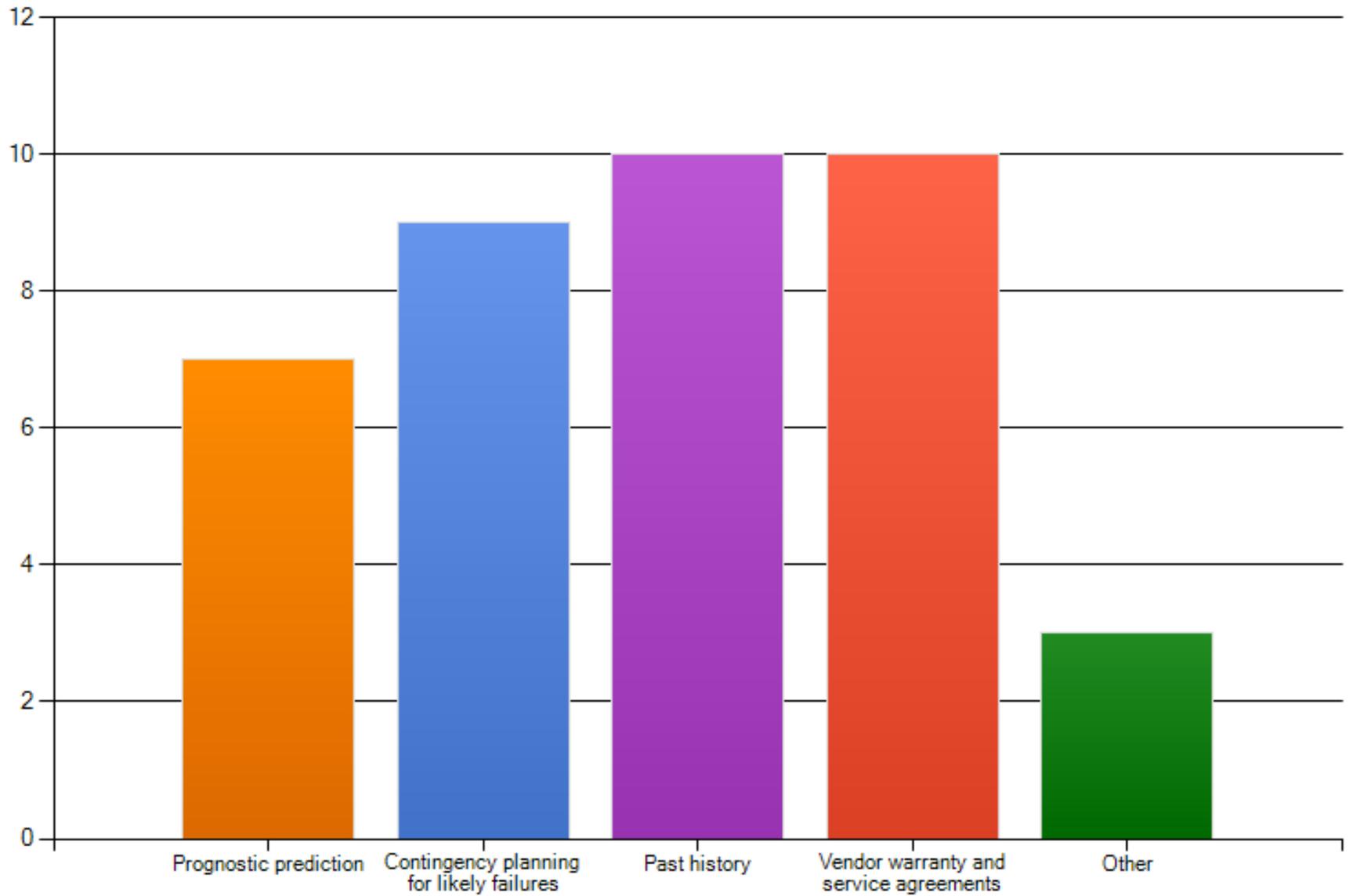


Other: A PV Systems process that addresses the project in total. The process must include accurate tools for determining real performance and reliability.

What predictive tools would you like to have available to you that you do not currently?

