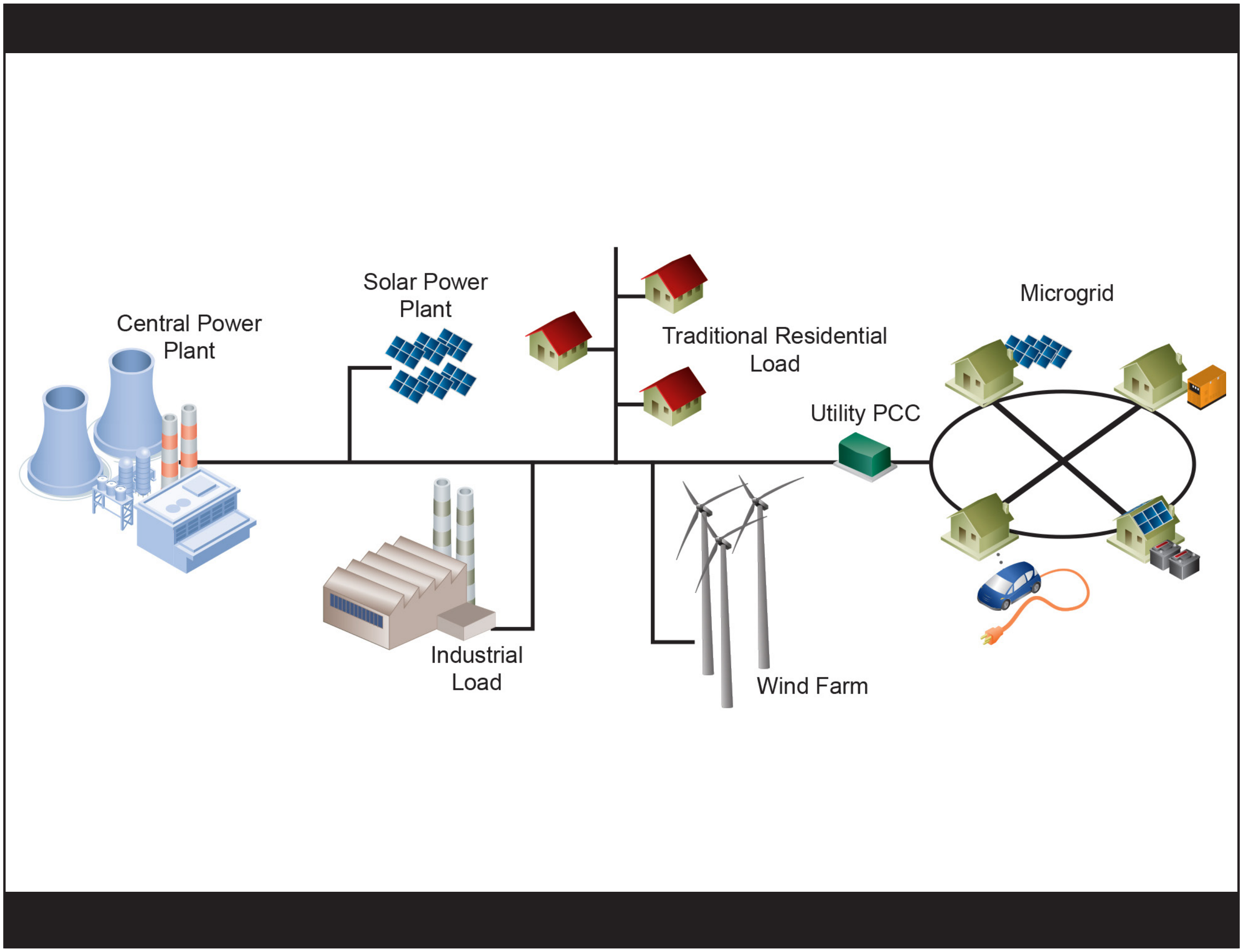
AN OVERVIEW OF ADVANCED ENERGY COMMUNITIES



