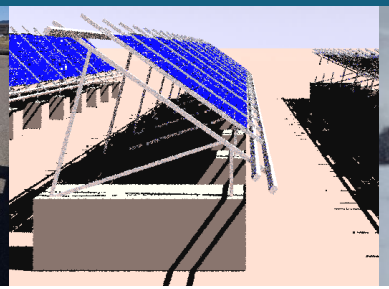
PVOperations & Maintenance
ANALYTICS COLLABORATIVE

Sandia National Laboratories

Updates from the PV O&M Analytics Collaborative (PVMAC)

Marios Theristis

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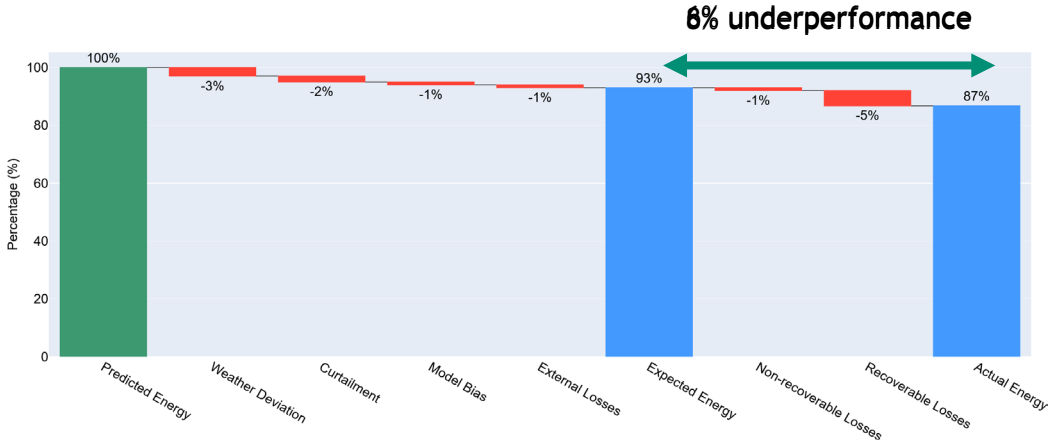
Persistent challenges in PV operations

- Underperformance remains widespread
  - Operational losses remain difficult to quantify consistently
- No shared definition of underperformance
  - Reported losses depend heavily on expected yield model and assumptions
- Monitoring platforms produce inconsistent results
- Increasing pressure on O&M
  - O&M budgets declined ~10× over the past decade (BloombergNEF)
- Operational decisions increasingly depend on software-driven analytics