- Something that correlates manufacturing to real world reliability, lets me know when to buy parts and when to relax.
- Integrated monitoring and O&M solution that verifies power plant performance. Alarm triggers at various levels of underperformance that can be used to dispatch the appropriate level of service (closer watch on monitoring, technician site visit, component replacement, etc.)
- Inverter failures, for instance, temp curves for power electronics
- Time to failure, Imminent failure
- More reliability information from equipment manufacturers/plant operators. More cost information from above.
- Calibrated reference module
- Multi sensor infrared equipment and software to evaluate modules in arrays.
- Anything! We don't have anything right now and don't really know of any products out there except for PVR0M, which we are hoping to begin populating soon.
- More data!
- A topology based tool that actually take into account the actual design of the Project.
- Mobile applications, I-pad application

What tools and strategies are you currently using to mitigate unplanned downtimes and system failures? Choose all that apply.

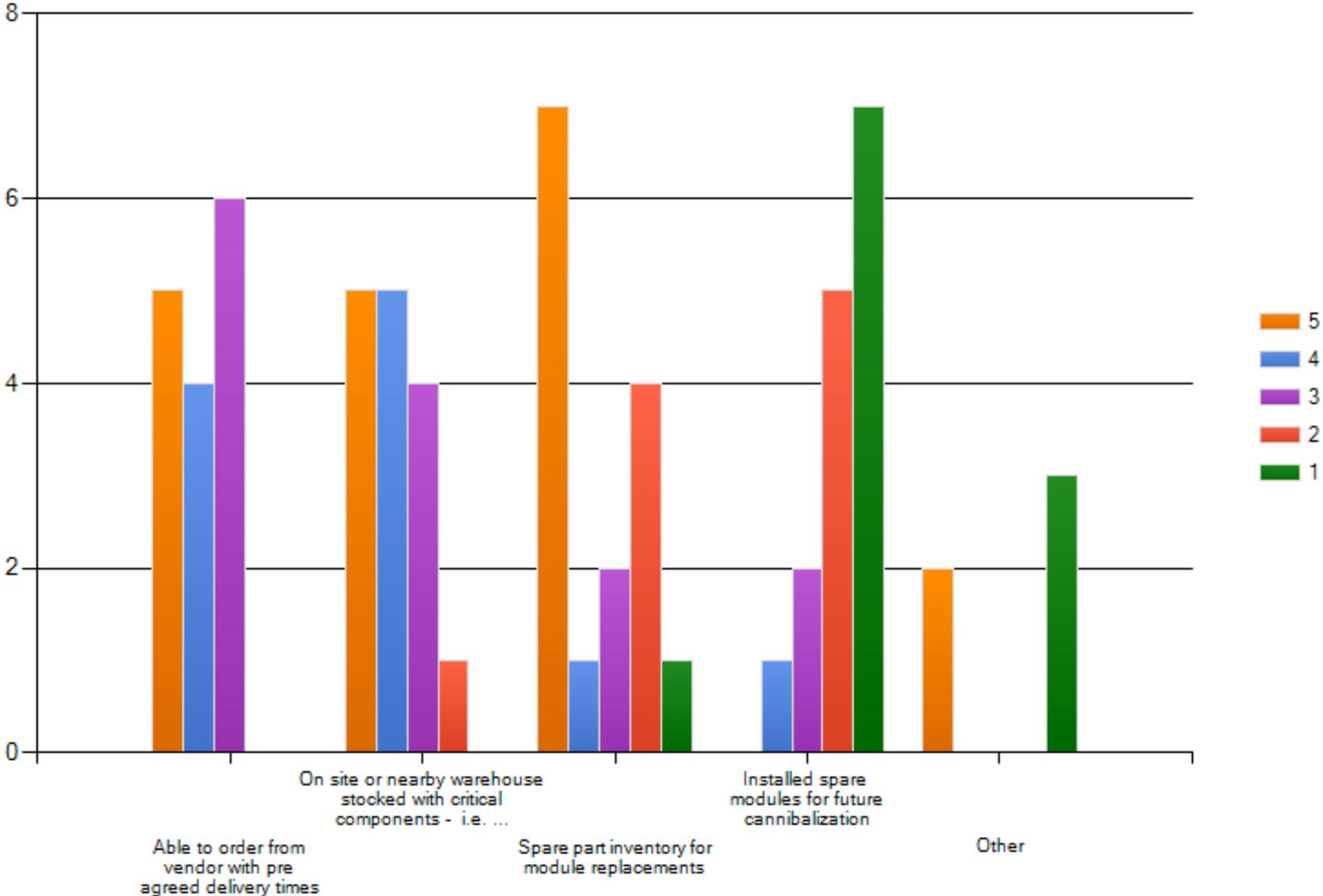


What tools and strategies are you currently using to mitigate unplanned downtimes and system failures?

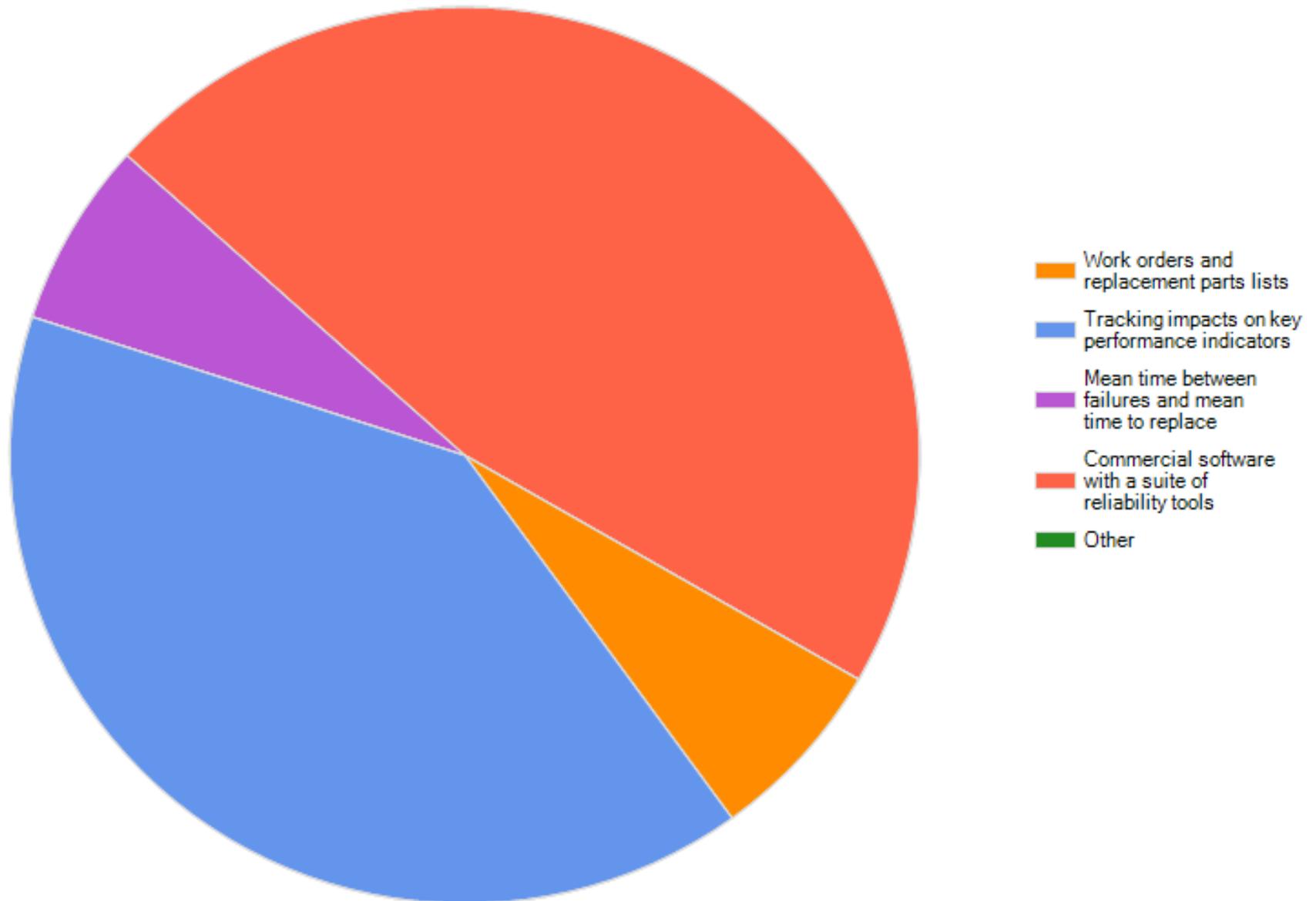
Other:

- Experience in correcting decades of errors and an education process that include documentation and access to cause and effect results which provide historic solutions.
- Prognostic prediction
- Wait for the customer to find the problem

Rank the optimal approaches to the below spare parts strategies (5: most optimal, 1: least optimal)



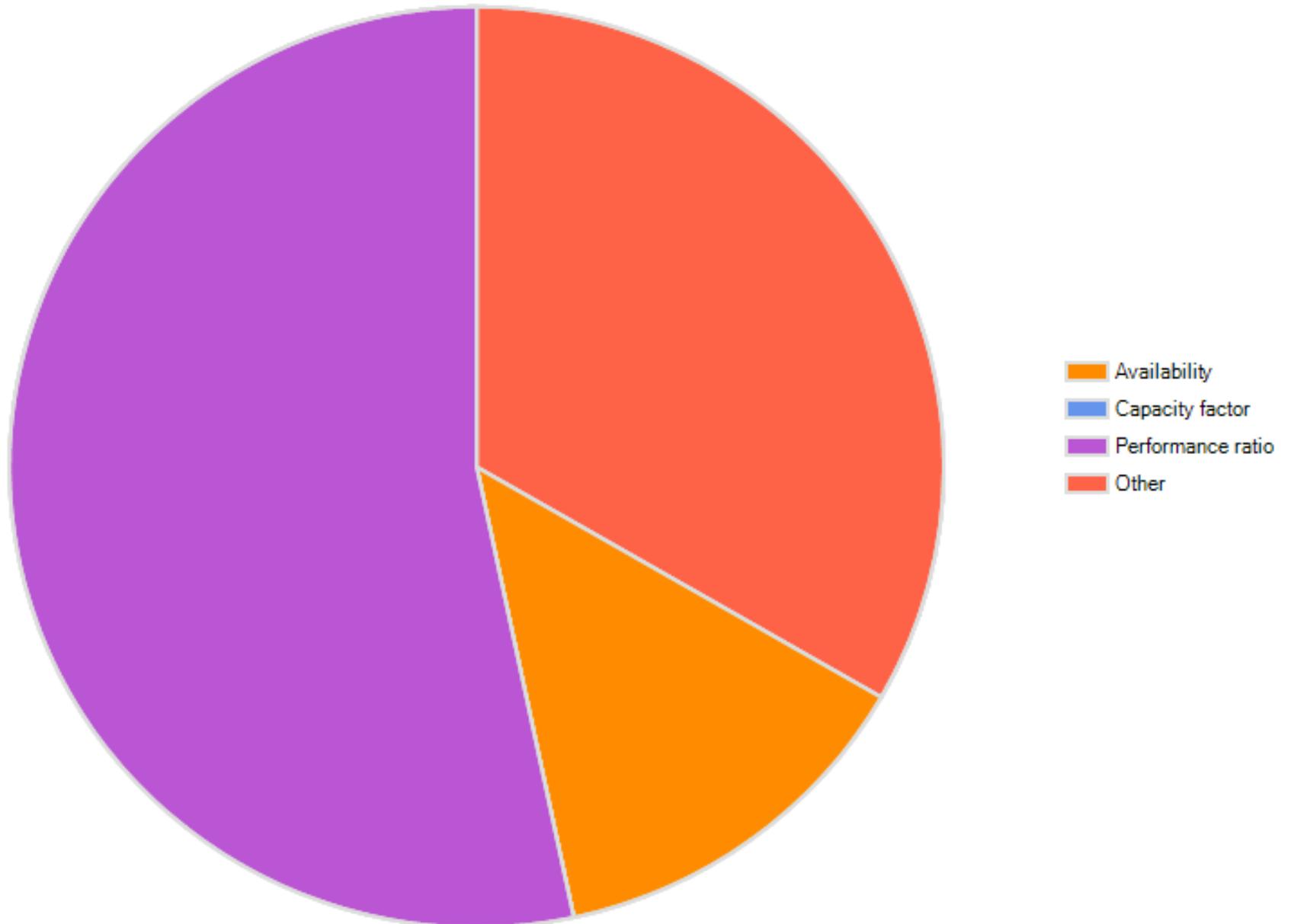
What is the right level of detail for tracking repairs and replacements?



