U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Securing Solar for the Grid (S2G): Cybersecurity for Solar Systems

DOE/EERE/SETO Systems Integration Webinar

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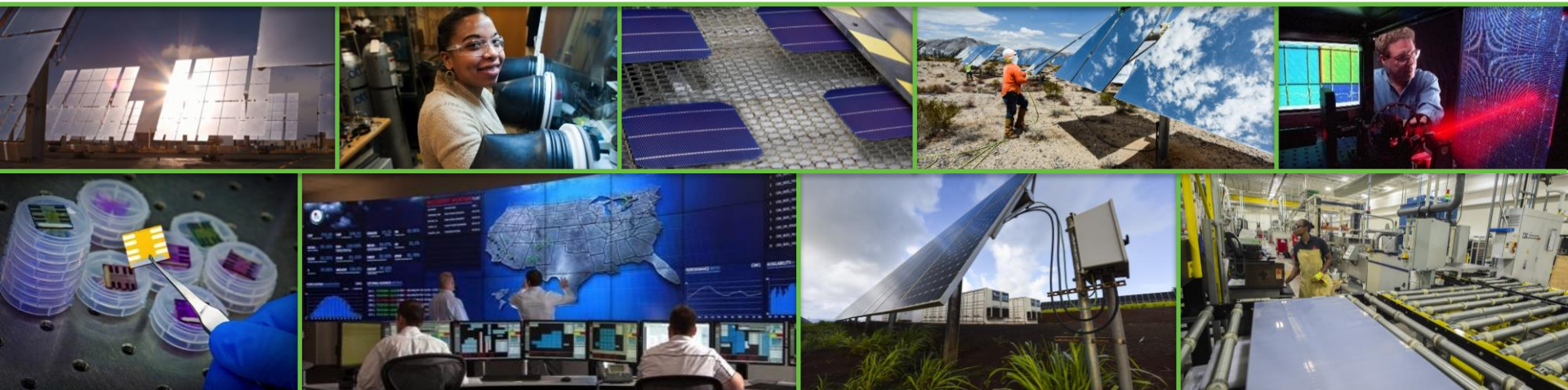
May/2023

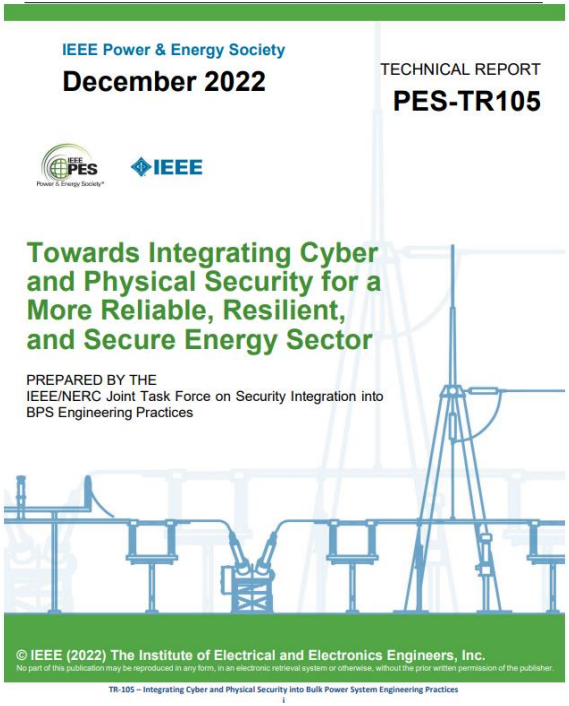


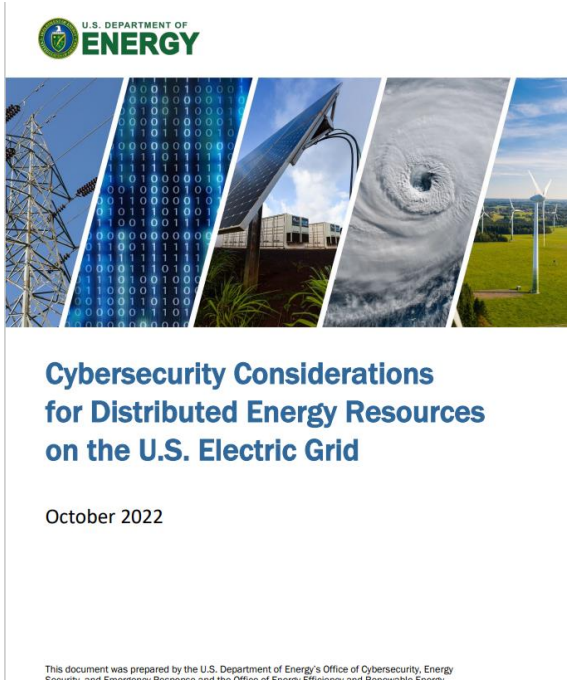
Agenda

- **Motivation**
- **Alignment with DOE Activities**
- **S2G: Securing Solar for the Grid**
  - Research Areas
  - Accomplishments
  - Get Engaged!
- **Conclusion/Summary**


To manage, optimize, and secure the future grid, new technologies, control techniques, and supporting reliability and security standards will be required.

