EPRI

incubate:energy labs

2021 CHALLENGE

Final Report & Pilot Demonstration Summaries



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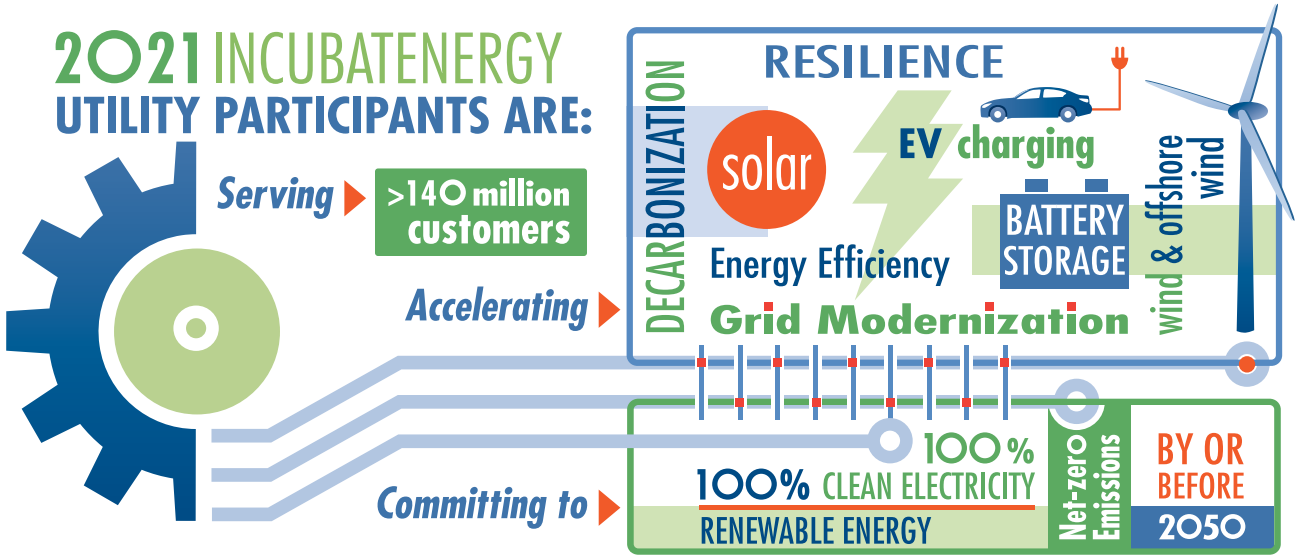
Introduction

Overview

EPRI's Incubatenergy Labs® (IEL) provides quick and objective assessments of how disruptive technologies can be applied in today's rapidly changing energy system. IEL's open innovation process borrows concepts from design thinking, agile development, and the business model canvas to enable the rapid identification and demonstration of impactful and potentially disruptive innovations in decarbonization, electrification, grid modernization, resilience, and customer engagement.

IEL, managed through EPRI's Technology Innovation program, is built upon EPRI's collaborative approach to applied R&D. By crowd-sourcing the scouting, screening, selection, and execution of technology demonstrations across a group of interested utilities, IEL is able to test a large number of startup innovations in a short timeframe. Similarly, startups benefit by engaging many utilities at once through a single demonstration, getting rapid feedback on the viability of their solutions in real-world environments, and working across the group to map follow-on test and deployment opportunities.

This report summarizes the 2021 IEL program and includes cohort statistics, results, and key learnings, challenges, and plans for 2022. The report also includes summary reports for each of 20 pilot demonstrations, augmenting videos and summary presentations available from labs.incubatenergy.org.



Program Participants

2021 IEL program participants included Ameren and Tennessee Valley Authority (TVA) as lead sponsors and hosts plus Consolidated Edison of New York (Con Edison), Duke Energy, ENEL, FirstEnergy, Fortis, New York Power Authority, Pacific Gas & Electric (PG&E), Portland General Electric, Salt River Project, Southern California Edison (SCE), Vermont Electric Power Company, and Xcel Energy.

Collectively, these companies serve more than 140 million customers around the world and are focused on transforming electricity supply, delivery, and use to achieve ambitious energy/climate goals, as shown in the figure above.

The AI.EPRI program also participated in IEL21 to join in collaborative scouting and testing of solutions for accelerating the adoption of data analytics, machine learning, and other artificial intelligence (AI) methods in the electric power industry. Through AI.EPRI, innovation topics of industry interest and outreach to the AI community include grid operations and planning, distributed energy resource management, resilience, and cyber security, as further detailed at epri.com/thought-leadership/artificial-intelligence.

EPRI ARTIFICIAL • INTELLIGENCE

Innovation Challenge Topics

In November 2020, participating utilities shared their respective innovation priorities for 2021 and defined seven IEL challenge topics shared across the group:

- Accelerating Power Industry Adoption of AI
- Customer & Community Engagement
- Customer & Community Resilience
- Decarbonization & Sustainability
- Digital Utility
- Electrification
- Workforce of the Future

In addition, EPRI and participating utilities included an "open" innovation challenge category in their outreach to the startup community.

Startup Application Process

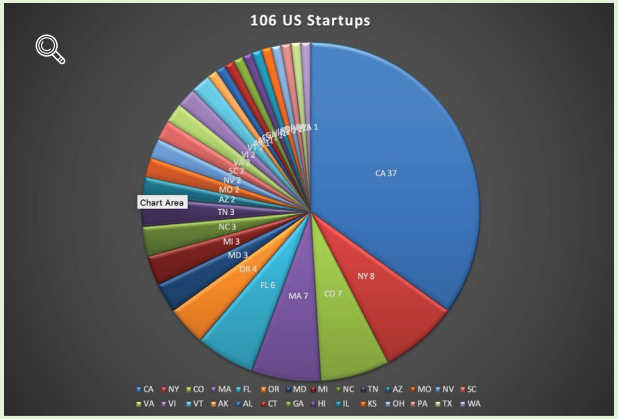
In the run-up to launch IEL21, EPRI and participating utilities agreed that the 2021 program should leverage prior-year learnings and be fully virtual in light of continued pandemic-driven restrictions on travel and in-person gatherings. Deciding this up front allowed the group to increase the number of startups brought through technical due diligence and invited to participate in online pitch events, more than doubling the capacity to screen startups as compared to previous years.

In December 2020, the program was publicly launched, with innovation challenge topics communicated to the startup community through the IEL website and EPRI's Incubatenergy Network – a group of leading U.S. and international incubators and accelerators supporting clean energy entrepreneurs. A total of 253 startups responded to the call, and the IEL21 program ultimately considered 142 complete applications submitted by the deadline of January 15, 2021. The breakdown of applicants by geographic location, Incubatenergy Network affiliation, and challenge category is shown in the accompanying figures below.

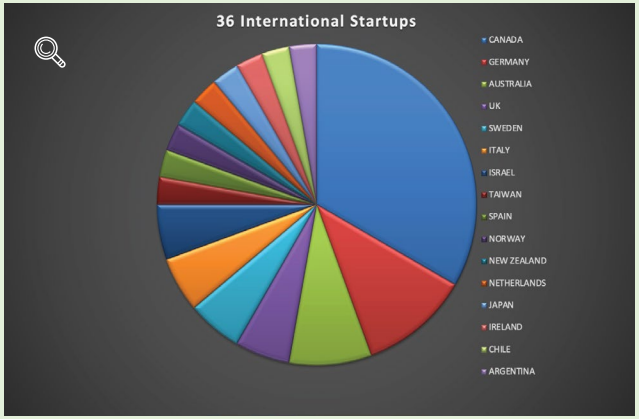
Cohort Selection and Participation

Startup screening was crowd-sourced among about 160 subject-matter experts (SMEs) from across EPRI, AI.EPRI, and participating utilities. SMEs leveraged an online platform to review and score submissions for initial screening, then interviewed top-ranked startups through phone and web conferences to dig deeper into the innovations and their readiness for market. By February, the group had narrowed the field to 37 finalists, who were invited to present at our virtual "Pitch Fest" spanning 3 weeks in March 2021.

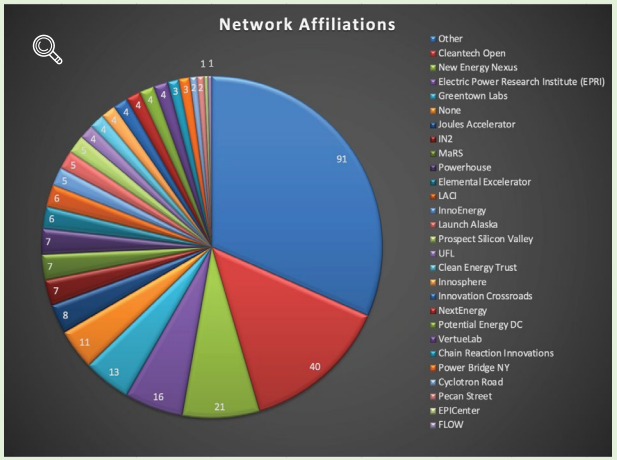
Based on those pitches, 20 startups were selected to participate in paid pilot demonstration projects, which doubled the number of demonstrations over the previous year. Half of these were supported through the AI.EPRI initiative.



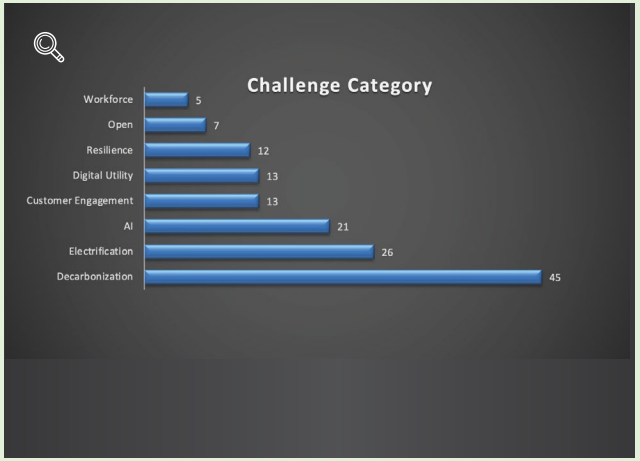
Startup applicants by U.S. location



Startup applicants by international location



Startup applicants by Incubatenergy Network affiliation



Startup applicants by innovation challenge topic

In just 3 years, Incubatenergy Labs has become the de facto pathway for engaging the startup innovation ecosystem in addressing pressing utility challenges—and for startups to prove their technologies in real-world utility settings. With utility practitioners working alongside peers to rapidly test and scale new innovations, the hyper-charged collaboration that takes place during these 16-week demonstrations is unique and offers all participants a terrific opportunity to learn, lead, and innovate.

Rob Chapman, Senior Vice President, Energy Delivery & Customer Solutions, EPRI

EPRI and utility project leads worked with the startups over the months of April and May to scope out the pilots and establish contractual agreements. The projects were implemented over the 16 weeks spanning from June through September, with all completing sufficient work to present findings at the 2021 Incubatenergy Labs Demo Day event held in October.

Lessons and Opportunities

As opposed to 2020, EPRI's IEL team and participating utilities went into the 2021 project year with full knowledge of the challenges imposed by travel and in-person event restrictions. While unsure whether demonstration projects would include some limited in-person engagement, the group was confident that the virtual engagement learnings from the prior year and new COVID safety protocols in place would help ensure productive demonstrations. This generally proved true, but some challenges were encountered.

Managing the pitch process. In 2020, IEL proved the viability of full virtual engagement, but there remains a limit on the number of startups a given innovation team can consider before experiencing "pitch fatigue." This year's Pitch Fest was spread over 3 weeks to accommodate the 37 startups chosen. Going forward, the group determined that the field should be narrowed to no more than 25 pitches. Alternatively, continued IEL expansion across the number of utility participants, challenge topics, and/or startup applicants will result in a likely need to create smaller cohorts or interest groups offset by several months each.

Negotiating the contracting and data gauntlets. Building on 2019-20 IEL experiences, EPRI and utility back-office teams developed a set of template contract modules and accelerated processes that address common issues (financial, legal, administrative, data access, safety, etc.) and help shrink the project scoping and contracting timeline down to about 6 to 8 weeks. This approach proved quite popular and effective across the 2021 cohort participants, with all of the demonstration contracts executed through EPRI. However, having 20 contracts flowing through EPRI's system at once created bottlenecks and is likely an upper limit without either increasing staff resources or extending the timeline of the scoping and contracting process.

Once contracting was complete, a number of project teams still faced hurdles associated with timely and secure data access. The IEL 2021 program timeline showed a June 1 start date, but several startups found themselves waiting many more weeks to get data sets (advanced metering data, imagery, GIS information, etc.) transferred from the utilities. EPRI's IEL team continues to explore solutions to address the challenges with data access and cyber security compliance.

Success Metrics

EPRI and participating utilities set expectations on several aspects of the IEL 2021 program related to the execution of the process, to the success of the demonstration projects themselves, and to the opportunities presented for scaling and follow-on effort within the utility industry. Expectations and outcomes are further described below.

In terms of execution, EPRI's IEL team and the participating utilities were striving to become more agile, collaborate on the selection of the startups, accelerate back-office processes, execute on a tight schedule, and collaborate on results. Targets and results are shown in the table below.

When measuring the success of innovation processes like IEL, typical criteria such as customer adoption give way to criteria around learning. Success is often achieved through failure or, maybe more accurately,

IEL 2021 Targets & Results

Criteria	Target	Result
Innovation Challenge Topics	6	7
Startup Applications	>100	142
SMEs Engaged	>100	160
Startups at Pitch Day	20 to 25	37
Demonstration Projects	15	20
Weeks to Scope and Contract Projects	6	8
Weeks to Complete Projects	16	16
Follow-On Startup Projects Defined by Demo Day	10	11

by disproving hypotheses incrementally and then iterating to find an approach that succeeds. A high failure rate is seen as acceptable so long as the value of learnings achieved exceeds the investment deployed. IEL does not, however, start at ground zero in the innovation process. The program focuses on demonstrating near-market-ready solutions that have some amount of technical validation and customer testing completed.

In general, the startups selected for IEL have already gone through many learnings and iterations on their approach. Given that, few technologies are expected to be outright failures. More likely, a few of the companies will be ready for market scale, while most will require continued testing in larger and more robust integrations and may benefit from evaluations focused on alternative use cases. By agreeing on common innovation challenges up front and encouraging utilities to participate in each other's demonstrations, IEL is intended to uncover those key learnings and to help define appropriate follow-on efforts for individual companies.

For startups, success depends on the ability to parlay their IEL demonstrations into additional opportunities with utilities independently or in conjunction with EPRI. For utilities, success is defined by an ability to learn from projects hosted by their peers and to quickly identify how to apply promising solutions in their own environments. Across the 2021 cohort, 11 of the 20 participating startups had identified follow-on opportunities among the group of participating utilities by the time of publication of this report. These involve continued collaborations or expanded engagements with demonstration project hosts, implementation within utility programs, and incorporation in ongoing or new EPRI projects.

The Incubatenergy Labs Journey: A Learning Experience

EPRI conducted the first IEL challenge in 2019. After 3 years, two high-level conclusions are evident:

Collaboration accelerates learning. *Utility participants have found the IEL process to be as important as the outcome. Before, during, and after pilot demonstrations, the process helps utilities change how they frame their innovation challenges, structure engagements with innovators around iterative learning, collaborate in bringing viable solutions to market, and achieve the greatest benefits for their customers.*

Demonstration is not the end. *IEL projects involve the testing of innovations selected by participating utilities based on their potential for improving operations and maintenance, delivering additional or new value to customer sectors, decreasing carbon emissions, increasing resiliency, growing revenue, and more. While validating benefits like these is important, successful demonstrations ultimately represent a starting point, opening the door to an even bigger challenge: implementing high-value use cases and scaling promising innovations into broad deployment.*

Next Steps

For innovations that showed great promise during 2021 IEL demonstrations, EPRI and utilities are collaborating with startups on next steps for moving their solutions toward broad adoption. In addition, due to pandemic-related supply chain and manufacturing complications that slowed progress in 2021, several pilots are continuing with physical deployment and testing into 2022.

Building on 3 years of IEL experiences, EPRI is planning to grow the number of participating utilities in the core program during 2022; to add a parallel European workstream; and to engage new innovation areas, starting with the Low Carbon Hydrogen Accelerator, focused on generation, distribution, storage, and end use of green hydrogen. At the time of this publication, all of these efforts are under way.

Additionally, EPRI's Technology Innovation program has expanded its focus on industry transformation—beyond providing strategic insights and accelerating new technology through IEL demonstrations and other early-stage R&D activities—to consider the "how" of innovation by utilities, spanning strategy, culture, resources, and processes. EPRI's Global Innovation Hub provides opportunities for information exchange, benchmarking against leading organizations, internal assessments, and custom innovation engagements.

The remainder of this report provides an overview of the 2021 IEL pilot projects, which are listed by challenge area on the next page. Individual project reports are available from labs.incubatenergy.org.

At Fortis, we are intensely focused on innovation as we transition to a cleaner energy future for our customers. Incubatenergy Labs provides a unique platform for our utilities to engage with the bright minds and important new technologies that will help us to deliver that future.

Kevin Woodbury, Director, Innovation & Technology, Fortis, Inc.



* AI.EPRI PROJECTS

2021 PILOT PROJECTS

BUILDING TECHNOLOGIES

Customer-Centric Technology for Commercial Buildings and Campuses 7
Community Energy Labs, hosted by SCE

*Intelligent Energy Monitoring and Control for Commercial Space Conditioning** 10
Enerbrain, hosted by EPRI, Duke Energy & SCE

Wireless Real-Time Energy Monitoring for Demand Management and Grid-Edge Intelligence 13
Copper Labs, hosted by Xcel Energy

Circuit-Level Monitoring and Analytics for a Multifamily Residential Community 16
DCSix Technologies, hosted by SCE

*Machine-Learning-Based Load Shaping for Residential Water Heating** 19
Shifted Energy, hosted by Tucson Electric Power

Snap-On WindowSkin® for Improving Performance of Existing Windows 22
WexEnergy, hosted by TVA

Interior Storm Window Insert for Improving Performance of Existing Windows 25
Indow, hosted by TVA

E-MOBILITY

End-to-End Electric Vehicle Charging Solution for Long-Duration Parking Locations 28
HeyCharge, hosted by EPRI, Ameren & Tucson Electric Power

Zero-Emission Fleet Transition Planning and Simulation 31
Microgrid Labs, hosted by Ameren

DECARBONIZATION

"Decarbonization-as-a-Service" Platform for Utility Planning and Customer Engagement 34
Dynamhex, hosted by Ameren

GRID MODERNIZATION

*PowerAI Platform for Automated Visual Inspection of Grid Infrastructure** 37
Buzz Solutions, hosted by Newfoundland Power

*Automated Drive-By Distribution Asset Inspection** ... 40
Noteworthy AI, hosted by FirstEnergy

*Predicting Incipient Failures in High-Pressure Fluid-Filled Underground Cable Systems** 43
Eneryield, hosted by New York Power Authority

*Using Smart Meter Data for Distribution Network Visualization and Management** 46
Future Grid, hosted by FortisBC & Vermont Electric Cooperative

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*Satellite-Based Post-Storm Disaster Monitoring and Damage Assessment** 49
LiveEO, hosted by Ameren & FortisBC

*360-Degree Imaging for Wildfire Situational and Locational Awareness** 52
Pano AI, hosted by PG&E & Portland General Electric

*Wireless, AI-Powered Cyber Anomaly Identification** 55
ThermoAI, hosted by EPRI

Zinc Manganese Dioxide Battery for Long-Duration Stationary Energy Storage 58
Urban Electric Power, hosted by EPRI

WORKFORCE OF THE FUTURE

*Intelligent Voice Assistant for Substation Job Planning by Field Workers** 61
Datch, hosted by Con Edison

Instructor-Led, Live-Streamed Augmented Reality Training for Remote Workers 64
Design Interactive, hosted by Con Edison

COMMUNITY ENERGY LABS

SOUTHERN CALIFORNIA EDISON®
An EDISON INTERNATIONAL® Company

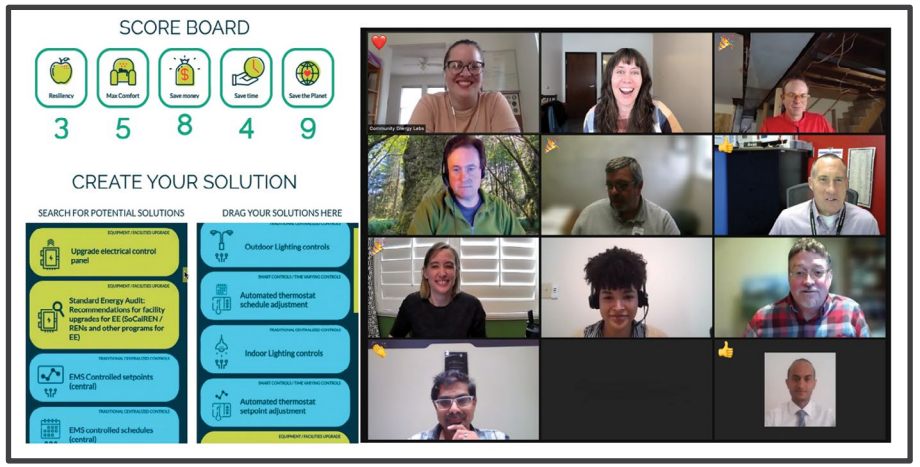
Customer-Centric Technology for Commercial Buildings and Campuses

Startup
Community Energy Labs
Portland, OR

Host
Southern California Edison

Technology Solution

In 2019, the U.S. commercial sector consumed 18 quadrillion Btu of primary energy, with the municipal, university, and school (MUSH) segment making up 28% of total commercial floorspace. Electrical end uses in this sector have huge energy efficiency and peak shaving potential, but fewer than 10% of MUSH customers use advanced controls due to lack of awareness, competing objectives, and limited capacity to operate and maintain state-of-the-art systems.



Interactive workshops help customers understand the benefits of building energy technologies and utility offerings.

This project was launched to test an innovative engagement strategy and Internet-of-Things (IoT) control platform developed by Community Energy Labs (CEL) for improving customer uptake of and experiences with emerging technologies and utility offerings. Interactive workshops increase understanding of energy use, technology opportunities, and utility rates and incentive programs among building operators, occupants, and other stakeholders. CEL's IoT platform features a user-friendly interface enabling facility managers and occupants to meet comfort, performance, cost savings, and decarbonization goals based on wireless sensors, intelligent and distributed controllers, and machine learning software.

Project Overview

This project focused on piloting CEL's customer engagement strategy as an initial step in assessing the scalability of grid-interactive connected building products and services when combined with utility offerings for commercial customers—such as flexibility incentives, non-wires alternatives, time-of-use (TOU) tariffs, and demand response and energy efficiency programs—that reward the shifting, shedding, and shaping of building energy loads

CEL, partnering with Southern California Edison (SCE) and EPRI, scaffolded six 2-hour user experience research and education workshops that were attended by MUSH building occupants, operators, and administrators, primarily from elementary and secondary school districts. To test how stakeholder preferences interact with smart building control of space conditioning, electric vehicle charging, and onsite solar and battery systems, CEL explored answers to the following questions through a series of experiments involving end-use loads and energy system interfaces:

Workshop 1: Discover personas through card-sorting exercises – What do customers and end users believe drives energy usage? How do they perceive relationships between usage, carbon emissions, and costs?

Workshop 2: Explore mental models through journey mapping – What do customers believe about end-use technologies? Does this differ by persona?

Workshop 3: Identify persona journeys through gamification – How do customers operate end uses to meet their goals? Does this differ by persona?

Workshop 4: Interact with utilities – Why do customers engage, or not engage, with utility tariffs/programs?