How should O&M functions be “designed-in” to future PV plant designs?

- Remote monitoring capability and software (3)
- Accessibility to equipment, landscape control, water, non-proprietary specifications (2)
- Ability to isolate small sections of a plant and make repairs without taking large sections off-line
- Improve design for ease of maintenance. Data acquisition designed for maintenance, in addition to performance
- System delivery must begin with designing for the systems lifetime O&M based on accurate data and real cost numbers. This information and related metrics are then applied during the specification and design process for the system, its installation and going O&M. It needs to be synthesized in a continual feedback loop based on real numbers and not just historic averages or projections.
- There are many design choices that can help reduce O&M. We are already doing many of these but would like to know more about what other folks are "designing-in"...
- First of all don't think of O&M as a cost burden. Allocate \$\$ to make sure you are covered for protecting your yearly revenue stream

What is the best measure of plant performance?

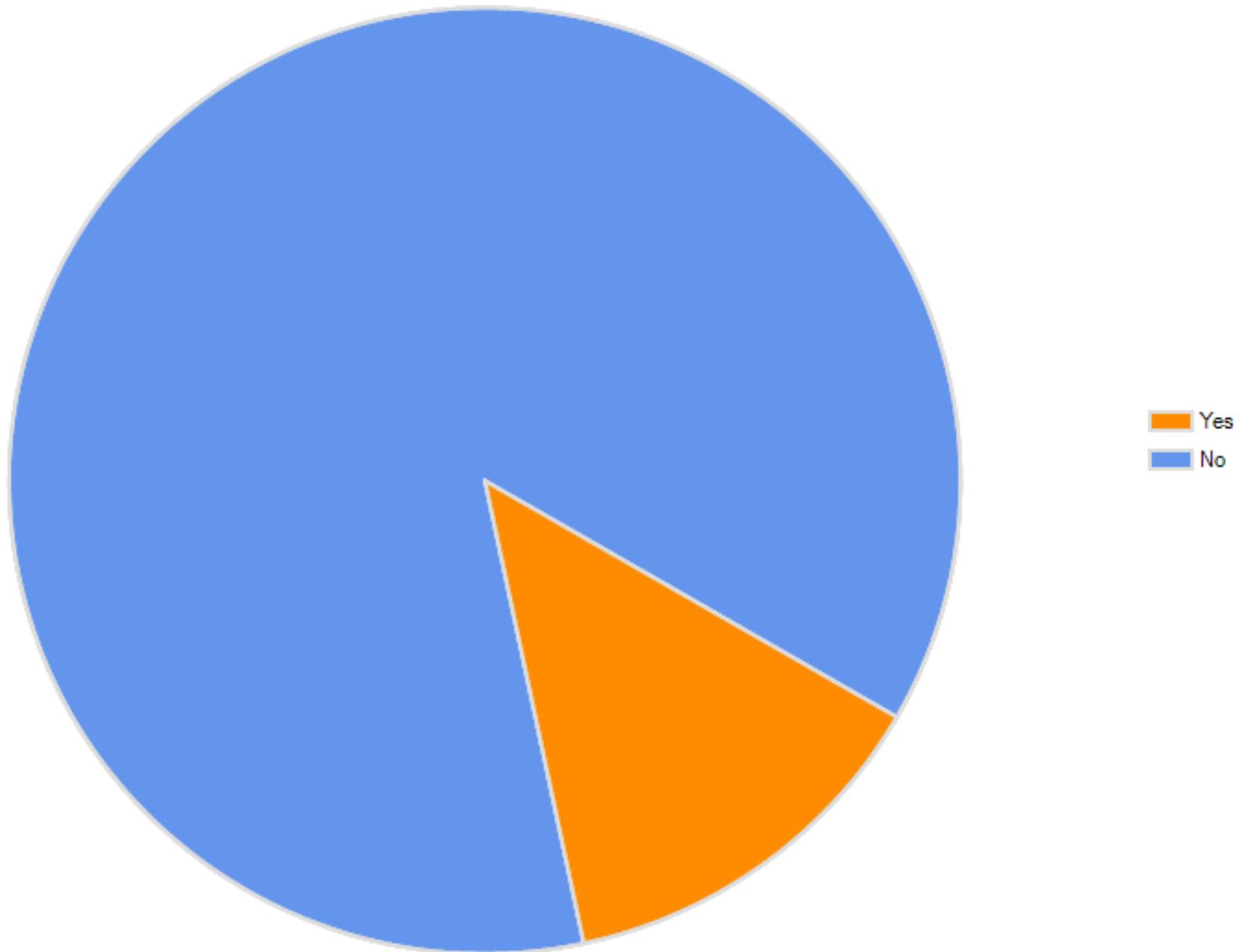


Best measure of plant performance

Other:

- Needs to be two of the above, not just one
- Performance Index, comparing plant output to weather-adjusted model
- Energy Performance Index
- Short term: The plant's Solar Performance Factor (SPF) AC kWh/DC watt over 365 contiguous days. This allows comparisons of all system installation, environmental and operational factors. Long Term: "PV System Performance Factor" based on the real "ALL IN" costs of the whole system life to determine the real cost per AC kWh from project concept through dismantling. This is better than using the often abused LCOE which is similar but in many instances is based on guesses, assumptions and myths.
- Understanding the design, as-built and the topology of the plant to enable proper metrics to identify the expected production number before comparing to the actual numbers.

Washing of modules is not needed.



What tools could the labs/EPRI produce that would be helpful for O&M?

- Aggregate performance data to identify trends
- Mfg ratings, service levels (recommended methods, procedures)
- Performance implications of common power plant failures/mechanism of under-performance. This allows for a simple cost vs. gain analysis when such events occur.
- Database of interchangeable components and suppliers, especially key inverter parts
- Software Techniques for optimal O&M
- Self cleaning pyranometer