Recent Reports





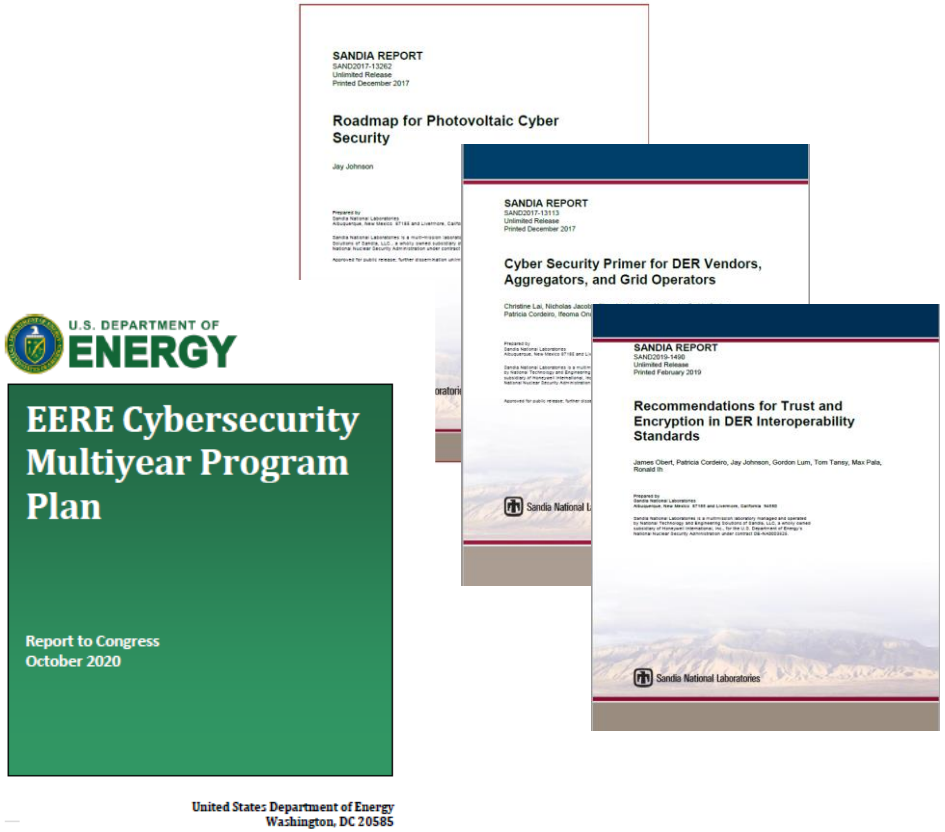
Cybersecurity a Key Challenge and an EERE Priority

Goal 1: Accelerate Cyber Resilience R&D of EERE Operational Technologies

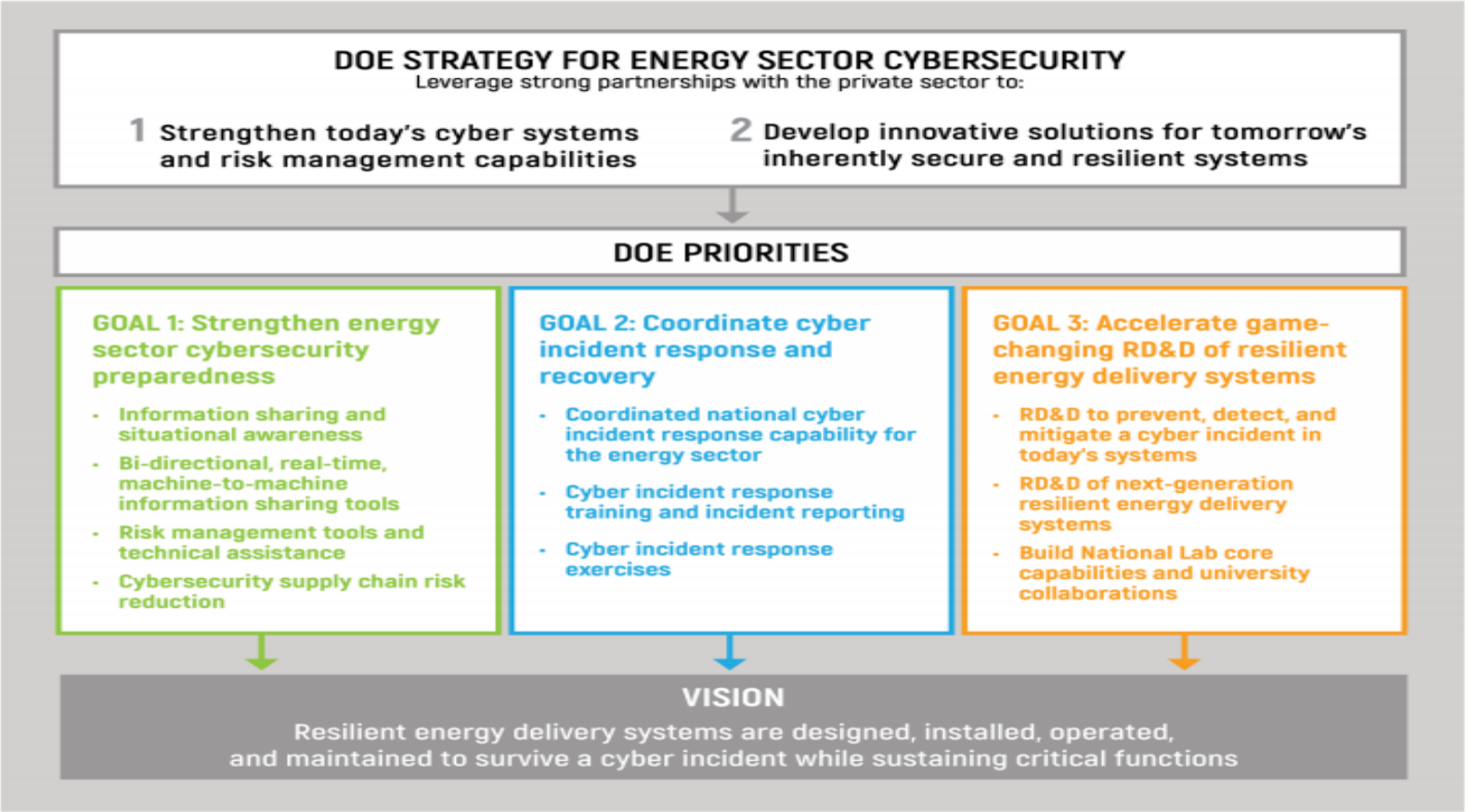
- 1.1 Improve cybersecurity defenses and resilience.
- 1.2 Mitigate vulnerabilities
- 1.3 Next-generation cyber resilient technologies.

Goal 2: Increase EERE Stakeholder Cybersecurity Awareness

- 2.1 Improve situational awareness.
- 2.2 Enhance EERE technology cybersecurity maturity.
- 2.3 Identify opportunities for EERE stakeholder participation in cyber incident response exercises.