April 2017

Table of Contents

Introduction

As distributed generation and grid balancing technologies gain market share, local areas are becoming more interested in integrating various distributed energy resources to balance the grid and ensure reliability. EPRI's Integrated Energy Network views these efforts as pivotal to the future of energy, as well as leading to the development of Advanced Energy Communities (AECs). These electrically contiguous areas will integrate **multiple customer-owned distributed energy resources (DER)** such as energy efficiency, demand response, customer storage, photovoltaic (PV) or other local generation, electrification, electric vehicles, combined heat and power (CHP), and district heating and cooling systems. Utility customers will look to these advanced technologies to provide benefits in comfort, convenience, and cost. Such communities also can achieve larger **societal and utility goals** such as decarbonization, grid hardening, and grid support. An AEC can either be a new community development or involve reconstruction and retrofit of existing residential, commercial, or industrial communities. Figure 1 illustrates a basic AEC architecture.

Smaller distributed generation such as solar PV generation, small wind turbines, natural-gas-powered fuel cells, and low-emission engines can be installed at or near the point of end use. These technological developments have coincided with society's increased interest in renewable energy for environmental benefits, resiliency, and security. In many areas, these social factors have led to legislative and regulatory incentives for distributed generation. Advanced Energy Communities are integral components and microcosms of Smart Cities—much more local in scope, but with similar energy generation, use and management technologies.

The rapid adoption of DER can affect the power grid in many ways, especially utility distribution systems. The distribution system is designed to be a 50-year asset, but many areas are challenged to sustain high levels of service reliability with the increased pene-tration of distributed generation. Distributed generation's variability and intermittency differ in fundamental technical characteristics compared

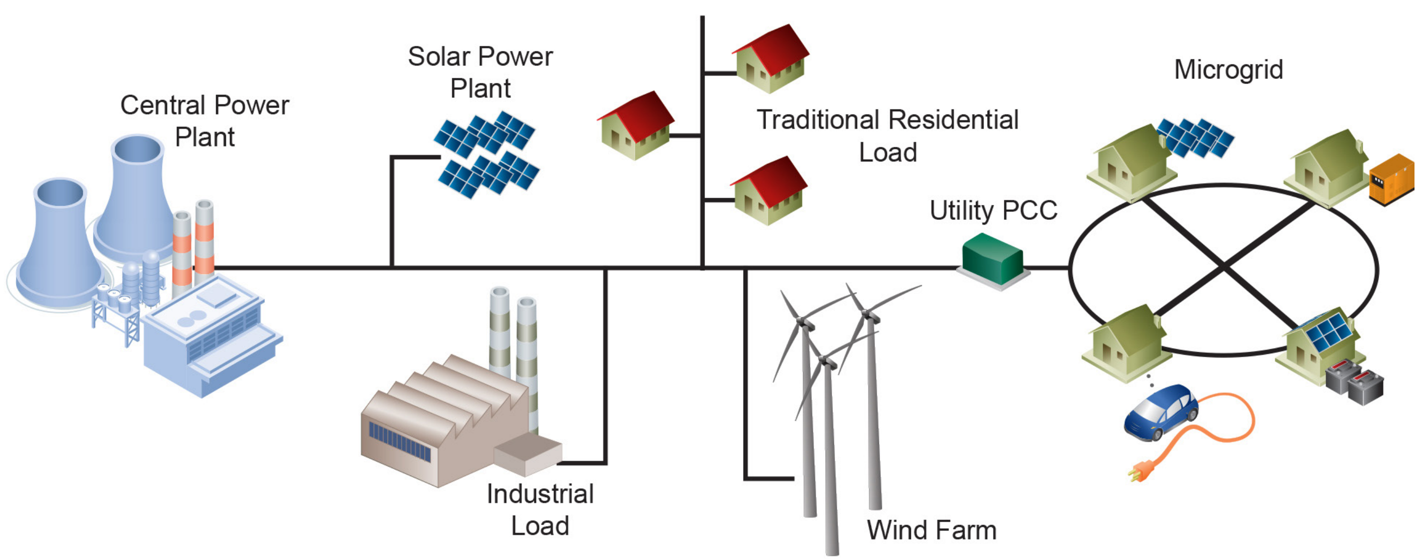


Figure 1 – Example of AEC Architecture

with central power stations. At the system level, the penetration of large-scale solar and wind, introduction of new loads such as plug-in vehicles, and load electrification can shift peaks or other aspects of the system load shape.

