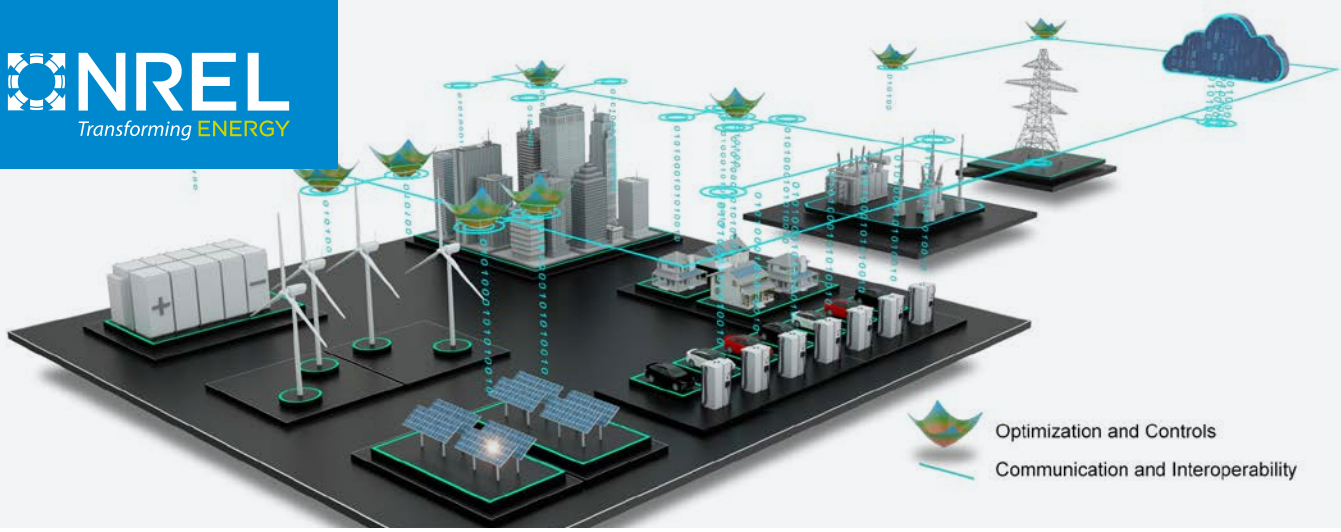

Autonomous Energy Systems

Intelligent and robust solutions for operating highly electrified, heterogenous energy systems

Energy systems are increasingly complicated by the proliferation of clean energy technologies such as solar, wind, storage, electric vehicles, and building automations. Future energy systems will require secure, autonomous, and reliable communications, control, and interoperability among millions of distributed generation points and billions of buildings, vehicles, and more.

To enable effective management of the anticipated growth of distributed devices and the deluge of data and extensive metering that will follow, the National Renewable Energy Laboratory (NREL) has developed the concept of autonomous energy systems (AES).

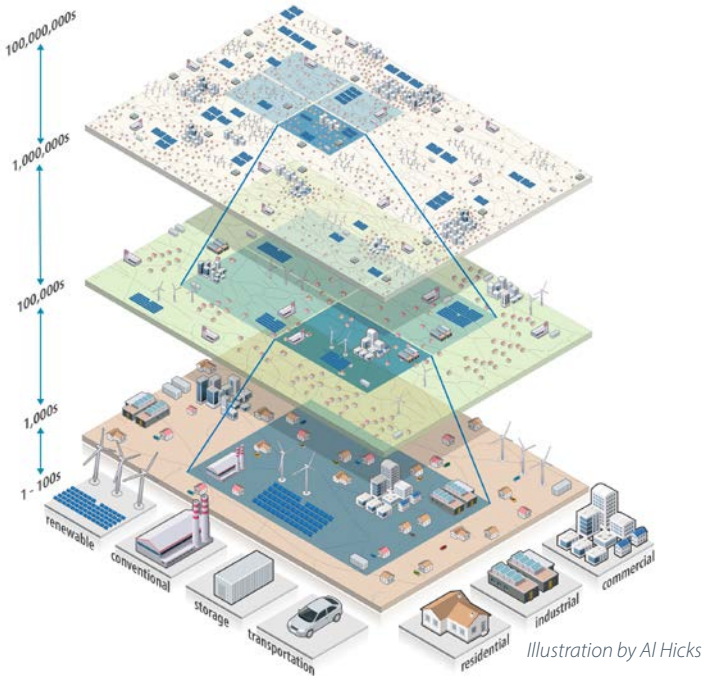

Illustration by Al Hicks

NREL has validated AES approaches and technologies both in the laboratory and through small real-world demonstrations. Now, NREL is taking the next step with AES through partnerships—public and private—to rapidly scale and accelerate transitions to large-scale, low-emissions, intelligent, autonomous future energy systems.

