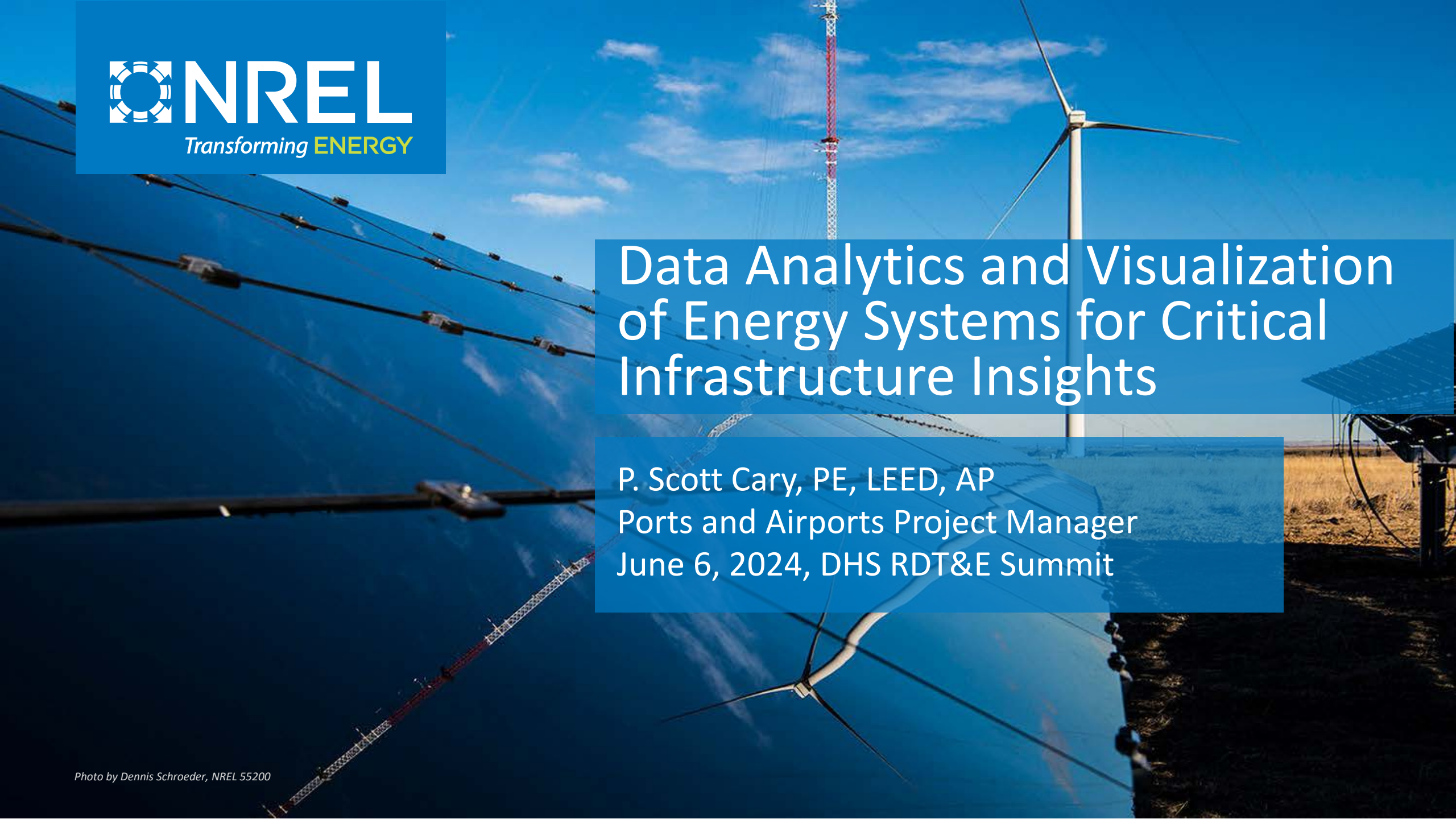


Data Analytics and Visualization of Energy Systems for Critical Infrastructure Insights

P. Scott Cary, PE, LEED, AP
Ports and Airports Project Manager
June 6, 2024, DHS RDT&E Summit

Photo by Dennis Schroeder, NREL 55200

Contents

Introduction

NREL at a Glance

3,675 workforce, including:

- 2,732 regular/limited term
- 490 contingent workers
- 211 postdoctoral researchers
- 152 graduate student interns
- 90 undergraduate student interns

—as of 9/30/2023

World-class research expertise in:

- Renewable Energy
- Sustainable Transportation & Fuels
- Buildings & Industry
- Energy Systems Integration

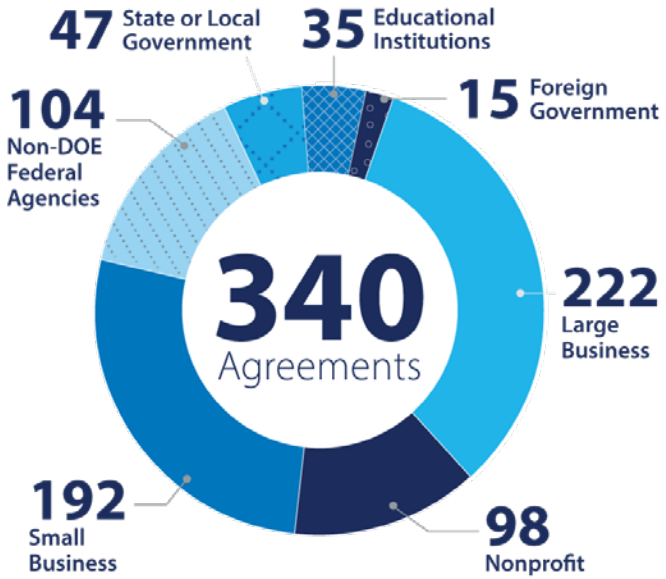
Partnerships with:

- Industry
- Academia
- Government

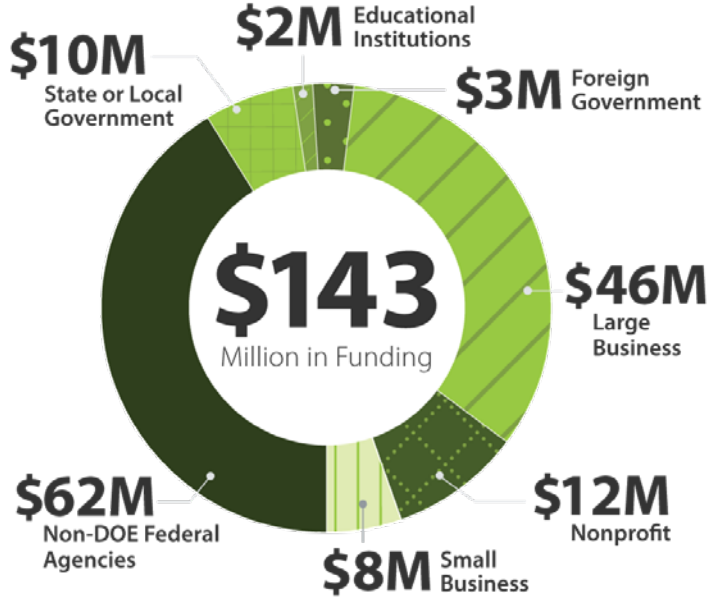
20 major laboratory and DOE user facilities

