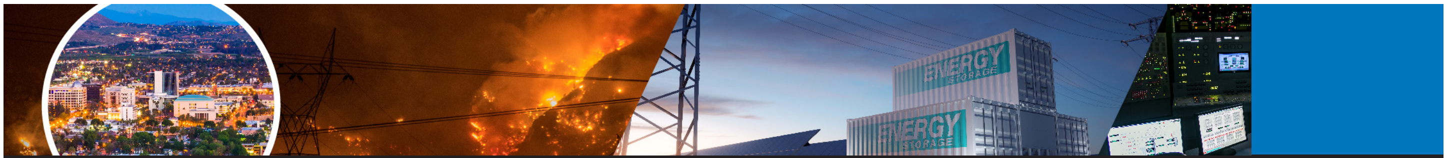
# WILDFIRES AND PUBLIC SAFETY POWER SHUTOFFS

**Distributed Energy Resources for Community Electricity Resilience**


December 2021



## Executive Summary

Climate and extreme weather resilience are acutely important issues to society and to managers of electric power systems. This is particularly true when climate and extreme weather combine to create ideal conditions for catastrophic wildfires, a large and growing challenge to California, the American West, and many other high fire risk regions worldwide.

This paper highlights wildfire risks and the challenges to electric power and societal resilience, experienced and addressed at the levels of individuals, businesses, governments, and electric utilities. This paper discusses the following topics:

1. Value of electricity resilience to customers and society during power safety power shutoff (PSPS) events
2. Drivers and alternatives for emerging technology solutions for electricity resilience, including equity considerations
3. Issues currently impeding the adoption of advanced distributed energy resource (DER) and microgrid solutions
4. EPRI research projects addressing key barriers and helping accelerate potential solution readiness

Since 2013, California has had more than 12 million acres scorched by catastrophic wildfires, an area nearly the size of Maryland and New Jersey combined, resulting in the loss of over 54,000 structures and 202 lives. Much of this destruction follows a seven-year drought which ended in 2016 and caused critical vegetation fuel conditions. Also potentially contributing to the loss of property and lives are decades of human development in the Wildland-Urban Interface (WUI) zone,[1] which led to more than two million California homes being built in high or extreme wildfire risk zones.

Any spark, under the right conditions, may ignite a wildfire, including the possibility of sparks from electric power infrastructure. As a result, electric utilities continue to invest billions of dollars into asset hardening and wildfire risk mitigation. Due to the extensiveness of the electric grid, however, it is not technically or economically feasible to fully eliminate risks through grid hardening. Electric utilities therefore also use proactive de-energization of certain high-risk pathways, widely known as Public Safety Power Shutoffs (PSPS), during critical fire weather, to avoid or minimize fire risks.

Unfortunately, PSPS events coupled with an extreme fire danger may negatively impact and introduce new risks to society and to vulnerable customers. Emergency and community support services (e.g., emergency communication, transportation for potential evacuation, water delivery systems for firefighting, medical support services) may be in high demand during these events and difficult to access. While PSPS events can reduce opportunities for wildfire ignition, the risk of wildfire cannot be eliminated. The value of electricity resilience during PSPS may be immeasurably high for certain purposes, and access to alternative solutions may not align with needs of the customer, thereby requiring a robust solution set. These customers and purposes may require local solutions to support the resilience needs, and these solutions should be (a) affordable, (b) safe, and, preferably, (c) aligned with societal decarbonization goals.

Historically, customers have often relied upon gasoline, diesel, or natural gas generators in times of power outage. These solutions may be valuable during disasters, but they also have the potential drawbacks of being noisy, generating emissions, requiring fuel access and storage, and being inaccessible to certain customer types. However, new renewable and emission-free options are emerging. For example, driven by falling costs and product emergence, customers are beginning to adopt solar battery and microgrid solutions to provide backup power and achieve other economic and environmental goals. A microgrid is defined as a group of interconnected DER and loads with a defined electrical boundary that can connect and disconnect from the wider electric power system and acts as a single controllable entity with respect to the grid.[2] DER or microgrid solutions may include a range of energy assets, including:

- Rooftop or canopy solar PV
- Stationary or mobile battery energy storage

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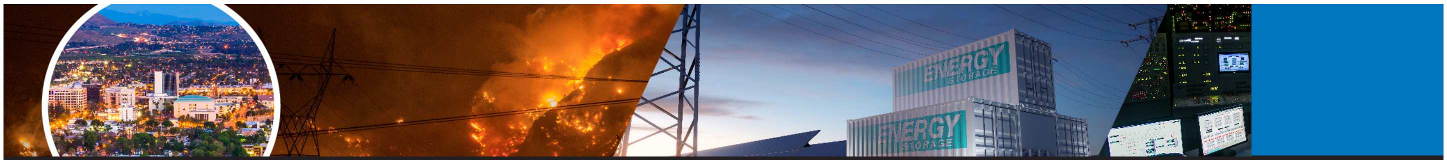
*This white paper was prepared by EPRI.*

[1] https://www.science.org/doi/10.1126/sciadv.abe6417.