Examples of Advanced Energy Communities

Advanced Energy Communities can vary in form and function. Examples (many shown in Figure 2) include solar residential communities and zero net energy (ZNE) communities; campuses with multiple buildings and various modes of local generation including district heating, steam, CHP systems, large commercial buildings with on-site generation, energy efficiency, and thermal storage; multifamily housing with solar and community storage; and microgrids serving critical facilities.

AECs can provide grid services such as demand response to the larger grid without islanding. In many cases, the principal purpose of an AEC may be to reduce the cost of energy or infrastructure to end users. In contrast to a DER management system (DERMS) or other utility-managed controls, AECs may be managed not with a central controller, but with aggregation of local controls—enabled through data acquisition and controls operation.

Microgrids

Microgrids are a popular example of AECs and potentially share many DER technologies and controls (see Figure 3). Microgrids are not a replacement for traditional utility infrastructure, but instead form a self-contained organization of distributed generation and demand management that is capable of self-balancing when necessary. The U.S. Department of Energy (DOE) defines microgrids as *a group of interconnected loads and distributed energy resources (DER) within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid.* A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected and island mode.

Individual microgrids are expected to spend most of the time operating in a grid-tied mode, with power flowing both ways between the microgrid and the surrounding system. A bi-directional connection help achieve operational goals, such as improved reliability, cost reduction, and diversification of energy sources. The ability

Figure 2 – Examples of Advanced Energy Communities

to separate from the grid adds the resiliency values and provides a backup or emergency operation mode. The primary objective of a microgrid is to guarantee resiliency; therefore, the DER operations and infrastructure upgrade needs might be different from those of other types of AEC.

Microgrids and AECs leverage clustering of loads and generation to enable facilitation of system-level planning while minimizing the number of local control points. They aim to provide balance between load and the portfolio of DER while adding precise control of local power flow that enables scalable "blocks" of DER solutions, while at the same time maximizing the hosting capacity at each node in the system. While the resiliency benefit of microgrids has commanded the most attention in the past, many investigators have pointed out that the control infrastructure required for microgrids brings many additional benefits even while operating with the grid. In particular, microgrid controllers can bring together diverse DER systems and allow them to act in concert, potentially improving asset utilization, optimizing energy consumption, reducing energy losses, and ultimately reducing overall energy costs. In this way, microgrids act as an extension of existing distribution system operations.

Many customers, on the other hand, may not need the high level of resiliency, reliability, or power quality a microgrid can provide—and may not be willing to pay the higher cost of creating a microgrid. For such customers, local controllers can be used to create AECs in a way that minimizes the net power draw on the grid without eliminating it entirely.

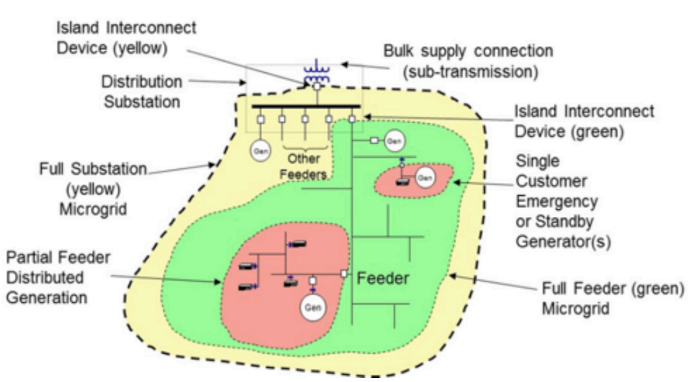


Figure 3 – Example of a Microgrid Structure

Research Questions Focused on Advanced Energy Communities

Key aspects of future research around AECs center on the role of the electric grid with customer-procured DER. In particular, there is a focus on addressing the question of how DER improve reliability and efficiency of the existing grid and can defer future grid investment. Research is required to evaluate questions such as:

1. What are the costs and benefits of customer-owned DER to achieve specific types of grid benefits?
2. With respect to design and deployment, where are optimal locations in a utility service territory that offer the greatest benefit to ratepayers and the grid?
3. How can we evaluate distribution systems and optimize DER penetration?
4. How can we obtain useful insight into expected customer adoption and the impacts to the distribution grid?
5. How can we evaluate the design and sizing of microgrids and assess their benefits?
6. How can we develop demonstrations targeting specific types of communities—such as low income housing, new residential construction, college campuses, and industrial and agricultural facilities—with a goal of understanding distribution system impacts?
7. How can technologies to aggregate multiple types of DER be developed and demonstrated to enable both utilities and aggregators to deploy and control DER effectively?
8. How can we develop customer programs to promote DER adoption that is targeted with respect to both technology and location?
9. What are the economics and effectiveness of off-grid applications?
10. How can emerging technologies be integrated through AECs to enable underserved segments of the customer base—such as low income, rural, and small business customers?
11. What innovative financing strategies can support development of such communities and make them financially attractive or practical relative to developments lacking advanced energy attributes?

This research will be driven by field demonstrations along with modeling, customer research, and big data analytics. AEC initiatives will produce significant data on energy use by load, smart meters, transformer and distribution systems, and customer surveys and connected customer devices. Researches will use the data to better understand, predict, and manage customer benefits and grid impacts and to calibrate grid and customer models.

The Benefits of Advanced Energy Communities

Examples for both customers and utilities include:

- ***Enabling customer choice in DER.*** AECs can direct utilities and aggregators to incentivize targeted DER, which can help customers choose DER options that best serve them for economic or other reasons while enabling the grid.
- ***Resource adequacy and flexibility.*** AECs can provide the right type of services from DER depending on need, whether on the distribution or bulk grid.
- ***Accommodating growing deployments of DER.*** AECs could help minimize the need for new energy infrastructure costs such as transmission and distribution upgrades. More local load and storage resources can balance variability in renewable generation and reduce costs of large-scale storage and transmission while accelerating deployments.
- ***Energy efficiency, demand response, and energy arbitrage.*** Energy efficiency has been shown to have significant capacity benefits to both the distribution and bulk grid, while demand response and storage can provide effective load shaping. AECs can point the way to an effective mix of these customer-owned resources to meet these needs.
- ***Support grid reliability and power quality in areas with high distributed generation.*** Local communities with a large base of solar PV or natural-gas-fueled distributed generation may further benefit from the development of AECs and help balance the system locally.
- ***Enable better understanding of adoption rates of new customer technologies.*** AECs could provide easier grid integration of new capacity resources and help determine location and the number of controllable loads, smart inverters, and storage that are required.
- ***Balance ISO-DSO needs.*** AECs can show how DER can be leveraged to ensure that the needs of the ISO local capacity requirements and the long-term procurement challenges are met.
- ***Engage multiple disparate stakeholders to align to common objectives on future energy generation and use.*** AECs can provide the opportunity for very disparate players such as builders, commercial real estate owners, utilities, and solar providers to understand various viewpoints and solve future grid issues.

Status of Current Research on Advanced Energy Communities

EPRI is leading several large demonstrations of these communities, and they involve energy efficiency, demand response, customer-connected demonstrations, solar PV, and customer-side storage to various extents. One example, shown in Figure 4, is the development of California's first Zero Net Energy community that examined how solar, storage, energy efficiency, electrification, and connected devices can shape the distribution grid. In another initiative, the potential of energy efficiency and solar to provide cost and comfort benefits to low income customers was evaluated. A third example is looking at how DER can be deployed by utilities in a targeted manner to enable the electric distribution system to operate more reliably and efficiently. Other initiatives include demonstration and evaluation of DER deployment in large new-home communities, integrated demand side management in multifamily and low income housing, investigation of building mass storage and battery storage to balance solar output, and deployment of targeted energy efficiency, demand response, storage, and electric vehicles to resolve high-penetration PV circuits.