4 campuses operate as living laboratories

More Than 1,000 Active Partnerships in FY 2023



Agreements by Business Type



Funding by Business Type

NREL Science Drives Innovation

Renewable Energy

- Solar
- Wind
- Water
- Geothermal

Sustainable Transportation & Fuels

- Bioenergy
- Hydrogen and Fuel Cells
- Transportation and Mobility

Buildings & Industry

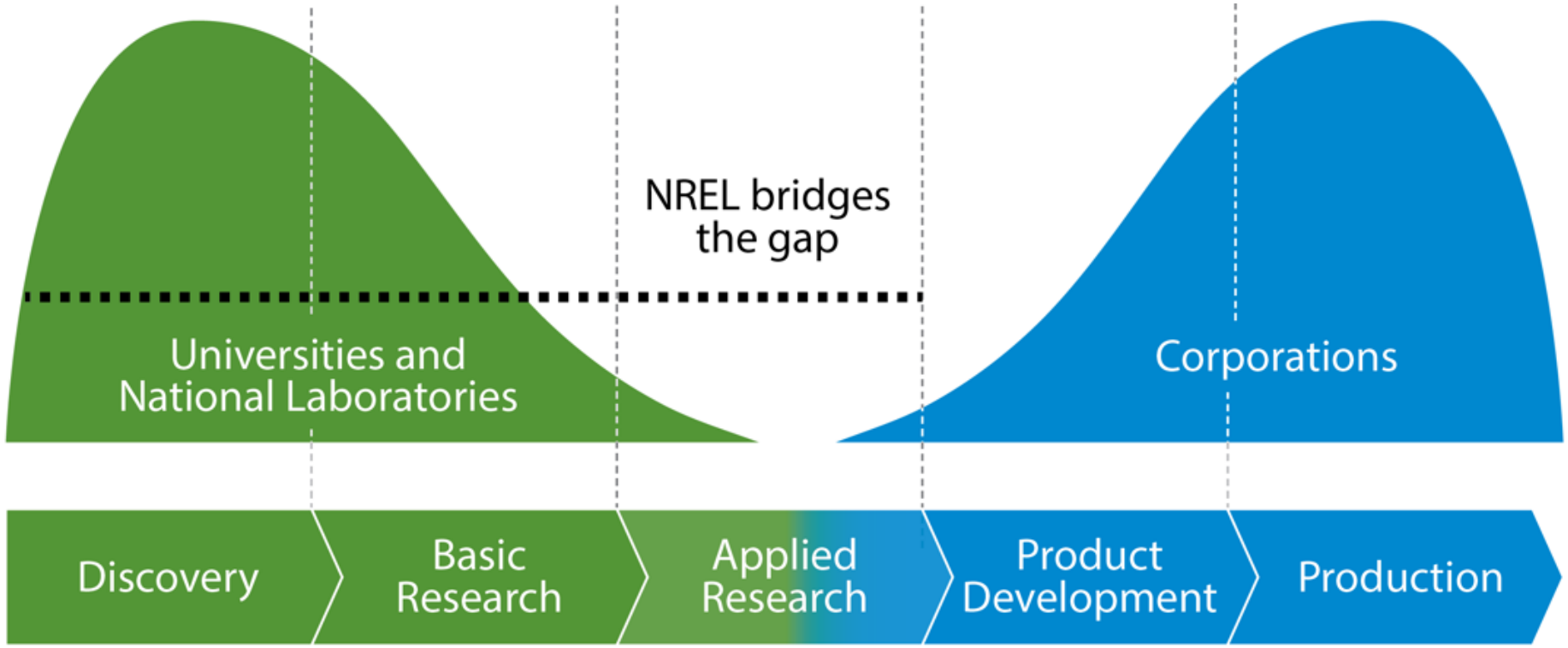
- Buildings
- Industrial Efficiency and Decarbonization
- Advanced Materials and Manufacturing
- State, Local, and Tribal Governments

Energy Systems Integration

- Energy Security and Resilience
- Grid Modernization
- Integrated Energy Solutions

Photo by Werner Slocum, NREL 66364

We Reduce Risk in Bringing Innovations to Market



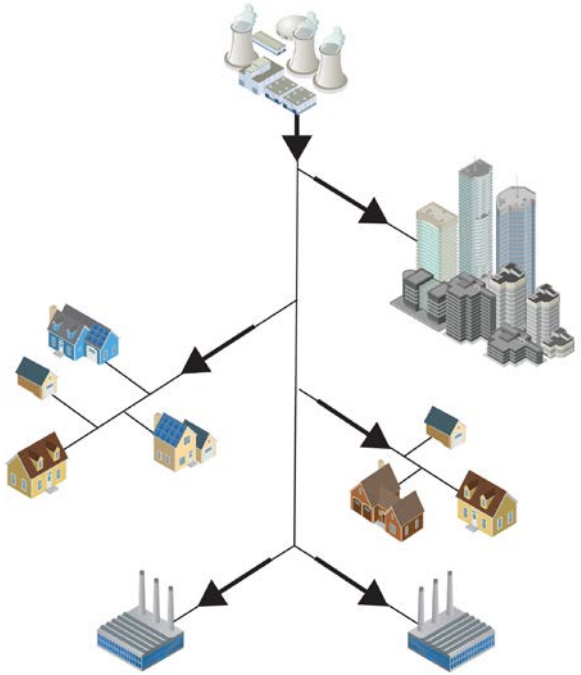
NREL helps bridge the gap from basic science to commercial application.

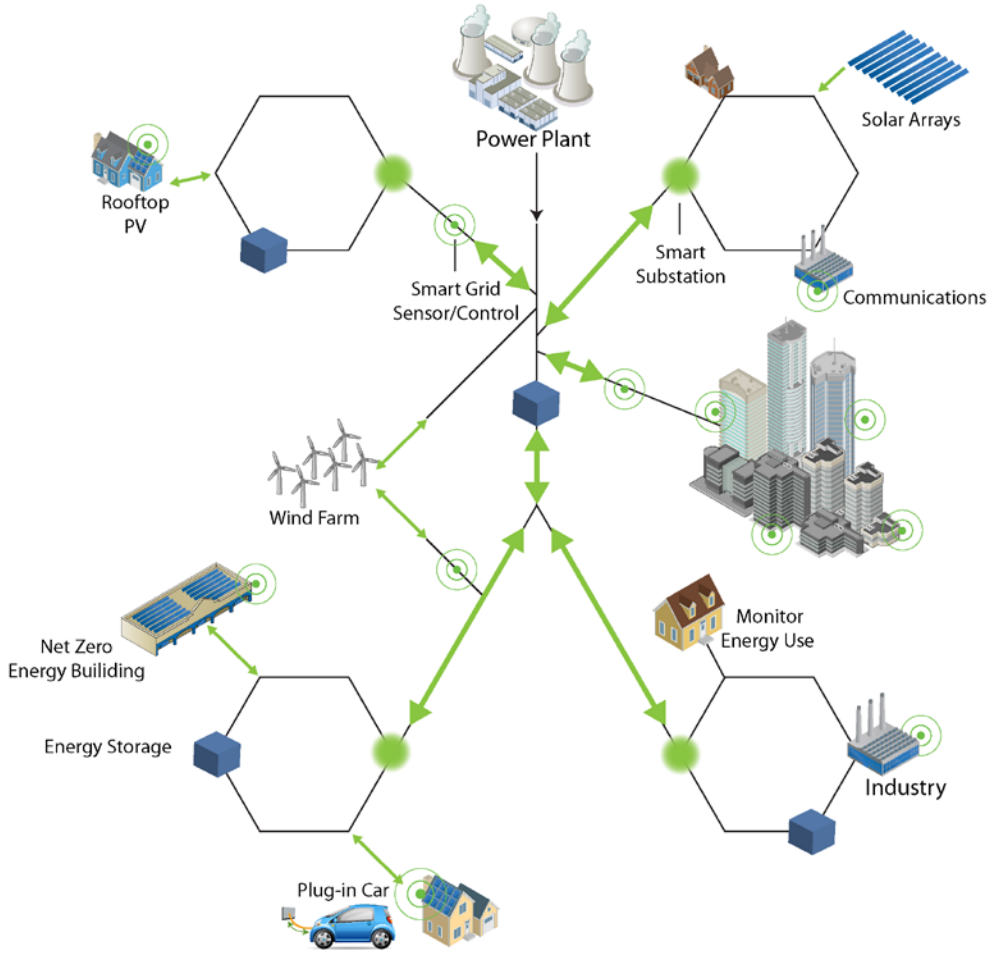
Forward-thinking innovation yields disruptive and impactful results to benefit the entire U.S. economy.