[2] *The U.S. Department of Energy's Microgrid Initiative*. https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy's%20Microgrid%20Initiative.pdf.



- Portable batteries for small, critical appliances
- Electric vehicles with vehicle-to-grid or vehicle-to-building (V2G/V2B capability
- Stationary or mobile fueled generation, with renewable gas or low-carbon fuel

DERs may be purchased and operated by individuals, businesses, government agencies, electric utilities, or third-party businesses. However, because society shares an interconnected power system, a single customer's actions may have positive or negative impacts on others. A residential customer may purchase a solar-plus-battery system for backup power during PSPS events, but this system may also be used to prevent system outages by supporting peak load times for the entire grid on hot, summer days, creating value beyond the purchasing customer. In another case, an electric utility may invest in a large, mobile battery or generator to support grid maintenance events, but this system also may be used to provide power to the main street of a remote, high wildfire risk community during a PSPS event. Numerous other opportunities are dynamically emerging with shifting needs, technology capabilities, and regulatory evolution. The 2020 Federal Energy Regulatory Commission's (FERC) Order 2222 encourages system operators to find new ways to incorporate and properly compensate DERs for contributing to power system reliability, innovation, competition, and reducing costs for consumers.

There may be great opportunities for DER and microgrid solutions to address wildfire resilience challenges, and potential solutions should consider probability, severity, equity of risk, and access to mitigations. EPRI and other organizations have identified several research areas which are covered in this paper in detail, including:

1. Validating DER and energy storage product readiness
2. Facilitating safe and efficient interconnection of customer energy resources
3. Improving investment and reliability with utility planning integration
4. Operations for Resilience and Optimized Performance

## California's Wildfire Challenge

### *Wildfires and Electric Utility Infrastructure*

The Western United States and similar climate regions have faced unprecedented challenges with increasing risk of wildfires and their catastrophic consequences to people and property, driven by

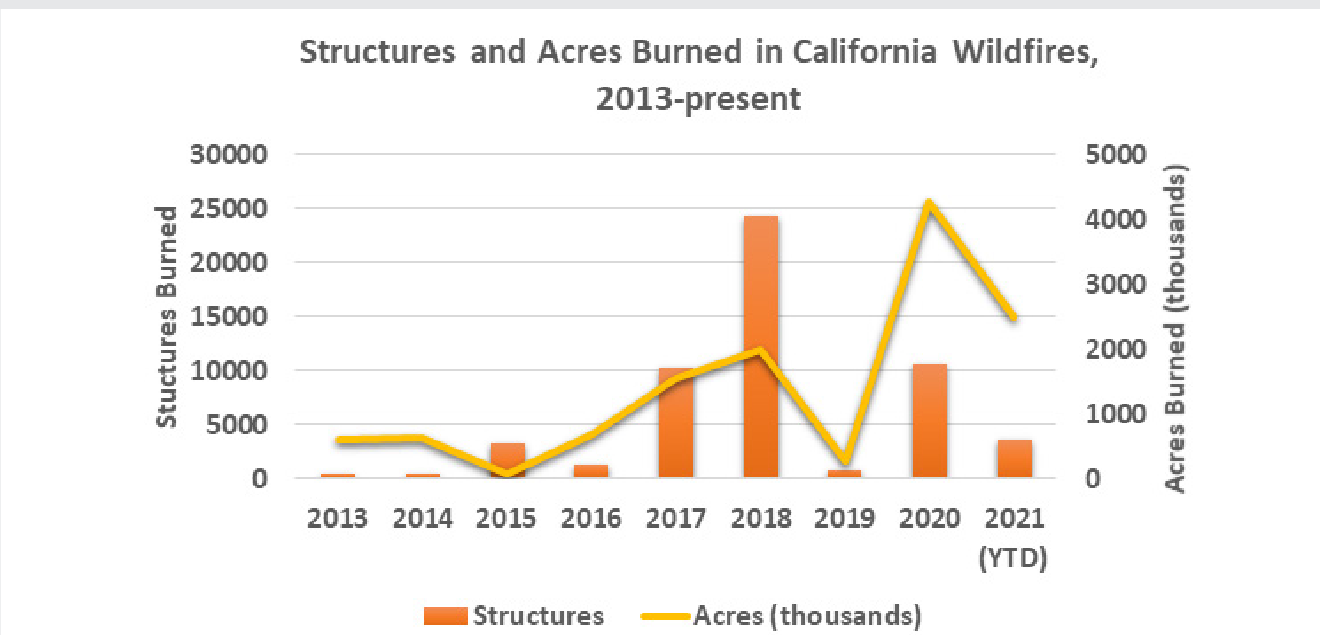
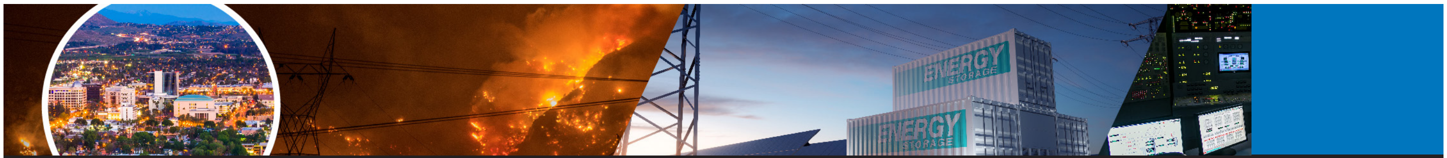