EERE and SETO Activities Align With DOE's Broader Cybersecurity Strategies



S2G: Securing Solar for the Grid

VISION

Achieving high cybersecurity maturity levels for solar technologies, equipment, supply chains, facilities, as well as the bulk and distribution electric power grids.

GOAL

Ensure the cybersecurity of electric grids with high penetration levels of solar PV and other DERs

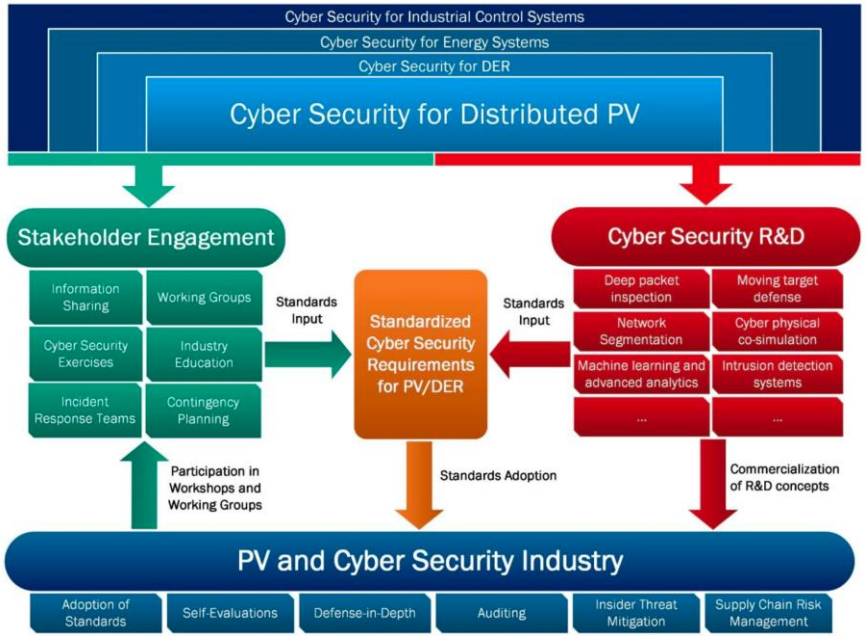
APPROACH

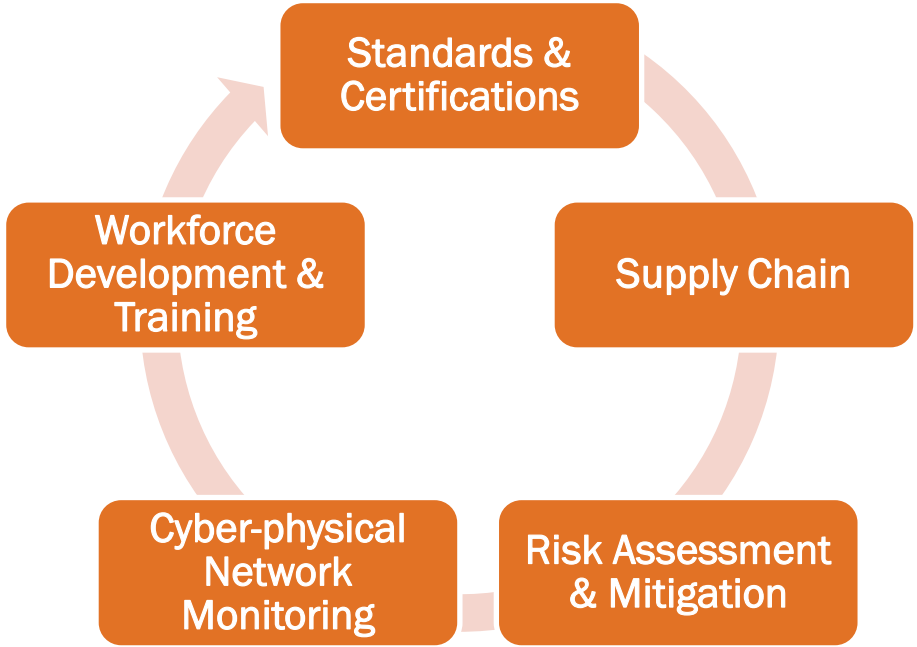
A collaborative effort by multiple national labs, DOE offices, and industry to address gaps in requirement standards, best practices, testing and analysis for solar PV and DERs cybersecurity

EXPECTED OUTCOMES

Development and dissemination of **requirement standards, best practices**, **equipment testing procedures, assessment tools, as well as education and training materials** for cyber defense, posture and maturity tailored to solar technologies.