Workshop 5: Dive-in customer/technology interaction experience – What do customers like/dislike about their experience with building energy management systems and outcomes? What is not currently addressed by today's technology?

Workshop 6: Unroll service blueprint – What have we learned about engaging customers in the technology as a pathway to engaging in utility programs/tariffs?

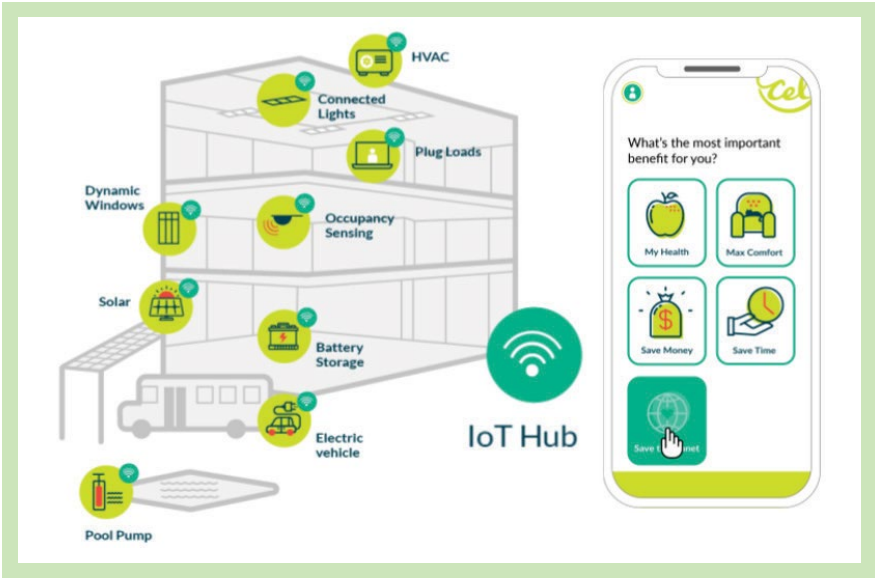
Results & Learnings

The workshop series engaged a total of 33 participants, characterized as follows:

- 60% of participants were facility managers, architects, maintenance directors, district energy managers, or administrators in charge of facilities at municipalities and K-12 school districts.
- 51% participated in at least 2 hours of workshops and follow-up interviews regarding energy end uses, building controls, space conditioning, lighting, and utility programs and tariffs.
- 27% of registrants participated in a minimum of 8 hours of workshops and 1:1 conversations, with a subset of school maintenance, facility, and energy management staff forming a core group devoting more than 12 hours of time.

Key customer insights include the following:

- Energy professionals and building operators are heavily impacted by outages and aging equipment and see their primary responsibility as serving occupants followed by keeping costs low and following district policies. Even the best informed have little insight into TOU rates and what drives demand charges, despite wanting to better understand.
- Customers articulate a variety of business challenges that could be addressed by building and equipment controls, such as constant manual adjustment (through programming or bypass) of thermostats; poor visibility into grid conditions, indoor air quality, and solar PV output; and difficulty understanding which end uses and conditions drive energy consumption and bills.
- When forced to choose solutions to the competing demands of operating a building cost-effectively without disrupting occupant comfort, operators prefer pragmatic time-saving solutions such as sensing, automation, and control as well as user-friendly interfaces as a scalable means to communicate with occupants.
- K-12 users will continue to opt out of utility programs, even at great expense (one district gave up $550,000 in annual incentives), if participation forces operators to choose between cash and occupant comfort. On a scale of 1 to 5 (least to most likely), the willingness to participate in programs without smart controls averages between 2 and 3.
- Participants expressed strong willingness to pilot and adopt AI-based control technology that can autonomously manage demand charges—particularly during unoccupied periods—and allow flexible and tailored adjustment of zone comfort controls.



CEL's IoT system and user interface provide monitoring and control capabilities.

Based on workshop experiences and interviews, four school districts in SCE's service territory and three districts elsewhere in California and in Washington expressed strong interest in being considered for follow-on pilot testing of CEL's technology.

Implications & Next Steps

Drawing on learnings from this project, CEL plans enhancements to its IoT platform and collaboration with EPRI, SCE, and additional utilities focused on the interest of commercial customers in addressing the

loads that drive demand charges without decreasing occupant comfort. Customer interfaces will be updated to incorporate new dashboards for building operators and occupants that provide insight and rewards for being good grid stewards, such as quantifying the saving on demand charges or other benefits salient to specific end users.

CEL also is developing the control capability to respond to local load management pricing, circuit loading, and other types of grid capacity constraints, and the company plans to work with utilities in identifying potential levers, in terms of carrots and sticks, and conducting field tests focused on engaging customers in managing bulk and local distribution constraints. Key next steps are to deploy CEL technology in a handful of representative small to mid-size building types exposed to time-varying utility tariffs or other demand-shaping signals. Information gathered over a single heating and cooling season in multiple climate zones will provide generalizable insight on impacts that programs and tariffs coupled with CEL technology could provide.

Small-scale commercial deployment will apply CEL technology for delivering customer benefits while (1) determining the location-specific value of building flexibility inclusive of behind-the-meter distributed energy resources and electrification; (2) estimating the value that specific customer segments with similar end-use load types could provide to the grid; and (3) assessing other incentive/technology combinations for providing grid services. Early experience will guide scale-up using combinations of rates, incentives, and technologies for promising customer segments and distribution system applications.

TESTIMONIAL: Community Energy Labs

Working with SCE, other utilities, and their customers was fantastic. Before even concluding our customer engagement workshops, we learned that one of SCE's school district customers was already wondering when a pilot that included our technology was going to start!

TESTIMONIAL: Southern California Edison

The experience with Community Energy Labs and EPRI has been utterly amazing. Early on, we did not know what we were getting into, but the process and outcome turned out to be more than we could have expected, generating useful insights that SCE will put into practice in working with our customers.

TESTIMONIAL: EPRI

Through the workshop series, we were able to gain new understanding of energy management needs and experiences in schools from the perspective of operators, occupants, and administrators—how well they understand end-use loads, distributed energy resources, and rate structures, as well as how control strategies may fit into this segment's operational routine and culture.

Resources

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For an intelligent use of energy

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Intelligent Energy Monitoring and Control for Commercial Space Conditioning

Startup
Enerbrain
Turin, Italy

Hosts
EPRI
Duke Energy
SCE

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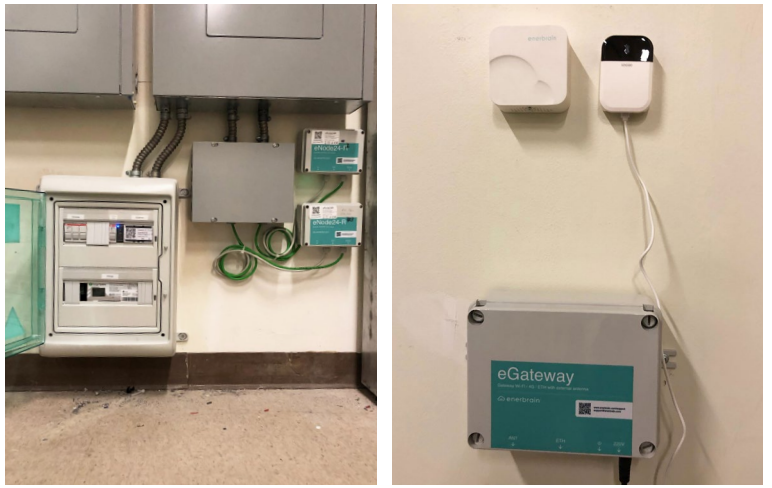
Technology Solution

Commercial buildings in the United States consumed 18 quadrillion Btu of primary energy in 2019. According to EPRI and other studies, up to 20% of peak load in commercial buildings can be temporarily curtailed for demand response without significantly impacting comfort, while Internet-of-Things (IoT) sensing and connectivity combined with control system replacements and upgrades can reduce overall building energy use by as much as 30%.

This pilot project was launched to test the IoT sensing and AI-based monitoring and control solution developed by Enerbrain for increasing the efficiency and demand responsiveness of heating, ventilation, and cooling (HVAC) systems in small to medium commercial buildings. Self-calibrating networked sensors provide building data to cloud resources hosting Enerbrain's proprietary reinforcement learning algorithm for optimizing indoor temperature control and building energy consumption. Plug-and-play operability and IoT-AI integration support fast and scalable deployment.



Networked metering, sensing, and communications hardware deployed at EPRI's headquarters provided the data required for optimizing HVAC control to reduce energy consumption without impacting thermostat settings.

Project Overview

The project team included Enerbrain as the technology supplier, EPRI as the host of the demonstration at its headquarters in Charlotte, North Carolina, and Duke Energy and Southern California Edison (SCE) as utilities interested in exploring new demand-side management offerings for customers.

The objective was to demonstrate the capabilities of Enerbrain's IoT kit and AI algorithm for achieving energy and demand savings while maintaining the desired level of comfort (temperature and relative humidity) via remote control of standard HVAC units serving four electrical rooms at EPRI's headquarters. This pilot test environment is representative of small to medium commercial buildings that may not have a building automation or energy management system, whereas Enerbrain's current customer base includes larger buildings in European markets.

Key milestones for this pilot included the following:

- Installation of data loggers to monitor electricity consumption by the Daikin heat pump units and IoT sensors to monitor temperature, relative humidity, and CO_2 levels within individual rooms.
- Full data acquisition via Sigfox connectivity to cloud computing resources and data ingestion and training by Enerbrain's proprietary algorithm.

- Remote monitoring and control of HVAC energy consumption and ambient conditions within individual rooms via web interface.

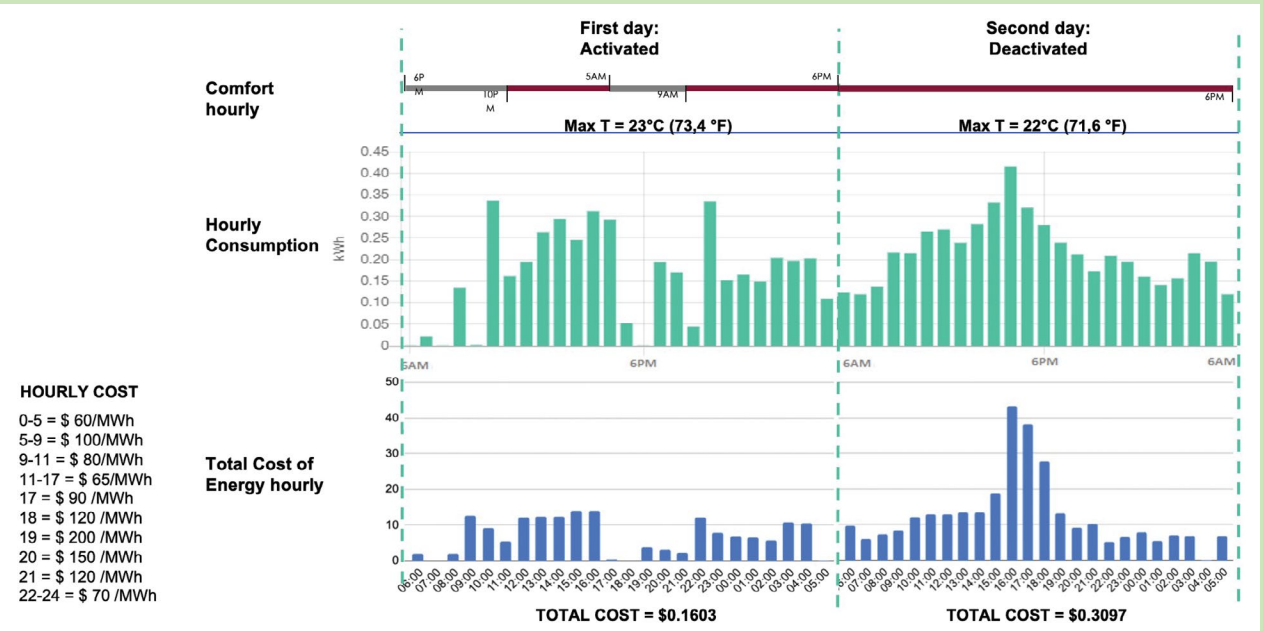
Enerbrain offers guaranteed energy savings, but this project was not designed to verify that. For the project to be considered successful, the project team set a minimum savings goal of 9%, calculated according to the "International Performance Measurement and Verification Protocol." More broadly, the project was intended to evaluate the scalability of Enerbrain's solution as a utility program offering.

Results & Learnings

This pilot project highlighted key advantages of Enerbrain's IoT-AI system for commercial building energy monitoring and control and provided the company with deployment insights specific to U.S. markets and utility interests. The plug-and-play installation was completed fully remotely by Enerbrain in just a couple of days, supported by physical deployment of sensing, metering, and communications hardware by EPRI's contractors.

The web-based interface allowed remote monitoring and management of the four HVAC systems with advanced calendar settings. Enerbrain's solution delivered energy savings on HVAC consumption by maintaining the same comfort levels, as measured by indoor air temperature and relative humidity, while optimizing control of the existing Daikin units. Energy savings of more than 20% were recorded, but this was achieved in a testing environment in rooms with no occupants, no windows, and limited operating equipment.

The system also was tested for control based on load management objectives in order to assess the potential for demand response. As shown in the figure above, applying Enerbrain's algorithm to one Daikin unit based on an hourly cost profile resulted in reduced energy use, both across the day and during peak pricing periods. Using lower-cost energy to pre-cool the room helped cut energy costs by ~50% with a maximum 1°C change from the standard setpoint.



Initial field testing of the Enerbrain solution's load management capabilities in response to price signals demonstrated reduced hourly consumption (top left) and energy cost (bottom left) with minimal impacts on comfort.

During the course of the project, several issues with potential to influence U.S. deployment of Enerbrain's solution were identified. The technology appears suitable for applications without automation or energy management systems, but installations in buildings that have a centralized point of connection will require engagement of a local system integrator to implement the solution using a Modbus or BACnet protocol.

Also, Enerbrain's system is currently not compatible with HVAC technologies offering variable air volume or variable air volume/temperature capabilities, a common feature in the U.S. market. This could be a future development opportunity for Enerbrain, along with building out its features as a demand response solution, as was tested in this project for the first time.

Implications & Next Steps

This pilot project highlighted the potential for beneficial application of Enerbrain's solution in the U.S. commercial building marketplace and generated insights for tailored business planning and technology development around utility use cases.

While commercial customers are primarily motivated by energy and cost savings, utilities have particular interest in untapping the potential of demand-side management in buildings for managing peak loading, and this first test at EPRI's headquarters was very successful. Enerbrain plans to develop a full integration of demand-side management capabilities and tools—including for participation in demand response programs and flexibility markets—to allow both utilities and customers to capture value. Completing the UL certifications required for deployment of Enerbrain's hardware also is planned.

EPRI, Duke Energy, and SCE are interested in identifying larger case studies for experimenting with advanced technologies for improving building efficiency and demand responsiveness and for assessing the interest of customers in Enerbrain's HVAC solution or similar approaches.

Resources

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Anthony James, *Senior Engineer, Technology Engagement/Grid Technology, SCE,* anthonyn.james@sce.com

TESTIMONIAL: Enerbrain

Thanks to EPRI and utility sponsors, we were able to demonstrate that our technology can deliver substantial energy savings in U.S. markets and also to identify the developments needed to bring forward a full solution for load shifting and peak shaving by commercial buildings.

TESTIMONIAL: EPRI

Enerbrain's technology combined energy monitoring and control in one complete package, installation was fast and straightforward, and pilot results showed potential. Participating utilities like the promise of "guaranteed savings" and hope to verify that in a field demonstration.

TESTIMONIAL: Duke Energy

This pilot showed that Enerbrain's plug-and-play solution, using IoT sensor data for remote monitoring and control of HVAC systems, can be effective for commercial buildings that do not have energy management systems, opening the door for utilities to explore new program offerings and demand response opportunities.

Wireless Real-Time Energy Monitoring for Demand Management and Grid-Edge Intelligence

Startup
Copper Labs
Boulder, CO

Host
Xcel Energy

Technology Solution

With the growing deployment of renewable energy and distributed resources, as well as the increase in extreme weather events, understanding when and where electricity is used is becoming increasingly important. In 2020, the number of U.S. homes equipped with advanced metering infrastructure (AMI) surpassed 100 million. While smart meters can capture high-resolution usage data, they typically deliver data to the utility once daily. Other electric meters—as well as most gas and water meters—generally only transmit data every 30 days, via drive-by automated meter reading (AMR). Actively tracking real-time use and demand across multiple infrastructures is essential in meeting decarbonization targets and other resource management objectives.



Wireless hardware deployed at the meter and inside buildings supplies real-time usage data to support analysis, visualization, and informed interventions by customers and utilities.

This pilot explored the use of wireless, web-based energy monitoring technology developed by Copper Labs for informing demand-side management at customer and utility scales. Copper Labs' hardware collects usage data in 30-second intervals from smart meters (AMI) and from meters designed for drive-by AMR, including for electric, gas, and water service. It also conducts in-home voltage and frequency measurements. Near-real-time data are delivered to the utility through a web-based portal for customer targeting and grid-edge intelligence, enabling utilities to engage targeted consumers when load flexibility is required. A customer app displays real-time energy usage in charts, identifies anomalies relative to historic patterns, supports goal-setting for ongoing energy conservation, and provides real-time community comparison feedback during demand response (DR) events.

Project Overview

This project, hosted by Xcel Energy, was driven by broad corporate goals related to leading the clean energy transition, enhancing the customer experience, and keeping bills low. Long an industry leader in wind energy, Xcel Energy is also looking to solar, storage, and other technology advancements—including in the area of demand-side management—to achieve an 85% reduction in carbon emissions by 2030 and a 100% carbon-free goal by 2050. In Colorado, the company is currently transitioning to AMI meters. This project sought to evaluate how real-time data from existing AMR electric meters can impact customer energy use in behavioral DR programs for the benefit



Copper Labs' app characterizes energy use and provides notifications about DR events to promote energy-saving behaviors.

of the grid and individual consumers. The findings may inform future demand-side management programs, as well as customer engagement features for AMI meters with home area network support.

More specifically, the project involved deployment of Copper Labs' wireless real-time energy monitors in more than 1100 new homes in a master-planned community southwest of Denver known as Sterling Ranch. With an emphasis on sustainability, this community was identified as a key market for clean energy technologies and a potential example of future developments with a high adoption of rooftop solar and electric vehicles that may pose unique grid-edge challenges. Each resident was provided access to real-time electric, natural gas, and water usage insights delivered via mobile app. Xcel Energy leveraged that new mobile channel for ongoing customer education and behavioral DR messaging enabled through Copper Labs' web-based utility portal.

Results & Learnings

Findings summarized below reflect both experiences during this project and comparisons to similar wireless real-time energy management projects involving other utilities and Copper Labs:

- **Deployment:** As this pilot involved new residential construction, field technicians involved in other tasks were leveraged to install Copper Labs' devices inside homes. While efficient, this required unique process adjustments to update WiFi connections when ownership transitioned from the builder to the new residents. In a typical program for existing homes, Copper Labs' devices are distributed directly via the mail, with energy kits, through retail marketplaces, or as energy audit leave-behinds, with a simple process for homeowners to connect and configure the device using a smart phone.
- **Customer engagement:** This lesson, while also related to the new construction aspect of this project, is broadly applicable. The community deployment of Copper Labs' technology—where consumers self-install hardware—leads to more awareness about how to use the system and also sets expectations for notifications from the utility related to DR events. In the future, Copper Labs and Xcel Energy plan to send a pre-season notification to customers to set expectations and explain why they are receiving messages.
- **DR reductions:** This project provided consumers with no-cost access to real-time data through Copper Labs' in-home device. While the DR events did involve timely messages and enable real-time community comparisons, no rebates or performance incentives were offered for reducing usage during peak periods. Similar to bring-your-own-thermostat programs, design variables for behavioral programs also can be adjusted to incentivize enrollment, ongoing connections, and participation in energy-saving events. Experiences elsewhere show that Copper Labs' technology can enhance peak time rebate, time-of-use, conservation voltage reduction, and other performance-based programs.
- **Project scale:** Copper Labs' technology is designed to support low-cost, real-time customer engagement, demand management, and grid-edge intelligence at substantial scale. As demonstrated in this pilot, the capability to initiate DR notifications with a randomized control from the utility portal provides an opportunity to quickly assess results using revenue-grade meter data. However, sample sizes—in terms of numbers of events and participants—need to be large enough to account for anomalies and inherent biases.

Implications & Next Steps

This wireless real-time energy monitoring pilot generated important insights in areas such as technology

deployment, program design, and customer usage. Xcel Energy continues the ongoing work in the Sterling Ranch community, including installation of Copper Labs' technology in every new home, customer surveys, and evaluation of electricity DR event results. Additionally, Xcel Energy is planning to test natural gas DR in Winter 2022.

Xcel Energy also has selected Copper Labs to participate in a natural gas study designed to understand DR opportunities and gain insights into load curves in a growing Colorado mountain community where some pipelines are constrained. This will help the company and its customers access gas usage data every 30 seconds instead of every 30 days, providing the lead time required for creating the load flexibility needed to accommodate supply constraints due to peak demand.

Copper Labs is actively delivering real-time energy usage data for multiple electric, gas, and water utilities across North America, with and without smart meters. The company continues to refine its recommendations for customer program design and will soon launch new neighborhood-level data collectors to complement in-home devices in supporting larger deployments for customer engagement, demand management, and grid-edge intelligence based on the results and learnings above.

TESTIMONIAL: Copper Labs

Copper Labs was proud to be selected by the innovative companies participating in Incubatenergy Labs and is leveraging this experience and EPRI's expertise by applying technical insights to inform product design and value delivery for utilities and customers through wireless real-time energy management.

TESTIMONIAL: Xcel Energy

New knowledge and experience developed by Xcel Energy through Incubatenergy Labs supports our continued work with Copper Labs to gain better insight into customer energy usage and behavioral demand response across electric and gas infrastructure.

Resources

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Circuit-Level Monitoring and Analytics for a Multifamily Residential Community

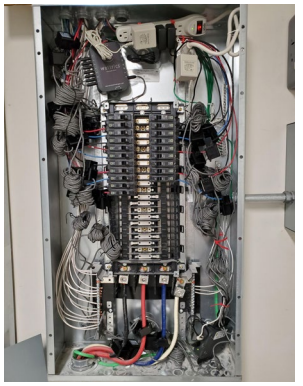
Startup
DCSix Technologies
Cork, Ireland

Host
Southern California Edison

Technology Solution

Electric utilities have a growing need for more reliable and granular information on behind-the-meter (BTM) electricity consumption in buildings to optimize the design and performance of demand-side management programs and to support operational and planning decisions. Meanwhile, customers are increasingly interested in understanding their own energy consumption and available options for reducing energy costs and carbon emissions. Diverse technologies are being marketed as solutions for meeting these needs.





Wattrics devices, which apply current transducer clamps to monitor up to 14 circuits (left), were installed in one of the main electrical cabinets in a community building (right), as well as in five residential units.

The goal of this project was to assess the capabilities of an energy monitoring and cloud-based analytics platform developed by DCSix Technologies for obtaining reliable visibility and improving customer understanding of BTM usage in a multifamily residential community. Known as Wattrics, this tool can monitor 14 individual circuits within a home using passive clip-on current transducer clamps. Data are stored in a cloud database, analyzed, and made accessible via customizable web dashboards providing visualizations and insights addressing energy usage, costs, and carbon emissions and technological and behavioral interventions. In addition to helping customers reduce bills, this can provide value to utilities by providing greater visibility into and understanding of demand-side energy consumption.