*Figure 1. Total structures destroyed and acres burned due to wildfires. [4]*
NOTE: The term "Structures" refers to homes, outbuildings (barns, garages, sheds, etc.), and commercial properties.



both natural and human-caused factors. In California, wildfires have always been a risk due to the state's Mediterranean climate of cool, wet winters and hot, dry summers, with seasonal hot and dry offshore wind events (e.g., Santa Ana / Diablo). Recent droughts in California also are significantly increasing dead wood in forests, providing a key fuel needed to feed wildfires. [1] [2] Between 1972 and 2018, California's annual burned area has increased fivefold. [3] The climate and fuel conditions that have driven this increased wildfire threat are expected to remain or to intensify in the coming years.

The electric power system is of particular concern for potentially causing wildfire risk because of its sprawling geographical scope and exposure to the environment and weather. California's transmission and distribution infrastructure includes nearly 200,000 miles of overhead wires [5] and hundreds of thousands of transformers. Much of this infrastructure provides electricity service to remote customers in high fire risk zones or passes through these areas. Although powerlines and other electrical infrastructure are not the only cause of wildfires, high wind events correlate both increased probability of electrical infrastructure fire ignition and increased severity of wind-driven fire spread. Electrical issues or powerlines have been identified as initiating four of the top ten most destructive fires in California history (Table 1).

**Climate-Influenced Wildfire Growth:** California's *Fourth Climate Change Assessment Report* (2019) predicts that the mean annual area burned statewide could increase up to 77%, and extreme wildfires (fires larger than 10,000 hectares) could occur 50% more frequently, by the end of the century. [53] Furthermore, wildfire projections for California developed by William (2018) do not consider all factors that may increase wildfire activity in the future due to drastic changes in climate. [54] Historical weather data does demonstrate an increase in global average land and sea surface temperatures, an increase in average sea level, and changing patterns of extreme weather events. Extreme heat has become more common, precipitation is increasing in intensity, the number of coastal flooding events is increasing, and wildfires have been growing in frequency and average area burned. There can be inherent uncertainties in projecting future trajectories of these trends, but historical data demonstrates warming and increasing frequency and intensity of extreme events.

Attribution of wildfire frequency changes can be difficult, especially since 80% of all wildfires from 1992-2021 were started by humans. However, climate change plays a role in both natural and man-made wildfires due to increases in temperature and changes in precipitation patterns, which impact drought and fuel aridity. These are two factors that may determine whether a man-made fire can be easily contained and extinguished, or if a small fire will transform into a wildfire.

The implications of increasing frequency and intensity of extreme weather events on the power sector vary by threat type, region, and community.

*Table 1. Top 10 most destructive wildfires in California, ordered by most structures burned. [6]*

| Fire Name (Cause) | Cause | Date | Structures | Acres |
|---|---|---|---|---|
| Camp Fire | powerline | Nov-18 | 18,804 | 153,336 |
| Tubbs | electrical | Oct-17 | 5,636 | 36,807 |
| Tunnel – Oakland Hills | rekindle | Oct-91 | 2,900 | 1,600 |
| Cedar | human related | Oct-03 | 2,820 | 273,246 |
| North Complex | under investigation | Aug-20 | 2,352 | 318,935 |
| Valley | electrical | Sep-15 | 1,955 | 76,067 |
| Witch | powerline | Oct-07 | 1,650 | 197,990 |
| Woolsey | under investigation | Nov-18 | 1,643 | 96,949 |
| Glass Fire | under investigation | Sep-20 | 1,614 | 229,651 |
| Carr | human related | Jul-18 | 1,614 | 229,651 |

### *Public Safety Power Shutoffs (PSPS)*

A combination of dead vegetation with periods of high temperature, low humidity, and high winds creates high risk of fire ignition and spread during California's summer and fall. High winds and fallen trees can damage electric infrastructure, which may result in faults that cause sparks or fires. To reduce the probability and severity of wildfire events, utilities are employing a suite of mitigation measures, including advanced vegetation management, hardening infrastructure, replacing infrastructure, and enhanced situational awareness.