OneTech

Monitoring Platforms Benchmark Results for PVMAC

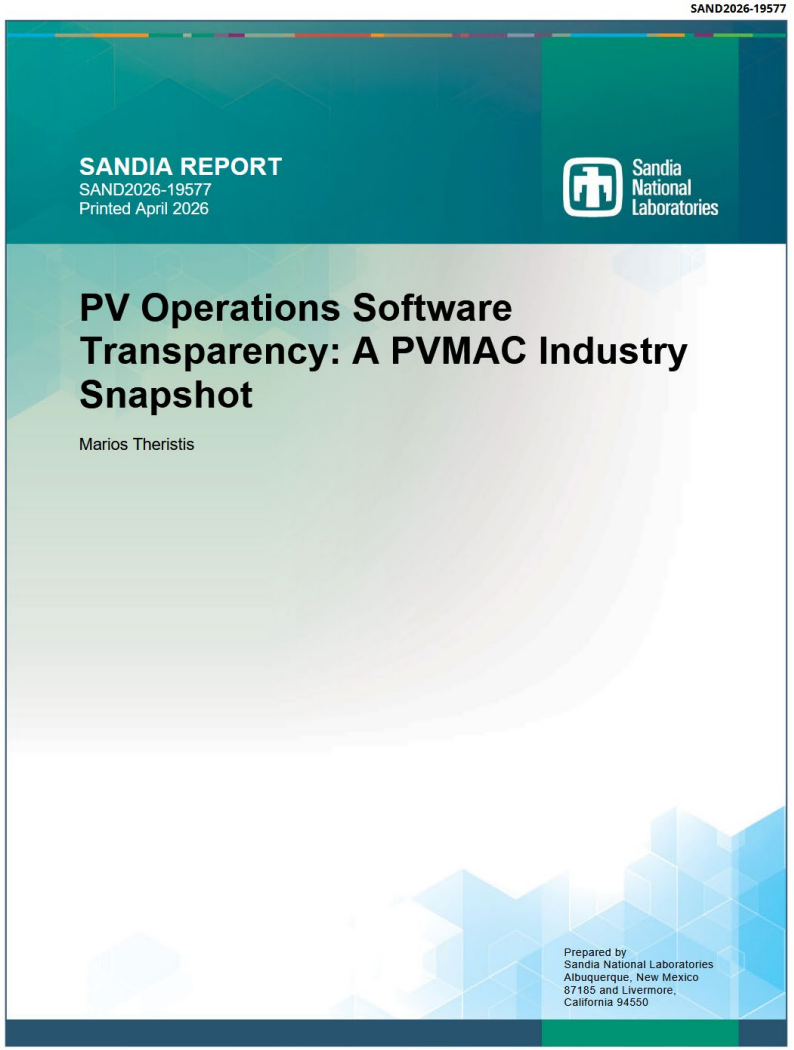
April 2025

Losses on production (%)	On site inspection	Monitoring platform A	B	C	D	E	F
Performance losses (soiling, shading)	3.06	5.54	6.24	22.11	0.03	1.13	✗
Downtime losses (inverter)	✗	✗	0.38	0.00	0.45	✗	0.02
Meter losses (DC to AC)	✗	0	✗	✗	✗	-8.75	✗
Contractual losses (curtailment, grid)	✗	✗	0.00	0.00	0.00	✗	✗
Unknown	0.04	✗	✗	0.00	14.13	1.39	✗
TOTAL LOSSES	**3.11**	**5.54**	**6.62**	**22.11**	**14.73**	**-6.23**	✗

PV operations software industry snapshot

What is happening in the PV operations software ecosystem?

- The PV industry lacks clear and consistent understanding of PV operations software
- Many stakeholders are not fully aware of the importance of these tools for improving operational performance
- Difficult to compare capabilities and make informed decisions
- First structured, industry-wide questionnaire by PVMAC assessing software capabilities and practices
- Findings provide a maturity snapshot, highlight gaps, and identify improvement areas (with raw data published for transparency)



Report and raw dataset published on PVPMC website: https://pvpmc.sandia.gov/pvmac/pv-operations-software-transparency-a-pvmac-industry-snapshot/

Industry snapshot participation

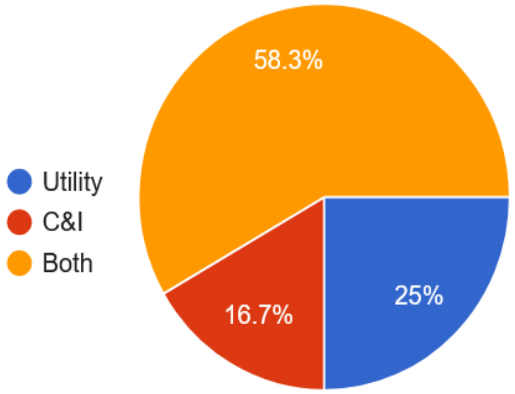
24 software providers

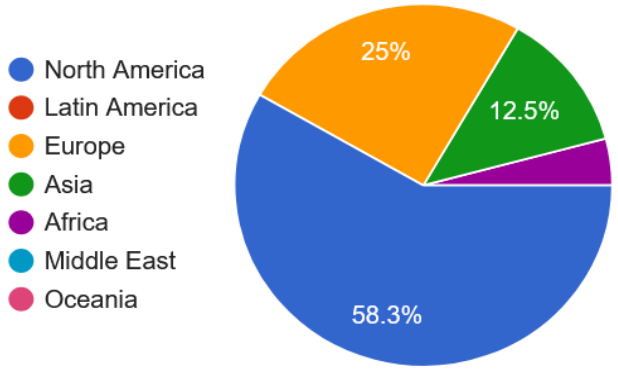
1.1 TW

115k sites

56 questions

Coverage:
- Onboarding & integration
- Data quality & QC
- Digital twins & yield modeling
- AI/ML, KPIs, transparency
- Business models





Ampere cloud · above · SOLAR GRADE · ALECTRIS · 3E · Denowatts · ECOSUITE · enSights · enurgen · RAPTOR MAPS · MANA MONITORING · IBM · Gantner instruments · POWERFACTORS · Proximal Energy · PowerUQ · raicon · Quadrical Ai · stem · SmartHelio · Sitemark · solar square · SKYLARK DRONES · Wattch