Project Overview

This project involved a collaboration between DCSix, utility host Southern California Edison (SCE), and EPRI along with Linc Housing, property manager for the Willowbrook multifamily residential development. Among other features, Willowbrook includes community solar power and battery storage capacity, is enrolled in OhmConnect's demand response (DR) network, and is an "Advanced Energy Community" research and demonstration site. Currently, water heating is provided by a gas-fired boiler.

Pilot project objectives included the following:

1. To deploy Wattrics devices and provide residents with access to data dashboards for their own units and the property manager with access to a community-level dashboard,
2. To identify opportunities to improve energy efficiency and reduce costs and carbon emissions, and
3. To understand the potential use cases and value of the Wattrics platform.

Wattrics dashboards aim to communicate energy data in a meaningful way to specific customers/users. Additionally, the Wattrics platform leverages granular



Wattrics dashboards can display energy usage data for each appliance or circuit (left), as well as overall consumption (kWh), demand (kW), and onsite solar generation.

circuit-level visibility with AI-enabled data analytics, creating opportunities to assess how to achieve energy, demand, cost, and carbon savings through efficiency, DR, and other solutions.

At Willowbrook, a total of 25 Wattrics units were deployed across two residential buildings, in the community center, and within five apartments. In evaluating the success of this project, key indicators include demonstration of Wattrics for reliably monitoring residential circuits and identification of additional use cases that may be valuable to customers and utilities.

Results & Learnings

Key milestones were met during the project period. The project team installed Wattrics devices and sensors in the Willowbrook community—with no power shutoffs required—and set up a secure communications network to gain full circuit-level visibility and reliably monitor BTM energy data at 10-second intervals. In addition, data dashboards were developed to visually communicate how and where energy is being used at the community and apartment levels.

Initial analysis of granular data showed that no "low-hanging fruit" are left at Willowbrook since a significant number of efficiency measures and clean energy technologies had already been deployed and are proving effective. In addition, during the compressed pilot period, several logistical issues combined to delay deployment of Wattrics units and limit the ability of residents and property management to interact with the dashboards. Experiences and lessons learned relating to residential installations, international sourcing, network configuration, and wireless access will be applicable to future deployments.

Follow-on work is planned to collect several months of real-world energy usage data as Willowbrook residents and the property manager interact with the Wattrics dashboards. The project team has identified several use cases and opportunities for further analysis as shown in the table on the next page.

Drawing on familiarity gained with the Wattrics platform during this pilot and on early deployment experiences in the European Union, EPRI, SCE, and the DCSix team also assessed customer value for the following applications:

- **Dairy farms:** This offers the highest potential customer value, reflecting both the size of the market in California and the demonstrated ability of Wattrics to reduce costs at dairy farms by improving the efficiency of the milking process with a combination of active energy management, heat recovery, thermal storage, and solar; and by alerting farmers of malfunctioning pumps and other equipment.
- **Commercial and industrial facilities:** While site-specific potential varies across large energy users such as factories, offices, hotels, retail, etc., Wattrics has demonstrated value in helping building owners reduce energy costs by delivering targeted insights, informing behavioral adjustments, and modeling technology investments.

Implications & Next Steps

The effectiveness of Wattrics at Willowbrook will be evaluated into 2022, but data collected and analyses

performed in this pilot demonstrate potential for helping quantify and validate the value of efficiency measures and clean energy technologies for multifamily communities that have not previously been upgraded.

More broadly, this project has illustrated the value of combining reliable BTM monitoring hardware with a data analytics platform. This combination could benefit customers with ongoing energy management insights while providing data-backed projections of the performance and payback of technology solutions with potential to reduce operating costs and carbon emissions. Utility use cases for customer-deployed circuit-level monitoring also have promise.

Deploying Wattrics for the first time in the United States and in a residential setting has provided the DCSix team with experience applicable for streamlining future installations. At Willowbrook, next steps are to provide dashboard access to property management and residents and to share circuit-level data with EPRI's research database and stakeholders. Once 6 to 9 months of data are available, analyses will be conducted to understand how Wattrics adds value in a residential setting. EPRI and SCE plan to scope a demonstration project focused on how the Wattrics platform can improve energy and water efficiency and reduce carbon emissions at dairy farms in California.

Resources

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Use Cases for Further Analysis at Willowbrook

USE CASE	DESCRIPTION	OPPORTUNITY AT WILLOWBROOK
Visualizing data insights for customers	Use customized dashboards to provide customers with insights on how they consume energy.	Present dashboards conveying unit-specific and community-wide insights and assess impacts on residential energy consumption and responses to behavioral DR and time-of-use (TOU) rates.
Identifying technology solutions at customer and community levels	Leverage BTM data to model the sizing, performance, and payback of efficiency, DR, and electrification measures.	Model and evaluate the cost-effectiveness of options for decarbonizing water heating by using using heat recovered from other building systems, and/or by applying solar output to run a heat pump water heater with thermal storage capacity.
Verifying technology performance	Leverage BTM data to quantify how technology investments are performing in terms of energy use, costs, and emissions.	Collaborate with stakeholders involved in EPRI's "Advanced Energy Community" research project to determine actual load drop from behavioral DR, verify and optimize control strategies for the solar-battery system, assess the efficiency of the DC microgrid, verify opportunity for shifting laundry load off peak, and enhance projections of flexible residential load capacity.
Testing customer segments	Leverage BTM data to better understand how different types of customer interact with utility offerings.	Examine and test how residents actually respond to TOU rates and behavioral DR messaging from the OhmConnect platform.

TESTIMONIAL: DCSix Technologies

Our mission is to support change by enabling people and businesses to make better decisions around their energy use. As demonstrated in this pilot project, we give customers a detailed understanding of energy consumption at their premises and how they can make the greatest reduction to their energy bills and carbon footprint for the lowest overall effort and investment.

TESTIMONIAL: Southern California Edison

Understanding energy use is foundational to achieving an affordable and 100% clean energy system. The 360-degree view provided by DCSix Technologies gives customers the ability to modify behavior and test new technology strategies, and it can help utilities better tailor demand-side management programs to achieve system benefits, for example through load flexibility.

TESTIMONIAL: EPRI

DCSix Technologies has developed a novel and effective solution for collecting behind-the-meter energy data, understanding customer usage, and harnessing the value of granular data with analytics. There is significant potential for this technology to help commercial and industrial users manage costs and model potential technology investments.

Machine-Learning-Based Load Shaping for Residential Water Heating

Startup
Shifted Energy
Honolulu, HI

Host
Tucson Electric Power

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

Electricity-based water heating technologies, including electric resistance water heaters (ERWH) and heat pump water heaters (HPWH), account for a significant fraction of building energy use and peak demand in some U.S. regions. While conventional load control methods have proven effective for lowering energy bills and shaving utility peaks by managing water heater operation, they have limitations that can reduce customer uptake and satisfaction. Connectivity and computing innovations could expand the benefits delivered by utility controls.





Shifted Energy's load control switches are IoT devices designed for interoperability across electric water heater technologies and products.

This pilot project was launched to test the active, intelligent load control solution developed by Shifted Energy for transforming electric water heaters into distributed energy resources that provide multiple grid support services without negatively impacting customers. The company's Grid Maestro platform integrates Internet-of-Things (IoT) control switches with machine learning to enhance load forecasting and optimize the dispatch of individual and aggregated water heating systems while avoiding cold-water events.

Project Overview

The project team featured Tucson Electric Power (TEP), a Fortis company, as the host utility working with subject-matter experts from EPRI and Shifted Energy to deploy and demonstrate IoT control switches as the hardware basis and communications hub for a virtual power plant built within Grid Maestro and comprised of a fleet of residential water heater units operated based on machine learning algorithms.

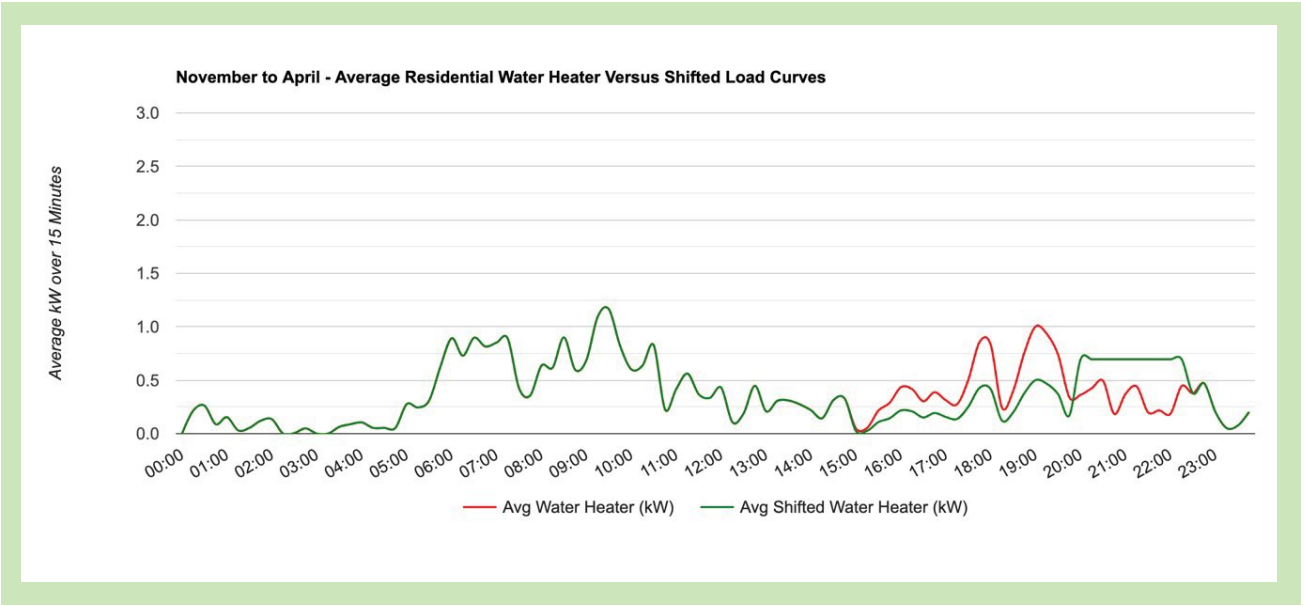
One key goal was to test the hypothesis that AI-based analytics and controls can provide better load forecasting and shaping than status quo approaches, including during shoulder months and peak demand periods. A second was to provide experience and learnings supporting development of a utility program offering in support of TEP's vision for co-optimized behind-the-meter demand-side management of water heating and other connected technologies.

TEP partnered with Scotia Group, a multi-family property manager in the Tucson area, with the long-term goal of recruiting and enrolling 500 residents to host the load control units. The primary target population for deployment of Shifted Energy's IoT-based (LTE CAT-M1) controllers was single-family homes with HPWHs previously purchased through TEP's energy

efficiency rebate program. In addition, multi-family residential buildings were targeted.

The project scope also included delivery, installation, and commissioning of up to 525 controllers as CTA-2045 demonstration units, followed by machine learning training then intelligent management across several load shifting events and experiments. Project tasks spanned the following areas of interest:

- **Grid services and benefits:** quantify baseline water heater load shapes for single- and multi-family homes and water heater types (ERWH, HPWH); quantify overall water heater load (kW) and energy usage (kWh) and available reductions from shifting to off-peak time periods; evaluate potential grid benefits from shifting load from early morning and peak early evening hours to match solar production curves, accounting for seasonal variability; and evaluate cost-effectiveness and maximum potential benefits.
- **Consumer perceptions and impacts:** quantify potential customer benefits provided by combining water heater controls with TEP's time-of-use and demand rates; evaluate customer response to utility control of water heater operation; evaluate potential ancillary benefits for customers (maintenance and leak alerts, remote shut-off control, marginal energy savings, etc.) and the utility (frequency regulation, non-wires alternatives); and evaluate the opportunity to aggregate water heating load for grid services while maintaining customer satisfaction.
- **Machine learning for aggregated demand-side management:** evaluate forecasts of baseline consumption vs. actual consumption for aggregated groups and entire fleet; evaluate forecasts of load shift capacity and energy impacts vs. actual capacity and impacts; evaluate load shape elasticity with dynamic optimization and capacity tradeoffs of optimal load shape vs. maximum load shift; and extrapolate potential impacts and benefits, by month and season, for a full-scale water heater control program.



Control optimization based on machine learning algorithms can reduce utility peaks by shifting water heating loads to align with solar energy production—and to later in the evening when overall demand drops.

Results & Learnings

Reaching customers was challenging during the pandemic, as planned in-person interactions between property managers and tenants shifted to electronic outreach. Customers proved eager to participate in the load control demonstration, but the compressed pilot project schedule and laborious enrollment paperwork posed additional challenges. Controller installs in multi-family buildings averaged about three units per hour, while the process for single-family homes, though more time-consuming, was streamlined by use of the CTA-2045 standard.

Across the pool of participating water heaters, baseline per-tank total daily consumption was 4.0 kWh, compared to the U.S. average of 12.66 kWh. Per-tank peak loads averaged 0.15 kW in the morning and 0.33 kW in the evening. Intra-peak water heater load profiles varied significantly by customer, highlighting the value of Shifted Energy's solution in tailoring individual event dispatch profiles to match unique usage patterns.

TEP's overall load curve shows distinct seasonality, with a single peak during the summer and two peaks during the winter. Based on actual and simulated dispatch profiles generated in this pilot project, Shifted Energy's machine learning algorithm demonstrated the capability to shave the various seasonal peaks and also to project potential load shift capabilities at other times.

Shifting to align water heating loads with mid-day solar production (10 am - 2 pm) increased the baseline load by 5.5 kW for an aggregation of 86 heaters,

corresponding to 0.06 kW per tank. This boosted per-tank total daily consumption by 0.25 kWh. On the other hand, results suggest the potential for automated load control to deliver customer energy efficiency savings of ~7%. However, the economic gain for low-usage heaters like those involved in this study may not be worth the added wear and tear on load control components and the related reduction in lifespan.

Utility-led technology implementation, facilitated by Scotia Group, enabled direct communication and relationship development with customers and property managers. Learnings by TEP during customer enrollment will be applied to guide future program rollouts, including for multi-family buildings and under-served populations where tenant-landlord relationships may pose barriers. Property managers benefited from the project not only by helping their residents but also from the monitoring capabilities provided by Shifted Energy's controller, including detection of leaks and faulty heating elements.

Implications & Next Steps

This pilot project demonstrated the potential of Shifted Energy's solution for IoT-enabled, machine-learning-based load control of aggregated customer systems as virtual power plants. It also has laid the foundation for continued collaboration with TEP in deploying additional water heater control switches and conducting a more rigorous programmatic evaluation, enrolling sufficient customers to set up three aggregated groups for learning, optimized dispatch, evaluation, and continuous improvement.

Pending results, TEP will consider similar programs in support of the utility's larger vision of harnessing the demand-side flexibility provided by connected water heating and pool pump controls, rate-optimized thermostats, and both electricity storage by batteries and thermal energy storage by heating, ventilation, and cooling systems.

TESTIMONIAL: Shifted Energy

The opportunity to collaborate with EPRI and TEP in proving the benefits of machine learning applied to aggregated load shifting has improved Shifted Energy's product while also providing insights for developing even smarter algorithms to deliver greater value to our utility partners.

TESTIMONIAL: Tucson Electric Power

Having not built many customer programs from scratch, TEP has benefited from the support provided by EPRI and Shifted Energy, instilling confidence in our team from the very beginning of this project and as the rollout of our connected water heating program continues.

TESTIMONIAL: EPRI

As decarbonization proceeds, the need to manage electric loads will grow. Because the inherent thermal energy storage capacity of electric water heaters makes them an ideal controllable load, EPRI looks forward to continued analysis of the data streaming from this project to inform stakeholders on the benefits of AI-based technology for aggregated load management.

Resources

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Snap-On WindowSkin® for Improving Performance of Existing Windows

Startup
WexEnergy
Rochester, NY

Host
Tennessee Valley Authority

Technology Solution

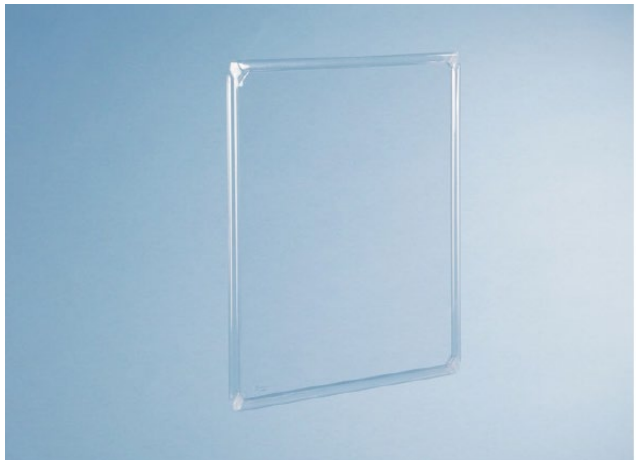
Windows are the most thermally porous component of the building envelope, single-pane models are the worst offenders, and aging windows of all kinds can suffer from performance problems. Windows also are very expensive to upgrade or replace, especially relative to other building envelope improvements. Consequently, poorly performing windows are often left unaddressed, especially in low-income or disadvantaged households.

This pilot project was initiated to demonstrate WexEnergy's WindowSkin® products as an interior-mounted retrofit solution for reducing thermal energy loss through aging and underperforming windows. At a small fraction of the cost of window replacements, PolarSkin™ adds a layer of insulation to existing window panes, while SolarSkin™ also offers heat gain reduction, which can be important for reducing space cooling costs. The products are designed for improving thermal performance in buildings with single-pane windows or with aging double-pane windows no longer as energy efficient as when installed.

Project Overview

For this demonstration, WexEnergy, Tennessee Valley Authority (TVA), and EPRI teamed up to demonstrate the impacts of installing a mix of PolarSkin and SolarSkin products in 12 single-family homes in Tennessee. The goals were to improve the thermal performance of each house, as well as gain first-hand learning about pre-installation requirements, installation best practices, and customer satisfaction for this type of window retrofit product.

The project was organized into four task areas: site selection, WindowSkin production, installation, and reporting. To support the first task, WexEnergy provided remote training to TVA and its contractor, CLEAResult, to assist them in screening homes for window compatibility and in applying measurement tools for correctly determining window dimensions and verifying minimum acceptable clearances.



WindowSkin inserts are designed and sized to improve the thermal performance of individual window panes by reducing heat loss and solar gain.

Homes were selected from a list of past participants in TVA's Home Uplift Program, which provides free energy upgrades to low-income and disadvantaged consumers in order to reduce energy bills and improve quality of life. Previously, windows had not been an addressable measure under this program due to the high cost of treatment. For the selected homes, TVA and CLEAResult were tasked with performing customer outreach and collecting window measurements.

WexEnergy reviewed measurement data for each window to confirm compatibility with WindowSkin

qualification criteria and, once approved, to place a manufacturing order. Due to production constraints, WindowSkin products were delivered in two phases to CLEAResult. After WexEnergy provided a virtual installation training session, the contractor visited homes to complete the installations, product features were explained to customers, questions were addressed, and initial feedback was collected.

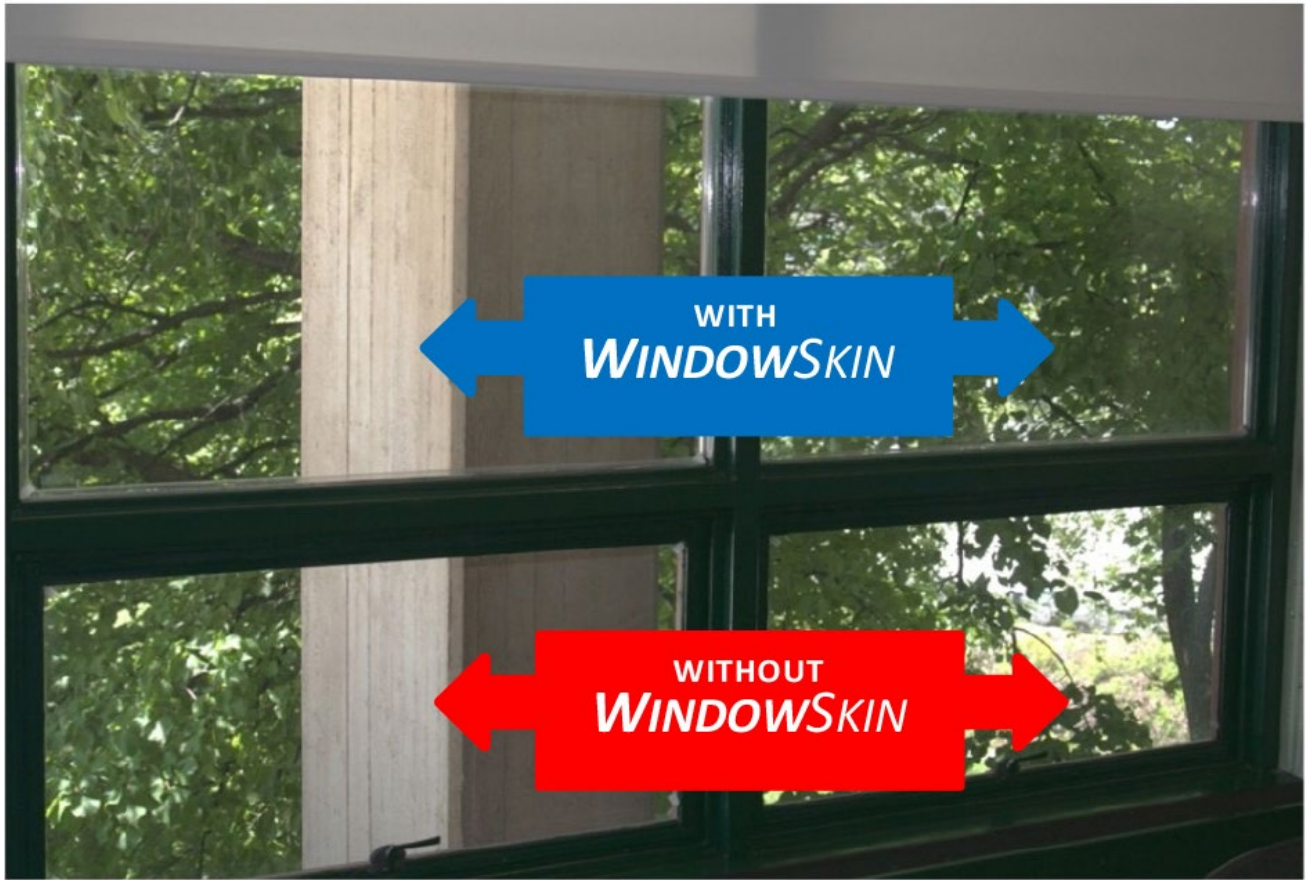
As part of this project's reporting task, both installers and customers were surveyed to gather their opinions about the process and the technology. TVA plans to continue to monitor the performance of the homes over the course of at least 1 year to better understand energy savings and other impacts.

Results & Learnings

The project team accomplished key tasks and applied learnings during the brief project timeline. Remote training proved successful in walking TVA's contractor through the necessary steps in assessing every window in a house and in properly determining the needed dimensions for every pane in suitable windows, including adequate clearances for operability.

One key learning is that the standard home energy audit would likely take twice as long if every window were to be measured for WindowSkins. In response, WexEnergy developed a streamlined process for small panes and is creating a new tool that is expected to reduce overall measurement time by at least 50%.

WindowSkin products ultimately proved to be highly compatible with the windows of the homes that were identified for inclusion. An initial constraint of the manufacturing process precluded pane dimensions less than 9 inches long, which would have prevented a number of windows from being retrofit during the project. WexEnergy modified the manufacturing process to include panes as small as 7 inches long, enabling 95% of the measured windows to be treated.



WindowSkins have minimal impact on visibility through windows, and treated windows remain operational.