Accelerated time to market delivers advantages to American businesses and consumers.

Modernization of Energy System

Modernization of Energy System Driven by Use Cases, Technological Advances, Digitalization, and Market Trends



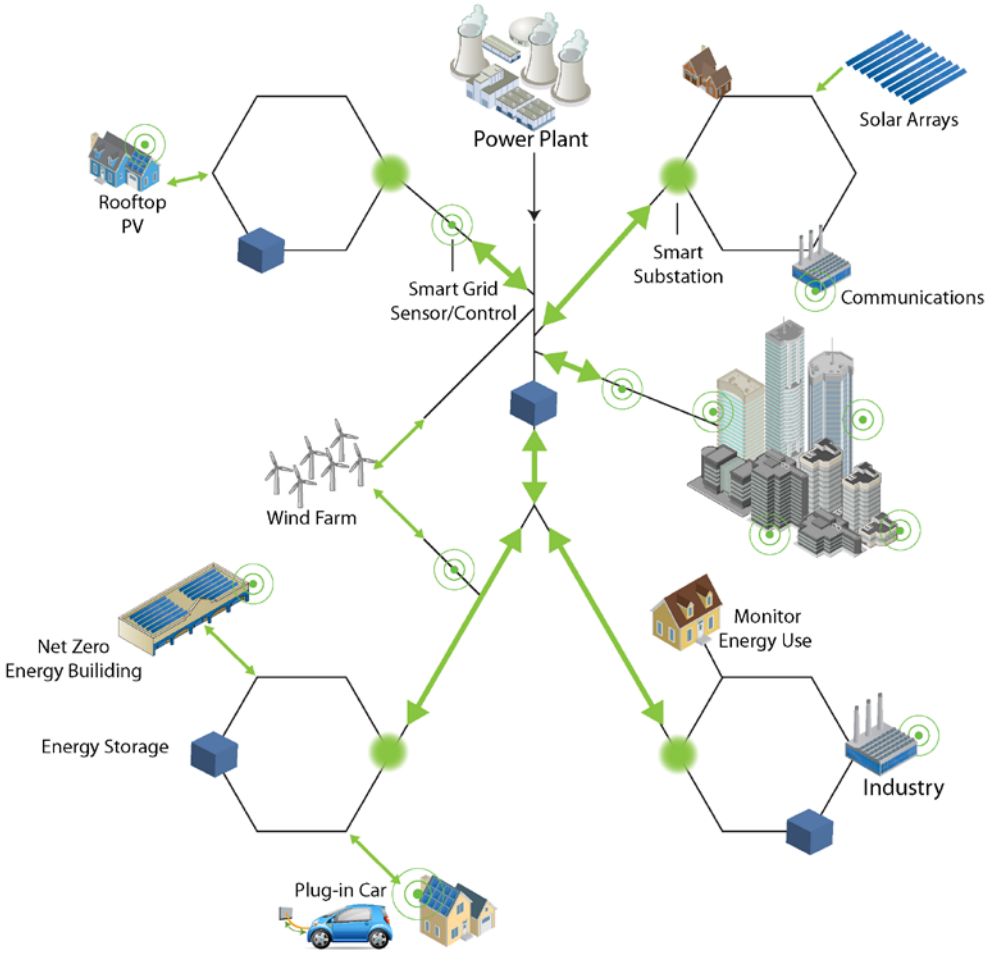


From monopoly power…To deregulated markets.

From top-down topologies…To smart distribution and bidirectional power flows.

From downstream power delivery…To autonomous local structures.

Modernization of Energy System



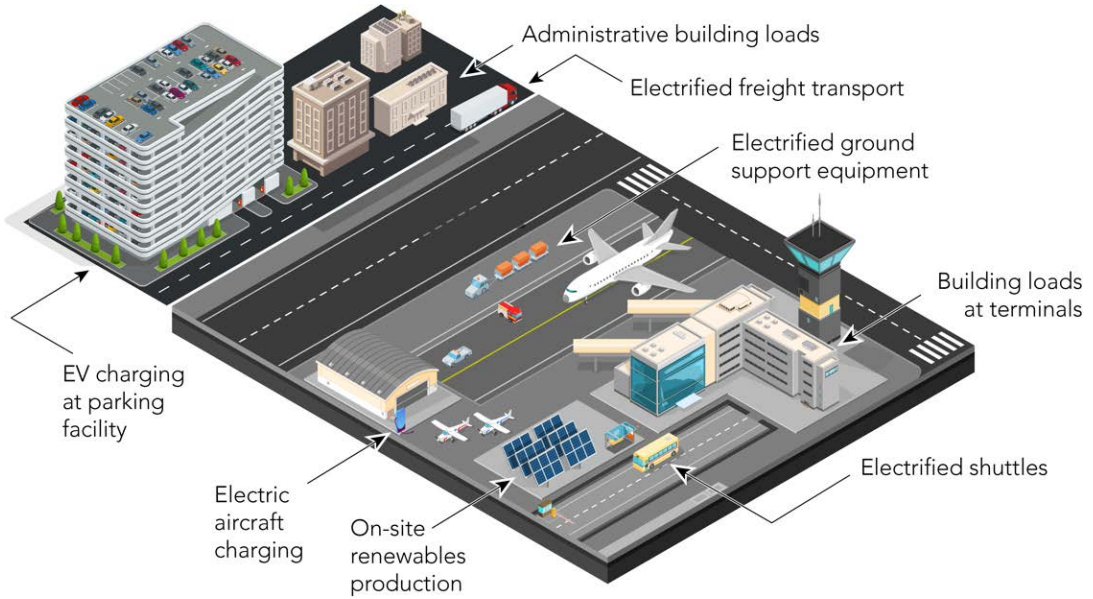
- Digitalization, electrification, and distributed energy resources:
  - Improves resilience, energy efficiency, and cost-effectiveness, and reduces greenhouse gas emissions
  - These benefits and operational challenges need to be evaluated, validated, and verified.

Challenges to Federal Agencies

Challenges for Federal Agencies Including DHS

- Energy system modernization—benefits:
  - Increased efficiency
  - Expansion of commerce
  - Decentralization of power generation.