Theme 1: Fragmentation limits scalability

- Integration capability is increasingly available

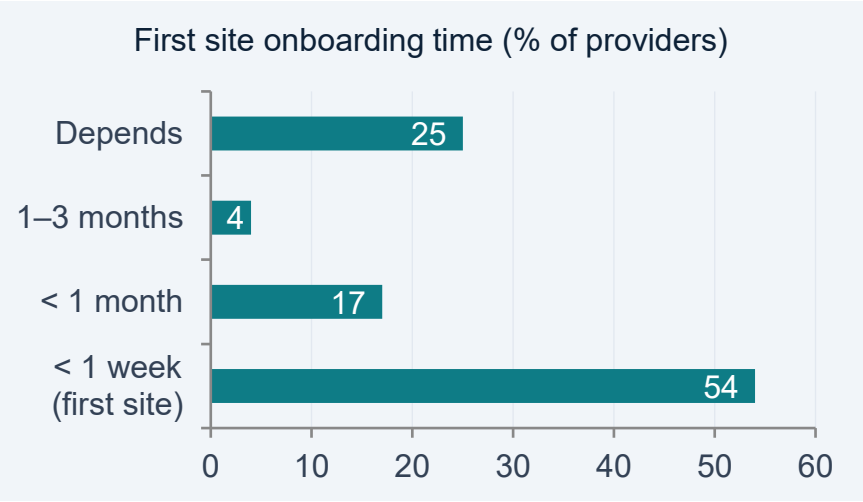
~70%
offer public documented API

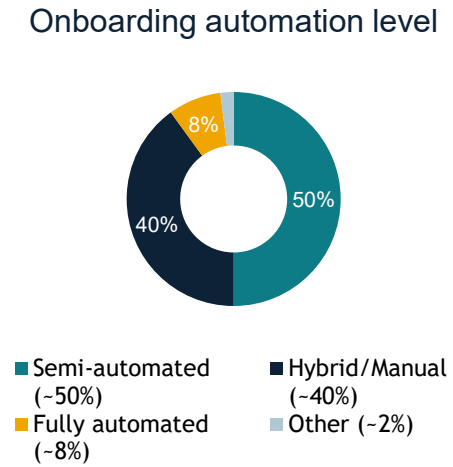
~60%
allow free data export

- Onboarding remains difficult to scale
  - First-site onboarding is often within a week
  - Mainly semi-automated onboarding
  - Additional sites may integrate in hours but only when SCADA and metadata structures are consistent

- Data harmonization is the primary bottleneck
  - Inconsistent SCADA naming, metadata conventions and bilateral integrations continue to limit automation and scalability

→ The limiting factor is not platform capability, but upstream data consistency.

