Thank you for joining.

The ARIES Industry Workshop will begin shortly.

Please note:

Your microphone will be muted throughout the meeting. If you wish to contact the host or panelists, please use the Chat or Q&A features.
### ARIES Industry Workshop

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<tr>
<td>12:00 p.m.</td>
<td>Welcome and Agenda</td>
<td>Juan Torres (NREL), Bill Farris (NREL), and Martha Symko-Davies (NREL)</td>
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<td>12:05 p.m.</td>
<td>Energy Vision</td>
<td>Peter Green (NREL), Kevin Lynn (DOE, EERE), and Gary Smyth (Advisor)</td>
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<td>12:20 p.m.</td>
<td>About ARIES</td>
<td>Jen Kurtz (NREL)</td>
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<td>12:40 p.m.</td>
<td>Introduction to ARIES Capabilities</td>
<td>Martha Symko-Davies and Rob Hovsapian (NREL)</td>
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<td>1:00 p.m.</td>
<td>Illustrative ARIES Research</td>
<td>Matt Futch (NREL)</td>
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<td>1:15 p.m.</td>
<td>How to be a part of the Vision</td>
<td>Keith Ropchock (NREL)</td>
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<td>Feedback and Q&amp;A from Participants</td>
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<td>1:50 p.m.</td>
<td>Concluding Remarks</td>
<td>Gary Smyth, Kevin Lynn and Johney Green (NREL)</td>
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NREL’s 10-Year Plan: A Vision for the Future

Integrated Energy Pathways

CRITICAL OBJECTIVES

Circular Economy for Energy Materials
- Circularity for Polymers and Composites
- Advanced Energy Materials and Technologies
- Future Adaptive Materials for Energy Systems

Integrated Energy Pathways
- Generation, Storage, and Integration
- System Security and Resilience
- Advanced Mobility

Electrons to Molecules at NREL
- Hybrid Approaches to CO₂ Reduction and Electrons to Molecules at NREL
- Reactive Carbon Capture and Conversion
- Novel Electricity-Driven Processes for Industrial Manufacturing

Megatrends
- Population Growth
- Economic Development
- Urbanization
- Cyberthreats
- Resource Competition
- Electrification

Working Toward Our Vision
ARIES Research Platform – At-Scale

Virtual Emulation Environment

IESS at Flatirons Campus

20MW

Utility-Scale Solar

Hydrogen Plant

Battery Storage

Wind Farm

Fossil & Nuclear Generation

Transmission/Distribution & Storage

ESIF

<2MW

PV Inverter

Thermostat

HEMS

Electric Vehicle

Smart Meter

Water Heater

Battery

Generation & Storage

Labs & Storage
The New Normal: Rapid Innovation – Disruption – Exponential Growth

“Nikola wants to be the Tesla of Trucking”
*Barron’s - June 2020*

“I believe that the automotive industry will change more in the next 5 to 10 years than it has in the last 50”
*Mary Barra - CEO General Motors - 2018*

“Welcome Salesforce stock to the Dow Jones”
*MSN Money - August 2020*

“Amazon to acquire autonomous driving startup Zoox”
*TechCrunch - June 2020*

“Elon Musk teases building new Tesla GigaFactory in Texas”
*ABC News - Feb 2020*
Trends Driving Change in Energy

- Increasing Interdependencies
- Energy Diversification
- Vehicle Electrification
- Grid-Connected Smart Buildings
- Big Data, Artificial Intelligence, and Machine Learning
- Cybersecurity
- Resilience
- Millions of Devices at the Grid Edge
About ARIES
ARIES
Advanced Research on Integrated Energy Systems

ARIES is a research platform designed to de-risk, optimize, and secure current energy systems and to provide insight into the design and operation of future energy systems. It will address the fundamental challenges of:

• Variability in the physical size of new energy technologies being added to energy system
• Controlling large numbers (millions to tens of millions) of interconnected devices
• Integrating multiple diverse technologies that have not previously worked together
ARIES Integrated Research
A Focus on Energy Storage Challenges

- Purpose driven integration and controls for flexibility and security
- Accelerating diverse technologies (e.g., electrochemical, molecular, thermal, and mechanical storage)
- Balancing for various size and timescales
A Focus on Advancing Power Electronics