Securing Solar for the Grid (S2G): Cyber-physical Integrated Approach





Source: RoadmapforPhotovoltaicCyberSecuritySAND2017-132624-10-2018

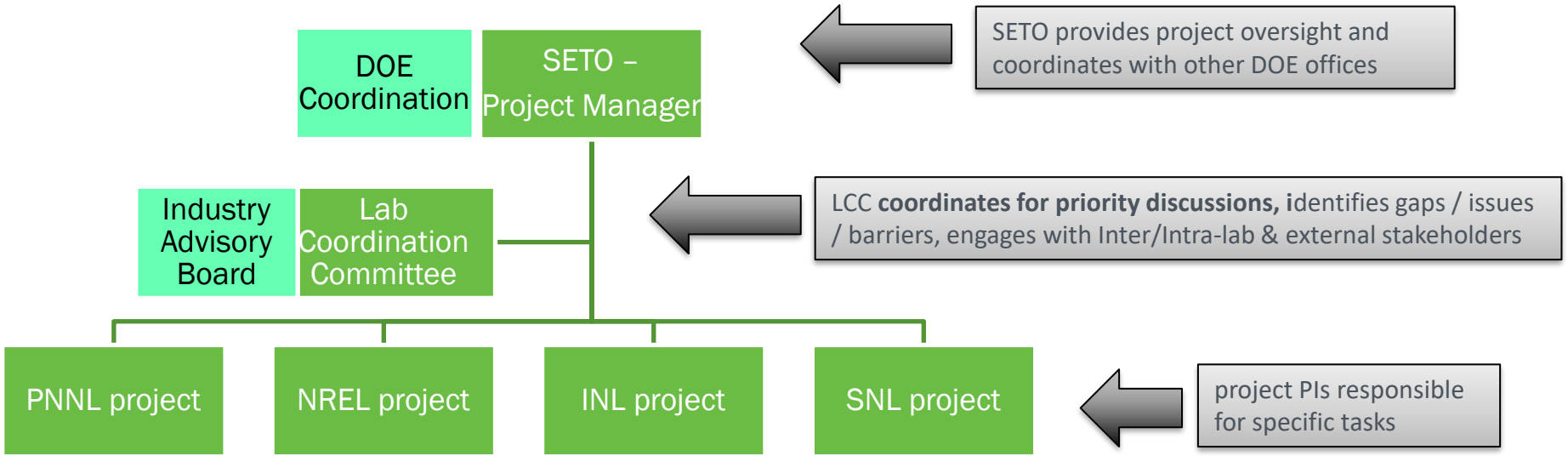
Sandia National Laboratories

Idaho National Laboratory

NREL Transforming ENERGY

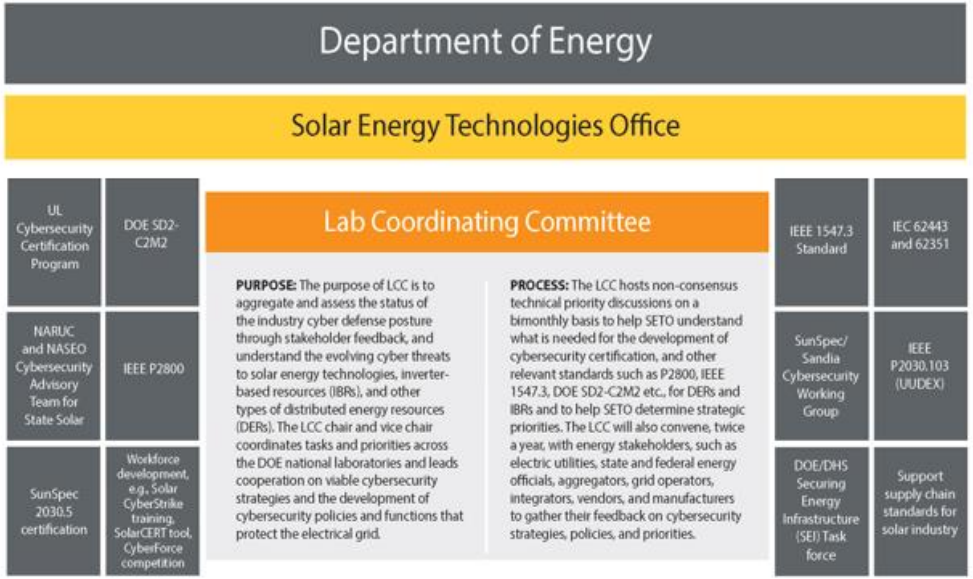
Pacific Northwest National Laboratory

Project Management Structure



LCC Activities

- Regularly meet to assess current industry trends and facilitate non-consensus discussion and debate on project priorities.
- Coordinate activities and promotes collaboration with CESER and EERE offices.
- Facilitate Industry Advisory Board meetings. The purpose is to:
  - Gather industry priorities and effectiveness feedback
  - Perform stakeholder engagement to assess industry gaps, issues, and barriers
  - Disseminate project outcomes
  - Perform continuous reprioritization evaluation.
- Facilitate periodic informational webinars, led or supported by the national labs.



Sandia National Laboratories

Idaho National Laboratory

NREL Transforming ENERGY

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Research Areas

STANDARDS DEVELOPMENT & BEST PRACTICES

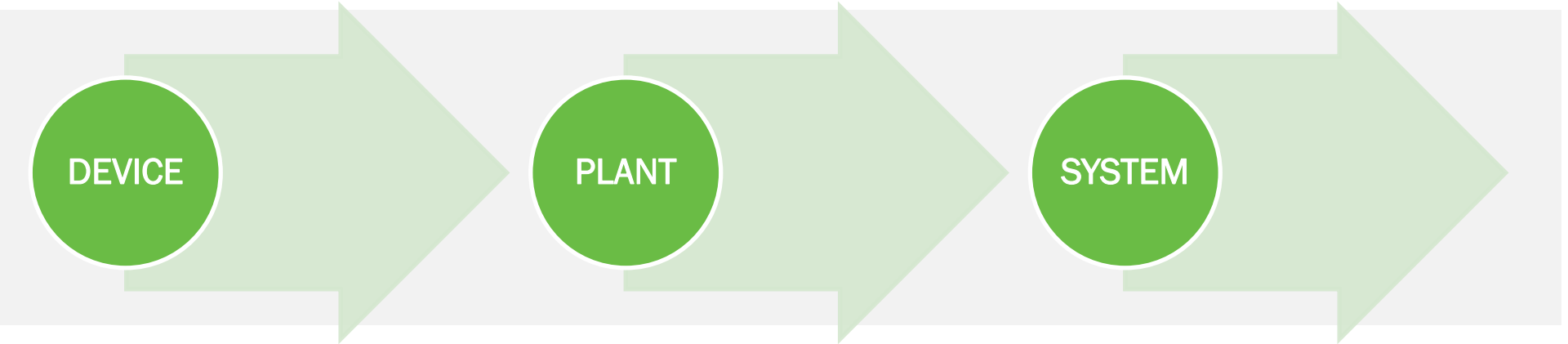
Stakeholder engagement to investigate gaps and develop best practices that can become standards to enable the secure integration of inverter-based resources and DERs.

EDUCATION & WORKFORCE DEVELOPMENT

Development of educational modules and training to increase cybersecurity awareness and knowledge within solar stakeholders.

CYBERSECURITY TOOL KIT & SUPPLY CHAIN

R&D of tools to understand cybersecurity posture, risk assessment to inform investments, and device design security & maturity model for cyber supply chain.