For future deployments, WexEnergy plans clearer upfront messaging to mitigate the potential for disappointment. Homeowners need to clearly understand that window measurements are part of the qualification process—and that not every building or window is suitable for the product.

Recruiting, scheduling, and measuring homes during COVID proved challenging. TVA and its contractor worked very efficiently to complete upfront work early in the project timeline, enabling fulfillment and delivery of an initial manufacturing order and installation of WindowSkins in a few homes by October 2021, with the remainder of installations occurring before the end of the year.

According to CLEAResult, the installation process itself was easy, and customers were not concerned about visibility through the treated windows.

Implications & Next Steps

While changes in customer energy use attributable to the deployed WindowSkins will not be known until the end of 2022, this project achieved notable successes in advancing quickly from planning and assessment to manufacturing and then installation as part of TVA's Home Uplift Program.

The primary research question—how building energy usage has changed after 1 year—will be answered based on analysis of billing data from before and after the installations. TVA also plans to survey customers during both the heating and cooling seasons, addressing questions such as the following:

- Is your room/home more comfortable since WindowSkins were installed?
- Has visibility through windows changed?
- Do you ever open your windows?

For WexEnergy, a key next step toward WindowSkin integration in utility program offerings is to demonstrate its new measurement platform for speeding up residential site assessments and product sizing by energy auditors working alone. In addition, a small-pane product that also can be installed quickly and easily is under development.

TESTIMONIAL: WexEnergy

This opportunity to build relationships with important industry contacts helped WexEnergy accelerate market introduction of our SolarSkin product, with the first units reserved for TVA's customers, as well as advance our window measurement process.

TESTIMONIAL: Tennessee Valley Authority

We had no problem finding homes that qualified for Wex Energy's technology, the WindowSkin products were easy to install, and visibility through the window was not impacted.

TESTIMONIAL: EPRI

WindowSkin technology showed high compatibility with various types and sizes of older windows in this pilot project, creating potential to improve thermal performance and reduce heating and cooling loads in diverse residential buildings without having to replace windows.

Resources

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Interior Storm Window Insert for Improving Performance of Existing Windows

Startup
Indow
Portland, OR

Host
Tennessee Valley Authority

Technology Solution

Windows are a significant source of heating and cooling losses and comfort issues in homes. Exterior storm windows are commonly employed to mitigate these issues but can be expensive and difficult to install and operate. Applying plastic sheeting to interior window framing is an inexpensive but cumbersome and temporary solution that often reduces visibility.

This pilot project was launched to test interior storm window insert kits designed and manufactured by Indow for improving comfort while reducing heating and cooling bills and carbon emissions. By creating a tight seal within window openings, the inserts reduce air in-leakage and the associated drafts and thermal energy losses. Indow Kits arrive with all parts needed—about 15—for quick and easy assembly and installation by contractors and homeowners alike. Additional items needed to ensure a proper fit of the transparent film in the aluminum frame include a butter knife and hairdryer. The frame includes a mechanical attachment system suited for providing a secure seal in a variety of window configurations.



Indow's interior storm window insert kits are designed to facilitate assembly, installation, and seasonal removal as appropriate.

Project Overview

The goal of this project was to equip all windows in up to 20 homes with Indow Kit inserts in order to evaluate qualification, measurement, assembly, and installation processes and energy-saving performance. Project team members included TVA as the utility host, EPRI as subject-matter expert, Indow as technology developer and supplier, and CLEAResult as TVA's contractor for window qualification and measurement and window kit assembly and installation.

TVA identified 94 potential customer participants based on homes in a localized area that had already been provided with various weatherization improvements through the utility's Home Uplift Program. Indow provided remote trainings to CLEAResult addressing frame capability and window qualification and

measurement, and homes were assessed as potential sites for installing Indow inserts. CLEAResult reached out to customers with suitable windows, conducted in-home visits, and collected measurements, providing the data needed to initiate the first-large scale production run of Indow Kits.

After kit manufacturing, packaging, and delivery, CLEAResult assembled and installed the storm window inserts and conducted a blower door test, allowing comparison of post-treatment air exchange to pre-treatment test results. Indow, first and foremost, focused on developing experience with manufacturing, assembly, and installation of its new energy-saving product and on evaluating the improvement in quality of life for homeowners participating in the project through before-and-after qualitative surveys. Changes in energy usage, bills, thermal comfort, and air quality also were important metrics for project participants.

Results & Learnings

During the pilot project, CLEAResult identified and measured six homes, and Indow Kit inserts for 62 windows were manufactured to order. An additional eight inserts for TVA's Tiny Home demonstration were delivered. This provided the first test of large-scale kit manufacturing, allowing Indow to better understand the resources needed to continue to scale production of its new product. Despite supply chain issues for certain parts, Indow amassed enough materials to build up to 500 inserts.

Assembly and installation by CLEAResult after training conducted by Indow went smoothly and offered unique insight into the workflow within a utility program environment. Factors not considered by homeowners as typical Indow customers or by Indow staff closely involved in development of the product were identified.

In summary, Indow provided remote frame compatibility and window measurement training lasting less than 2 hours in total, and CLEAResult was able to measure qualified windows in a straightforward process. Indow manufactured the inserts kits in timely fashion, and the initial manufacturing ramp yielded a number of process efficiency improvements. Shipping a large number of kits via a single crate provided cost efficiencies.

Assembly and installation training supported by printed materials enabled ease of installation. Blower door test measurements showed a reduction in air infiltration relative to pre-install conditions, but impacts on energy use and comfort are still to be determined.



While customer recruitment proved challenging, the project team succeeded in installing Indow inserts for various window configurations.

One key learning is that Indow Kit uptake in utility programs is influenced by regional architectural styles within target demographics. Among the homes identified as potential participants in this project, the window incompatibility rate was dramatically higher than anticipated based on previous Indow experience. Very shallow frame depths, protruding hardware, and curved frames, all of which can preclude insert usage, were commonly encountered—sometimes all in the same window!

Additionally, over 90% of the homes in the initial candidate pool had already being outfitted with exterior storm windows. To reach the target of 20 participating homes, the project team expanded the pool of potential participants through the Home Uplift Program, including customers previously served in neighboring communities plus new program participants.

Implications & Next Steps

While deployment progress during the pilot demonstration period was slowed and the performance of Indow inserts remains under assessment, the project team succeeded on several collaborative fronts. In short, product qualification, measurement, assembly, and installation training guided the deployment of the initial large-scale production run of Indow Kits, and several opportunities along the value chain were identified for achieving significant efficiencies at scale.

Going forward, as Indow plans product rollouts in conjunction with utility programs, architectural characteristics and common window types across the

potential pool of participating homes will be investigated. This will help in identifying and mitigating compatibility challenges and determining realistic metrics of success in engaging customers and deploying storm window inserts.

Indow also is interested in exploring alternative approaches to customer engagement, such as hub-and-spoke recruitment strategies organized around retrofits of schools and other community buildings. Students and volunteers working on interior storm window measurement, assembly, installation, and reporting tasks—as well as beneficiaries, in terms of improved comfort, reduced energy bills, and lower emissions—could then serve as Indow customers or advocates.

Resources

Sam Pardue, *Chief Executive Officer, Indow,* sam@indowwindows.com

James Linder, *Technology Scout, TVA,* jlinder@tva.gov

Doug Lindsey, *Technical Leader, EPRI,* dlindsey@epri.com

TESTIMONIAL: Indow

Working with TVA, EPRI, and CLEAResult helped identify lever points in our value chain that once addressed will enable Indow to rapidly scale sales and production through utility programs—and make improved comfort and lower bills accessible to more people.

TESTIMONIAL: Tennessee Valley Authority

The onsite assembly and installation of the Indow Kits went smoothly, and customers were pleased with the look and feel of the product. Early measurements indicate a 5 to 10% reduction in air infiltration in the home.

TESTIMONIAL: EPRI

Indow Kit technology provides a unique approach to the challenge of improving the performance of existing windows. The fact that efficiency contractors and homeowners can easily measure for, order, assemble, and install the product could help reduce deployment barriers and costs.

End-to-End Electric Vehicle Charging Solution for Long-Duration Parking Locations

Startup
HeyCharge
Munich, Germany

Hosts
EPRI
Ameren
Tucson Electric Power

Technology Solution

Providing electric vehicle (EV) charging for long-dwell locations, like multi-unit residential buildings, can be challenging due to the cost of charger hardware and controls. Innovations that simplify charger installation and charging management have the potential to enable more widespread deployment in these situations, improving the customer experience for EV owners.

This pilot project tested the end-to-end technology solution developed by HeyCharge to enable low-cost installation of plug-and-play EV charge points that communicate exclusively through a mobile app. The lightweight charger simplifies installation and includes wireless communications capability, avoiding telecommunications costs while providing connectivity for customers regardless of mobile network coverage. The app's interfaces for EV owners and service providers support charging, metering, and billing functions.



HeyCharge's plug-and-play hardware is designed to reduce the costs and complexities of EV charge point deployment.

Project Overview

EPRI acted as the site host for the demonstration, working directly with HeyCharge to deploy hardware and evaluate the end-to-end solutions at its EV lab in Knoxville, Tennessee. Ameren and Tucson Electric Power (TEP), a Fortis company, also participated in the project as sponsoring utilities.

Three HeyCharge units were installed, commissioned, and operated by EPRI personnel. The units, manufactured for the European market, were not listed to UL standards, limiting the type of testing that could be performed. A Nissan Leaf EV battery was applied as a test load with a lab-grade power quality analyzer used to log energy usage during charge sessions.

The lab testing protocol was designed to investigate the following questions:

- How well does the app work for drivers?
- How well does the smart phone communications path support operation?
- How useful are the system-level web portal tools?
- How well does the software work for billing the correct party?

If successful, the next step would involve field demonstration of the HeyCharge hardware involving a larger

number of units and live EV charging at diverse host locations.

Results & Learnings

The installation process was relatively simple—for hardware units, comparable to 240 V_{AC} receptacles; and for software, involving straightforward use of a computer to access the HeyCharge "Admin" Portal via the internet and set up the EPRI "Admin" account.

System-level station management and EV customer tools were simple to use with clearly labeled tabs allowing access to needed information. Adding drivers involved a fully automated invite process. To set up user accounts, the HeyCharge phone app was installed on several iPhone and iPod devices by following the email invite to the app store and using a HeyCharge-assigned username and password. HeyCharge also provided an Android device with the app already installed.

Unit commissioning—done via smart phone app during a live lab demonstration hosted as a web conference with the supporting utilities—involved a simple and intuitive process that took only a few minutes to complete. Initiating charger operation via the app also was straightforward; charge sessions for both the Leaf battery and a live EV were conducted. In addition, system-level tools were demonstrated.

Over several days of testing, use of both cell phones and iPod devices to conduct charge sessions proved reliable with no problems relating to Bluetooth™ communications.

To assess capabilities for billing the correct party for charging sessions, EPRI was able to access HeyCharge's data application programming interface (API) using the instructions provided. JSON-structured files were downloaded and documented to assist the participating utilities in evaluating the data for use in isolating the energy consumed during individual charging sessions at each access point from the main meter's total.

A couple of issues were encountered throughout the course of the pilot. During hardware installation, terminal blocks were found to be small, relative to typical U.S. wire sizes. HeyCharge updated the terminal blocks in the units being evaluated for UL standards compliance and certification for the U.S. market.

During operational testing, an offset in metered energy measurement was detected and traced to the use of 120 V_{AC} power (the European units were natively designed to operate at 230 V_{AC}). This issue was addressed via firmware upgrade, executed via Bluetooth without problems.

Testing also indicated that an active charge cable can be unplugged and moved to serve another vehicle without the session being interrupted, suggesting that the start/stop logic for charging sessions requires an update to support a more robust approach to theft prevention.

According to HeyCharge, this logic is already configurable via back-end settings that can be remotely adjusted and optimized without further software development. The plan is to expose this and other advanced configuration options as HeyCharge gains more experience with the settings preferred by charger hosts and customers.



At EPRI's EV laboratory, three HeyCharge access points with Bluetooth capability were deployed and tested for app-based, end-to-end management of the EV charging process.

Implications & Next Steps

This pilot proved successful in demonstrating the HeyCharge solution's ease of installation and use, though some minor updates, such as larger wire terminals, will be needed for the U.S. market.

HeyCharge is in the process of starting early commercial deployments with individual building owner/operators and utilities. Both standalone hardware and the end-to-end solution with the Bluetooth-based charge management system are expected to be available for European markets in early 2022.

For U.S. markets, a field demonstration using UL-certified hardware, HeyCharge units deployed at several locations, and dozens of real EV drivers is needed to provide a more robust evaluation of capabilities and costs. This could include development and testing of an automated approach for extracting

metering data from HeyCharge's API for integration with a utility billing system.

Resources

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John Halliwell, *Senior Technical Executive, EPRI,* jhalliwell@epri.com

Travis Herman, *Contractor Services Supervisor, Ameren,* therman@ameren.com

Ray Martinez, *Principal of Emerging Technology & Innovation, Tucson Electric Power (now with Arizona Public Service),* raymundo.martinez@aps.com

TESTIMONIAL: HeyCharge

Incubatenergy Labs afforded an amazing opportunity to test HeyCharge hardware and our end-to-end platform in a realistic environment and collect the real-world feedback needed for partnering with utilities to bring the advantages of low costs and underground usability to the U.S. market.

TESTIMONIAL: EPRI

During our lab testing experience, the HeyCharge hardware proved easy to install and operate, and web-based tools for both EV owners and charging station hosts provided simple and intuitive user interfaces.

TESTIMONIAL: Tucson Electric Power

The HeyCharge product provides a novel approach for filling a gap in the fast-emerging market for vehicle electrification by looking to overcome cost, billing, and connectivity obstacles to the installation of charge point locations serving multi-unit dwellings, hotels, and underground parking lots.

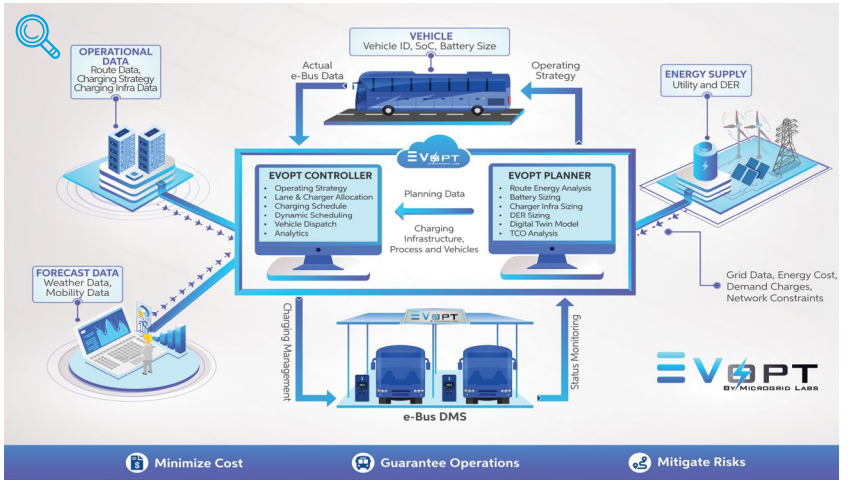
Zero-Emission Fleet Transition Planning and Simulation

Startup
Microgrid Labs
Boulder, CO

Host
Ameren

Technology Solution

Cost and complexity are two key factors standing in the way of a faster transition from conventional vehicle fleets to electric mobility. Electric school buses, for example, have much higher purchase prices than diesel buses and need additional investments in charging infrastructure, but they promise lower operations and maintenance (O&M) costs plus reduced emissions of pollutants and greenhouse gases. Myriad design, cost, and performance variables influence the appropriateness and the outcome of electrification projects. Planning is the first crucial step in fleet electrification, as early decisions can have significant impact.



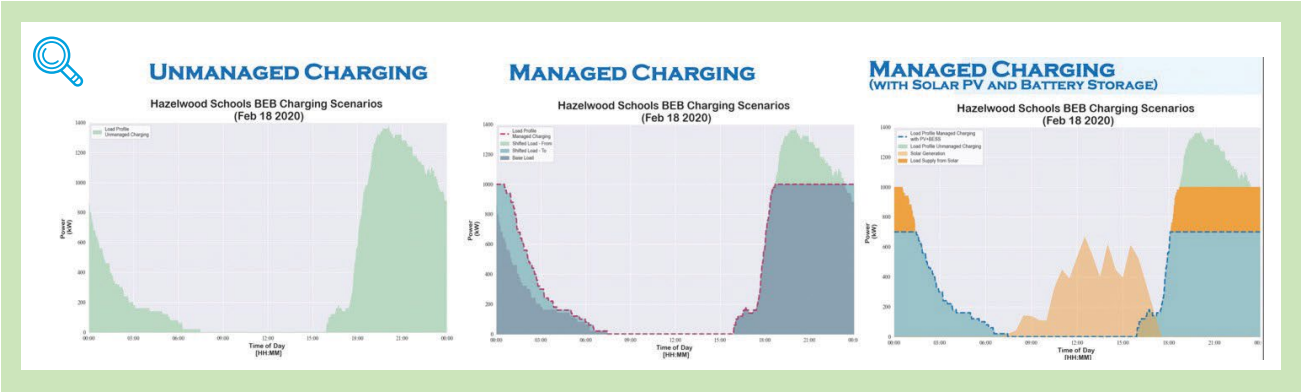
While this demonstration focused on planning applications, the EVOPT platform is also designed to support operational decision-making by customers and utilities.

This pilot project tested the EVOPT software platform developed by Microgrid Labs (MGL) for completing a feasibility study and system-level design for transitioning a diesel bus fleet into an all-electric fleet. The EVOPT platform is used to build a detailed digital twin of the application in question, addressing existing fleet vehicles and uses, charging and electrical support infrastructure, utility rates, and other factors. Simulation of the driving and charging process for an electrified fleet helps determine optimum capital and operating parameters for minimizing costs and achieving other goals. "What if" analysis functions support evaluation of alternative scenarios, helping reduce risks and costs while managing uncertainties.

Project Overview

The Hazelwood School District (HSD) in St. Louis, Missouri, is considering the possibility of transitioning its school bus fleet from diesel to zero-emission vehicles. As the local utility and electricity provider, Ameren is interested in understanding potential impacts on the distribution network and, more broadly, in exploring how to facilitate a faster transition toward zero-emission fleets. In this project, MGL, Ameren, and EPRI teamed up to provide HSD with planning services and support while determining the efficiencies and challenges associated with the use of EVOPT in a real-world setting.

The first step was to document existing operations. This included gathering telematic data for 120 buses to understand daily routes, duty cycles, and other details, as well as data relating to fuel costs, maintainance charges, behind-the-meter electric



Operational simulations of EV charging load profiles illustrate peak shaving and load shaping opportunities achievable by managed charging and use of solar plus battery storage.

infrastructure, the localized distribution network, electricity pricing and tariffs, electrification and resiliency goals, etc. After integrating all the data in EVOPT, MGL conducted modeling and analysis to come up with recommended specifications for the electric bus (battery and motor size), charging infrastructure (number, type, and size of chargers), and electric infrastructure (transformer size, panel size, cable/conduit, etc.). In addition, technical and business factors such as load profiles, rate structures, vehicle-to-grid and vehicle-to-building integration, and on-site solar and battery storage were considered.

Results & Learnings

Working during the summer, during a pandemic, presented challenges not only in collaborating with HSD staff but also in applying EVOPT. In an ideal scenario, model development is based on the most recent 12 months of normal fleet operations. For this pilot, pre-shutdown (February 2020) and recent (May 2021) data were applied, with assumptions made to fill gaps. This did not impact the ability of the project team to generate important insights as introduced below.

Innovative fleet decision-making approach. Under a traditional approach for considering new technology, a few electric buses might be purchased and operated on a demonstration basis, easily costing upwards of $1 million and taking 18 to 24 months. The EVOPT-Planner tool combined with real-world telematic data provided a detailed, simulation-based analysis of a futuristic, all-electric fleet scenario at this location, supporting evidence-based decision-making for a fraction of the cost on a much shorter timeframe.

Fleet suitability for electrification. Based on telematic data, about 100 HSD buses are on route daily, averaging about 100 miles (160 km) with a maximum daily distance of about 270 miles (430 km). EVOPT modeling determined that about 80% of the fleet could be electrified using commercially available technology and that immediate operational savings could be realized by replacing the older vehicles that account for about half of the fleet.

Charging strategy. Armed with infrastructure and hourly pricing data from Ameren and as shown in the above figure, EVOPT provided insights on hosting capacity and peak load shapes for electric fleets under various charging scenarios. The existing 12 kV feeder has sufficient capacity to support electrification. Managed charging could reduce feeder peaks by more than 25% and HSD's electricity bill by about $2000/month at current rates. Integrating fleet charging with onsite solar and battery storage could provide additional benefits.

Capital and operating expense. An electric school bus, on average, costs about three times as much as a diesel bus and requires charging stations and upgrades to onsite and utility infrastructure. Electric buses also bring the promise of lower fuel and maintenance costs. For Hazelwood, EVOPT estimates a total cost of fleet electrification in the range of $50 million and a reduction in annual O&M costs of about $1 million.

Emission reduction. EVOPT estimates total annual CO_2 emissions from the current HSD fleet to be around 4000 tons. Electric buses could reduce tailpipe emissions to zero, and onsite solar could be installed to support a fleet with net-zero electricity consumption.

Utility infrastructure upgrades. According to EVOPT analysis, the much higher power levels needed for EV charging (1.5 to 2 MVA) would require an upgrade of the existing stepdown transformer (150 kVA at 12 kV-480 V). A separate but nearby 12 kV feeder could be tapped to increase resiliency for an all-electric fleet by having multiple connections to the local substation.

Implications & Next Steps

Consistent with its committment to net-zero carbon emissions by 2050, Ameren is working with MGL to identify other fleets in the utility's territory for which to perform detailed electrification planning studies. This will support system planning for huge EV charging loads coming online and the utility's goal of serving

them with clean energy production sited at large EV fleet hubs or elsewhere on the grid.

The team also is exploring integration of MGL's digital twin model of the HSD fleet's charging depot with the capacity profile of the medium-voltage feeder serving this location. EVOPT models can provide load profile and power quality forecasting on a 24-hour basis and real-time forecasting on a rolling 15- or 5-minute basis. Detailed evaluation of this capability could provide further insight into the value of MGL's technology for both utility planning and operational purposes. MGL is considering a white-label version of EVOPT for use by utilities in helping customers evaluate fleet transition options.

Resources

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Annie Haas, *Program Co-Lead, Incubatenergy Labs, EPRI,* ahaas@epri.com

TESTIMONIAL: Microgrid Labs

Transitioning to zero-emission bus fleets gives school districts and other transportation providers the opportunity to reach sustainability goals and reduce costs but also poses challenges. Working with Ameren and EPRI allowed us to dig deeper into utility integration issues and created learnings that will be used to enhance EVOPT's features and support a faster transition to electric fleets.

TESTIMONIAL: Ameren

Collaborating with MGL, EPRI, and the Hazelwood School District on this EVOPT pilot has provided Ameren with hands-on experience in understanding our customers' general struggles and areas of focus in vehicle fleet management, as well as in analyzing the capital and O&M expenses and grid impacts associated with fleet electrification projects. As a result, Ameren is better equipped to discuss electrification strategies with customers and identify options for helping them manage risks, reduce costs, and maximize benefits.

TESTIMONIAL: EPRI

This demonstration generated unique insight into the potential impacts of electrifying a fleet of school buses, both for the school district and host utility. EVOPT modeling and analysis provided information needed to make decisions about this fleet electrification application and, when done at scale, could help quantify and guide utility planning along a key decarbonization pathway.