California utilities also identified and launched PSPS events as an additional wildfire mitigation or preventive measure. During PSPS events, power lines that pass through high-fire-risk corridors during high-risk weather conditions are temporarily de-energized, eliminating these power lines as potential ignition sources.

A PSPS event begins before a wind event arrives, lasts throughout the wind event, and continues during a post-event restoration period, typically resulting in a power outage lasting one or more days per event. Restoration time may depend on the level of power system damage sustained during the wind event and the degree of automated situational awareness and control. Depending on location and weather patterns, many customers have experienced multiple electric power outages per year, typically during late summer and fall months.

### *Case Study: October 2019 Power Shutoff and Kincade Fire*

On October 23, 2019, during a red flag warning and associated power shutoff, the Kincade Fire was ignited in Sonoma County, California. This fire event lasted for more than two weeks and included multiple high wind events resulting in further power outages. During these power outages, approximately 200,000 people in Sonoma County were evacuated as the fire threatened large sections of the region. Cell phones were used as a primary means of notifying individuals to evacuate, a method complicated as over 100 cell phone towers in Sonoma County lost functionality due to the power outage. [58] The experiences of customers, businesses, and communities during this event serve as a useful case to evaluate the risks, benefits, and potential consequences of PSPS events.

## Customer and Community Impacts of PSPS

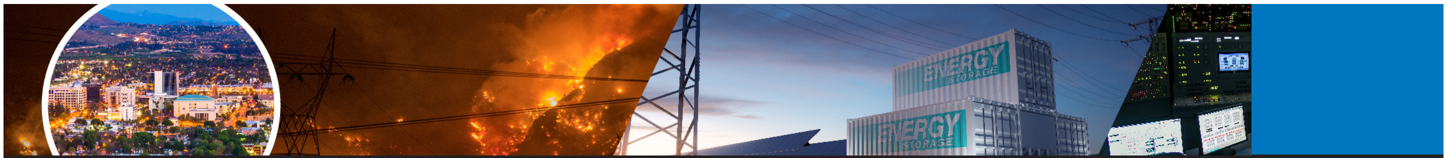
### *Limitation of conventional outage cost estimates*

The cost of electric power outages has undergone extensive study to inform the value of reliability investment for electric power systems. Value of resilience studies are typically performed from either a utility-centric or customer-centric perspective. A utility-centric valuation approach is intended to prioritize resilience investments based on average outage duration and frequency for customer groups, and it typically utilizes average outage costs for different durations and customer segments. [7] A customer-centric valuation involves a site-specific investigation of direct costs to a customer. However, these outage studies typically exclude extreme weather which may have severe and case-specific consequences to customers and communities. As a result, the true value of electricity during wildfire risk scenarios and PSPS has not been fully characterized.

The outage costs which reliability impact studies and surveys typically consider are direct costs of the outage for the individual customers, such as inconveniences, spoiled food, and lost economic productivity. Under PSPS scenarios it is important to also consider community impacts because these power shutoffs occur during times of heightened risk to public health and safety, and the power shutoffs may often persist for a long time.

### *Individual customer impacts of PSPS*

The consideration of community and wildfire situational impacts may result in greater cost of outage than previous estimates. In addition to estimated costs of outage to typical residential and commercial customers, PSPS outages can result in inoperable home medical equipment, telecommunication devices, and refrigeration. Commercial customer outages may result in the unavailability of essential items to customers in the affected community, such as food, sanitation, and important home supplies. Consideration also should be given to the many end-use devices that are switching from natural gas to electric, such as induction cooktops, heat pump water heaters and space conditioning, and electric vehicles. All customers are unique, and wildfire risks and associated power outages may result in wide ranging impacts and costs that cannot be easily



generalized. Therefore, the value of reliability and resilience could be in the "eye of the beholder" to individual customers and remain difficult to quantify.

### *Community impacts of PSPS*

In addition to the individual customer impacts of PSPS, there are numerous community resources which hold heightened importance during wildfire risk scenarios.

- **Public Health and Safety:** Police and fire department services, hospitals, and first responder teams are particularly important during wildfire conditions and require situational awareness, communication services, and access to well-functioning transportation systems to respond to various emergencies.
- **Water System:** Water is essential for customers and also critical for individual and professional firefighting efforts in communities during wildfire emergencies, and electricity is required to move water and maintain water pressure.
- **Wireless Telecommunications:** Cellular communication disruptions may cause inconveniences and safety issues, as approximately 57% of American homes rely solely on wireless telephones, increasing reliance on reliability of the cellular network. Communications resilience is especially important during wildfire risk scenarios and evacuation periods for news and situational awareness, to ensure people can navigate themselves and their families to safety, and to communicate with personal and professional networks.
- **Transportation:** Transportation infrastructure is critical during wildfire emergencies. Outages may affect traffic signals and force tunnels to close, which can affect evacuation options and impact safety during emergency conditions. Access to electric vehicle (EV) charging also is important in evacuation scenarios as the relative share of EVs increases.
- **Other Government and NGO Services:** Outages may affect the effectiveness of numerous social support functions, such as assisted living facilities, non-profit organizations, and government social support services. Financially, socially, or medically disadvantaged populations can be disproportionately impacted by displacement and resource scarcity, and may require rapid support, during wildfire emergencies.