INCREASING CYBERSECURITY LEVELS OF SOLAR TECHNOLOGIES

Project Activities

STANDARDS DEVELOPMENT & BEST PRACTICES

- NREL & UL established requirements for IBR/DER cybersecurity certification
- NREL published IEEE 1547.3 cybersecurity guide for DERs.
- NREL conducted initial gap analysis for supply chain cybersecurity.
- Cybersecurity risk analysis for DERS
- Cybersecurity requirements for DERMS.
- Support SDOs working groups

EDUCATION, WORKFORCE & STAKEHOLDER ENGAGMENT

- Leveraging CESER's Cyber Strike, SNL & INL developed training modules and demonstrations to train solar cyber defenders. Created first 5 lessons for the Solar CyberStrike program, DER Simulator with SunSpec Modbus and IEEE 2030.5 server, and single-axis tracking system.
- Support the development of cybersecurity requirements for state energy officials (NASEO and NARUC).
- Engagement with solar vendors for project participation.
- Industry Advisory Board

CYBERSECURITY TOOLKIT & SUPPLY CHAIN

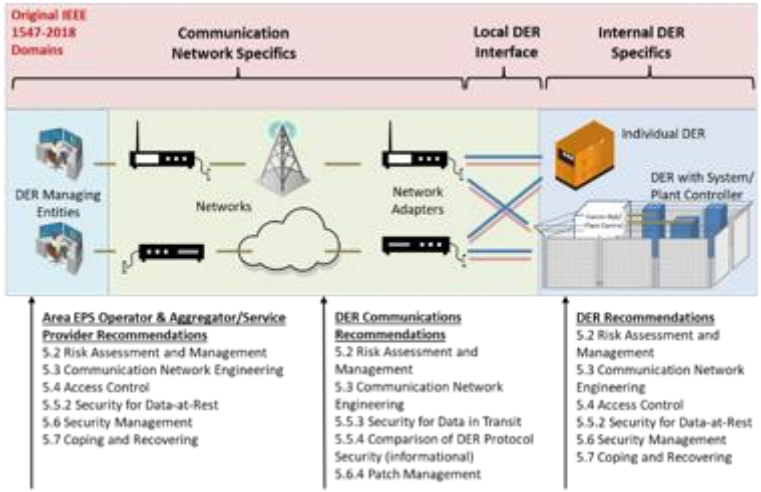
- SNL & INL created the Solar Cybersecurity Evaluation and Risk Informed Toolkit (SolarCERT) leveraging DHS' CSET.
- SNL Security Orchestration and Automation and Response.
- PNNL Cyber-Physical Detection and Range (CPYDAR) tool to enable the development, replication and benchmarking of cyber security test procedures for solar PV test system models.
- PNNL Secure-design & development maturity model and assessment tool for DERs (S2D-C2M2) solar vendors.

S2G: SECURING SOLAR FOR THE GRID

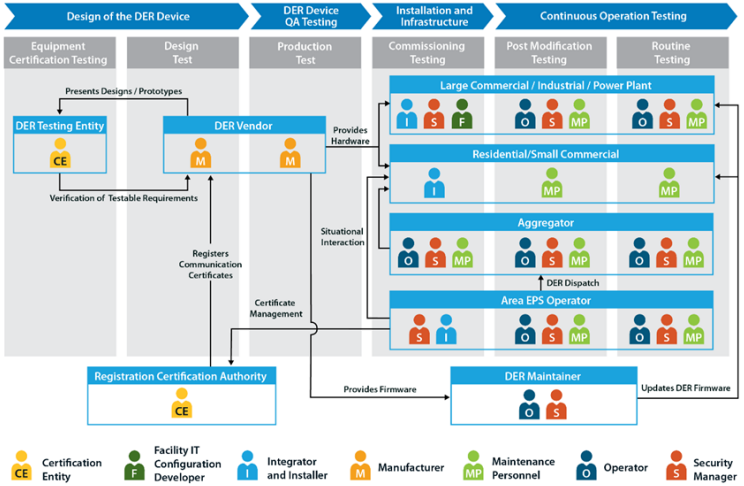
STANDARDS & CERTIFICATIONS

Upcoming Guides & DER Certification Programs

- **Cybersecurity Guidance**
- IEEE 1547.3 “Draft Guide for Cybersecurity of Distributed Energy Resources Interconnected with Electric Power Systems”
- **DER Certification Programs**
- UL 2941 “Outline of Investigation for Cybersecurity of Distributed Energy and Inverter-Based Resources”
- SunSpec DER Cybersecurity Certification Program, announced April 28, 2022 (https://sunspec.org/sunspec-cybersecurity-certification-work-group/)