- Challenges:
  - Lower petroleum demand = higher electrical demand
  - Increased communication requirements = higher risk of cybersecurity
  - Efficiency improvements of the last 20 years have resulted in lower infrastructure investment
  - New technology adoption suggests need for validation before deployment
  - Limited resources or tools to estimate transportation energy consumption and resulting delivery and generation needs
  - Updating polices and regulations to adapt to new technologies.



- *Xcel Energy is working with two airports in their service area and recently published information projecting an up to fivefold increase in peak electricity demand in the next 25 years.*[1]
- *Concurrently, the U.S. Government Accountability Office (GAO) recently surveyed 30 commercial service airports identifying more than 300 outages of more than 5 minutes between 2015 and 2022.*[2]

[1] Enterprise Mobility. 2024. *Electrifying Airport Ecosystems*. https://www.enterprisemobility.com/content/dam/enterpriseholdings/marketing/innovation-in-mobility/vehicle-innovation/airport-electrification-study-full-report-2024.pdf

[2] GAO. 2023. *Airport Infrastructure: Selected Airport's Efforts to Enhance Electrical Resilience*. Washington, D.C. https://www.gao.gov/products/gao-23-105203.

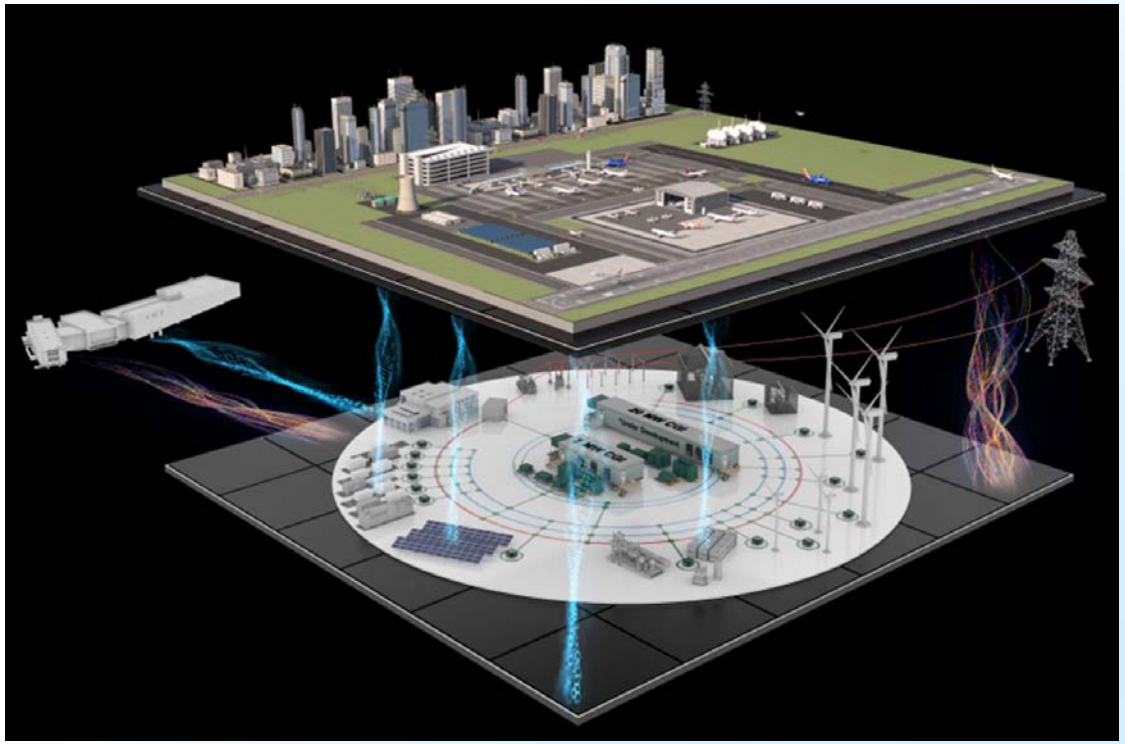
Potential Solution

Potential Solution

- NREL proposes developing methodologies:
  - To allow owners, utilities, and federal agencies to dynamically analyze, forecast, and manage energy loads at critical transportation facilities such as airports.
  - Intent: Predictive energy management to maintain the flow of commerce in an efficient, sustainable, and resilient way.
- To address these energy challenges, a suite of technologies and methodologies can be leveraged to validate concepts, inform design, de-risk solutions, and optimize energy management for the utility industry and the U.S. Department of Homeland Security.
- These technologies include the digitalization of energy systems, microgrid methodologies, and related energy technologies for building and vehicle loads.

Data Analytics and Visualization of Energy Systems

- Data analytics and visualization of energy systems:
  - Data collection
  - Development of various models:
    - Vehicle energy estimation
    - Charging/resource station design
    - Overall energy estimation for the facility
    - Utility infrastructure impact estimation
    - Distributed energy resource sizing
    - Costs/benefits
    - Resilience assessment
    - Energy management system.
  - Validation and verification (hardware-in-the-loop)
  - Leverage existing U.S. Department of Energy (DOE), Federal Aviation Administration (FAA), and National Aeronautics and Space Administration (NASA) research to develop nationwide energy model.



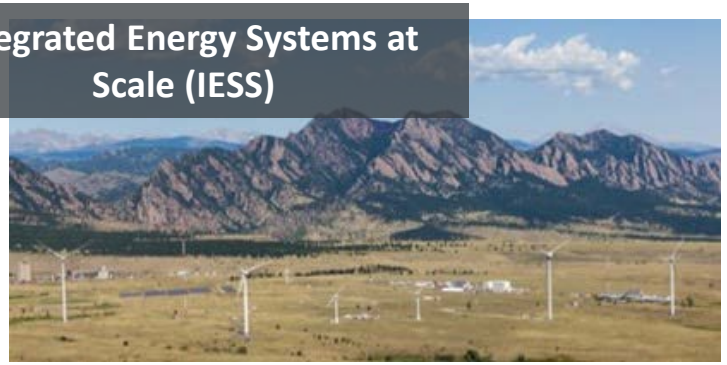
Outcome of Data Analytics and Visualization of Energy Systems

- Understand impact on grid infrastructure
- Provide technology evaluation (e.g., chargers)
- De-risk use case scenarios: Improve resilience to weather events, address fuel crisis
- Forecast operation parameters
- Identify potential vulnerabilities, including cybersecurity
- Provide insights in safety protocols, policy development
- Of interest to electric utilities, transmission and distribution companies, state/local aviation, planning departments, and technology companies.