The initiative on grid integration of ZNE communities offers an example of how an AEC project is implemented and its learnings. Power usage of each end use in each home was monitored. Half of the homes included battery storage to examine their benefit in providing grid benefits. The homeowners purchased the homes directly from the builders, and most were representative of the general population with not a significant knowledge of energy management.

Figure 4 – Zero Net Energy Neighborhood in Fontana, California

Figure 5 – Data Integration and Control Architecture

The real insights of the demonstration came through data—1 minute from each circuit—that revealed how customers use energy in homes, how load shapes will evolve into a random series of needle peaks, how delivering the promise of energy storage for load management will require significantly more complex operation than available today, and that the least-cost method to address the distribution system might be to size up transformers and wires. Another major advance on the data side was the development of a new data acquisition architecture that leveraged devices installed for other customer benefits to obtain substantial amounts of data at low cost compared to traditional data acquisition methods.

Figure 6 – Results from Completed AEC Efforts

From a customer perspective, we are able to demonstrate that net cash flow from solar and energy efficiency was positive for homeowners with the current Net Energy Metering rules—and that this drives adoption of solar and other DER. On the grid side, the results illustrated that these buildings have a load shape similar to the "duck" curve, both at the single home level and at the distri-bution transformer. They showed that the load shape is no longer a smooth load shape at the single building level, but a series of needle peaks—some as high as 12 kW due to electrification of heating loads. They also showed that the load peaks occur in the late evening and that solar PV generation has very little distribution system capacity benefit. Finally, they showed the potential of energy storage to shift net load and reduce peaks—but the cost effectiveness could be a challenge compared to enhancing traditional utility infrastructure.

The Future: New AEC Demonstrations for DER Integration

Leveraging the success of current and completed AEC efforts, EPRI is launching a new set of demonstrations—many of which are utility driven, some customer focused, but all significantly engage customers and offer social equity considerations to enable ratepayer benefits. Figure 7 is a snapshot of ongoing research supported by government agencies and utilities. The options range from a highly customer-centric approach, where the DER "happen" on the grid and the utility role is to "manage" DER, to utility-driven initiatives in which distribution systems analysis drives the targeting of DER within the utility grid, and the DER are utility controlled. While classical utility and governmental organizational structures might not be aligned with AEC concepts, it is important that cross-functional work be conducted within utilities to leverage the rapidly changing DER landscape. Though DER deployment in AECs occurs at the distribution level, adoption patterns and actions to enhance distribution will also impact bulk system operations.