IEEE 1547.3 Scope

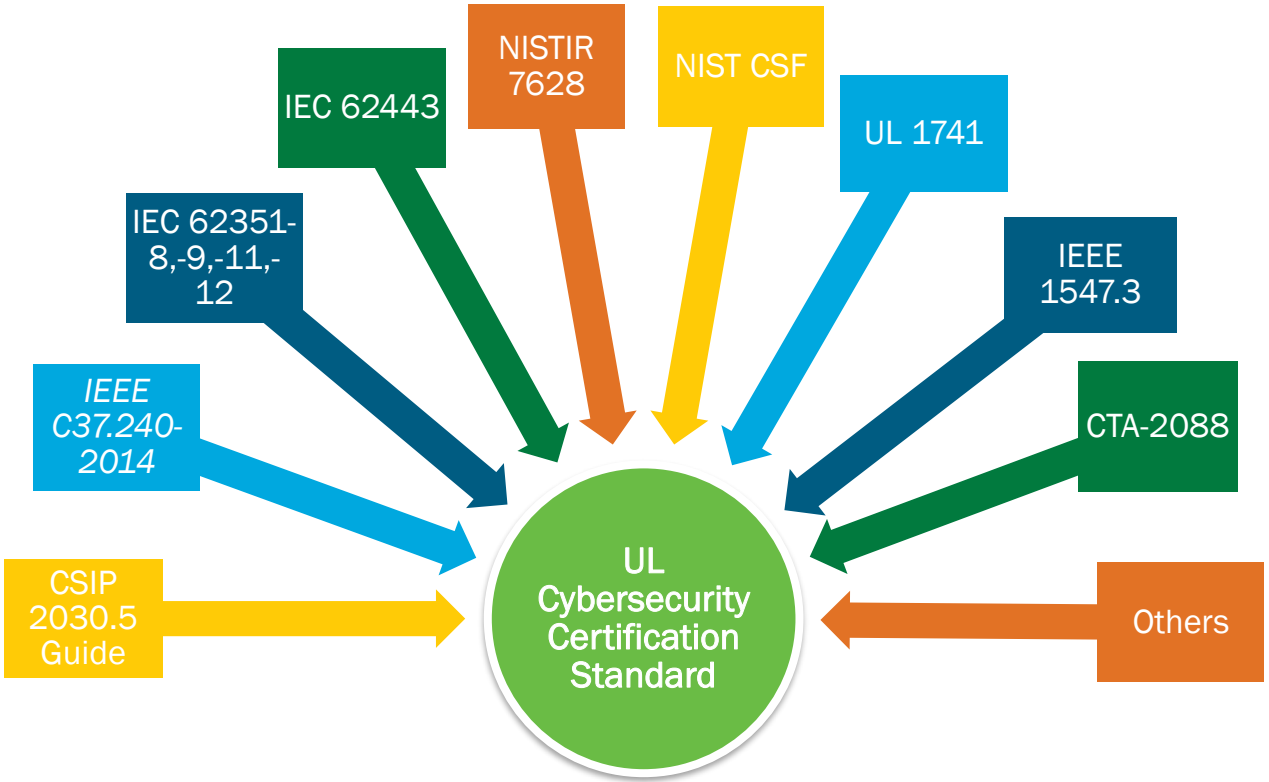


Cybersecurity Tests in IEEE 1547.3

Many Standards and Guides Exist – Why a New One?

The UL cybersecurity certification standard will:

- Build on past work
- Map and leverage security requirements from industry best practices for hardware and software
- Provide an information hub for DER Industry stakeholders
- Establish “security by design”



Note: All these standards serve a different purpose. The UL cybersecurity certification standard will not replace them by any means.

Outline of Investigation (OOI) for UL 2941

- The requirements will provide a single unified approach for testing and certification of DERs *in advance* of deployment.
- The certification will be applicable to generation and energy storage technologies.

- UL and NREL are actively developing the OOI.
- **We will welcome participation from industry.**
- To receive news and information, please visit UL news.

PRESS RELEASE

UL and NREL Announce Cybersecurity Testing Recommendations for Distributed Energy Resources and Inverter Based Resources

UL and the National Renewable Energy Laboratory will complete an Outline of Investigation as a precursor to the first cybersecurity certification standard for distributed energy resources.

Home > News > UL and NREL Announce Cybersecurity Testing Recommendations for Distributed Energy Resources and Inverter Based Resources

March 7, 2022

NORTHBROOK, Illinois – March 7, 2022 – UL, a global safety science leader, has released a report, co-authored with the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL), titled "Cybersecurity Certification Recommendations for Interconnected Grid Edge Devices and Inverter Based Resources." The report includes recommendations that enable distributed energy resources (DER) and inverter based resources (IBRs) to maintain a strong cybersecurity posture.

With support from DOE's Solar Energy Technologies Office, UL will continue working with NREL on developing requirements to support cybersecurity certification standards for DERs and IBRs. NREL and UL are currently working on an Outline of Investigation for a standard that will apply to energy storage and generation technologies on the distribution grid, including photovoltaic inverters, electric vehicle chargers, wind turbines, fuel cells and other resources essential to advancing grid operations. These new requirements will prioritize cybersecurity enhancements for power systems dealing with high penetration inverter-based resources, including those interfacing with bulk power systems for periods of instantaneous high wind, solar and hybrid/storage generation. It will also help ensure cybersecurity is designed into new IBR and DER systems.

"Currently, there are no cybersecurity certification requirements to which manufacturers and vendors can certify their DER and IBR devices against an established and widely adopted cybersecurity certification program. The development of these new cybersecurity certification requirements will provide a single unified approach that can be taken as a reference for performing the testing and certification of DERs before being deployed and while in the field," said Kenneth Boyce, senior director for Principal Engineering, Industrial, group at UL. "Drafting comprehensive certification requirements with peer review requires effective leadership and stakeholder participation. We are pleased to be working with NREL in this effort to bring additional performance-based security to electrical grid infrastructure."

S2G: SECURING SOLAR FOR THE GRID

RISK ASSESSMENT & MITIGATION

INL Cyber SHIELD-INL CERT

INL *Cybersecurity Risk Evaluation Tool*

Main Goal

Deliver a standardized, repeatable cybersecurity valuation methodology that is tuned to the needs and characteristics of the renewable industry subsectors and can provide insight and guidance quantitatively to better informed, broader, risk-based investment decisions surrounding renewable IT and OT cybersecurity programs

Key features:

- ✓ Renewable Sector Focused Capability
- ✓ Leverages DHS CSET tool, with multiple years of $$$ investment
- ✓ Open-Source and tuned for Solar industry

Top 3 Benefits:

1. Guided cybersecurity assessment and risk-based report to enhance cybersecurity programs leveraging established framework tuned for renewable asset sector
2. Design tool to map network architecture and obtain clear view to common design related risks and mitigation options
3. Immediate access to input supporting program and resource planning capabilities to more quickly meet maturity objectives