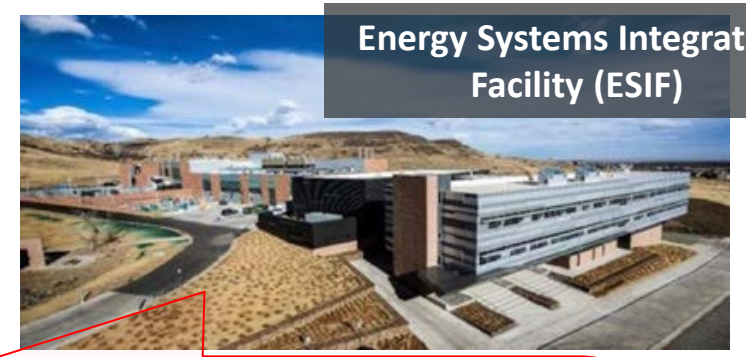
ARIES Platform

ARIES Research Platform—Scale

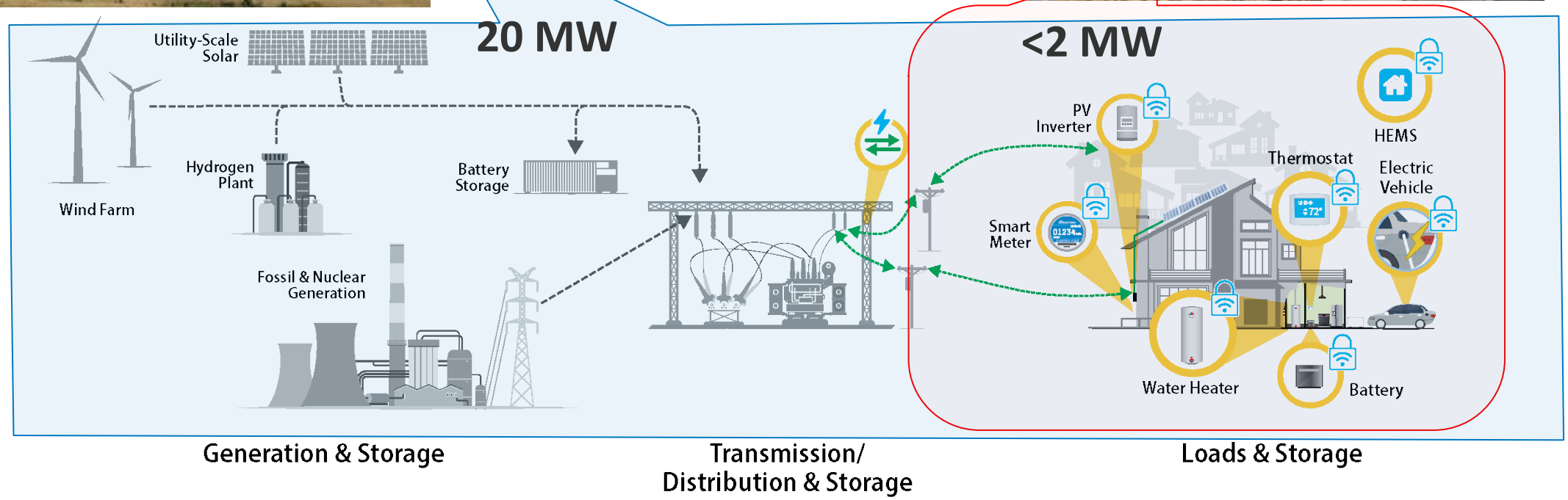
Integrated Energy Systems at Scale (IESS)



Energy Systems Integration Facility (ESIF)



Photos by NREL



Virtual Emulation Environment

U.S. DEPARTMENT OF ENERGY

CESER

EERE

IN

OCIO

OE

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Sandia National Laboratories