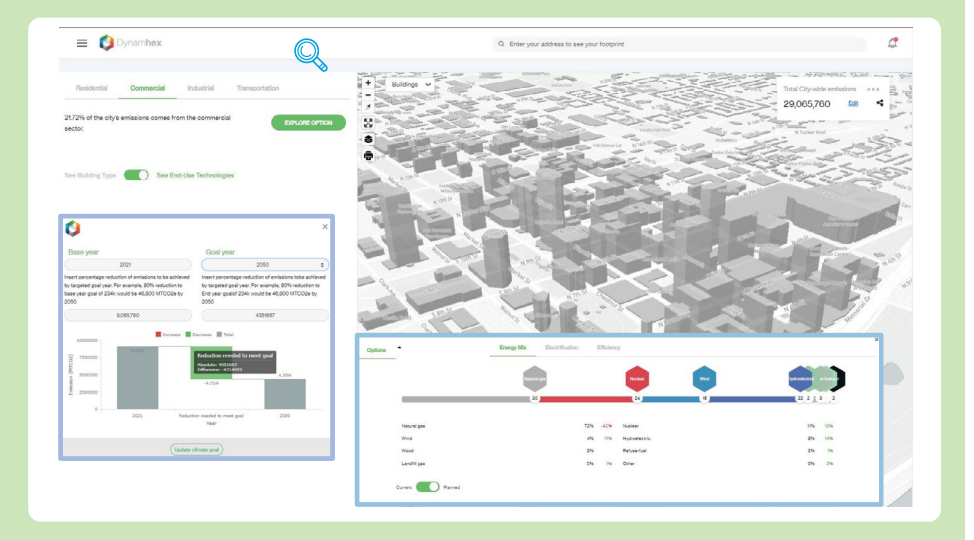
"Decarbonization-as-a-Service" Platform for Utility Planning and Customer Engagement

Startup
Dynamhex
Baltimore, MD

Host
Ameren

Technology Solution

With many states, cities, local jurisdictions, institutions, and corporations joining utilities in establishing decarbonization and other sustainability goals, the role of buildings as a lever for achieving economy-wide emission reductions is gaining in importance. Utilities are ideally positioned to work alongside governments and other entities in aligning both internal and external decarbonization objectives with energy efficiency, demand response, electricity supply, and additional customer offerings. However, these customers often lack the data, expertise, and funds needed to create and manage their decarbonization plans.



Dynamhex's cloud-based platform includes both utility-focused and customer-centric features for analyzing and reducing carbon emissions.

This pilot was initiated to demonstrate the decarbonization-as-a-service (DaaS) platform developed by Dynamhex for assisting customers in meeting decarbonization goals by taking advantage of utility offerings. The platform aggregates energy use and other data to create digital twins for individual residential, commercial, and industrial buildings within a geographic region or service area. Geospatial modules calculate emissions for each building, and built-in analytics deliver targeted, prescriptive decarbonization roadmaps that identify actionable energy- and emission-reducing opportunities and available utility programs and incentives. Bottom-up modeling of building-level actions supports tracking and standardized reporting of progress toward decarbonization by individual stakeholders and collectively.

Project Overview

Dynamhex, Ameren, and EPRI teamed up to demonstrate and test the DaaS platform by analyzing how Ameren's customer programs can help in decarbonizing the building sector within its service territories in Missouri and Illinois. Estimating the current and potential future carbon footprint of the building stock—while taking factors such as demographics, equity, and social justice into account—is expected to help optimize program design and rollout.

Specific pilot project goals were to apply the platform for mapping and modeling carbon emissions, with granular details, across three municipalities covering

1.1 million residents; and to gather feedback from internal Ameren teams, as well as external stakeholders, addressing the following:

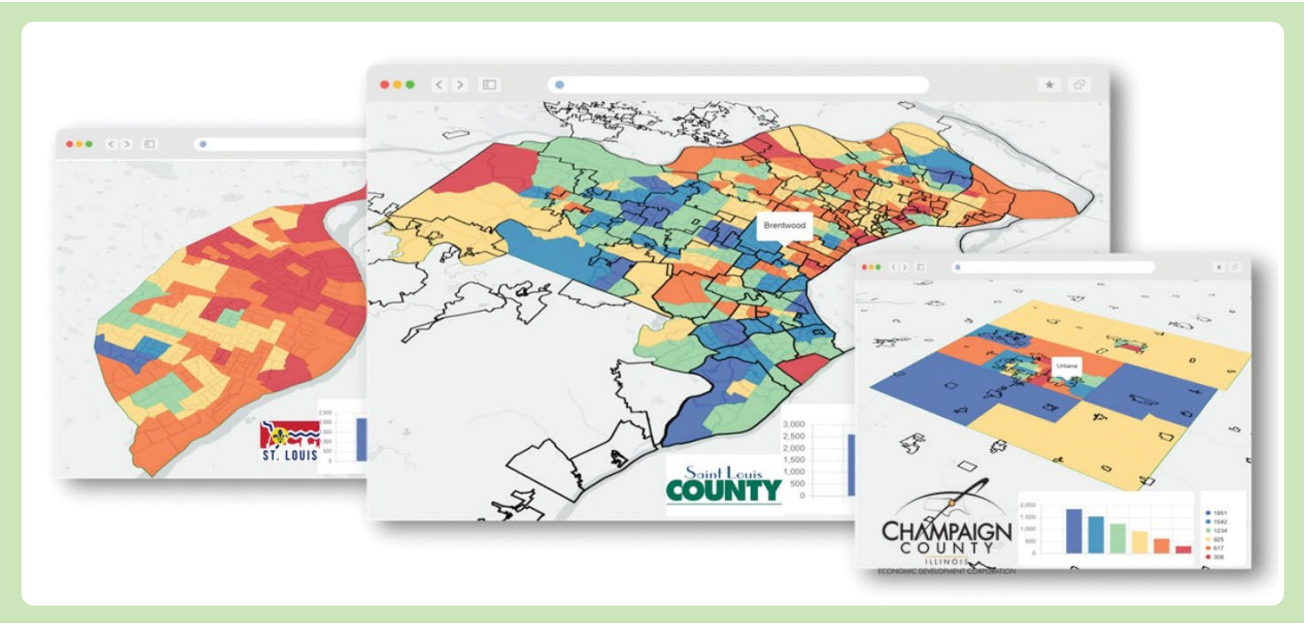
- Platform capabilities and user experiences for Ameren and its customers;
- Clarity on emission reduction potential and mitigation solutions;
- Consistency with assumptions, methodologies, and standards commonly used for quantifying emissions and benchmarking performance at building, sector, and other levels; and
- Future data types and platform enhancements and features.

Participating municipalities included St. Louis County and the city of St. Louis in Missouri, as well as Champaign County in Illinois. In addition, the project team interacted with and solicited feedback from the cities of St. Louis and Urbana, IL, plus six large customers—three corporations and three universities.

Results & Learnings

Over a 24-day period, the overall Ameren territory was analyzed to quantify total greenhouse gas emissions. Additional model calibration was conducted on all buildings, facilities, and transportation activities across the three participating municipalities and in collaboration with individual corporate customers.

Dynamhex simplified the process of collecting and aggregating the needed data—including metering data, historical building upgrade information, permitting records, rooftop imagery, local grid conditions, etc.—and standardizing models to provide Ameren with a ready-made platform with which to engage customers across its service territory. This included creation of an on-demand web portal to facilitate the ongoing transfer of customer energy consumption data programmatically, through a single sign-on process, effectively bypassing lengthy manual processes and related workflows. Ameren's portal also included more than 30 utility programs available to residential, commercial, and industrial customers.



The Dynamhex platform facilitated the process of integrating diversity, equity, and inclusion considerations in evaluating decarbonization opportunities across municipalities by analyzing demographics, community risk profiles, environmental justice concerns, and other factors.

The platform's target-setting module enabled Ameren to align its programs and initiatives with the overall emission reduction targets and sustainability goals of individual customers and communities. For example, on the supply side, the utility's current electricity supply portfolio and its future mix can be used to show planned reductions in regional emissions from the generation fleet and the associated impacts on the electricity-related emissions of customers. Similarly, demand-side solutions can be overlaid on existing service addresses and building footprints to provide personalized decarbonization solution packages on a proactive basis, thereby improving the customer experience.

Dynamhex modeling showed that select utility programs could help individual customers reduce their emissions by almost 32%, enabling significant progress toward their decarbonization goals. According to utility interviews, the typical process of measuring the carbon footprint of a single customer normally takes hours. Offering tailored emission reduction recommendations tied directly to available utility programs requires additional investment of time and resources. Without the DaaS platform, delivering this level of customization across thousands of customers would be impractical.

By establishing relevant demographic and ethnographic predictors, the Dynamhex platform also was able to shed light on which of thousands of building

owners have the highest propensity to take advantage of specific utility offerings in carrying out upgrades. In turn, the ability to represent the source, location, time, and other characteristics of emissions proved highly valuable in helping customers understand their carbon footprints and evaluate reduction opportunities given their unique load profiles. Going forward, the platform will provide a means for customers to verify the impacts of actions taken.

During the customer demonstrations, the platform also was applied to new use cases, ranging from completing a regional greenhouse gas footprint exercise across five counties to capturing and visualizing customer uptake of specific utility programs in the city of Urbana.

TESTIMONIAL: Dynamhex

Working with Ameren and EPRI helped demonstrate how AI-enabled platforms can support complex, multi-goal, multi-stakeholder workflows. Governments and individual customers are actively seeking data to inform their emission reduction and sustainability initiatives, and this project showed how utilities using our DaaS platform can both facilitate and deliver data-backed results.

TESTIMONIAL: Ameren

Based on the Dynamhex demonstrations, several of our customers initiated engagement regarding next steps to put plans and solutions in place to address their specific decarbonization goals.

TESTIMONIAL: City Customer

The Dynamhex platform was amazing—exactly the type of solution we need to estimate our annual emissions from different sources and to understand where and how we can collaborate to reduce them through utility programs, projects, and offerings and other available interventions.

Implications & Next Steps

This project has shown that the Dynamhex platform can help Ameren in collaborating with municipal, corporate, and institutional customers in developing actionable plans for reducing their current emissions and meeting longer-term objectives. Bottom-up modeling based on data and insights specific to individual buildings and customers increases accuracy, flexibility, and depth of analysis, as compared to traditional top-down models. Currently, Ameren is planning a broader deployment.

As customers look to better understand their energy consumption and emissions for buildings and additional assets, the DaaS platform shows promise for helping Ameren and other utilities both position and promote existing programs and design and roll out new offerings in a data-backed manner. In particular, utilities and their partners can apply the platform to rapidly produce and deliver proposals that specify how energy savings and other customer benefits can be increased by implementing multiple technologies and measures. This will facilitate the process of bundling individual upgrades and programs, which has traditionally been done in a piecemeal fashion.

The DaaS platform also enables utilities to better set and communicate decarbonization and sustainability goals internally and to apply best practices for engaging customers and additional stakeholders in these areas. Improving understanding of utility offerings—in areas such as efficiency and load management, electrification, neighborhood and community solar, solar plus storage, smart charging, green power choice, etc.—is expected to help in turning internal and external decarbonization commitments into actions.

Recognizing that each utility and customer has their own set of objectives and challenges, the platform can be used to start the engagement process using pre-integrated, publicly available datasets and then can be customized based on data, needs, and goals identified during interactions. Built-in interoperability supports seamless connection with existing applications and datasets and facilitates reporting.

In addition to evaluating enhancements based on lessons learned and customer feedback, Dynamhex is actively exploring collaborative opportunities to apply the DaaS platform in decarbonization-related research projects sponsored by EPRI and by agencies such as the U.S. Department of Energy and California Energy Commission.

Resources

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Siva Sankaranarayanan, *Senior Technical Leader, Electrification & Customer Solutions, EPRI,* ssankaranarayanan@epri.com

Buzz Solutions

NEWFOUNDLAND POWER
A FORTIS COMPANY

PowerAI Platform for Automated Visual Inspection of Grid Infrastructure

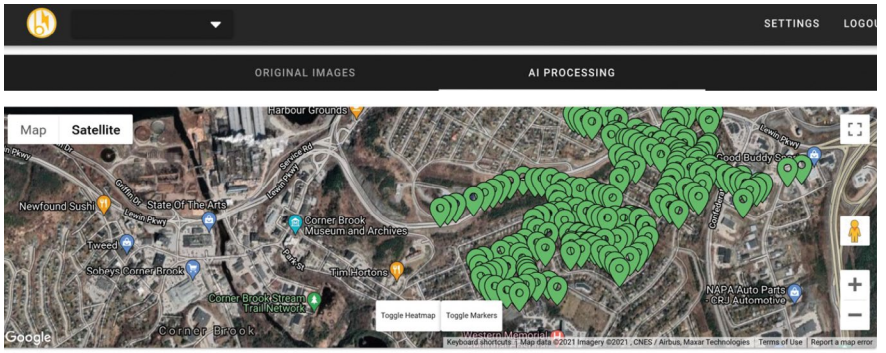
Startup
Buzz Solutions
Palo Alto, CA

Host
Newfoundland Power

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

Today, visual inspection of transmission and distribution (T&D) infrastructure can involve the review of millions of images captured in the field by workers, surveillance systems, drones, helicopters, fixed-wing aircraft, and other means. Analyzing these images to turn raw data into actionable inspection information currently requires technical expertise and substantial labor investment, and this can hamper timely response.



The PowerAI platform's geolocation functions allow easy visualization of, and access to, distribution pole inspection results.

This pilot project's objective was to demonstrate the PowerAI system developed by Buzz Solutions for supporting rapid, automated review of drone-based distribution inspection imagery. This software platform provides an end-to-end solution for cost- and time-efficient visual data management, processing, and analytics. Machine vision technology extracts and ingests imagery data for AI-based analytics to detect and map faults, anomalies, and risks relating to T&D equipment, including vegetation management along rights-of-way. Insights and analysis into the location of existing asset management issues or concerns and the potential location and timing of future problems can help T&D network operators in preventing failures, outages, and wildfires.

Project Overview

This project team involved a collaboration among Buzz Solutions; Newfoundland Power, a Fortis company, as the host utility; EPRI as subject-matter expert; and Altomaxx Technologies as the drone service provider. The PowerAI technology platform was applied with the goal of demonstrating the following:

- Scalable and secure visual data ingestion and management,
- Mapping of visual data to field assets and structures with GIS functionality,
- Machine vision algorithms for AI-based asset health assessment and anomaly detection,
- Customer-in-the-loop workflow allowing continuous process improvements,
- Actionable inspection insights and accurate predictive capabilities, and
- Integration of exported results with work order management systems, GIS systems, etc.

Major tasks included collection of drone-based inspection imagery of distribution assets, integration of drone-collected imagery into PowerAI software, integration of the platform with utility systems, model development and deployment within PowerAI, model

evaluation and retraining based on inspector feedback, and assessment of inspection and predictive capabilities.

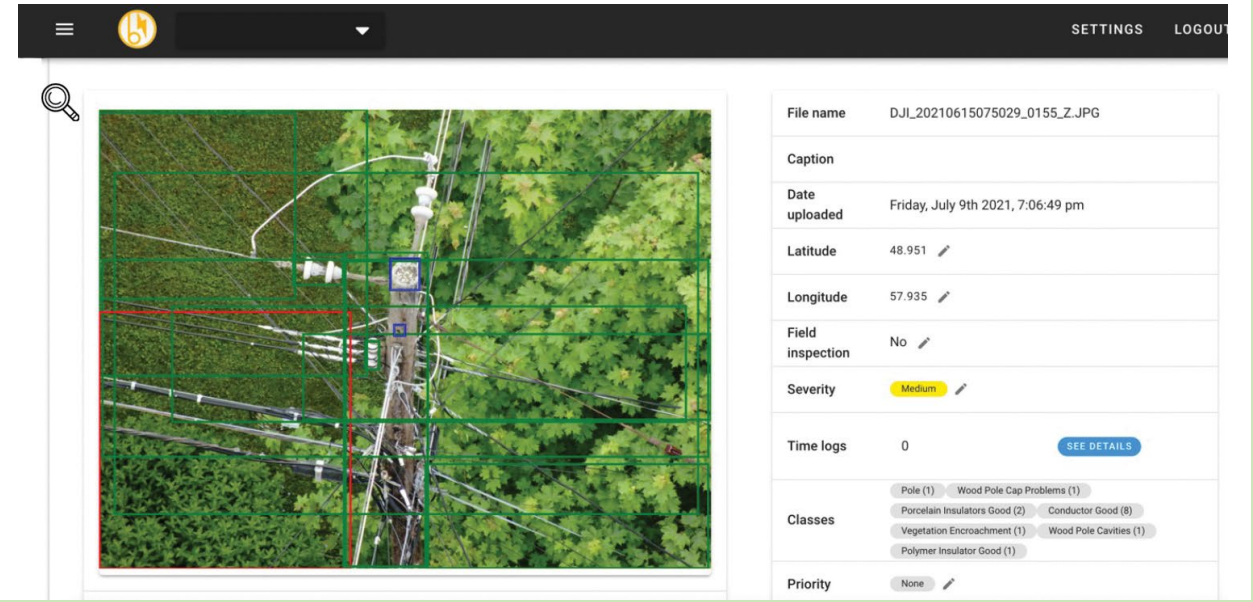
Results & Learnings

Drone data were collected on utility infrastructure per guidelines set to align the volume and resolution of data to be captured and the data capture methodology with the PowerAI platform. Over 30,000 images were collected. PowerAI ingested, modeled, and analyzed imagery data to generate maps, labeled images, and other information products.

Newfoundland Power team members evaluated the platform's ability to identify distribution assets, characterize health, and identify issues and anomalies. With 100 hours of time devoted to this project, five work planners leveraged PowerAI to geospatially manage and inspect about 5000 distribution poles and performed their own visual inspections of the imagery for 275 poles.

Through the PowerAI interface, they were able to evaluate the AI-developed fault detection labels and to update, add, or remove them. Some mismatches in GIS mapping were encountered. Performance improved over time, but the source(s) of error could not be identified. More broadly, user feedback helped in model retraining to increase inspection accuracy. Post-pilot survey results are summarized below:

- All five participants indicated that their suggested feedback was implemented, making PowerAI more useful for their workflow.
- All five indicated that the AI-based predictions improved over the short-duration project.
- Three of five identified the PowerAI tool as "promising to essential" for drone data management and review.



AI-based deficiency detection, severity assessment (as indicated by the red circle), and labeling help automate and streamline the visual inspection process.

Buzz Solutions performed internal benchmarking throughout the pilot and also noted improved accuracy in AI-detected labeling. Generally, the performance of AI models improves with more training data and when feedback is added, but longer-duration testing and more detailed analysis are required to assess predictive capabilities.

In addition to recognizing the value of PowerAI's inspector-in-the-loop workflow, utility participants identified platform enhancements, such as faster processing capabilities and additional components and diagnostic indicators beyond the default inputs.

Implications & Next Steps

The PowerAI solution demonstrated innovative capabilities as an alternative to traditional methods for performing image-based visual inspection of T&D assets. Newfoundland Power's feedback enabled improvements in the user interface, pole mapping, and deficiency prediction for distribution applications. Buzz Solution's AI-based diagnostics, along with the inspector-in-the-loop and other features, result in a flexible platform capable of advancing utility asset management programs.

Follow-on tasks involve implementation of advanced clustering algorithms for improving locational accuracy and asset tracking, as well as integration of PowerAI with Newfoundland Power's legacy GIS system to support continued technology evaluation, including for inspection of a transmission line segment. In addition, the imagery collected in this pilot is being added to EPRI's growing database to support the development and advancement of AI-based innovations for T&D and other applications.

Resources

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Dexter Lewis, *Principal Technical Leader, EPRI,* dlewis@epri.com

TESTIMONIAL: Buzz Solutions

With AI-based systems and new business cases bringing about a digital transformation in how utilities monitor their infrastructure, the Buzz Solutions team was excited to work with Newfoundland Power and EPRI in demonstrating our technology for efficient inspection of grid assets.

TESTIMONIAL: Newfoundland Power

We service a large territory, which makes it challenging to capture detailed information about the health of our infrastructure. Throughout this pilot project, Buzz Solutions was responsive to our feedback, facilitating an enjoyable experience and improving AI-based deficiency detection. PowerAI enhanced our inspection process, and use cases could expand into other utility workflows.

TESTIMONIAL: EPRI

Seeing PowerAI being applied to improve asset health assessment in real time was very exciting, as visual inspection is very complex, and significant training data are required. Sharing the imagery collected and insights gained during this demonstration will support continued advancement of AI technology for the electric sector. If you are interested in sharing your data, please reach out at AI@EPRI.com!

Automated Drive-By Distribution Asset Inspection

Startup
Noteworthy AI
Stamford, CT

Host
FirstEnergy

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

The increasing severity and frequency of extreme weather and wildfires threaten the reliability, resilience, and safety of the electric grid. Proactive inspection of the inventory of distribution lines can help guide maintenance and safety upgrades to mitigate risk from extreme events. However, currently available inspection methods—from the ground, a bucket truck, or by unmanned or manned overflight—are costly and time consuming and require active worker involvement.

This pilot project tested Noteworthy AI's automated system for distribution asset inspection using machine vision, edge computing, and AI technology deployed on existing utility fleet vehicles. The Inspector Edge pairs a rooftop-mounted high-performance camera with an in-vehicle computer with machine vision software, allowing assets to be surveyed during normal driving. Poles are automatically geolocated, pole-top components are identified, and problems and defects can be diagnosed, drawing on the remote Inspector Cloud. This innovation transforms travel between work sites into an opportunity for passive inspection via collection of real-time data. Benefits include a higher level of asset monitoring and risk mitigation at reduced cost compared to existing processes.



The Inspector Edge's exterior unit features rooftop-mounted cameras for capturing images of roadside distribution infrastructure.

Project Overview

The objective of this pilot project, hosted by FirstEnergy, was to test Noteworthy AI's data capture solution and its ability to collect and analyze high-quality imagery of distribution assets for use across a variety of field inspection functions including GIS cleanup, equipment inventory, and defect detection. The demonstration project scope included the following: install the Inspector Edge system on two FirstEnergy bucket trucks, capture at least 80 hours of field-collected imagery, filter and label the imagery to support AI model development, and assess technology value.

The camera portion of the Inspector Edge system, designed for deployment on diverse vehicle types, was installed on the roof of each bucket truck's cab using a suction-cup attachment, and the computer was deployed behind the passenger seat and plugged into the vehicle's electrical system outlet. Images were captured by driving along pre-defined distribution segments—an urban/suburban setting and a rural setting—and then labeled and used to develop and train an AI model for inventorying pole assets and recognizing problems.

The trained model was deployed to the fielded Inspector Edge units, and a field test commenced: One of the FirstEnergy bucket trucks was driven along a route with 86 existing distribution poles, according to GIS information provided by the utility.