• Grid operation at high-levels of power electronic interfaced generation and load
• Real-world proving grounds
• Develop and validate new power electronic technologies
A Focus on Hybridization Opportunities

- Optimizing dynamic controls of diverse technologies
- Understanding the interdependencies and effects
- Quantifying hybridization benefits
A Focus on Future Energy Infrastructure Needs

- Protection for highly connected systems
- Advanced system-level operations
- Controls for operational efficiency and stability
A Focus on Cybersecurity

- Proactive defense and automated response
- Improved situational awareness
- Secure communication innovation
ARIES Research Capabilities
ARIES Research Platform

Integrated Energy Systems at Scale (IESS)

Energy Systems Integration Facility (ESIF)
Facility Attributes

• Designated Technology User Facility

• 8 Petaflop HPC, data center, and visualization room

• Hydrogen system and chemistry labs
  – production, compression, storage, dispensing

• Integrated Labs
  – REDB, Thermal, Modeling/RTS, Outdoor Test Areas, Fixed Equipment, Future ESR/AMP/NWTC 2.0

Key Research Enablers

• Hardware and controls experimentation

• Power Hardware in the Loop (PHIL) and Controller Hardware in the Loop (CHIL)

• Fundamental science for energy materials

• Modeling and simulation

• Data analytics and visualization

• Education and training
Integrated research capabilities advancing diverse technologies for buildings, vehicles, and fast charging
Facility Attributes:
- At-scale evaluation of resiliency reliability and flexibility services
- Flexible configuration of hybrid energy experiments
- Grid integration research pads
- Science of nonlinear scaling
- Advanced controls and optimization
- Electrons-to-molecules-to-electrons
- Integration with national-scale research and robust validation platform

Key Research Enablers
- Total of 7+ MW variable renewable generation (Wind and Solar)
- 20MVA (7MVA + 13MVA) Controllable Grid Interface (CGI)
- Multi-MW energy storage research facility
- 2.5MW and 5MW dynamometers
- Distribution network at 13.2 kV MV grid upgradable to 34.5 kV
- At scale power and controller HIL up to 20MW
- Digital Real Time Simulation (DRTS)
- High Speed ESnet Connectivity, with Internet2 links at 10 Gb/sec
- Electrical interconnections to all plausible configurations of grid integration research assets (e.g. loads, generators, storage) on utility grid or isolated research grids
ARIES At-Scale Infrastructure at Flatirons Campus

- AES 250kW Solar PV-battery Hybrid System
- Grid Integration Research Pads (6)
- First Solar 480kW PV array
- Planned location of new 20MW Controllable Grid Interface (CGI)
- 5MW Dynamometer
- 6.3MW CGI
- CGI Harmonic Filter
- Planned location of new Control Center Facility
- 2.75MW wind turbine research drivetrain
- Grid Integration Research Pad Electrical Switchgear, metering, research data acquisition

Highly integrated capabilities to understand the science of scaling
Facility Attributes

- Ability to integrate 10K+ devices as HIL, CHIL to emulate real world environment
- Establish Digital Twin (DT) of Electrical, Mechanical and Thermal systems to evaluate dynamic interactions of those devices and systems
- Provide communication layer to emulate cyber physical network of systems
- Emulation capability for millions of devices with DRTS and HPC
- At-scale research of complex interaction of devices at multiple timescales
- Verification and validation environment using device characterization at HIL

Key Research Enablers

- Large cluster of Digital Real Time Simulators for Rapid Prototyping and Digital Twin development
- Communication Emulation - Configurable high-speed field-programmable gate arrays development environment
- Power Electronics Grid Interface (PEGI) - Power Electronics CHIL platform
- Hybrid Energy Real Time Hub (HERTH) - A platform for Real Time electrical, mechanical, thermal and communication integration and evaluation
- Integrated DRTS with HPC for 1 million device emulation
Virtual Emulation Environment
Emulating complex virtual systems using digital multiplier
Virtual Emulation Environment (MW to GW Scale) + (Millions of devices)

Integrated Energy Systems at Scale (IESS) at NREL's Flatirons Campus
(20MW) (10,000s of devices)

Energy Systems Integration Facility (ESIF) at NREL's Main Campus
(Up to 2MW) (100s of devices)

For regional and national level energy systems R&D
The interconnected nature of the ARIES platform enables significant opportunities to coordinate its research capabilities across industry, academia, and other national labs.
Case Study | Preparing the Grid for More Plug-In Hybrid Electric Vehicles

CHALLENGE:
How will more plug-in, hybrid electric vehicles (PHEV) affect power quality on the grid?