Idaho National Laboratory

Argonne NATIONAL LABORATORY

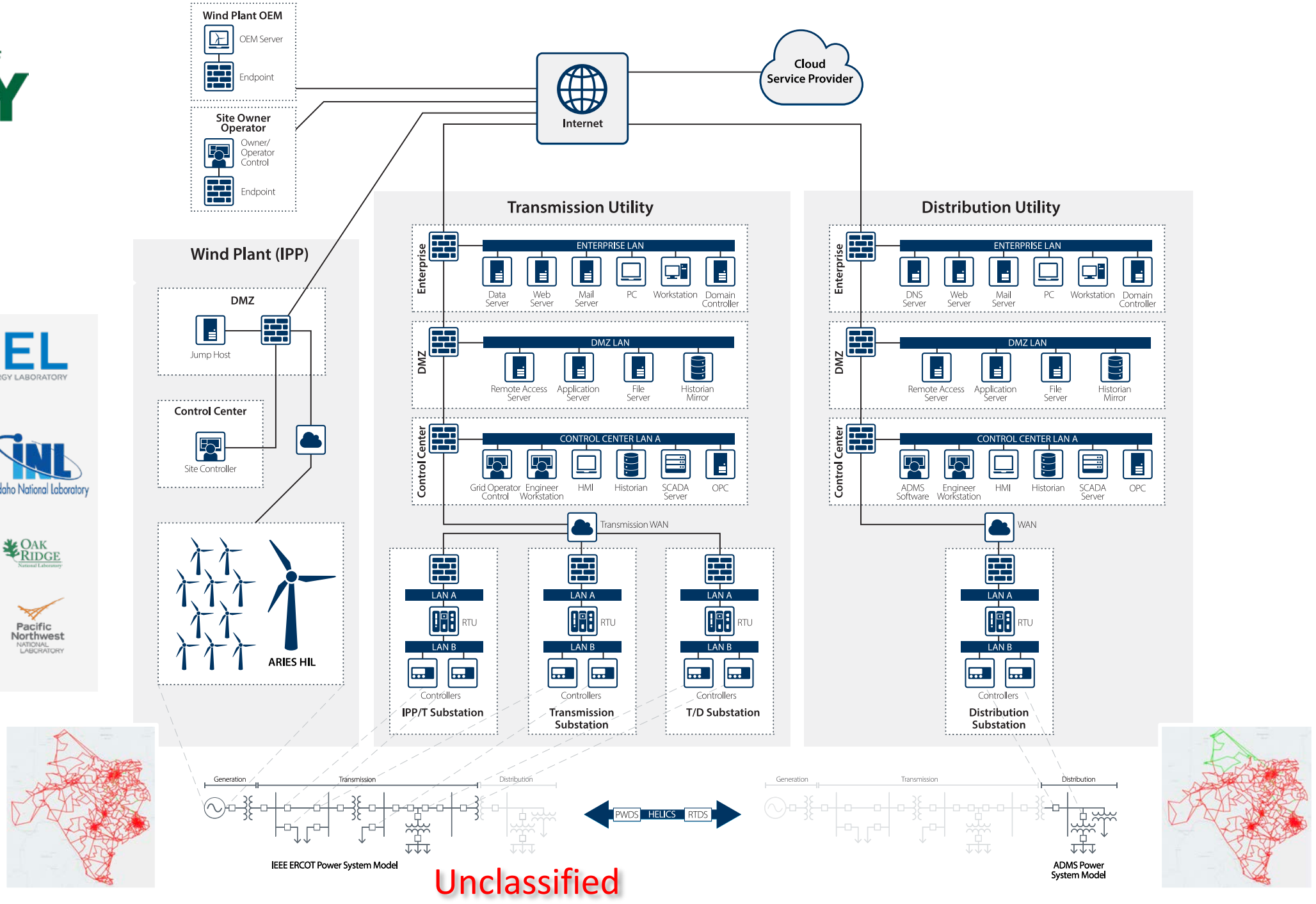
BERKELEY LAB

OAK RIDGE National Laboratory

Lawrence Livermore National Laboratory

Pacific Northwest NATIONAL LABORATORY

Los Alamos NATIONAL LABORATORY



Unclassified

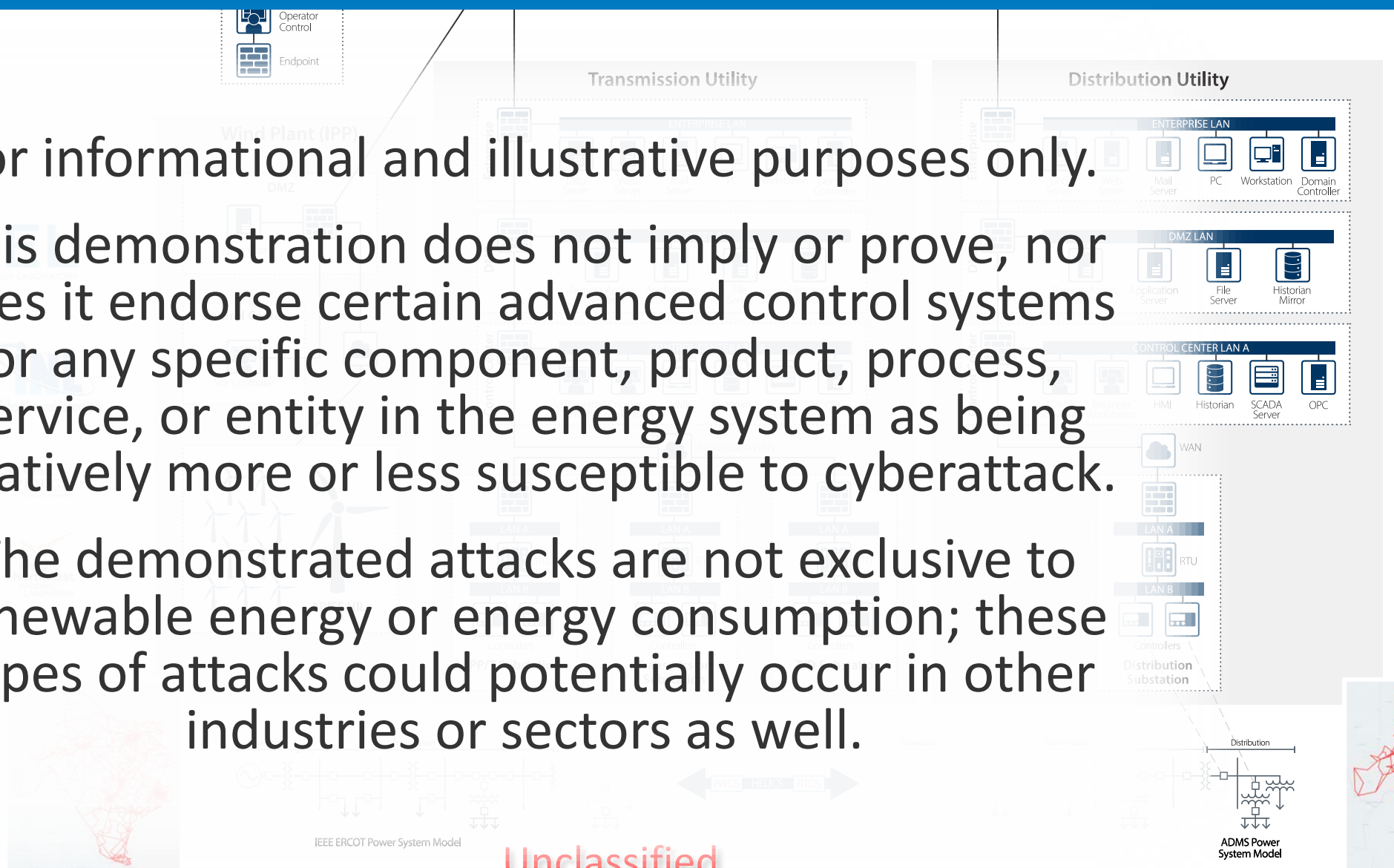
ARIES Cyber Exercise Disclaimer

- CESER
- EERE
- IN
- OCIO
- OE

For informational and illustrative purposes only.

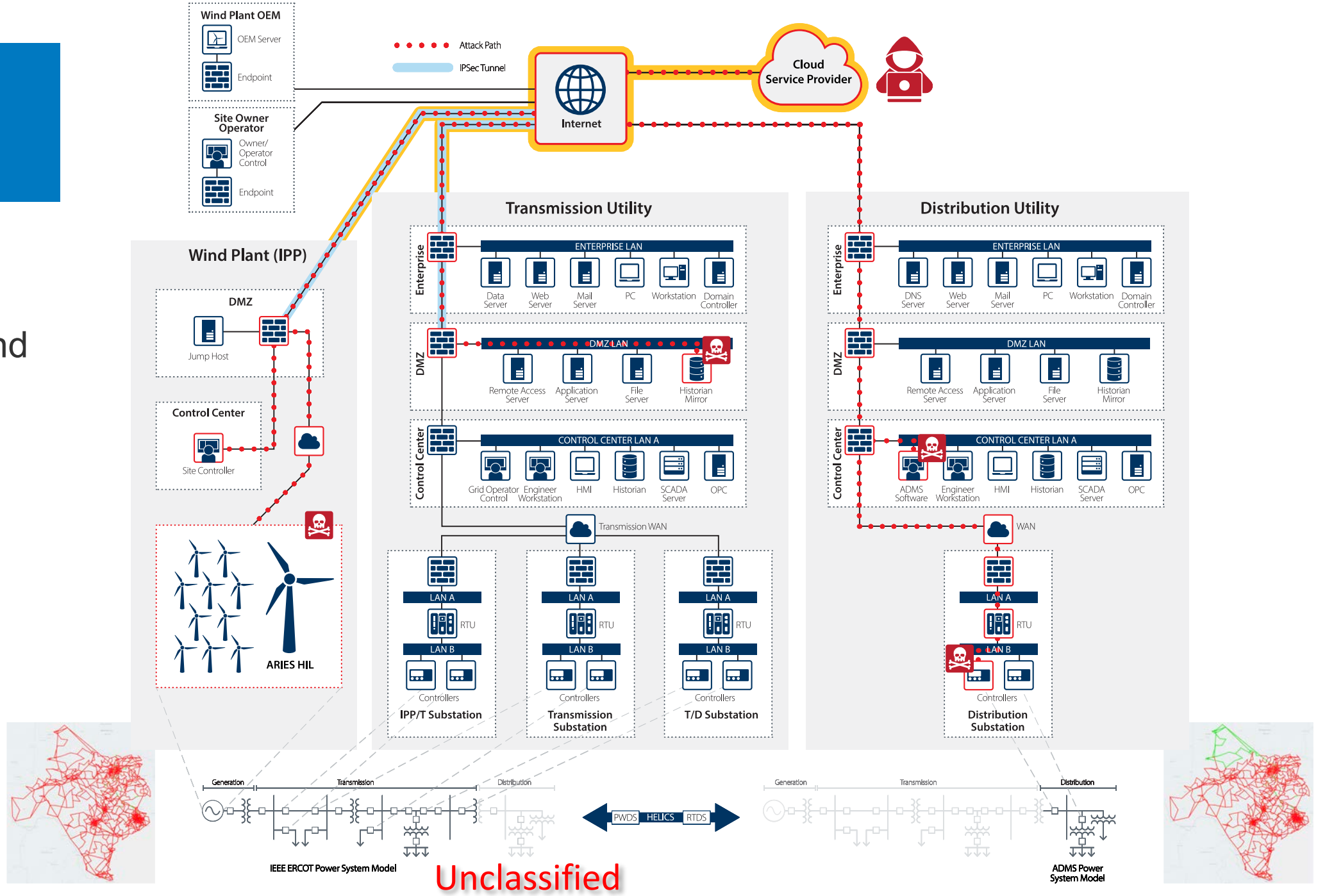
This demonstration does not imply or prove, nor does it endorse certain advanced control systems or any specific component, product, process, service, or entity in the energy system as being relatively more or less susceptible to cyberattack.