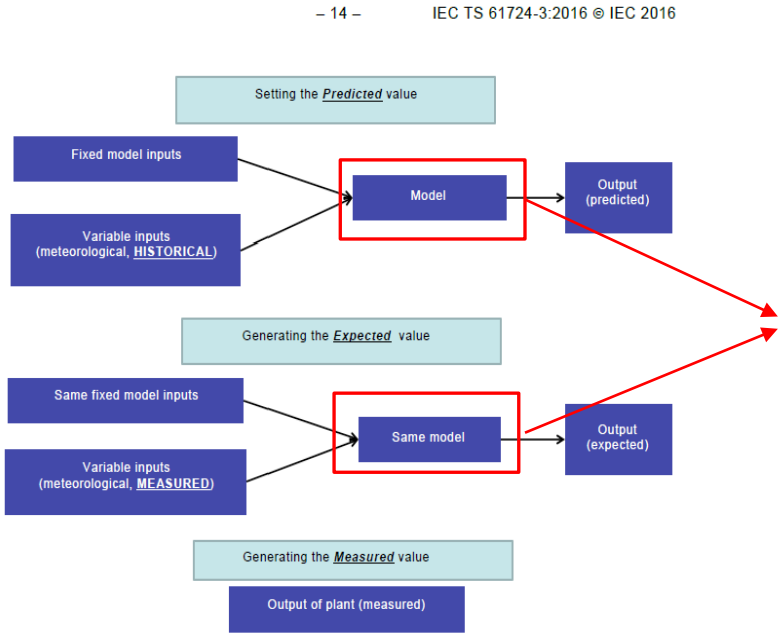




Theme 2: No shared definition of performance

- Digital twin definitions and capabilities vary widely

- Providers use different expected yield modeling approaches/adjustments

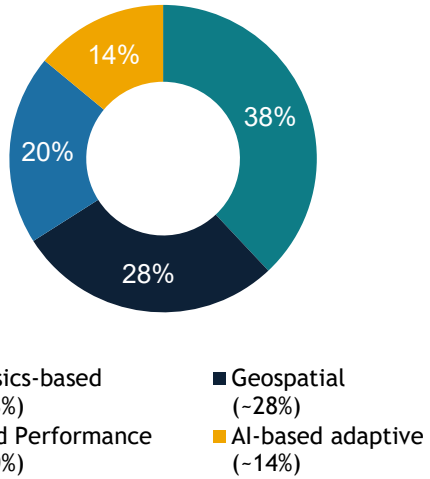


It requires re-running the same model with measured weather!

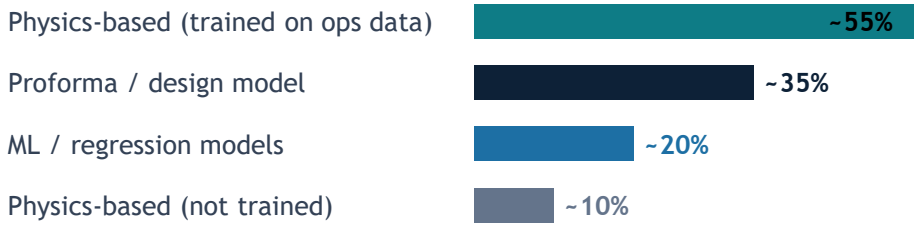
- Different assumptions produce different operational conclusions
  - Variations in modeling approaches directly affect KPI calculations, benchmarking, and underperformance attribution

→ We need shared definitions, modeling transparency, validation and standardized terminology

Digital twin categories (75% claim DT)



Expected yield modeling approaches (~83% calculate expected energy)



Theme 3: Results are not reproducible or auditable

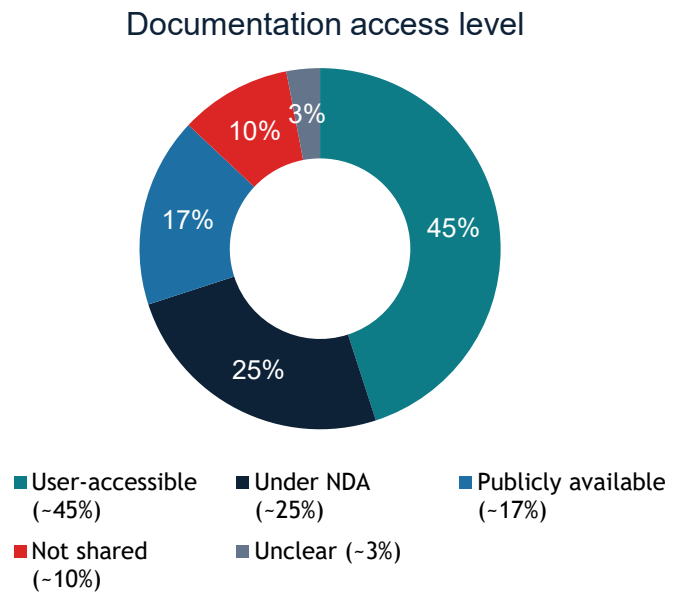
- Reproducibility is limited

KPI & yield reproducibility claims

50%	25%	25%
Yes	Partial	No

- Methodology transparency varies substantially

- Limited auditability affects trust and benchmarking
  - Without reproducible workflows, cross-platform comparison and contractual accountability become difficult



→ Transparent methodologies and reproducible workflows are essential for trusted operational analytics

PVMAC initiatives to address these gaps

Establishing a standardized **energy accounting** (Solar GAAP) framework	Moving from continuously "patched" KPIs to **physics-informed metrics**	**Interoperability:** common schemas, metadata consistency	**Benchmarking** analytics and reducing variability across platforms
PVPMC 2026		PVPMC 2027	

More on PVMAC:
pvpmc.sandia.gov/pvmac

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