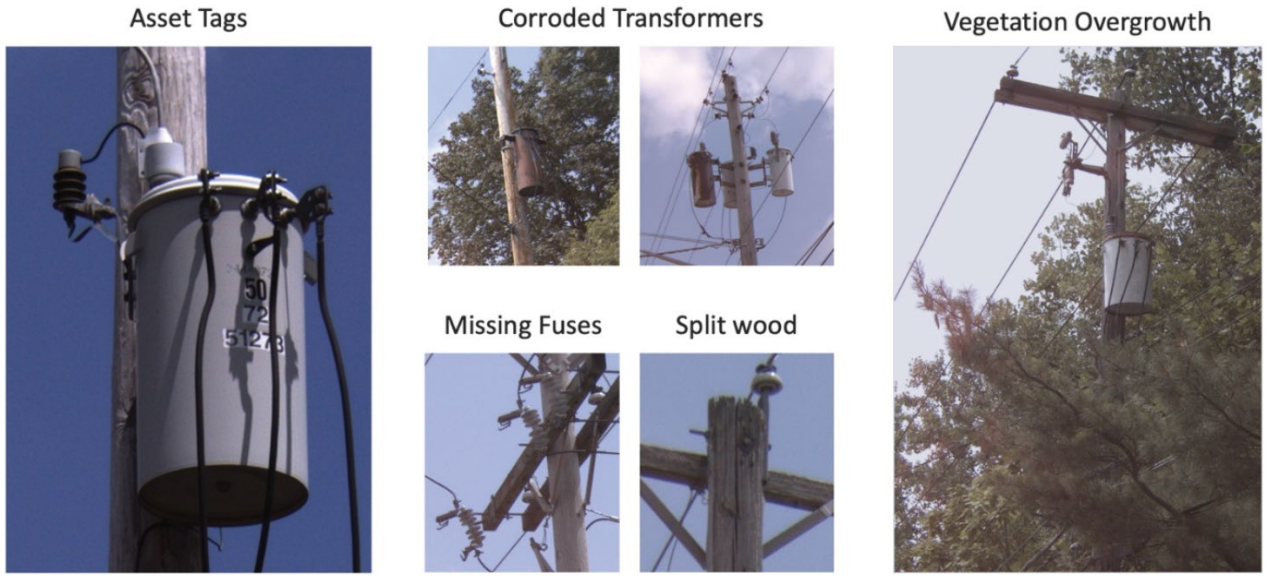
The Inspector solution is active when a vehicle is in motion. The computer vision models, which run entirely on the computer deployed within the vehicle, employ object detection to perform the following tasks:

- **Pole detection and geolocation:** identifies distribution poles and provides the approximate geographic coordinates.
- **Component detection:** identifies pole-top components such as transformers, insulators, cutouts, lightning arrestors, crossarms, etc.
- **Defect detection:** identifies corroded transformers, broken lightning arrestors, damaged crossarms, etc.

Results & Learnings

Approximately 5000 images of distribution poles were captured during drive-by testing of the Inspector solution, and its capability for identifying assets and assessing field conditions was demonstrated. Raw images illustrating examples of corroded transformers, missing fuses, cracked poles, vegetation overgrowth, and asset tags are shown in the photo.

The key challenge encountered in this pilot test involved basic photography 101: getting the shutter speed needed for a vehicle moving at different speeds, getting the aperture opening correct under dynamic lighting conditions, getting the camera angle right while passing by infrastructure, etc. After substantial work by the project team, the Inspector Edge system obtained imagery sufficiently detailed to enable reading of ID numbers on distribution poles.



Digital images automatically captured by the Inspector Edge are suitable for identifying individual assets and for highlighting a variety of potential problems.

In terms of asset identification, Noteworthy AI's solution was able to detect poles ~80% of the time, with an average GPS precision of ~20 ft, over three passes of the vehicle along the drive-by testing route. The success rate was a function of vehicle speed, pole location relative to the road, and other environmental conditions. Additionally, the technology proved capable of accurately identifying pole-top components using the trained object detection model. During this short-duration project, the model's mean average precision improved from 81% to 90% at an intersection over union of 0.5.

Field tests of new and innovative technology often encounter unexpected obstacles, and this distribution inspection automation project was no exception. Key lessons learned relate to attaching and operating the Inspector Edge hardware. The suction-cup mounting approach was improvised because the planned magnetic solution was unsuitable for the aluminum roofs on FirstEnergy's bucket trucks. Also, a battery-powered uninterruptible power supply was added during the pilot to protect the on-board computer from voltage drops experienced during vehicle startup. Production versions will need to include a more permanent mounting solution capable of withstanding frequent tree branch encounters. Additional refinements may be needed to avoid interference with bucket arms and vehicle antennas and to protect the on-board computer.

Implications & Next Steps

Overall, this project demonstrated the feasibility of terrestrial-based distribution asset imaging and data capture from passing utility vehicles.



Building on successful demonstration of AI-based asset identification, next steps will focus on training and testing algorithms for automated detection and proactive mitigation of pole-top problems.

Despite challenges related to vehicle integration and variable lighting conditions, the Inspector system was able geolocate poles, capture imagery, and inventory assets with a high degree of accuracy and precision.

FirstEnergy and Noteworthy AI plan to continue with an expanded pilot in 2022 focused on assessment of Inspector's defect detection capabilities alongside its potential for reducing operations and maintenance costs and improving resiliency to extreme weather. Additionally, Noteworthy AI will apply many of the learnings uncovered during this project to further develop its solution. This includes upgrading the Inspector Edge unit to more easily integrate with vehicle electrical systems, as well as providing more options for mounting the camera unit.

TESTIMONIAL: Noteworthy AI

This pilot provided an opportunity to not only prove Inspector's capabilities with a major utility but also to afford our team with invaluable learnings for advancing our technology. All of the hard work by both FirstEnergy and EPRI during this project is greatly appreciated, and we're excited to continue the relationship.

TESTIMONIAL: FirstEnergy

Building on the overwhelming success of this Incubatenergy Labs pilot, FirstEnergy plans on expanding the project to help develop other use cases for vehicle-mounted imaging and to gain an understanding of the potential for real savings on an enterprise level.

TESTIMONIAL: EPRI

Noteworthy AI's innovative approach demonstrated viability as a utility vehicle retrofit solution for distribution inspection that couples their AI-based analytics with commercial off-the-shelf technologies. Images collected in this pilot also augment our growing AI.EPRI library, and we encourage utilities to share data in support of diverse AI-assisted innovations.

Resources

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Predicting Incipient Failures in High-Pressure Fluid-Filled Underground Cable Systems

ENERYIELD

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

Startup
Eneryield
Gothenburg, Sweden

Host
NYPA

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

High-pressure fluid-filled (HPFF) cables underpin the majority of U.S. underground transmission systems, and many of these cables are reaching or have exceeded their design lifetime of 40 years. Innovative methods for detecting incipient cable failures are needed for preventing high-impact events, improving reliability, and optimizing asset management and maintenance interventions.

This project was initiated to test Eneryield's machine learning (ML) algorithms and other AI-based techniques for generating data-driven insights and predicting imminent disturbances or HPFF cable faults. Eneryield's proprietary AI/ML technology is being developed and applied in a variety of utility and industrial settings for maintaining system health based on insights that are not normally apparent when using conventional situation awareness and condition assessment methods.

Project Overview

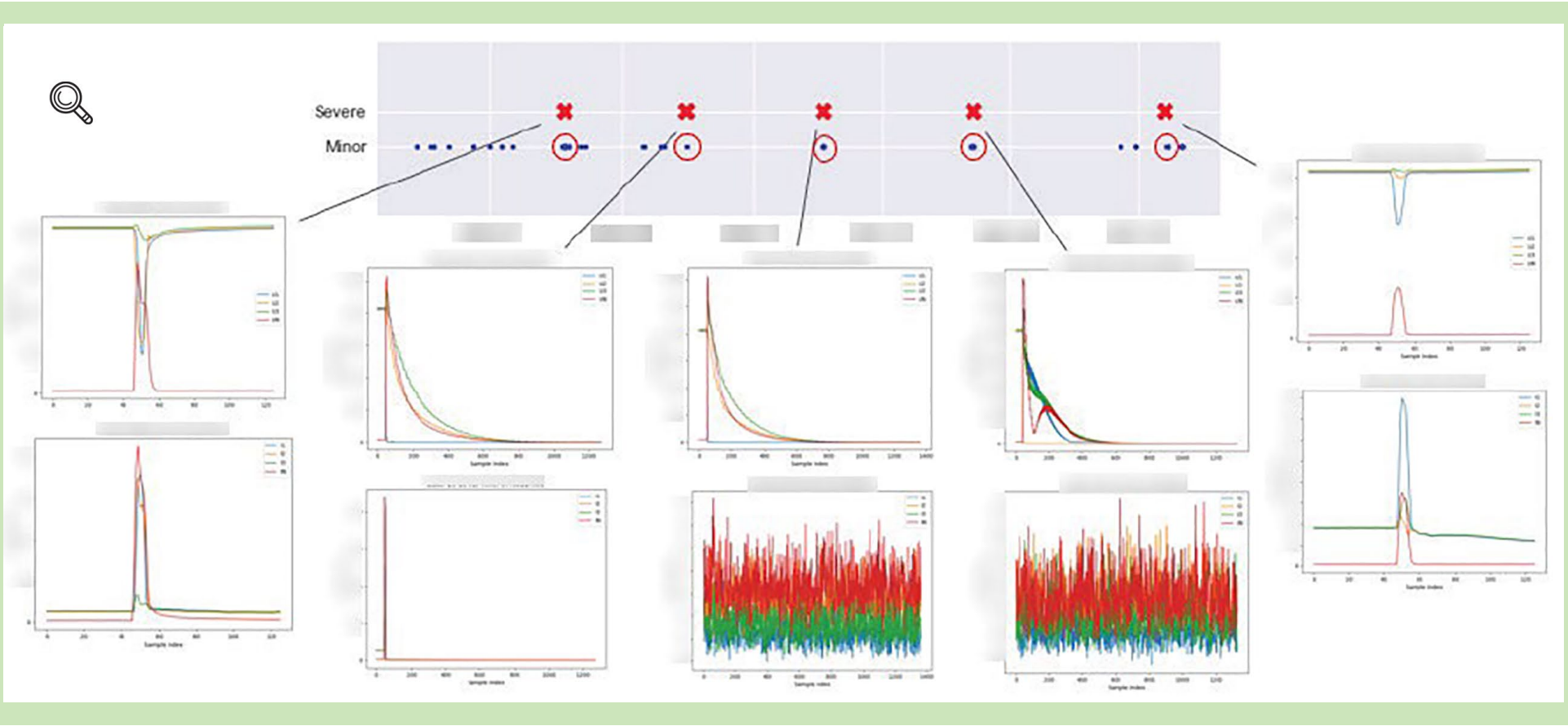
The project team from Eneryield, New York Power Authority (NYPA), and EPRI scoped out the demonstration to focus on collecting and combining historical data from various sources and applying AI/ML techniques with the goal of identifying small anomalies, deviations, and patterns that can be used to predict incipient but larger cable disturbances/faults with as long a time horizon as possible. Key research questions included the following:

- Can AI/ML techniques identify unique data correlations, indicators, and characteristics to help predict incipient failure of buried/underwater cables, going beyond the capabilities of more conventional analysis techniques?
- What are minimum data requirements for getting high value from AI/ML techniques in this application, what level of confidence can be assigned to specific uses, and what are key drivers?



Advanced analytics support early indication of incipient failures in underground/submarine transmission cables.

To support the project, NYPA facilitated access to data resources—including historical records from power quality meters, relays, and phasor measurement units—relevant to the condition and performance of the Y-49 cable system, an underground and undersea connector between Long Island and mainland New York. A total of 155 Comtrade-format data files were initially identified, of which 87 were found to have potentially useful data. The data were divided into two sets, the first used for training of the AI/ML system and the second for validation of its ability to predict faults before they happen using a blind data set from an existing Y-49 cable failure.



Data related to five distinct cable failure events were applied to train and assess the predictive capabilities of Eneryield's AI-based algorithms.

Results & Learnings

Much of the pilot project period was spent acquiring data resources relevant to the Y-49 cable's performance and its occasional failures, filtering and conditioning those data resources to make them useful, and conducting training. In the limited time available for applying AI/ML techniques to generate useful insights, Eneryield was able to identify several instances where clusters of events—including voltage unbalance and transformer saturation—appeared to pre-sage subsequent cable faults. In addition, the techniques were applied to characterize event type and location (upstream/downstream), identify correlations between events, and develop predictive capabilities.

Data related to five severe cable events were provided, including three severe faults used in algorithm training, one severe fault used in validation testing, and another event known to NYPA but not Eneryield. In addition, numerous minor events were identified and subsequently tested to see if they could be used to predict major events.

Preliminary results show that initial cable faults can be predicted within 2 months of occurring and with an 80% level of confidence. Even more impressive, subsequent faults following on the initial one can be predicted within 24 hours of occurring and with a near 100% level of confidence. Given the limited data sets available to the project, these results generally exceeded initial expectations.

Implications & Next Steps

This project's main objective was to test the ability of AI/ML techniques to discover useful information that would otherwise be invisible and, in particular, to apply these techniques to an existing underground transmission asset for incipient failure detection. A secondary objective was to see if the capability to predict failures before they occur is possible even in situations with limited data resources.

The project achieved success on both of these objectives, highlighting the potential for utilities to "know what is coming" and to prepare or take remedial action. Significant additional investigation and development are needed to increase the level of confidence in the results of Eneryield's predictive analysis and to better quantify the frequency of detection errors, including both false negatives (missed failures) and false positives. Further work is planned to focus on identifying additional data sources for training the AI/ML algorithm and for validating the level of confidence in incipient failure predictions.

Resources

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TESTIMONIAL: Eneryield

This project was valuable as a practical demonstration of Eneryield's AI-driven algorithms for supporting proactive maintenance to avoid serious cable faults that could otherwise lead to service interruptions, as well as damaged equipment.

TESTIMONIAL: New York Power Authority

The goal of this effort is ambitious—to develop a technology that can identify the precursors of underground cable faults, predict if and when a fault will occur, and determine the causes of failures. A system that can predict problems and identify causes could be invaluable in maintaining the resiliency of the transmission system not only for NYPA but other utilities as well.

Using Smart Meter Data for Distribution Network Visualization and Management

Startup
Future Grid
Melbourne, Australia

Hosts
FortisBC
VEC

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

The roles of distribution system operators (DSO) will continue to transform due to increasing customer adoption of distributed energy resources (DER), as well as electrification of transport, heating, and other end-use sectors. DER deployment and electrification can create challenges for DSOs by introducing variable renewable generation and by changing energy flows and load profiles, especially on secondary networks where visibility typically is limited. New grid management tools are needed to help DSOs take advantage of DERs and other sources of demand-side flexibility as solutions for improving reliability.



Using smart meter data to gain visibility into low-voltage network assets opens up new possibilities for highly granular distribution system planning and operations.

This pilot project was launched to adapt and test Future Grid's software, which is widely used by utilities in Australia, for providing DSOs in North America with low-voltage network visibility for grid and customer assets. Future Grid's solution leverages advanced metering infrastructure (AMI) for distribution system management by applying smart meter energy consumption, voltage, and power quality data to model secondary networks and support DER detection, grid diagnostics, phase balancing, predictive analytics, grid planning, and other uses.

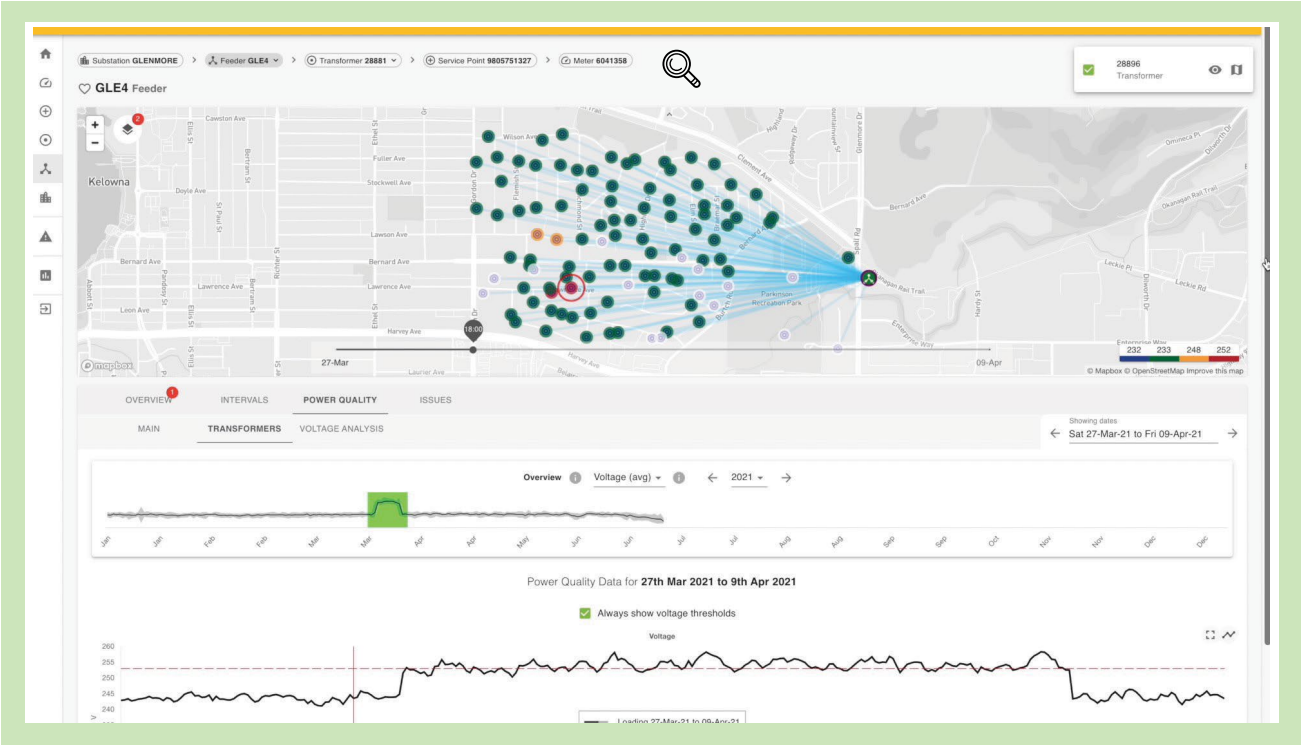
Project Overview

This project engaged Future Grid, EPRI, and host utilities Vermont Electric Cooperative (VEC) and FortisBC, a Fortis company, in pilot software deployments focused on demonstrating the leveraging of both smart meter and GIS topology data for building digital twins of secondary networks supported by analytics that can be utilized to inform operational and planning decisions.

Primary use cases explored for Future Grid software included providing visibility for secondary network assets (tranformers, fuses), detecting DERs and electric vehicles (EV), ensuring voltage compliance, and monitoring and managing transformer/transformer bank utilization. In addition to ingesting data transferred from FortisBC and VEC sites, the pilot project scope involved use of Future Grid's cloud-based software for the following tasks:

- Detection and mapping of power quality anomalies, DER installations, EV locations, etc.;
- Mapping of overall solar PV and EV counts by feeder;
- Visualization of consumption data per site and per meter, transformer, feeder, and substation;
- Visualization of voltage, constraints, and exceptions; and
- Visualization of transformer demand, constraints, and exceptions, including aggregation of exceptions per feeder.

Metrics of success included demonstrating how existing smart meter and GIS data can be used (1) to accurately represent and characterize secondary networks to support operational and planning workflows; and (2) to provide insights for identifying problems, anticipating upgrades or service requirements prior to outages, accommodating the growth in EV and distributed generation and storage, and improving the safety and reliability of the distribution grid.



Future Grid demonstrated the ability to detect utility and customer assets, visualize power quality and other characteristics, and provide insights on the operations of secondary distribution networks.

Results & Learnings

Originally developed for the Australian grid, Future Grid's solution was quickly adapted for use by host utilities in the United States and Canada.

Apart from typical data ingestion difficulties, such as GIS anomalies and obvious data errors, the pilot project went smoothly. Using the software to identify actionable anomalies on secondary networks—such as overloaded transformers, outages, and under- and over-voltage events—proved to be effective and useful.

The project demonstrated the importance of thoughtful design in turning large volumes of data into actionable intelligence. Users found it relatively easy to navigate from a high-level "issues" report in order to check on a particular transformer and its associated meters, and then to actually view the transformer in question via a tie-in to Google Street View. The ability to sort transformers by capacity factor was useful in identifying those with little available capacity, suggesting areas within the network where the utility might be able to take preventive action in order to prevent outages and improve customer service.

The software's intuitive web-based interface also was able to assist FortisBC in identifying and visualizing customer power quality issues. Valuable insights were gained even though the pilot used only data from a single substation, and the data were relatively sparse (60-minute voltage and energy data). Using finer-grained data—for example, at 15-minute intervals or less—is expected to allow Future Grid's software to deliver even more value across a range of use cases.

Implications & Next Steps

Based on the success of this pilot project, FortisBC is working on transferring all of its AMI meter and GIS data—approximately 850 GiB—into the Future Grid platform to see how the tools work with larger data sets. In addition, FortisBC is planning on reprogramming its smart meters for 5-minute intervals and deter-

mining how best to live-stream the data for software ingestion.

Many of the insights gained by Future Grid about differences between the Australian and North American grids have already been incorporated into the software, such as per-phase analysis and visualization for multiphase meters. The company is continuing to enhance its EV charger detection capabilities and plans to collaborate with FortisBC to pilot this feature.

Resources

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Ed Beroset, *Principal Technical Leader, EPRI,* eberoset@epri.com

TESTIMONIAL: Future Grid

This demonstration project tested our solution in a new operating environment, generating learnings both for Future Grid and our utility partners. For example, upon discovering that meters in North America can report multiple voltages because of phase-to-phase arrangements, we modified and augmented our software to enable multiphase visualization.

TESTIMONIAL: FortisBC

Within a few weeks of ingesting an extract of our hourly meter data and GIS distribution network topology data, Future Grid started to deliver results. This has helped us identify minimum and maximum voltage excursions and instances of transformer overloading, and it has provided a more granular view of distributed generation and potential feeder-level impacts.

TESTIMONIAL: EPRI

This Future Grid demonstration showed the value that can be gained by intelligently processing the large volumes of AMI data many utilities already have. Coupling that data with a smart and responsive user interface means that utilities can spend less time learning and more time applying the tool to maintain and improve the grid.

Satellite-Based Post-Storm Disaster Monitoring and Damage Assessment

Startup
LiveEO
Berlin, Germany

Hosts
Ameren
FortisBC

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

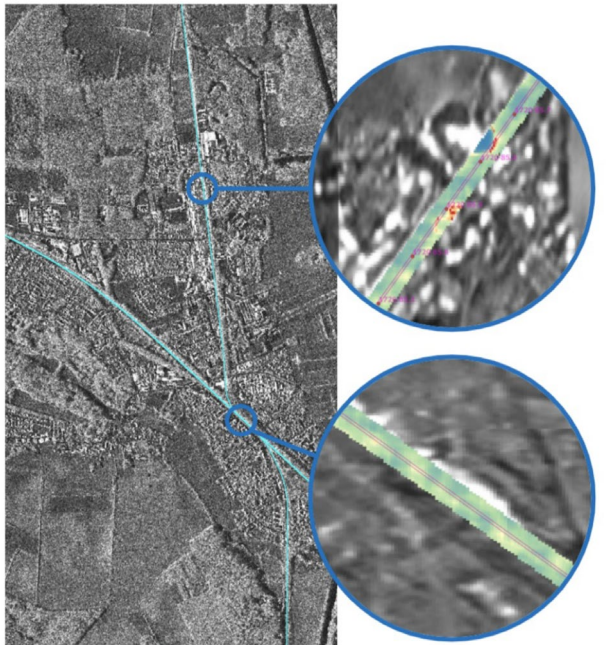
After a major storm event, attaining a comprehensive picture of downed and damaged vegetation along utility rights-of-way (ROW), impacts to transmission and distribution (T&D) infrastructure, and the conditions of access roadways can be time consuming and may delay initial recovery processes. Remote sensing methods like drones cannot operate in many types of weather conditions. For reconnaissance based on typical optical satellite imagery, cloud cover is a major obstacle.

This pilot was initiated to test the damage assessment capabilities of LiveEO's satellite-based solution, which uses synthetic aperture radar (SAR) technology that is unaffected by cloud cover and night to allow near-real-time damage assessment and monitoring. SAR images are acquired before and immediately after storms and are then analyzed using LiveEO's AI-based change detection models. In utility applications, fallen trees and other ROW impacts can be reported as individual detections, heat maps, or additional indicators that can directly inform storm damage repair processes and allow efficient allocation of personnel, equipment, and other resources.