The demonstrated attacks are not exclusive to renewable energy or energy consumption; these types of attacks could potentially occur in other industries or sectors as well.



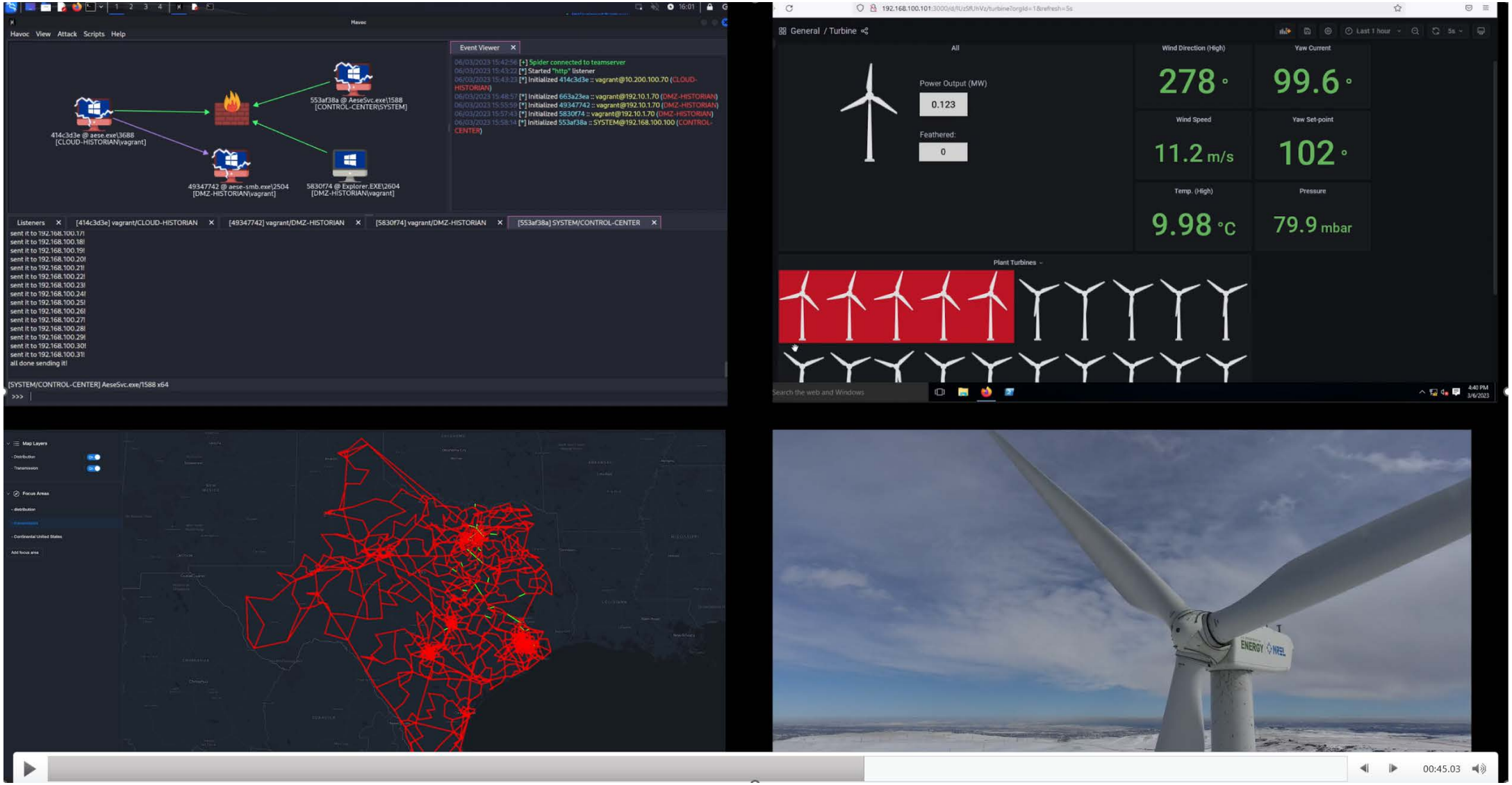
Threat Details

A Combined IT/OT Scenario With Existing and Future Threats



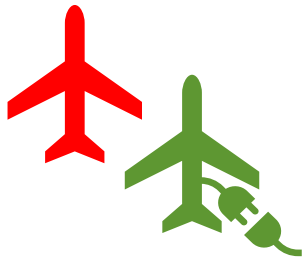
Unclassified

ARIES Cyber Video Screenshot

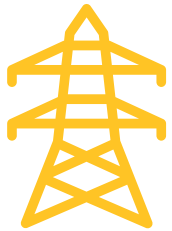


NREL Efforts

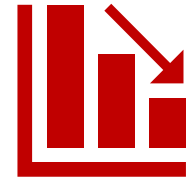
NREL Studies: FAA Vertiport Electrification Study

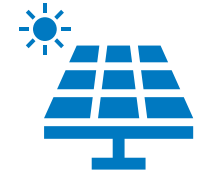


- **Justification: Electric Aircraft are flying and expected to be certified in 2025 and beyond.**



- Charging demand modeling: Adding ~1 MW of load to each site—34 aircrafts, 8 vertiports, up to 3 chargers per vertiport
- From derived charging demand study:
  - Utility bill: Energy consumption increases: 6%–20%; peak demand increases: 200%–1,100%; bill increases: 17%–300%
  - Grid impact analysis: May require upgrading thermal equipment, battery energy storage system (BESS) may reduce upgrade required
  - On-site generation opportunity: PV + BESS (up to 30 min) can reduce bill up to 74%
  - Greenhouse gas emissions calculations: Depends on grid, reduces as on-site renewable generation increases
- Cybersecurity analysis: Employs a common framework early in the development process and throughout the overall aviation charging system
- Electrical hazard analysis: Considers electrical safety codes, hazards impact, and cybersecurity aspects associated with charging infrastructure
- Job and economic development impact analysis: Overall positive impact.





Athena ZEV

Athena ZEV will develop an electrification pathway for U.S. airports.

Justification: Airports are difficult ecosystems to electrify due to the complexity of their operations and high energy use. The Athena ZEV project identifies and develops technologies that airports can use to electrify operations, beginning with rental car fleets.

Solution:

- Athena ZEV, an evolution of the Athena project, will use expertise and tools to support the development of an electrification pathway for U.S. airports, starting with analyzing the needs associated with rental car fleet electrification.
- This project will be developed as a joint effort among NREL, Oak Ridge National Laboratory, Dallas Fort Worth International Airport (DFW), and aviation stakeholders.

Impact:

- Tools and learnings from Athena ZEV will be replicable to all airports. High-performance computing models will identify commercially viable ways to integrate energy storage, solar production, and flexible building loads.

An electric rental car charges at a DFW charging station.
Photo by Werner Slocum, NREL

More information: https://www.athena-mobility.org/

NREL Studies: NASA Regional Air Mobility Study

Purpose: Evaluate electrical implications of using existing regional airports for small passenger air service—up to 30-seat aircraft.