Network Diagram

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SHIELD–Malcolm

Asset Interaction Analysis

Main Goal

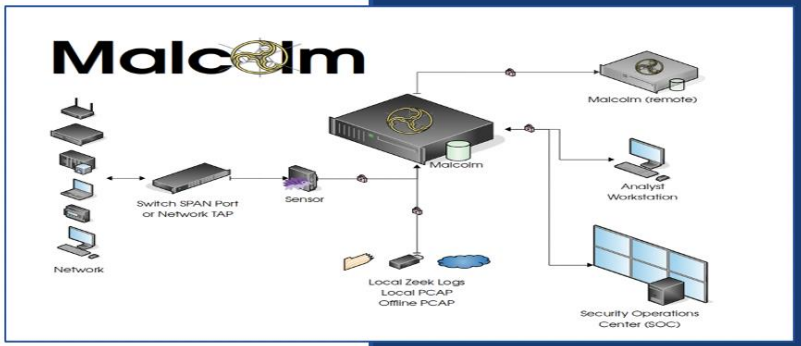
Links assets to business processes and translates business processes to OT devices. Supports deeper threat and vulnerability identification/analysis for user

Key features:

- ✓ Malcolm: A first step in asset to business processes mapping
- ✓ Works with a spectrum of cyber maturity adding capability at their level
- ✓ Significant investment by others (DHS)

Top 3 Benefits:

1. Get to know what you have, better view of asset level risks - devices, protocols, misconfigurations
2. Helps you identify potential attacks, vulnerabilities, active exploits with more precision specific to your assets/devices
3. Increases visibility into your network to inform decisions and improve reliability



Asset Interaction Analysis
Malcolm
Malcolm Key Benefits & Deployment Overview

Deploying AIA

INL will deploy hardware (spec'd to multiple environments) and work with your team on installation and configuration for your network

INL will work with your team to identify capture points and configure data collection

INL encourages plant owners and operators to incorporate the capability after engagement

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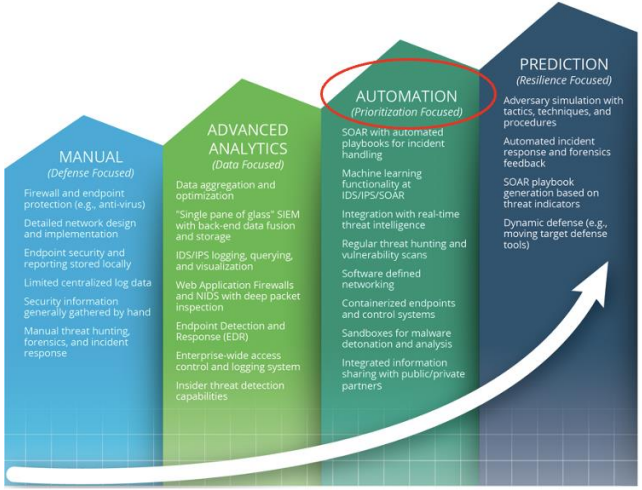
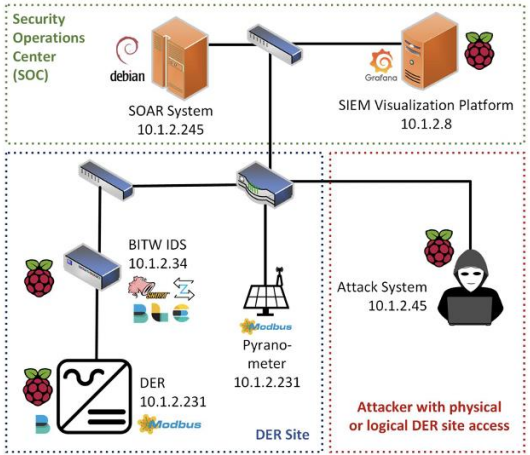
CYBER-PHYSICAL NETWORK MONITORING

Security Orchestration for DER Equipment

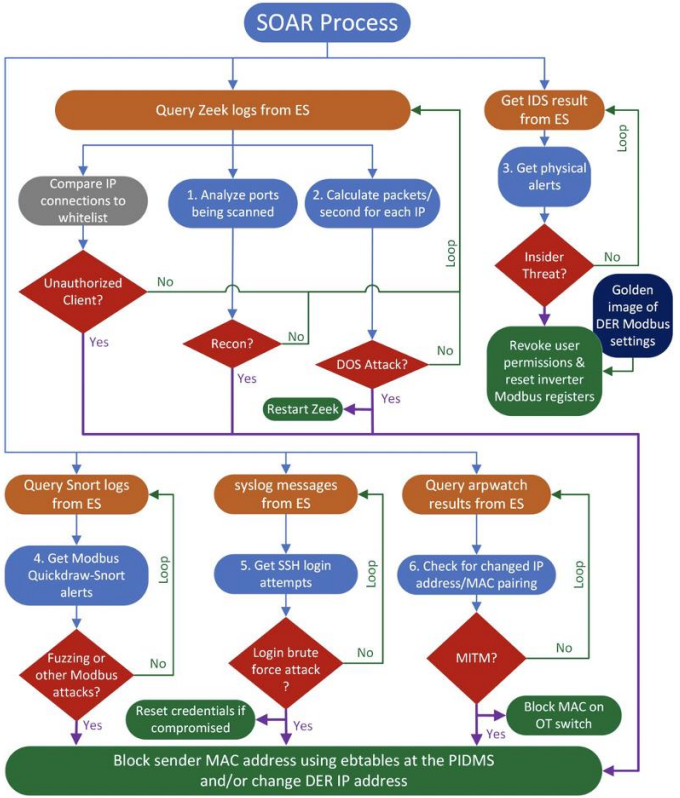
- Sandia developing next-generation **security automation** incorporating multiple data streams and threat intelligence.
  - Threat, intrusion detection, and other data is pooled into a Security Information and Event Management (SIEM) application in the **Security Operations Center** (SOC).
  - Detects a variety of DER attacks and **responds quickly** (<30 second response time).
  - Automated or human-in-the-loop responses: network topology changes, block IPs, revoke access/certs, modifying VPN/SSH access, etc.