- Financial based to assist maintenance decision
- Support the development of "PV System Design and Application Theory" and the development of in-depth experiential training. Develop a usable clearing house data base which will provide historic data and examples of cause and effect failures and performance enhancements.
- Wash vs. No Wash Economic Estimator, including weather forecast input.
- Predictive modeling for implementing O&M preventative maintenance schedules based on annual weather and post reporting tools to measure performance changes
- Open source code for analytics of PV systems
- Statistical analysis tools that are able to identify deviations from expected values that are calculated based on plant topology

How important is training and safety and what needs to be done across companies?

- Very important. Need qualification standards, see above. (7)
- Training and safety should be given the utmost importance. Something along the lines of the NABCEP program, but with less emphasis on installation best practices and a focus on the hazards of a functioning power plant already in its production life cycle.
- Industry standards that are specific to PV. Much of the accepted "best practices" are not consistent with the realities of PV systems.
- Developing system design techniques to improve LOTO processes is important. Taking the time to properly LOTO is rarely done, or is done poorly.
- It is absolutely critical and must be taught in a manner where all employees understand its value. The industry has been dumbing down PV specification, design and installation and as a result the system delivery chain has people who do not understand the technology, its best use applications, the concepts of performance and reliability and are married to a Subprime Solar business model and ethic. The industry has a mass of knowledge which if properly gathered, presented and discussed would lead to greater reliability, performance and cost reduction. To be a mature industry, we need to create a safe forum to be able to freely discuss common failures, challenges and solutions. This will require a buy in from companies who are willing to share information to reap the benefits of that common and often secretive experience.
- Safety is the number one value at our company and our safety training and procedures are well defined. O&M Training is less developed at our company, but I believe it is very important. More equipment manufacturers need to provide proper training for the maintenance of their equipment.
- Use common sense and OSHA standards