Completed:

- Collaborating with NASA Langley:
  - Investigated how advances in electrified aircraft propulsion, autonomy, and new air carrier operating models will impact regional air travel
- In collaboration with NASA forecasts, NREL evaluated a typical aircraft day use scenario across a nine-state mid-Atlantic region.
- Developed a static transmission and generation model of the electric grid in the study region and identified opportunities for generation/storage and meeting transportation demand.

In progress:

- AENodes—kicked off FY24.

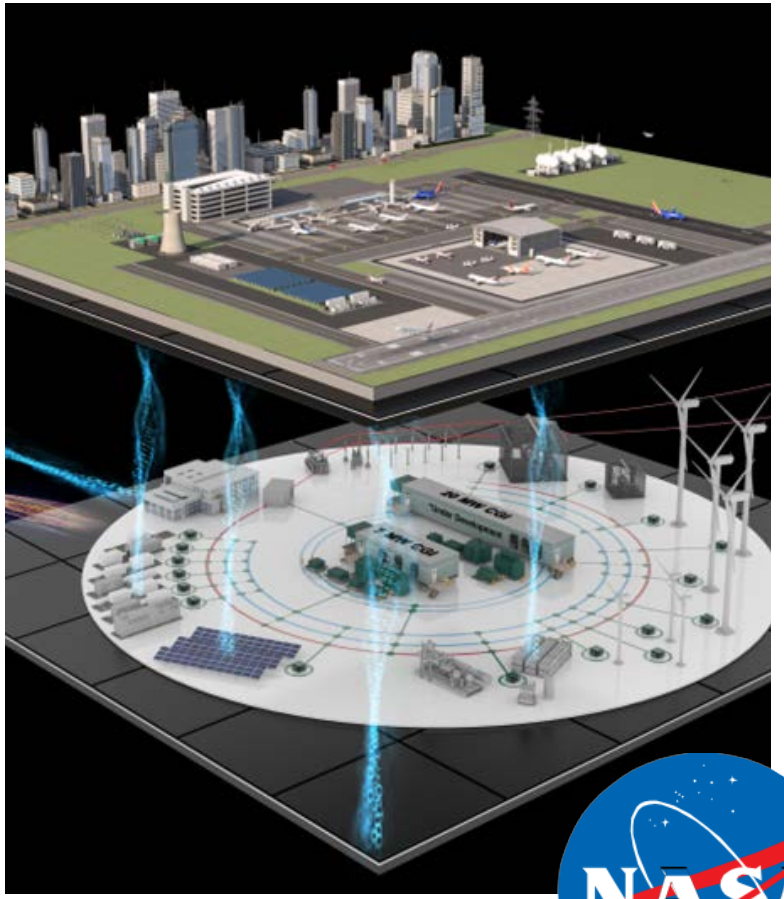
Airport Energy Nodes (AENodes)

Challenge:

- How can our existing infrastructure, with thousands of public-use airports, simultaneously contribute to the growth of advanced air mobility (AAM) and to the broader goal of net-zero emissions in all sectors?
- How can airports handle the energy needs of AAM in the future?
- How do we provide this energy in a sustainable, reliable, and resilient fashion at low cost to users?
- How do we leverage airport-hosted energy for nonaviation use in the face of current regulations?

Airport partners are focused on small commercial and general aviation airports:

- Two initial airports to sample: New Haven, CT; Winchester, VA
- Follow-on effort will explore detailed energy opportunities using the NREL Advanced Research on Integrated Energy Systems (ARIES) platform: https://www.nrel.gov/aries/.
- Joint partnership with NREL and NASA.

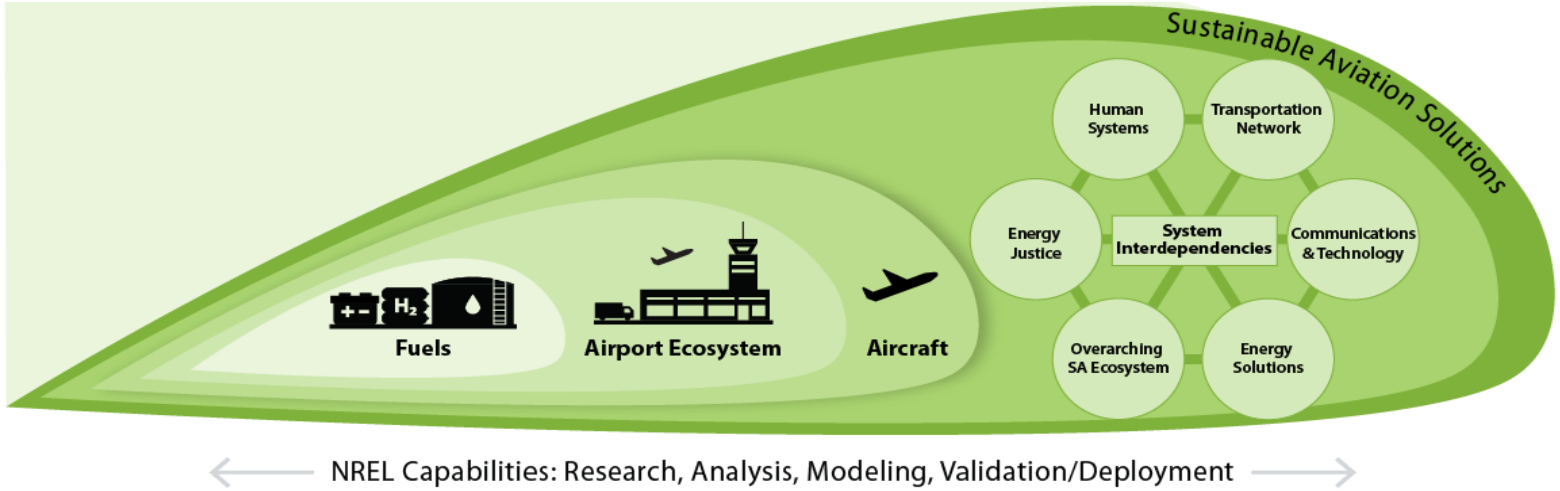


National Aeronautics and Space Administration

Resources

Sample resources for energy planning:

- GAO. 2023. *Airport Infrastructure: Selected Airport's Efforts to Enhance Electrical Resilience*. Washington, D.C. https://www.gao.gov/products/gao-23-105203.
- Ericson, S., J. Cox, M. Abdelmalak, H. Rabinowitz, and E. Hotchkiss. 2022. *Exceedance Probabilities and Recurrence Intervals for Extended Power Outages in the United States*. Golden, CO: NREL. NREL/TP-5R00-83092. https://www.nrel.gov/docs/fy23osti/83092.pdf.
- FEMP. 2024. "Electric Vehicles for Federal Fleets." https://www.energy.gov/femp/electric-vehicles-federal-fleets.
- Sample resources for resilience planning:
  - DHS CISA. 2024. "Infrastructure Resilience Planning Framework (IRPF)." https://www.cisa.gov/resources-tools/resources/infrastructure-resilience-planning-framework-irpf.
  - NREL. 2024. "Resilience Roadmap." https://www.nrel.gov/resilience-planning-roadmap/.
- Solanki, B., et al. 2023. *Federal Aviation Administration Vertiport Electrical Infrastructure Study*. Golden, CO: NREL. NREL/TP-5R00-86245. https://www.nrel.gov/docs/fy24osti/86245.pdf.



An ecosystem of partnerships is needed for realizing sustainable aviation.

Q&A

www.nrel.gov

NREL/PR-5R00-89914

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