Project Overview

The project—with LiveEO, Ameren, FortisBC, a Fortis company, and EPRI as team members—aimed to provide a proof of concept for swift and accurate detection of storm damage within or near T&D ROWs and local access roadways. The following questions were to be considered:

1. How long does it take to task satellites and capture SAR imagery for a target location?
2. What is the time period required to acquire and analyze the SAR imagery?



Synthetic aperture radar technology provided visibility into on-the-ground conditions within and near a utility right-of-way after a storm in Peoria, Illinois.

3. How high in resolution and accuracy are the SAR images and how effective are the AI-based algorithms in discerning changes within areas of interest?

For proof of speed, LiveEO planned to demonstrate how fast satellites could be tasked, imagery taken, data processed, and useful results supplied to the host utility. Proof of accuracy highlights the precision of the

analytics in processing SAR-based imagery to detect changes on and/or near utility ROWs.

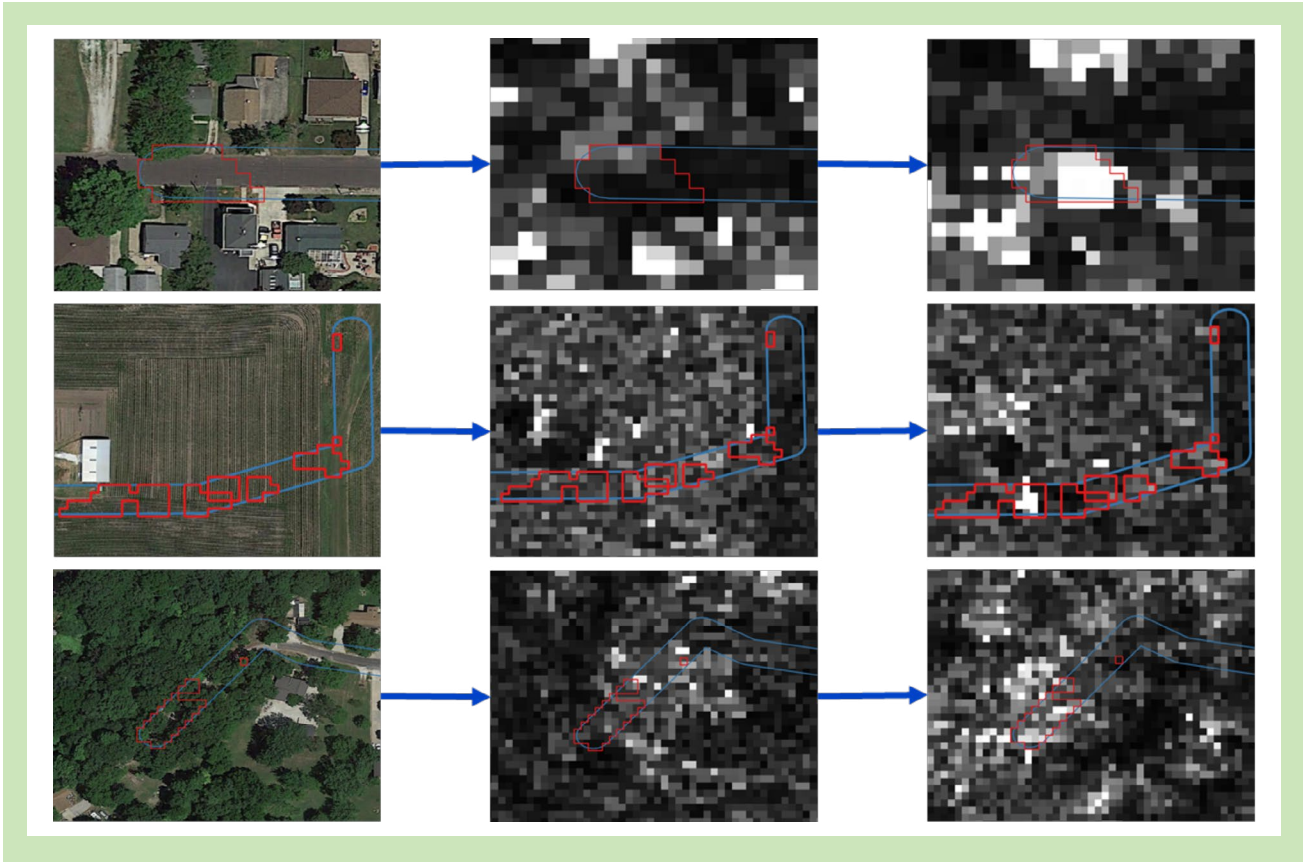
The goal was to test the concept on imagery of two different resolutions—stripmap (about 3 m) and spotlight (about 0.5 m)—for at least one storm event at each host utility and compare the accuracy of the analytics using both resolutions. Ameren and FortisBC picked target zones within their service territories known to be areas of frequent storms that generally result in damage to infrastructure.

Results & Learnings

During the project time window, only one storm met the criteria for both advance prediction and expected severity required to trigger a damage assessment process. Ameren identified a storm in the area of Peoria, Illinois, and notified LiveEO. Within 1.5 hours, a satellite was tasked to capture pre-storm imagery of the area of interest, and within 5.5 hours after tasking, the baseline SAR data were captured. After the storm, another satellite captured imagery of the area of interest.

LiveEO analyzed pre- and post-storm imagery and detected a number of plausible changes in conditions that can be attributed to fallen trees and other damage. Results were provided to Ameren within 17 hours of post-storm imagery acquisition, demonstrating the feasibility of adequate turnaround in producing actionable information relating to storm damage even with the existing constellations of satellites in orbit.

The proof-of-accuracy portion of the project was challenged because the satellites tasked with taking pre- and post-storm images had opposing orbits. LiveEO's AI-based detection method determined that 32% of the area of interest showed a significant change between pre- and post-storm images due to a high number of false positives attributable to differences in viewing direction and angle, which change how SAR is reflected back to the receiver. For example, utility poles clearly visible within a ROW in one image were not evident in a second image of the same location but captured from a different perspective. Even the same satellite, if flying in a slightly different orbit, can complicate the ability to pair images.



Changes detected between pre- and post-storm imagery demonstrate proof of concept for LiveEO's SAR-based approach.

These experiences highlighted the importance of tasking satellites with similar orbits in capturing imagery. Going forward, LiveEO plans to match viewing direction and angle when tasking satellites so that objects in pre- and post-storm imagery will be consistent unless damage occurred. This is expected to increase accuracy but could also extend the time required for image capture. With the increasing number of satellites being deployed, however, turnaround time can only decrease in the future.

Implications & Next Steps

To complete the planned work scope, Ameren, FortisBC, and LiveEO agreed to monitor weather forecasts to identify additional storms suitable for evaluating SAR-based damage detection solution and

assessing progress in reducing the incidence of false positives. Extended work will continue through Summer 2022. Upon successful completion of the project, a path forward for larger-scale technology implementation and evaluation will be defined—potentially through an EPRI demonstration project.

LiveEO also will continue working in both the speed and accuracy dimensions. In addition to being able to acquire images faster due to developments on the satellite operators' side, process improvements will be implemented to fully automate and streamline image acquisition and analysis. Detection accuracy will be improved using enhanced AI-based analytics that can differentiate between different types of damage and produce insights that can be directly integrated in utility processes. Improved delivery of results and insights, such as implementing detection mapping and analysis in LiveEO's web and mobile applications, will be further pursued.

Resources

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TESTIMONIAL: LiveEO

SAR-based detection of storm damage in near real time can produce high-value insights for utilities, other businesses, and governments. Working with experienced partners in the utility space is helping LiveEO further improve our service offering and build a product that leverages the full potential of SAR technology and data.

TESTIMONIAL: Ameren

SAR satellites offer unique capabilities for assessing a variety of vegetation attributes through clouds and at night. By testing SAR sensing capabilities in a real work application, this project has allowed an accurate assessment of state-of-the-art technology with potential for large impacts in improving disaster response and reliability.

TESTIMONIAL: FortisBC

Learnings developed through this proof of concept are helping inform FortisBC's approach for integrating advanced satellite-based remote sensing technologies and data to help improve both gas and electric utility operations.

TESTIMONIAL: EPRI

SAR's capability to capture images no matter the time or weather provides an innovative solution for surveying extensive storm damage as fast as possible. This project introduced utilities to an innovative company pushing the limits of a technology that has the potential to greatly improve the speed of storm damage assessment.

360-Degree, AI-Based Imaging for Wildfire Situational and Locational Awareness

Startup
Pano AI
San Francisco, CA

Host
PG&E
Portland General Electric

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

To improve situational intelligence and emergency response for ignition events and wildfires, utilities, government agencies, and other stakeholders seek new and improved methods to rapidly detect incidents, confirm their locations, and assess risks to critical infrastructures and communities. Current methods rely on many data sources, with incomplete coverage, significant noise, and no single source of truth. Fire starts can go unnoticed for too long, and quickly determining whether reported incidents are real fires, identifying exact locations, and evaluating risk factors can be difficult.



Pano AI stations deployed on existing towers (left) deliver live-feed images that are analyzed for smoke detection (right) and wildfire risk assessment.

This project was launched to demonstrate Pano AI's Rapid Detect platform, which applies continuously rotating cameras sited atop existing mountaintop towers to capture live images across broad areas, backed by AI-based methods for automated smoke detection, risk assessment, confirmation, and alerting. The cameras rotate 360 degrees every minute, delivering ultra-high-definition images that cover the entire field of view. The platform's web interface stitches images together into panoramas that can be simultaneously viewed and manipulated by multiple users. Features such as incident location triangulation and mapping relative to utility infrastructure and other GIS layers help users quickly assess whether individual alerts require further investigation.

Project Overview

The specific objective of this pilot demonstration was to assess the capability of Pano AI's platform for rapid and accurate detection of new wildfire threats and delivery of valuable situational awareness intelligence to help inform utility response and incident escalation decisions. The project team included Pano AI as the technology developer, Portland General Electric (PGE) and Pacific Gas & Electric (PG&E) as host utilities, and EPRI as technical advisor. In addition, a group of peer utilities—including Southern California Edison and Xcel Energy—participated in a series of project check-ins.

Site identification, analysis, and selection included drone-based audits of existing towers to assess camera mounting requirements, as well as reviews of physical accessibility, power supply, connectivity, permitting, and other needs. The PGE pilot included installation and web-based access to two Pano Stations. The PG&E pilot included access to 13 stations in the utility's service territory.

Each pilot ran through the end of the 2021 fire season and included support from the Pano Intelligence Center (PIC), which applies machine learning across data collected from all Pano Stations—a total of 23 in the western United States during 2021—to confirm smoke sightings and validate each incident and its risk before issuing alerts.

Metrics of success for the project included the following:

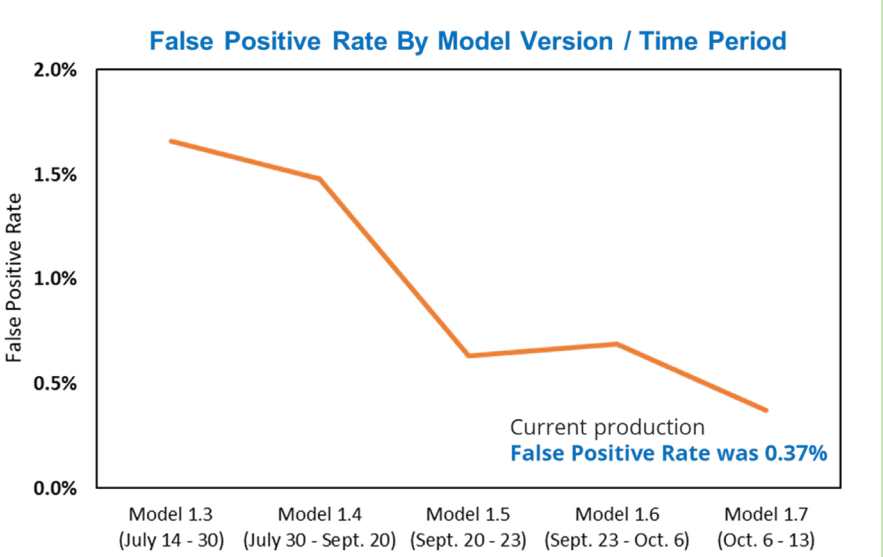
- **Time to detection for each incident with visible smoke:** Compare time to detection by Pano AI's system relative to when the smoke becomes visible in camera images, to the earliest known detection time, and to alerts received by utilities subscribing to the Integrated Reporting of Wildland-Fire Information (IRWIN) service.
- **Accuracy of detection:** Characterize accuracy of detection for wildfires caught during the 2021 fire season, accounting for false positives, true positives, false negatives, and true negatives.
- **Incident intelligence and software functionality:** Demonstrate triangulation (smoke location) accuracy, intuitiveness of the platform, and ongoing improvements to functionality and performance based on team feedback.

Results & Learnings

Although the recommended spacing of Pano Stations is about 10 miles (16 km) to facilitate incident triangulation, Pano AI's platform demonstrated wildfire watch and risk assessment capabilities spanning 360 degrees out to distances of about 25 miles (40 km) on clear days.

Because each camera rotation takes 1 minute, the fastest possible time for a confirmed detection would be for an imaged location to have no visible smoke, followed by a detection of smoke 1 minute later and a PIC confirmation of smoke on the next rotation. Throughout the pilot, the time to detection improved. Based on the final November production model and a control group of test vegetation fires, Pano AI's platform was able to detect 60% of the test fires within 4 minutes from the time smoke was first visible and 85% within 10 minutes.

Also, the number of false positives decreased throughout the pilot as the AI-based models improved. As shown in the figure, the false positive rate was about 1.6% in late July, declining to 0.37% in early October. Across more than 50 wildfire alerts sent to utility customers during the pilot, the alerting accuracy rate was above 90%.



Learning by AI-based models reduced the false positive rate during the pilot project, helping utility analysts focus attention on actual incidents posing potential wildfire risks.

For the Round Fire in northern California, which started in a recreational vehicle and eventually spread to vegetation, Pano AI detected smoke and issued an incident alert before the fire was reported to first responders. The PIC played a key role throughout the pilot in reducing the noise from false notifications by successfully pre-screening false positives attributable to industrial smoke, geyser plumes, dust clouds, and more.

The ability to apply a network of Pano Stations to accurately triangulate an incident's exact location and view its proximity to utility infrastructure helped analysts quickly assess whether detected incidents should be escalated, in terms of a deeper investigation or a rapid response—for example, reducing transmission line ratings or de-energizing circuits.

To facilitate their analyses, users took advantage of the software's customizability to add their own visual intelligence layers. The project team also identified a number of new functionalities that were implemented by Pano AI. This included a bearing scale and compass and map view widgets to enhance locational awareness while looking at images, as well as time-lapse and look-back features and email incident updates to improve situational awareness.

Implications & Next Steps

This demonstration highlighted the value of 360-degree imaging and AI-based tools for improving wildfire awareness by reducing the need for manual

monitoring and confirmation while decreasing the time required for smoke detection and incident alerting. Pano AI's Rapid Detect platform is now commercially available, and the company is working to build partnerships with utilities, forest managers, and state and local fire agencies.

A key lesson learned from this project is that confirmed incidents need context that can be quickly assimilated to decide which events should be monitored to closure and which events need to be escalated. The platform's ability to overlay detected incidents on maps displaying infrastructure and other features proved particularly valuable for informing utility decisions. EPRI and other project participants are exploring opportunities for integrating Pano AI's system and its results with other wildfire information sharing and dissemination platforms.

Resources

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TESTIMONIAL: Pano AI

Because minutes matter in wildfire response, our vision is to make the jobs of situational awareness teams, emergency dispatchers, and first responders easier while improving their effectiveness. As demonstrated in this pilot, we're deploying Pano Stations and improving our AI-based tools and intuitive software to help prevent small flare-ups from becoming massive infernos—and help save lives and avoid destruction.

TESTIMONIAL: Portland General Electric

Leveraging technology to enhance wildfire situational awareness is essential to help combat the increasing risks utilities and communities are facing due to climate change. Early detection from AI-enabled cameras promises to help locate and inform response to fires before they become uncontrollable.

TESTIMONIAL: EPRI

While fixed and panning cameras are commonly applied for wildfire detection, Pano AI's innovation delivers a 360-degree view that provides minute-by-minute situational and locational awareness on fire outbreaks—up to 25 miles out in all directions!

Wireless, AI-Powered Cyber Anomaly Identification

Startup
ThermoAI, Binghamton, NY

Host
EPRI

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

Detection of cyber security events is paramount to the defense-in-depth strategies applied by electric utilities. Past events have shown that sophisticated attacks can go several months or more before being detected. In part, this is due to technical challenges associated with identifying and analyzing operational anomalies in industrial control systems (ICS), including visibility gaps for non-networked but critical assets, disguised attacks and evasive measures by attackers, and conflicting needs to maintain vigilance while minimizing false positives.



External sensors positioned on pumps were used for building digital twins and detecting and diagnosing operational anomalies.

This project sought to establish proof of concept for use of ThermoAI's process optimization solution in creating digital twins of power plant systems, comparing them to real-world operating conditions, identifying and classifying anomalies, and detecting cyber security events. Typically, ThermoAI deploys wireless sensors—in addition to existing sensors used for instrumentation and control (I&C) applications—to collect the data required to build digital twins for modeling and optimizing industrial processes. Cyber security monitoring and protection represent a novel application.

Project Overview

The project team included ThermoAI and subject-matter experts from AI.EPRI and EPRI's digital I&C laboratory, where the proof-of-concept study was conducted to provide a controlled and safe environment for deploying different sensor technologies and introducing off-normal operations as a basis for anomaly detection and classification. The lab setup consisted of two closed water flow loops, each circulating water from a surge tank through a pump with heaters and back into the tank. The recirculating loops also included cross-connects for moving water between the two tanks when desired.

The project was divided into (1) sensor selection and architecture, (2) deployment and data capture, and (3) model development and analysis. The cyber security

sensor system was designed to capture acoustic, vibration, and motor current data from a single component using a wireless network isolated from existing I&C sensors in the flow loop. LoRa network technology was chosen for in-plant testing as a means of creating a separate out-of-band network to improve visibility and make evasion more difficult since attackers would have to compromise both the security sensor network and the normal ICS network.

The sensors were deployed to collect normal operational data for one shift. Four simulated attack scenarios were then performed to represent an attacker's manipulation of the system:

- **Malicious insider locally over-riding controls,** resulting in pump cavitation (Scenario 1).
- **Attacker changing logic** by operating pumps at constant speed and controlling flow by throttling the discharge valve (Scenario 2).
- **Attacker changing setpoint** by fixing discharge valve to positions of 50% and 75% open (Scenarios 3 and 4, respectively).

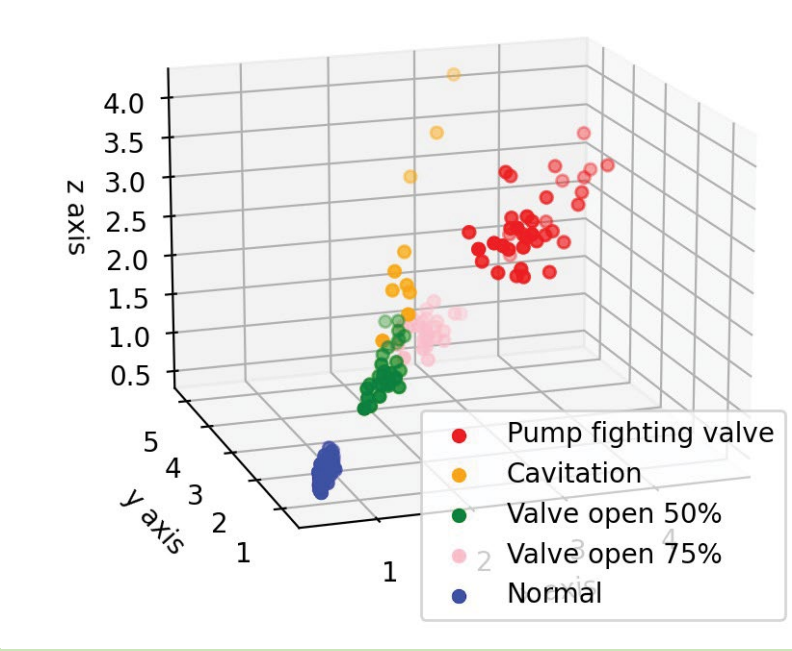
Collected data were used to train AI models on normal operations, generate digital twins of the pumps, and detect and classify deviations from normal conditions.

Results & Learnings

The lab-based cyber threat detection system demonstrated the capability to use digital twins and machine learning to identify and classify physical anomalies and to differentiate between different anomalies having different levels of severity. The figure at right displays results of a comparison between triaxial vibration measurements and physics-based modeling, with normal operating conditions and individual attack scenarios differentiated with a high degree of accuracy.

Scenario 1, illustrated in orange and labeled "Cavitation," represented an attack where a malicious insider overrode the system valve lineup, causing surge tank level to drop and a loss of static head to the pumps. This resulted in pump cavitation. While this scenario replicated a malicious insider, it could have also been caused by several other attack modes.

Scenarios 2, 3, and 4 represented cases where the attacker modified parameters to inhibit control functions—a technique exhibited in a number of real-world ICS attacks. Scenario 2 is shown in red and labeled "Pump fighting valve" to illustrate the abnormal control configuration. Scenarios 3 and 4 are shown in green and pink and represent the discharge valve being repositioned to 50% and 75% open, respectively.



Vibration anomaly identification and classification results demonstrate that machine learning models can differentiate anomalies indicative of cyber attacks.

While these controlled-testing results show that vibration modeling can aid in the classification of anomalies ranging from component degradation to cyber attack tactics, techniques, and procedures, this approach has real-life limitations due to the myriad factors that can influence vibrations.

The pilot also provided useful information on applying a LoRa network system to support online monitoring of hard-to-reach plant components, including for detection of cyber attacks.

Implications & Next Steps

This project represents a successful first step in developing an integrated physics-based cyber detection capability based on AI techniques. EPRI is continuing research and prototyping of tools to utilize physics-based models and network security data to enhance cyber detection and response capabilities.

One of the limitations of this lab project was its reliance on a relatively small set of training data collected under steady-state operating conditions. Next, ThermoAI seeks to deploy and demonstrate its solution in operating power plants. Field demonstrations will help to create digital twins based on a greater amount of historical data and to train the data models to

identify more types of anomalies over a wider array of conditions, including normal transients.

Complementing the insights gained in this project, ThermoAI plans to leverage field demonstrations as an opportunity to further productize its solution package to best fit within existing workflows for monitoring, diagnostics, and cyber security protection and to more easily integrate with existing I&C equipment and normal plant operations. This includes development of a platform and process for deploying LoRa wireless sensors to ensure secure and accurate data collection, as well as libraries of anomalies and causal factors for specific ICS applications.

Resources

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TESTIMONIAL: ThermoAI

To best guard against cyber attacks, prevention is ideal, but detection is a must. We see a strong case for using our AI to cross-check current monitoring and diagnostic systems and to immediately detect operational technology intrusions with potential for disruption and damage to vital equipment.

TESTIMONIAL: EPRI

There are many ways, beyond malware, that attackers can use in attempting to compromise systems. These can be difficult to detect. Including physical models and data sets in cyber data analysis may provide another tool for detecting sophisticated attacks.

Zinc Manganese Dioxide Battery for Long-Duration Stationary Energy Storage

Startup
Urban Electric Power
Pearl River, NY

Host
EPRI

Technology Solution

Energy storage is a key enabling technology in the electric grid's ongoing transformation to generate cleanly, be more resilient, and host ubiquitous distributed energy resources. Battery energy storage systems are being deployed to help increase the value of renewable generation at distributed and utility scales, provide customers with uninterruptible and backup power supply services, and meet grid support needs over durations of up to several hours.