## Opportunities to Enhance Resilience to PSPS Outages

Customers, communities, and utilities may need a portfolio of different strategies to mitigate the effects of wildfires and power outages, particularly during conditions when wildfires and outages happen simultaneously. While electrical infrastructure has been identified as one potential ignition source of destructive wildfires, other ignition sources (e.g., vehicle backfires, sparks resulting from the use of machinery, or other human and natural causes) cannot be controlled through PSPS measures. The range of ignition sources may create challenges for decision-makers, including individuals, communities, businesses, and electric utilities. PSPS events can help reduce wildfire ignition and damage risks; however, the temporary loss of electricity due to a PSPS event may significantly impact customers and communities. Investments into backup generators have been the traditional pathway for mitigating the impacts of outages. However, these generators emit pollutants and sound, and may create local nuisance. Generators also require fuel sources, such as diesel or gasoline, that may become scarce during emergency conditions.

Today, a range of DERs may be employed to support and provide electric needs, depending on the context. Potential solutions range in scale from small and simple to large and complicated. Table 2 summarizes the technologies, benefits, and limitations associated with these potential solutions.

### *Portable Batteries*

Due to continued improvements of battery technologies, product developers can fit increasingly more energy into portable storage appliances at lower cost [8]. The results are battery products, often targeting outdoor or camping markets, which can support larger appliances for longer durations, and other products which may be used by customers to support critical, valuable uses during wildfire power outages (e.g., powering certain medical devices, cell phone charging, or other relatively low consumption appliances). These portable battery products are simple to deploy, only used as a backup power source, and do not connect to the primary premise electric system or grid.

| Table 2. Summary of Wildfire Backup Power Mitigation Strategies | | | |
|---|---|---|---|
| | **Description** | **Benefits** | **Limitations** |
| Portable Battery Backup | Easy-to-move battery products that operate separate from electric grid with multiple AC and DC outputs | Ease of deliverability and use; targeted appliance backup | Limited continuous backup capacity may not support all critical appliances or for sufficient duration; ability to deliver when needed |
| Customer Premise Microgrid | Permanently installed battery, solar, and/or fueled generation connected to individual premise | Backup of appliances and loads within a complete premise or subpanel | Siting feasibility; customer ability-to-pay; possible under-utilization of assets; challenges to share energy beyond premise |
| Community Microgrids | Integrated and managed group of grid-connected energy resources across multiple premises or connection points capable of islanded operation | Support multiple customers who may have critical needs without feasibility for premise backup; broader resource diversity and potential robust-ness | Interconnection, protection, and controls challenges; potential design and operational challenges |
| Mobile Battery and Generation Systems | Generator, battery, or hybrid energy resources on wheels that may integrate standalone or with other permanent energy resources of individual premise or community microgrids | May be transported to needed sites across a region for event response and recovery in diverse cases; may target high value community resources | Ability to get systems where they are needed during; transportation system constraints; diverse interconnection requirements across sites; battery capacity or fuel supply limitations |

Portable battery limitations include energy capacity restrictions, to enable portability, so it is important to consider appliance-level consumption needs when making purchasing decisions. Also, the safety and reliability of such products should be validated since they are likely to be used within a customer's premise in proximity to people. Additionally, standardized certification for safety and performance for this segment is not yet defined. While "camping" batteries may work as a bridge solution to support critical medical devices, there is an industry certification and validation gap to ensure performance and safety requirements.

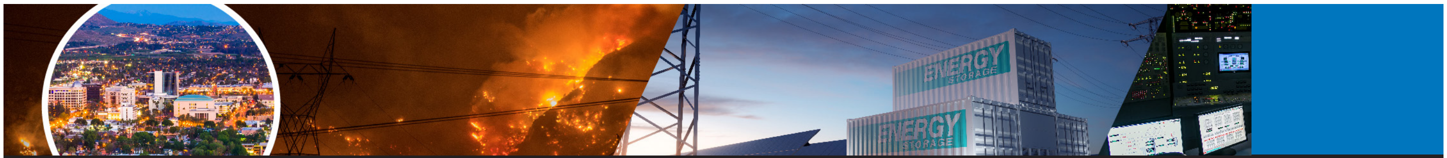
### Customer Premise Microgrid

Customer premise microgrids may contain multiple assets, e.g., solar generation and battery storage, battery storage (without solar), EV Vehicle-to-building (V2B) battery systems, and sometimes natural gas or low-carbon fueled generators. The cost of solar photovoltaic (PV) and battery systems has fallen in the past decade due to the growth of zero emission microgrids. Additionally, customers may take advantage of different incentives or rebates for solar-plus-battery systems, such as California's Self-Generation Incentive Program (SGIP) [9], a Federal Solar Investment Tax Credit (ITC) [10]. Additionally, during non-emergency times these types can shift or flatten customer electricity demand in ways that may lower monthly electricity bills.