Optimized Controls of Distributed Energy Systems

AES deconstructs large-scale, centralized control and operations into smaller decisions so that central operators are not overwhelmed by data and communications. AES also enables the addition of new distributed energy resources without risks to the grid. Control algorithms and architectures provide:

- **Efficient and cost-effective approaches** to streamline the use of variable renewable generation and innovative technologies
- **Real-time operations** to balance load/demand and generation/supply every second and make the best use of asynchronous data and control to accommodate changing conditions and delays in communications
- **Robust tolerance** to disturbances, faults, outages, and failures in both cyber and physical networks
- **Interoperability** with the integration of decisions, devices, platforms, and data with the aid of standard-based protocols
- **Scalability** to control hundreds of millions of energy resources across the grid, renewables, storage, mobility, buildings, inverters, and microcontrollers—from communities to neighborhoods to regions.

World-Class Resources and Facilities

As a U.S. Department of Energy (DOE) research laboratory, NREL offers unbiased, best-in-class capabilities supported by decades of scientific and applied research and expertise. Our renowned research staff, top-notch facilities, and networked platforms provide unprecedented information sharing and collaboration.

NREL's **Energy Systems Integration Facility (ESIF)** provides hardware evaluations and a high-performance computing-enabled virtual emulation environment that is scalable to a large city or region. The ESIF also enables high-speed data links to city- and campus-scale research assets at NREL's Flatirons Campus, other DOE national laboratories, and research partners.

The **Advanced Research on Integrated Energy Systems (ARIES)** platform combines research on accelerated grid modernization with extensive integrated infrastructure, computing, and simulation capabilities. Partners can develop use cases and explore all aspects of implementing energy technologies, including the impact of millions of new devices being connected to the grid daily. ARIES enables the holistic validation of AES algorithms and architectures to help partners gain unprecedented information before applying AES to real-world systems.

ARIES is connected to other DOE national laboratories via the **Energy Sciences Network (ESnet)**, a DOE Office of Science high-performance, unclassified network. ESnet provides reliable, low-latency connections that enable equipment to exchange frequent command and control information.

Demonstrated Solutions Address Partner Priorities

For decades, NREL has partnered with utilities, land developers, municipalities, and planners to improve existing and build new energy systems for neighborhoods, military installations, and tribal lands, among others.

Largest Microgrid in North America Within a Disadvantaged Community—Borrego Springs, California: NREL and San Diego Gas & Electric Company constructed a scaled virtual model including distributed energy resources with power and controller hardware. The model tested the microgrid—particularly disconnection and reconnection—to confirm its performance before it was deployed.

Military Energy Security and Resilience—Marine Corps Air Station (MCAS) Miramar, California: This partnership was formed around net-zero energy planning: installing distributed renewable energy systems and increasing energy efficiency. Now MCAS and NREL are tackling an installation-wide microgrid that will ensure that the MCAS flight line and other critical support facilities always have power, even during a blackout.

November 1, 2019—Within the Basalt Vista neighborhood in Colorado's rugged foothills, NREL is demonstrating AES with the customers of local electric cooperative Holy Cross Energy. The affordable housing development features some of the most energy efficient residential homes ever built, all controlled by computers as part of an autonomous grid. *Photo by Dennis Schroeder, NREL 60084*

Resilient Community—Basalt Vista, Colorado: NREL and Holy Cross Energy partnered to address geographic constraints, establish grid-interactive household loads, and leverage locally produced clean energy, with emphases on affordability and riding through power outages during extreme events. Planning is underway to scale this demonstrated autonomous grid control of distributed energy resources and energy storage systems from the current handful of homes to the entire system.

Virtual Power Plant—Stone Edge Farm, California: When NREL's algorithms were implemented on Heila Technologies' controllers, the team demonstrated that 20 of the farm's microgrid assets could function collectively as resilient virtual power plant. The 785-kilowatt microgrid powers the 6.5-hectare farm through a combination of solar panels, fuel cells, a microturbine that runs on natural gas and hydrogen, and storage in the form of batteries and hydrogen.

JOIN THE EFFORT

Tap into cutting-edge capabilities, leading expertise, and strategic partners—and make your mark on our autonomous energy future.

Learn more at www.nrel.gov/grid/autonomous-energy.html or contact NREL Strategic Partnerships Development Manager Ty Ferretti at Ty.Ferretti@nrel.gov.

Cover illustration by Josh Bauer

NREL Transforming ENERGY

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NREL is a national laboratory of the U.S. Department of Energy
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NREL/FS-5D00-82372 • March 2022