SOLUTION
Strategies to monitor, control distribution, and understand the effect of PHEVs on the grid.

OUTCOME
Managing the additional load will ensure grid stability and reliability.

Partner: Toyota
Case Study | Energy Storage with Power-to-Gas Technology

**CHALLENGE:**
Over production of renewable energy during off peak hours leads to curtailment

**SOLUTION**
Optimize water electrolysis and bioreactor technologies to convert water + waste CO$_2$ into cost competitive bio-methane.

**OUTCOME**
Maximize value of curtailed electrons leveraging existing utility gas and electric infrastructure for seasonal storage capability.

**Partners:**
Southern California Gas Company and Electrochaea
Case Study | Validation of DC coupled hybrid PV/BESS peaker plant

CHALLENGE:
De-risk system integration and control logic i.e. charging and dispatching of combined solar and storage system prior to installation in Kauai.

SOLUTION
Leveraged NRELs Controllable Grid Interface and RTDS in combination with AES 500kWh BESS and 240kW PV array to validate charging dispatch performance of system.

OUTCOME
Validated system performance and capabilities prior to installation de-risking the deployment of a new Hybrid Peaker Plant serving Kauai's 65,000 customers.

Partner: AES
Case Study | Validate large-scale storage hardware and advanced controls for high-renewable resilient microgrids

**CHALLENGE:**
Variable conditions challenge economics of energy storage for US DOD installations.

**SOLUTION**
Prove proposed power system designs for DOD installations in different climates, markets, and renewable generation.

**OUTCOME**
Transforms future military based microgrids to optimally exploit on-site renewable energy.

Partners: Cummins, Environmental Security Technology Certification Program (ESTCP), DOD
Key Research Challenge:
How to optimize MW scale building loads, charging loads, energy storage, and renewables production?

ARIES is the only research platform in the country able to address large scale energy integration challenges this scale
How to be Part of the Vision
Partnering With Business for Competitive Advantage

Nearly 900 active partnerships with industry, academia, and government

In 2019 NREL had:

- 299 new partnership agreements
- $74M value of new partnership agreements
- 255 unique new partners
- 587 unique active partners
Industry invests in short-term R&D when they are confident about a return on investment. NREL
• Assumes a longer, broader view
• Takes on early-stage, high-risk R&D
• Conducts research that makes it possible for industry to bring important new solutions to the market.

“It is often too risky for the private sector to be on that bleeding edge of research where profits are years and years away.”

Venkatesh Narayanamurti, Harvard Kennedy School professor of science and technology policy, told The Washington Post
Honored with **65 R&D 100 awards**, known as the “Oscars of Innovation,” to date.

- **571 patents to date**
- **40% licensed**
- **43,438 publications to date**
How to Partner with NREL

Talk to us about the research challenges in your space

We’ll match your interests with our technical team and research capabilities, and guide you through the entire process

There are options for agreement types to meet your goals

NREL can team/partner with you on any lab-eligible opportunity through a CRADA
Upcoming Opportunity!

DOE Solar Energy Technologies Office Power Electronics Opportunity
- 50/50 cost share for $3.6M in projects starting in late 2021, focused on grid stability related power electronics research
- Virtual workshop with full details will take place October 13, 2020, from 9 a.m.-3 p.m. MST

Recent Opportunity that will use ARIES Capabilities

DOE Fuel Cell Technologies Office H2@Scale 2020 CRADA Call
Up to $24 million in DOE funding will be awarded for collaborative projects at national laboratories in two priority areas of R&D:
- Hydrogen fueling technologies for medium-and heavy-duty fuel cell vehicles
- Technical barriers to hydrogen blending in natural gas pipelines
Please take a few minutes to complete the poll questions currently displayed in the right-hand panel on your screen.
Feedback and Q&A

Please use the Q&A feature to type in feedback or questions to the panelists.

• If you do not immediately see the Q&A option hover over the additional options icon and select the Q&A button.
Concluding Remarks
Contact

Email: aries@nrel.gov
Web: nrel.gov/aries
Thank you!

www.nrel.gov