Despite these positive drivers, adoption challenges include:

- Costly equipment: Costs are still high which may make microgrids inaccessible to individuals or difficult to justify for businesses based on monetizable benefits.
- Costly and challenging installation: Service panel and breaker integration requires highly skilled, specialized labor.
- Integration challenges of whole home backup: Compressor inrush currents, from devices such as refrigerators and HVAC units, can potentially cause equipment malfunctions and power quality issues if not managed correctly.
- Assurance of long duration outage backup: Energy management can be difficult during prolonged outage, particularly if rooftop solar potential is undersized or not available.
- Accessing additional value streams: Current monitoring and control systems may not have the ability to maximize value of grid-connected use cases for additional customer revenue potential

Due to these challenges and limitations, it may not be technical or economically feasible for all vulnerable customers to secure electricity reliability with on-site energy resources.



### *Community Microgrids*

Community or utility-managed microgrids may combine customer premise energy resources with portions of the electric grid to form larger energized areas during power outages. These microgrids may offer resilience to clusters of loads or customers during wildfire-induced outages, using the potential of a diverse set of resources. This community-level approach could benefit a larger set of customers compared to individual solutions due to the potential utilization of a broader set of resources which do not need to be installed and managed from an individual customer premise; accordingly, community or utility-managed microgrids may offer opportunities for greater inclusion, grid resilience, and economic efficiencies. Multiple strategies for topology and power and energy management also are possible (and are the subject of significant research efforts at EPRI and elsewhere).

#### *Community Microgrids in California*

Since 2009, the California Energy Commission (CEC) has invested $90 million in the deployment of 39 microgrid sites with the intent of accelerating deployment of technologies that support a more resilient energy system adaptable to climate change impacts. After two PSPS warnings and one 48-hour shutoff resulting in lost revenue for local businesses in 2019, the city of Calistoga , California is working with the Clean Coalition to assess the feasibility of a discrete microgrid network "with the ultimate goal to develop [an integrated] community microgrid that serves the full Calistoga substation grid area."

A primary driver for community microgrid adoption is the provision of resilient services following a grid outage. A microgrid's resilience is measured by its ability to withstand and rapidly recover from system disruptions and extreme events and maintain critical functionality of the microgrid area. Customers with critical load needs can benefit from the fast recovery of local power delivery during significant distribution grid outages. Community microgrids can be coordinated to improve the restoration time of wider areas and support distribution grid recovery times following a major outage event. Locally deployed community microgrids can black start and quickly energize critical feeder portions as islands while long-duration outages are addressed by the utility.

The outage recovery service of community microgrids provides the following customer value:

- Reduced load outage duration
- Wider load coverage during island operations

While community microgrids may benefit large number of customers and provide improved equity and access, significant challenges may exist to plan for and manage this larger type of system reliably and efficiently. For example, planning for the timing and duration of PSPS events is complex with a large microgrid. Furthermore, re-energizing sections of the utility grid may re-introduce potential and undesirable wildfire ignition risk.

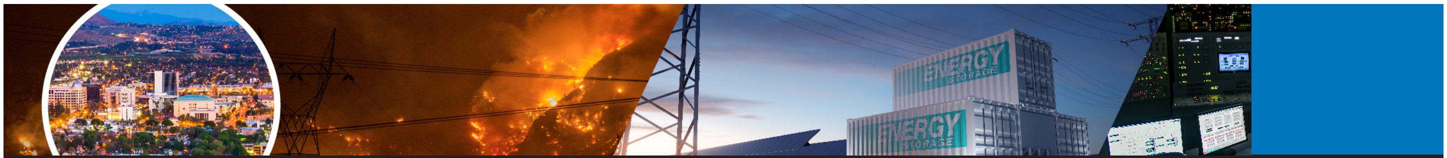
As shown in Figure 2, a community microgrid could exist on a partial feeder (including multiple customer meters) or include an entire feeder. In community microgrid deployments, a master controller is needed to manage the operations of larger clusters of DER, which may also be managed at the customer premise level. This layer of operations creates significant opportunity and complexity, because it needs to reconcile potentially conflicting objectives and it may only have indirect control over many of the energy resources.