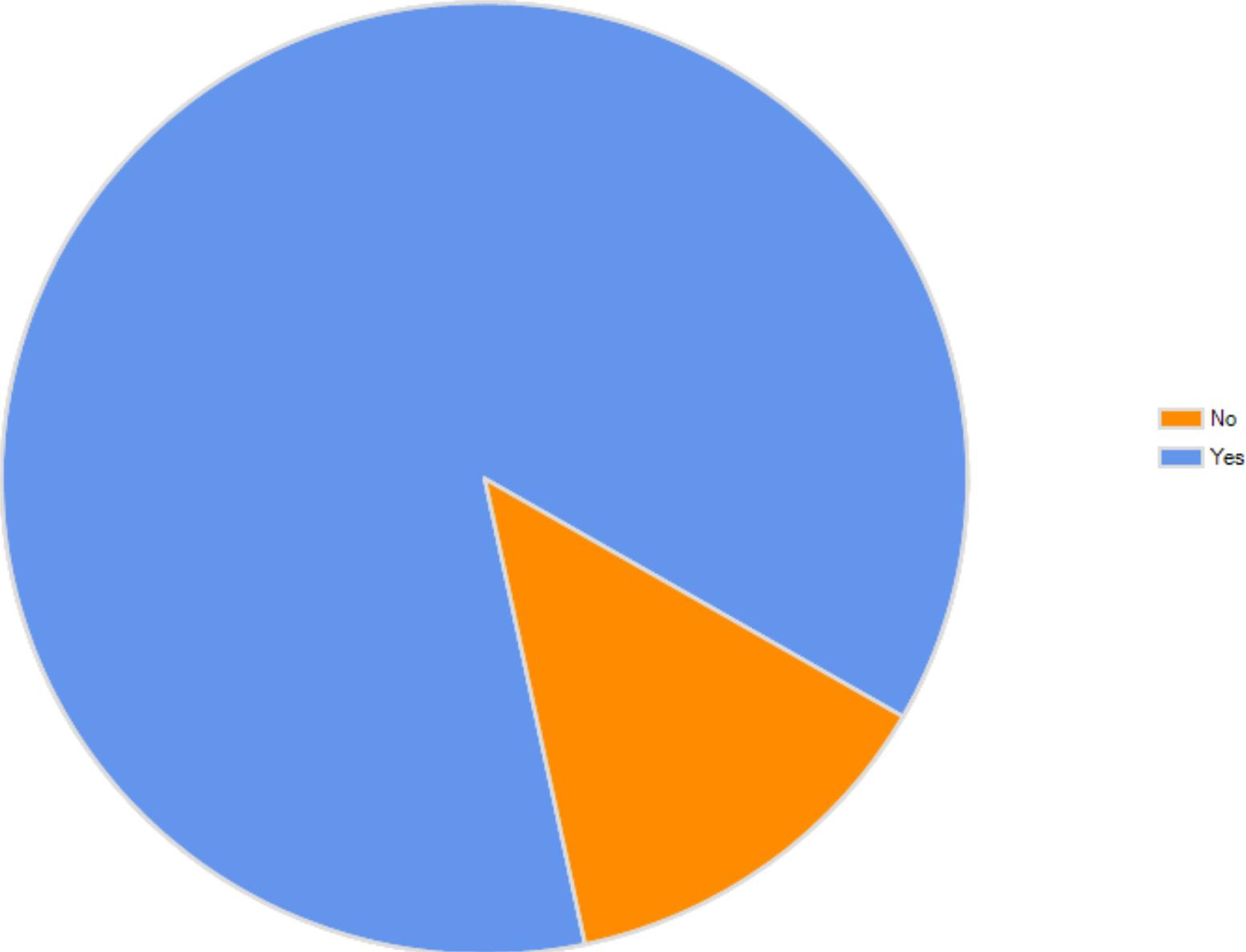
How should key performance indicators be tracked?