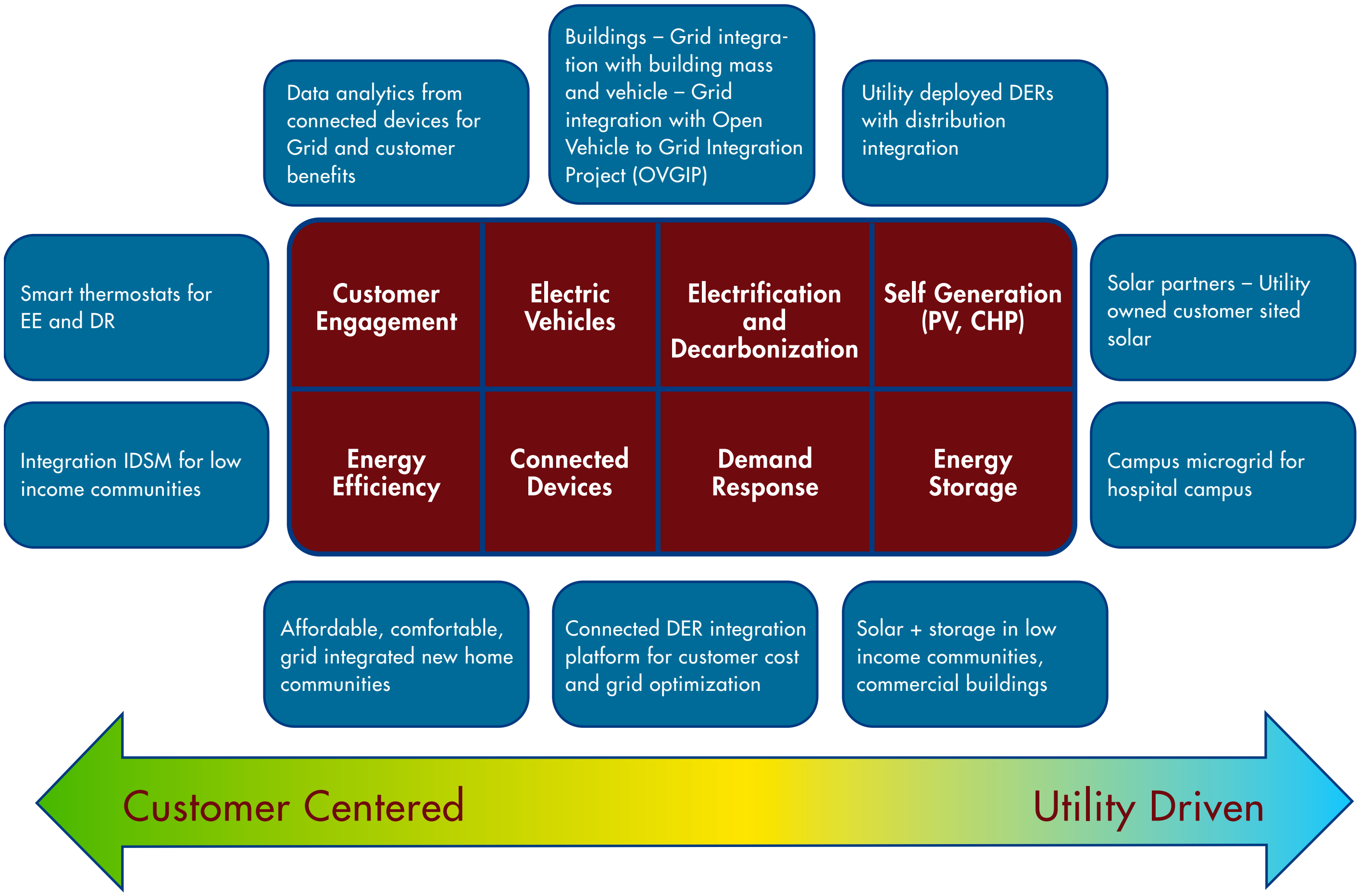


Figure 7 – EPRI Portfolio of Research in Advanced Energy Communities

Conclusions

Research into Advanced Energy Communities and microgrids represents a significant opportunity to study the future of the electric grid, with AECs being more common particularly when resiliency is less of a concern. To be effective, the design of AECs must be integrated into the planning and operations of the grid, from the point of customer interaction all the way up to the bulk system. The design of AECs must bring together a diversity of DER technologies, including solar PV, combined heat and power, energy storage, load management, and energy efficiency—coordinated and operating in concert to achieve customer goals, lower ratepayer costs, and ultimately greater societal benefits through improved grid reliability and reductions in greenhouse gas emissions.

EPRI RESOURCES

Haresh Kamath, *Senior Program Manager*
650.855.2268, hkamath@epri.com

Ram Narayanamurthy, *Technical Executive*
650.855.2419, rnarayanamurthy@epri.com

Energy Utilization, Storage and Distributed Generation Program

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI members represent 90% of the electric utility revenue in the United States with international participation in 35 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together . . . Shaping the Future of Electricity

3002011115 April 2017

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com