Multi-customer, utility-operated, community microgrids introduce complex design and operational challenges. The control of DER along with distribution automation devices, unmanned operation, protection coordination, and other aspects makes community microgrids challenging to implement and operate. Increasing need for distribution circuit reliability and resilience require a clearer understanding of utility-owned microgrid operational requirements.

### *Mobile Battery and Generation Systems*

Mobile battery and generation systems are typically integrated with flatbeds or trailers and powered with a fossil-fueled engine, fuel cells, or solar PV. These are alternatives to standard diesel generation systems and may provide on-site backup power for customer build loads, complete premises, microgrids, and, possibly, electric vehicle charging. [11]

The potential benefit of these mobile systems is they may be shared across a certain territory, with the flexibility to be used where and when needed, resulting in greater utilization of assets which are non-specific to a certain site. In addition, mobile systems may augment existing customer resources to provide additional backup power and duration during long-term outage events.



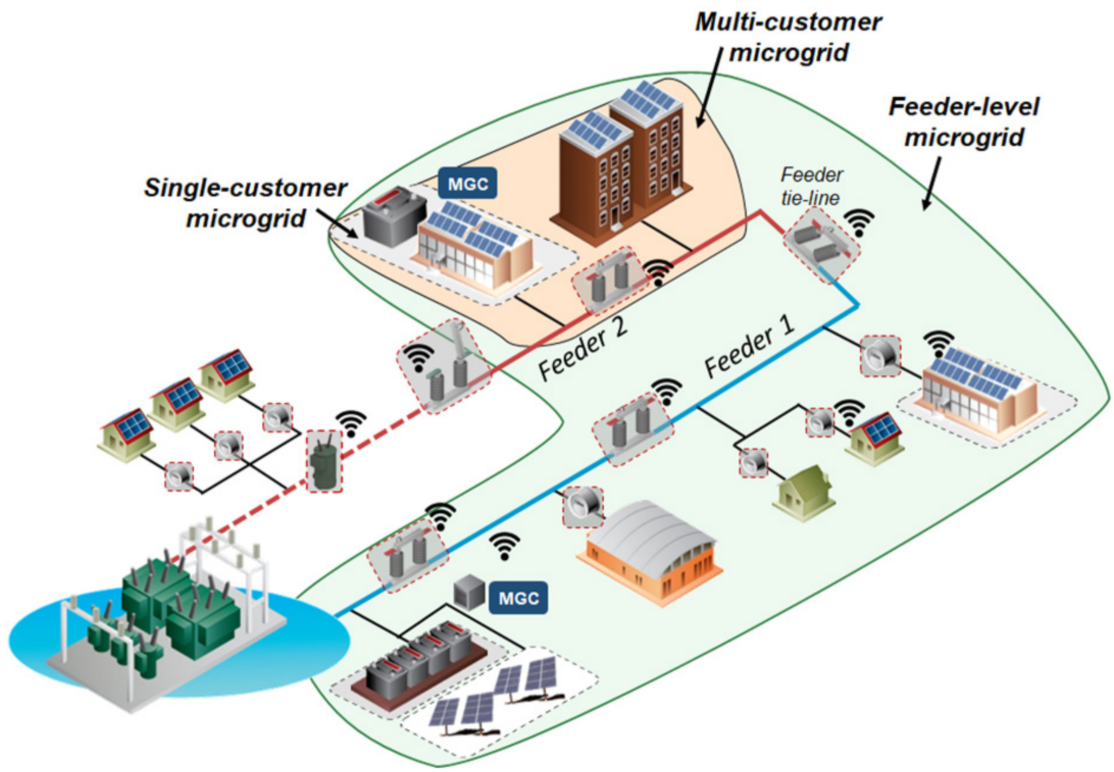


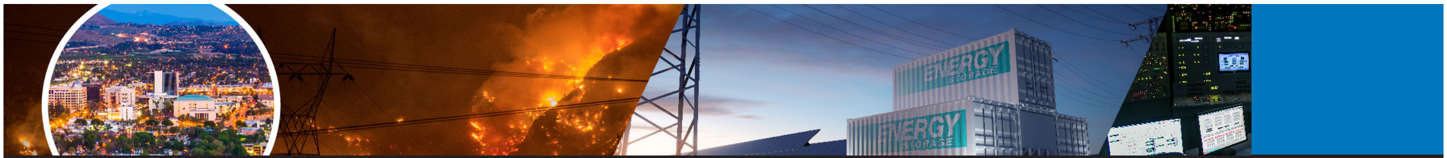

*Figure 2. Illustration of different community microgrid types and boundaries.*

### Mobile Generators and Resilience Zones

Pre-installed Interconnection hubs are designed to quickly, within a few hours, energize and sustain a microgrid by connecting mobile power generation sources to the affected microgrid. Pacific Gas & Electric (PG&E) has deployed these temporary microgrids (TMG) specifically to address PSPS events. PG&E built four TMGs between 2019 and 2020, with more in construction and design phases.