SOC Maturity Levels



Sandia Testbed



Automated Response Playbook

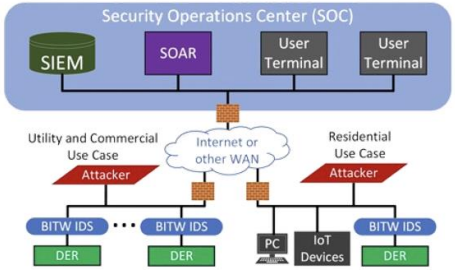
Intrusion Detection and Mitigation for Photovoltaics

2022 R&D 100 WINNER

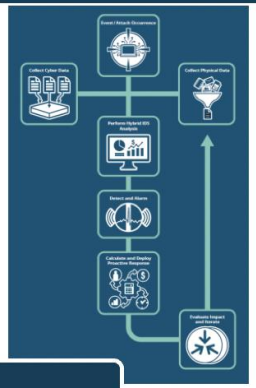
Sandia is developing solar-specific **Security Operations Centers** (SOCs) with **intrusion detection and automated mitigation**

- Cyber-physical approach uses network and power system data to detect attacks
- Adaptive Resonance Theory establishes detection thresholds for physical attacks with online learning

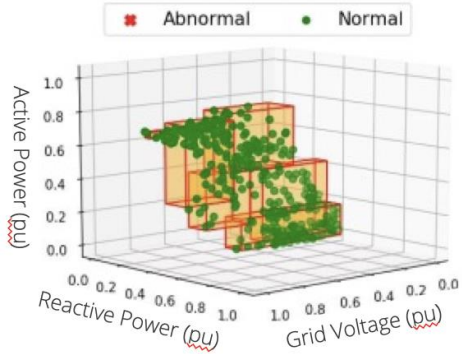
Security Operations Center



Hybrid analysis and mitigation process



Machine learning data classification



Physical DER data

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S2G: SECURING SOLAR FOR THE GRID

Workforce Development & Training

Training solar cyber defenders

- **Sandia is creating a new renewable energy cybersecurity CyberStrike training program for solar inverters, EV chargers, and wind systems.**
- **8-hour classes with lectures (slides) and exercises**
  - Virtual machine environment for hands-on training without hardware
  - Implementing a hands-on training with hardware including a single axis solar tracker.
- **Hardware prototypes have been designed and are being prepared for production.**

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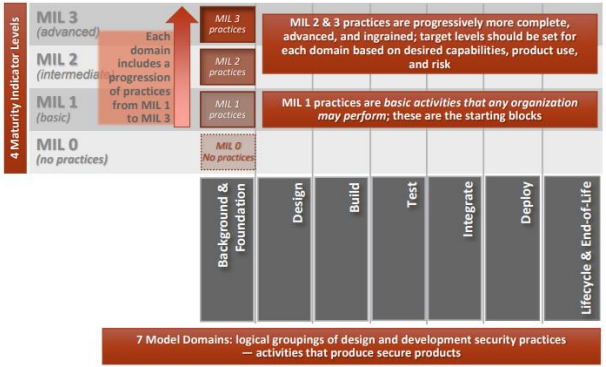
Supply Chain

Secure Design and Development Cybersecurity Capability Maturity Model (SD2-C2M2)

SD2-C2M2 Model Architecture

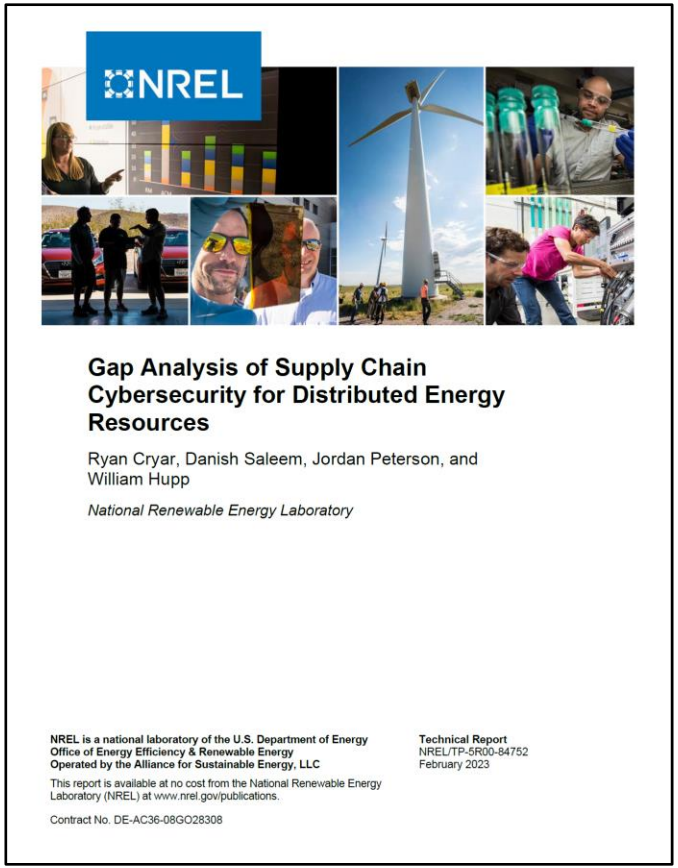


Assessment Workflow

1. Management selects desired MIL for each practice objective.
2. SMEs respond to individual Practice Statements.
3. SMEs and management review responses.
4. Management prioritizes gaps and establishes a plan to remediate them.
5. SMEs execute the remediation plan.
6. Re-evaluate to determine if gaps have been addressed (with or without re-assessment of Management priorities).

Report: Supply Chain Cybersecurity for Clean Energy Sector

- Establish a framework for DER supply chain cybersecurity
- Engage industry for assessments
- Create open-source software guidance
- Establish a testing and certification ecosystem for DER software supply chain cybersecurity
- Address the issue of lacking standards for DER supply chain cybersecurity
- Form working groups for best practices



In Conclusion

- The rapid deployment of renewables and distributed energy resources onto the power grid presents new challenges to energy sector cybersecurity.
- A **holistic approach** in information technology (IT) and operation technology (OT) risk management is needed that encompass utility systems with customer owned DER devices and third-party operated systems.
- Need to build **community awareness and information sharing** mechanisms to incorporates equipment standards and vigorous testing, validation, and certification – including global supply chains for products like solar inverters.
- The **DOE and national labs** can provide technical expertise, research and testing capabilities, and funding to support industry
- **Collaboration** is crucial – within DOE program offices, other federal agencies, state and local governments, and industry.

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End of Presentation