This pilot focused on performance testing of zinc manganese dioxide ($ZnMnO_2$) batteries developed and integrated into an energy storage system by Urban Electric Power (UEP) for long-duration applications. UEP's technology leverages the same chemistry used in familiar "AA" alkaline battery cells, drawing on abundant and affordable raw materials but instead rechargeable for grid-tied energy storage. Cells are compliant with applicable safety standards and, unlike lithium ion technology, are not susceptible to thermal runaway. UEP manufactures its batteries and assembles its storage systems in New York, and balance-of-system components also are made in the United States. In addition to uninterruptible power supply (UPS) products, UEP is developing energy storage solutions expected to reach commercial readiness in 2022 for customer and utility applications.

Project Overview

In this pilot project, EPRI and UEP collaborated to investigate the performance characteristics of the company's $ZnMnO_2$ battery storage system, assess suitability for utility use cases, and inform product development. Key project milestones included system manufacturing, shipping to the test site, system installation and commissioning, characterization testing according to Energy Storage Integration Council (ESIC) protocols, and use case testing.

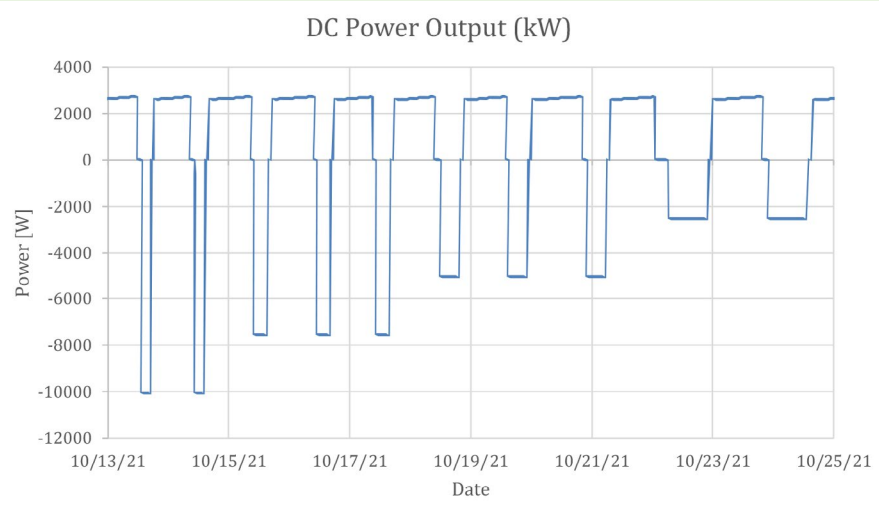


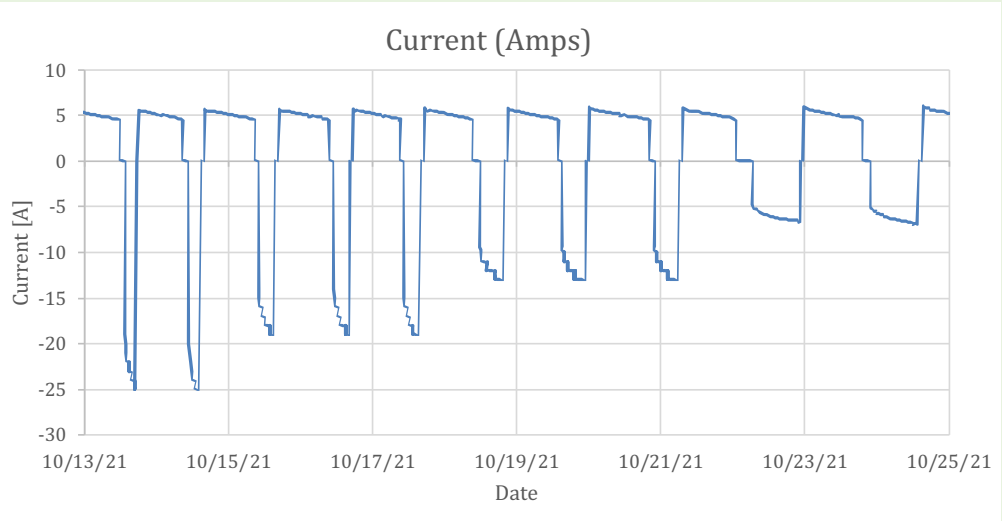
Like other stationary storage battery platforms, UEP's technology offers the advantages of modularity—but $ZnMnO_2$ batteries also are based on materials that are globally abundant and not subject to thermal runaway.

The $ZnMnO_2$ system under test has the following specifications:

- Rated power: 10 kW
- Maximum power: 20 kW
- Rated energy: 40 kWh
- Maximum energy: 60 kWh
- Operating voltage range: 600-350 V_{DC}

Due to technology challenges encountered with characterization testing at EPRI's SolarTAC facility in Colorado, a duplicate $ZnMnO_2$ system was manufactured and installed at UEP's factory in New York to support a parallel testing program.





Sample energy capacity testing results show power (left) and current (right) levels through 12 charge/discharge cycles performed at various rates. Discharge periods ranging from 4 to 16 hours demonstrate the UEP storage system's applicability for long-duration use cases.

Results & Learnings

The tight timeline for this project required expedited battery manufacturing and system assembly, as well as alternative sourcing of some components, such as the battery racks. Nonetheless, manufacturing and installation proved straightforward and were completed on time.

System characterization testing following ESIC protocols—including charging/discharging to establish nameplate power and capacity—was performed at SolarTAC and is ongoing at UEP's facility, to be followed by use case testing. Test results like those shown in the above graphs have been revealing in demonstrating discharge periods ranging from 4 to 16 hours applicable for long-duration energy storage use cases. Deployment experiences also are providing feedback to product development.

Additional commissioning support for demonstration and pre-commercial energy storage systems will help ensure batteries arrive safely, are monitored during initial use, and set up for optimum operation. The devices tested at SolarTAC and in New York do not incorporate a battery management system (BMS) as $ZnMnO_2$ technology does not require one. Learnings from the testing have prompted UEP to evaluate how BMS integration could improve performance and functionality for end users.

In addition, a power inverter designed to meet the unique needs of rechargeable $ZnMnO_2$ batteries is planned. UEP's batteries are compatible with commercially available power electronics, but most inverter products have voltage ranges that are too narrow, which usually results in underutilization of energy capacity.

Implications & Next Steps

Pilot project results highlight the potentially broad applicability of UEP's stationary storage technology. Use case testing will proceed once characterization testing is complete. Applications to be examined include peak load shifting, resiliency, and even substation power backup.

After successful completion of testing, UEP will look to deploy additional $ZnMnO_2$ storage batteries in collaboration with partner utilities and in demonstration programs administered by the California Energy Commission and New York State Energy Research and Development Authority. While current system controls are sufficient for a test environment, end users may require a more user-friendly control platform. Enhanced battery and energy management systems will be considered for use in future UEP installations.

Resources

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TESTIMONIAL: Urban Electric Power

Gaining traction with a new battery technology can be challenging because prospective users and deployment partners have questions around performance and safety that must be addressed. Incubatenergy Labs has provided an ideal platform to generate a credible data set and demonstrate our energy storage system's characteristics in a collaborative environment while gaining access to leading utilities.

TESTIMONIAL: EPRI

Working directly with the developer of a promising technology for long-duration energy storage is very exciting given the electric sector's great need for new options with potential for broad applicability and many high-value uses. Independent testing under controlled conditions also has provided feedback to help UEP accelerate the commercialization of its rechargeable alkaline battery energy storage system.

Intelligent Voice Assistant for Substation Job Planning by Field Workers

conEdison, inc.

Startup
Datch,
San Francisco, CA

Host
Con Edison

EPRI ARTIFICIAL • INTELLIGENCE

Technology Solution

Existing utility work planning processes can require field employees to spend time manually entering data and work plans using enterprise and third-party software, imposing an administrative burden that takes away from valuable work time. The ability to dictate job task requirements in the field would speed up the process of filling out work plans, completing work orders, and moving on to the next task.



Providing field workers with Datch's technology creates the opportunity to replace legacy work planning processes, like manual data entry or hand-written notation as shown here.

In this pilot project, intelligent voice assistant technology developed by Datch, Inc., was deployed in a test integration with Con Edison's existing third-party work planning application, Engage. The Datch Assistant app enables workers to interact with multiple databases simultaneously through a single interface that draws on AI techniques to support intuitive and natural conversations. Voice commands can then replace tedious frontline work processes, such as the manual entry of work plans, work orders, maintenance logs, safety reports, and other records.

Project Overview

Con Edison and Datch collaborated on this pilot to demonstrate and test the efficacy of using voice commands to conduct field-related administrative tasks in an effort to alleviate the burden of manual data entry while creating a richer system of records within Engage. The target work group within Con Edison was field supervisor and substation manager staff.

Con Edison selected specific staff members to perform the field demonstration tests with the goal of minimizing distractions, enabling consistent workflow analysis, and facilitating comparison to traditional methods. These staff baselined the current work process by conducting a series of timed, documented tests using the traditional method.

The Con Edison-Datch project team collaborated to securely integrate the Datch software with the appropriate utility enterprise resource planning (ERP) systems, first walking through the work process and describing which data fields and types to collect—such as names, numbers, codes, or freeform text—and the system structure. Datch's natural language processing training algorithm was applied to conversationally map the process before moving to the integration phase with

Con Edison's third-party work order management and job planning software.

In the field demonstration, Con Edison staff previously involved in baselining the work planning process used the Datch Assistant app to fill out job plans for work at Con Edison substations. To gauge the success of the proof-of-concept pilot, user experience, accuracy, and speed were identified as metrics for comparing the Datch work plan capture to that of the traditional method.

Results & Learnings

The process of mapping Con Edison's work planner process into the Datch interface was straightforward. This setup was quite typical for new Datch processes, which can be defined and trained rapidly—usually within in a few days. A key challenge involved timely integration with Engage, the third-party ERP system, on top of Con Edison's Maximo ERP database, while meeting the security requirements for both.

While ERP integration challenges were addressed within the compressed pilot schedule, the project team did not have sufficient time to fully test or confirm the Datch Assistant app's efficacy in reducing administrative burdens relative to the current job planning process. Key initial learnings are summarized below, with continued user testing and iterative optimization planned.

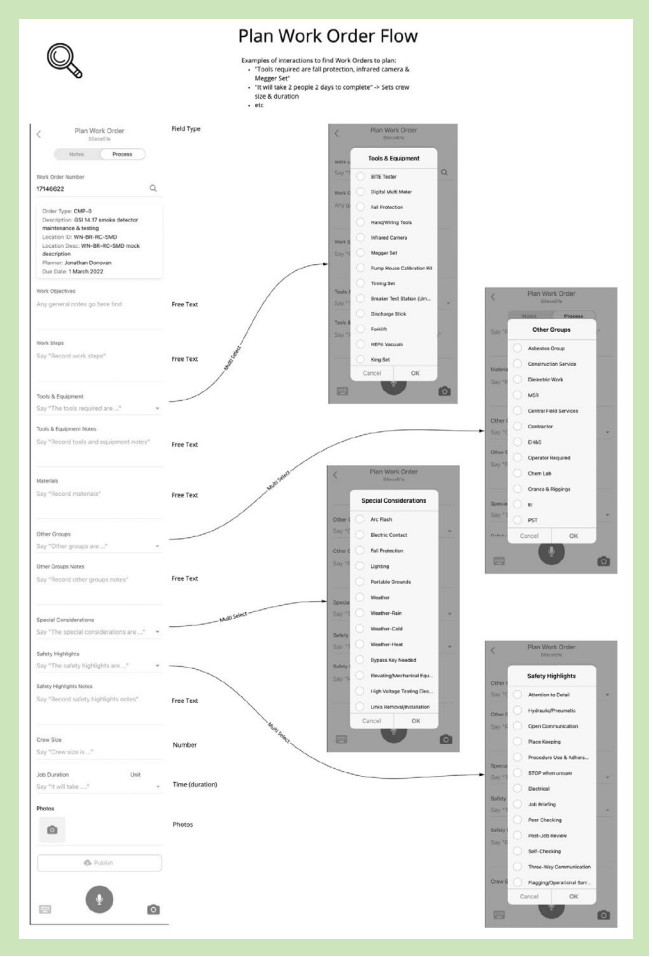
Integration. Understanding the security requirements of utility information technology (IT) systems (and third-party providers where applicable) is essential in planning efficient integrations. Some required fixes that became evident during the user testing stage of this pilot could have been identified and addressed earlier through proactive engagement of several IT stakeholders.

User feedback. Experiences in implementing, training, and comparing the Datch application against a manual data entry process—one that workers are comfortable with and have already optimized—highlight the importance of deeper user engagement. For example, the current process uses pre-populated fields in the work planning data collection application, and some Con Edison staff members employ "templates" as a starting point. These enhancements streamline data entry and are being implemented through Datch. Further, job planners employ various slang or shorthand terms for assets, processes, etc. Due to the short duration of this demonstration, the self-learning algorithms did not have sufficient time to adapt to the use of jargon.

Implications & Next Steps

The project team has continued with iterative testing and refinement of the Datch Assistant to help work planners adjust to using the app, explore features, and assess the potential for time savings and other benefits compared to current manual data entry processes. Con Edison intends to collaborate with Datch and EPRI to explore additional job planning tasks and other workstreams that may lend themselves well to using voice to record information in the field.

To support future applications and multiple parallel process implementations in daily utility operations, Datch is bringing in additional IT resources and plans on engaging subject-matter experts in each integration area, especially relating to security protocols, prior to beginning the integration process. Early engagement of end users for the voice assistant app also is essential to map out the work planning process and capture jargon, shortcuts, and other approaches currently used to optimize workflows suited to individual work style.



Workflow processes integrated in the Datch Assistant facilitate data entry by voice, through structured conversation.

Datch plans to build canned utility processes and data into the Datch data entry to match efficiency gains realized using the traditional method of data capture, as well as to develop new features to improve the Datch interface and make worker tasks easier and less administrative. This includes enhancements proposed by Con Edison such as assisted mode, to guide users through tasks without having to consult a screen; and

context sharing, to allow specific knowledge being captured by teams in one process to be shared with other processes or systems in order to reduce friction even further for field workers.

Resources

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TESTIMONIAL: Datch

The Datch team is proud to have worked with Con Edison and other project team members, and we appreciate their assistance and patience with the complexity of the integration and user testing and in helping us iron out problems rapidly when they arose. We look forward to continuing the current pilot, adding new processes, completing a rigorous assessment of the user experience, and improving functionality to match expectations.

TESTIMONIAL: Con Edison

This proof-of-concept demonstration is pushing the industry forward by illustrating the transformative possibilities of using voice assistant technology to complete common tasks by utility field workers. The Datch app, if fully integrated into current work processes and able to accurately translate complicated jargon, shows significant promise across various use cases at Con Edison.

Instructor-Led, Live-Streamed Augmented Reality Training for Remote Workers

conEdison, inc.

Startup
Design Interactive
Orlando, FL

Host
Con Edison

Technology Solution

Today's utilities have large and distributed workforces, and many face increasing attrition and challenges maintaining institutional knowledge. Worker training and development are essential, especially when job functions are added and specifications revised. Conventional face-to-face training at centralized facilities requires travel time, can be expensive, and introduces risks in a time of pandemic. Online learning has limited applicability for numerous utility field worker roles and skills. The ability to provide live-streamed, hands-on training to remote workers would help utilities transfer knowledge safely, effectively, and at scale with less disruption to productive activities in the field.



Augmented reality technology gives expert instructors the ability to provide remote trainees with a live, hands-on view of tasks as they are performed.

This pilot project was established to test an instructor-led augmented reality (AR) training system developed by Design Interactive (DI) for use in delivering live training to remote utility workers. XRMentor™ is a cloud-based authoring tool that helps instructors create AR training modules that feature live interaction and incorporate existing training content and resources, such as video, schematics, and 3D CAD models. ClassroomXR™ delivers the instructor-led modules using an off-the shelf AR headset, the Microsoft HoloLens 2. Following the "See One, Do One, Teach One" method, the expert first demonstrates a task in a live-streamed training session while attendees watch and interact. After, attendees can perform the task themselves using how-to guides and other resources and use video collaboration features to connect with the instructor to confirm task completion or make corrections.

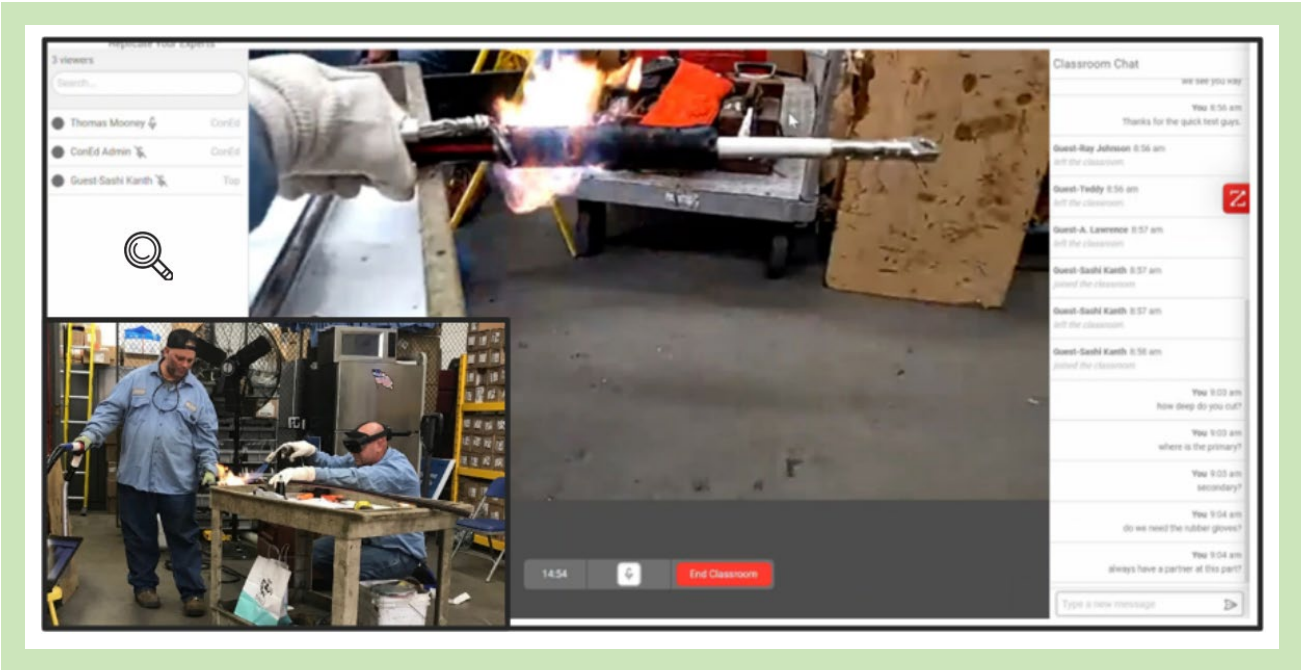
Project Overview

In this project, a team involving DI, Con Edison, and EPRI focused on demonstrating the ClassroomXR feature and addressing the following questions:

1. Can ClassroomXR be evaluated in a practical, representative training scenario, and is it an asset that makes the hands-on learning experience a positive activity?
2. What is the marginal cost of ClassroomXR over traditional training technologies, and does the technology hold value for utility training operations?
3. Does ClassroomXR support a positive, quality training experience from the perspective of instructors and trainees?

DI conducted a 2-day, in-person train-the-trainer session at Con Edison facilities, including a demonstration of the HoloLens 2 and lessons on creating training modules using XRMentor and deploying training content using ClassroomXR. Con Edison operations and training staff selected an underground distribution task for the training pilot—installation of a cold-shrink "hammerhead" cable termination, a newly enhanced process for completing an otherwise familiar task. Providing attendees in a live classroom with a clear view of what the instructor is doing would be difficult. In addition, due to the hands-on nature of the task, traditional online e-learning would be insufficient.

DI and Con Edison collaborated in developing an instructor-led training procedure. This included creating a 3D hologram of the hammerhead, as well as additional images and instructional content. Con Edison team members developed the instructor script and practiced its delivery while receiving feedback from remote DI staff and other project participants, with the goal of performing a live ClassroomXR session using Con Edison's information technology network.



Expert instructors live-stream training from the HoloLens 2 through ClassroomXR.

Results & Learnings

Generally, about 40 to 60 hours of development time are required to create 1 hour of instructor-led training. Two expert utility cable splicers from Con Edison—with no prior experience teaching or with using AR technology or e-learning training development software—were able to learn to use the XRMentor software and the HoloLens 2 such that they were confident enough to schedule and conduct a live-stream ClassroomXR training session after 40 to 80 hours of investment. Considering the need to use a new training technology and novel hardware device, the marginal cost of using DI's system to develop and deploy an expert-led training module was modest with respect to traditional methods.

Technical issues beyond the control of the project team precluded the live ClassroomXR session from being conducted on Con Edison's internal network. The demonstration was thus conducted using a hotspot device. Remote Con Edison, DI, and EPRI team members joined the ClassroomXR event from Windows-based computers at a secure website. The Con Edison instructor, wearing a HoloLens 2, then initiated the live stream, enabling remote attendees to view a first-person perspective from the AR headset.

While performing the live, hands-on demonstration of the cold-shrink hammerhead process, the instructor was able to stop at different points to ask questions and interact with the trainees. Remote attendees could watch and hear the instructor as the procedure was performed, see all the visual content added to the AR training module, communicate verbally just as if they were in the room with the expert, and use the chat feature in the ClassroomXR interface.

DI's virtual learning and AR technology solution allowed a Con Edison expert with no experience in worker training to develop and deliver a live-streamed, hands-on training session to remote workers on a new field installation task that has clear safety implications for field personnel.

Implications & Next Steps

This pilot demonstrated that applying XRMentor and ClassroomXR with the HoloLens 2 provides a unique, user-directed, hands-free platform for increasing the efficiency and efficacy of training remote workers. With a small investment in "train the trainer" time

focused on best practices for content creation and live delivery, XRMentor enabled an inexperienced instructor to capture and deliver technical expertise and facilitated the use of existing resources as content. Remote attendees graded the learning experience positively, suggesting that the live, first-person perspective offered by the HoloLens 2 had particular value for the chosen training application.

While a full test on Con Edison's corporate intranet was challenged by cyber security hurdles and connectivity issues, this project demonstrated that utility employees can quickly learn to use DI's technology, and that AR-based training has potential to deliver value above that of traditional training technologies with marginal additional investment of resources. The project team is planning a full demonstration.

DI also plans to apply experiences from this project in helping ensure seamless onboarding and integration processes for additional utilities and other customers. Additionally, EPRI will investigate specific utility industry training scenarios that may be particularly amenable to use of the XRMentor tool and ClassroomXR features.

Resources

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TESTIMONIAL: Design Interactive

This engagement provided great insight into the value of augmented reality and live-streamed training for the utility industry. Project participants quickly learned to use our technology and responded positively to the experience—both utility instructors and trainees. We come away with a better understanding of the needs of the utility community and collaborative ideas on how to improve our product moving forward.

TESTIMONIAL: Con Edison

XRMentor and ClassroomXR give Con Edison the ability to empower our experienced and expert workers to create training modules and share their exceptional knowledge with co-workers. Instead of bringing personnel to our corporate learning center, these technologies can be used to deliver knowledge to field workers. We look forward to demonstration of their full capabilities.

TESTIMONIAL: EPRI

This engagement with Design Interactive showed a practical way to effectively use augmented reality in the utility training environment. As partnerships develop and lead to demonstrations, EPRI plans to monitor progress and publish results to facilitate broader industry adoption.

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