- Publicly, make information available so not siloed at companies
- Monitoring with a granularity commensurate with the aforementioned cost vs gain analysis.
- Automatically within DAS/SCADA
- Software - Automatic and Manual Entry
- It depends on the size of the system, the relationship of operator and owner. This question is too broad to be answered.
- "Good day" energy performance index
- Using real-time and predictive analysis software
- Production and down time.
- APS has developed a dashboard that tracks Performance Ratio and cost per plant on a per kW dc level.
- Do the people that finance projects 'really' understand the meaning of Performance indicators?

What is currently missing that is needed in the area of O&M analytics and prognostics?

- POA pyranometer accuracy in tracking applications
- Detail from the events without analysis, more granular data
- Go-No Go tool for initiating a truck roll that can be configured with plant inputs.
- Reliability, Detail data analysis, Financial impacts
- Use of meaningful performance metric
- Reliable software infrastructure
- It is time to move to the Preventive Analytic Maintenance (PAM) model. PAM is based on large quantities of information from many systems and technologies both electrical and multi spectral to identify components and subsystems that have failed while tracking the failure process. This gives operators much better control over the timing to replace failing or failed equipment.
- Predictive Analysis
- Statistical analysis tools that are able to identify deviations from expected values that are calculated based on plant topology

Should differing monitoring levels for failure prediction be employed?



Should differing monitoring levels for failure prediction be employed?

- Soiling meters
- If one string is underperforming recommend course of action X, if many strings are underperforming recommend course of action Y. For example, if a string combiner is consistently showing lower production is this due to a systematic factor like soiling, overall panel degradation, shading-or has there been a diode failure, blown fuse etc. Combiner level monitoring would only pick up the former, whereas string level monitoring would pick up both.
- Temperature - MTBF of key inverter components
- More detailed information can only be stored when there is a fault
- Use trend analysis for earlier detection of failure.
- But more importantly, the move needs to be to Predictive Analytic Maintenance (PAM) Processes that begin to build a clearing house (of thousands of systems) of data based failures which are in process before components completely fail based on a variety of sensing technologies, including the electrical signature or finger print of a failing component.
- Large PV plants (>10MW) do not require module level monitoring.
- It depends on the size of the system and whom it is serving
- Let's get Inverter level Data and do proper Statistical analysis first before adding more Capital cost to get module level monitoring.

How should SCADA and Condition-based Monitoring be leveraged to better advantage for O&M?

- Obtain real spot values, perform control, resets
- Need tools that can allow for sites to be unmanned for longer periods of time.
- Condition based monitoring can reduce storage and transmission requirements
- Incorporate actual irradiance and weather data into assessment algorithm.
- Need software to detect the CBM that can trigger maintenance need.
- They need to be integrated with other tools like multi sensor Infrared, and establishing electrical fingerprints or signatures for different levels of failure. When properly integrated with a usable PAM data base, the computer monitoring the system will be able to identify partial to full failures early on, increasing overall reliability, component selection, up time and yield while dramatically lowering labor cost.
- APS uses SCADA and condition-based alarms to monitor the large PV plants (>10MW). We track everything from inverter failure codes to tracker positions. We use it more for Operations than for Maintenance, but the data can trigger corrective maintenance.
- SCADA is an overkill.
- Faster response time, lessened outage

What's missing from current PV O&M practices?

- Clarity around what can be done without voiding warranties
- SCADA/DAS optimized as an O&M tool
- Too many to list
- Merging operational data with maintenance data. Keeping good maintenance records at all. Standard procedures.
- Cost benefit calculations for when O&M is justified.
- Established third party firms with expertise and balance sheets
- No off the shelf tool.
- Effective system integration practices and standards combined with the experiential education to provide skilled, competent and more productive PV professionals. An effective systems process covering all phases of system delivery from cradle to grave and a better understanding of how the components work as a system and impact each other in the environment they are placed in.
- Standardized failure modes, standardized failure codes from inverters.
- Quality analytics
- Lack of understanding that PV systems need MAINTENANCE!
- Commissioning, recommissioning