48-hour shutoff resulting in lost revenue for local businesses in 2019, the city of Calistoga , California is working with the Clean Coalition to assess the feasibility of a discrete microgrid network "with the ultimate goal to develop [an integrated] community microgrid that serves the full Calistoga substation grid area."

A challenge of the mobile battery and generation approach is added product complexity. These systems must be capable of being transported along roadways, which requires effective planning, engineering, operation, and acknowledgement of roadway load limits. They also need to be capable of quick interconnection with a diverse range of potential sites in order to be useful as a backup response during emergency events, requiring advance analysis and design engineering of candidate sites to ensure reliable operation.



### Adoption Pathways

There are three potential ways investments may be made for the outage mitigation strategies described above, including:

1. **Customers** purchase, own, and operate mobile or permanent solutions
2. **Utilities** connect and manage mobile or permanent solutions, connected to grid and customers
3. **Utilities or third-party customer programs** for customer-sited and maintained permanent systems, possibly co-operated by a customer/aggregator or utility

## Key Opportunities to Advance Wildfire Outage Mitigation Solutions: Research

### Research Issues Summary

DERs and microgrids may offer significant opportunities as well as layers of complexity to achieve resilience and economic goals. Several EPRI research efforts are underway that potentially provide safe, reliable, environmentally responsible, and equitably accessible solutions for customer and community resilience, despite not being exclusively wildfire-related power shutoff resilience solutions. This section of the paper uses a layered approach to organize EPRI's research to support electric power resilience, beginning with individual asset considerations and subsequently considering integration and more advanced applications of these assets.

These layers include:

- DER technology and asset considerations
- Deployment and interconnection of local energy resources
- Local or on-site control of energy resources
- Incorporation of DER into power system planning
- Coordinated control of energy resources and power systems to maximize benefits

For convenience, issues are summarized in Table 3 below and further discussed in the subsequent section.

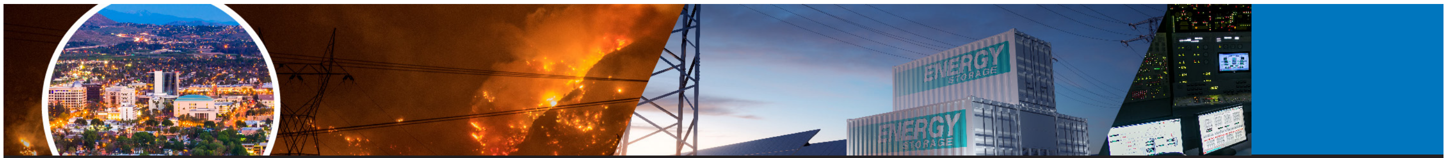
### Validating DER and energy storage product readiness

DER customer resilience and electricity reliability requires producing and/or storing energy with a focus on and commitment to safety, reliability, and security.

- **Safety:** Fire safety, with the use of fuels, and as a potential ignition source, is critically important in the context of wildfires to avoid replacing the fire ignition risks from traditional electric utility infrastructure faults with new ignition risks from DER. Evaluating new technologies and products for potential hazards and mitigation approaches may help avoid potential fire safety events. For example, batteries should be handled and operated safely, as they have known fire risks under abusive conditions or due to manufacturing defects. Research into battery storage fire prevention and mitigation [12] [13] is working to answer open questions and to develop toolkits for the safe deployment and use of energy storage assets. Customer electrical equipment also

*Table 3. Summary of Research Topics to Support Resilient and Economic Use of DER*

| Category | Research Issue | Related EPRI Products |
|---|---|---|
| Validating DER and energy storage product readiness | Fire safety; Asset reliability (degradation, downtime); Security (cyber, physical) | [8] [12] [13] [14] [15] [16] [17] [18] [19] |
| Safe and efficient interconnection of customer energy resources | Electrical safety for customers and utility workers; Streamlined permitting; | [12] [13] [20] [21] [22] |
| Improving investment and reliability through utility planning integration | Customer adoption forecasting; Utility program and tariff design; Equity and access considerations; Utility transmission and distribution forecasting | [21] [23] [24] [25] |
| Operations for Resilience and Optimized Performance | Enabling resilience functionality; Optimizing economics with grid services support; Navigating asset owner operational constraints | [7] [11] [23] [26] [27] [28] [29] |



has been identified as causing past catastrophic wildfires. Additionally, local power distribution equipment within a microgrid should be considered as part of a fire hazard mitigation analysis.

- **Reliability:** Asset reliability is another key attribute for battery storage as these assets are evolving and their deployment track record is limited and mixed. It is important to collect and analyze DER field data to understand and plan for product downtime and degradation as customer resilience supported by these assets is predicated upon performance meeting expectations and robust design approaches that account for real-world conditions. Data collection and analysis continues through an ongoing EPRI research initiative into Energy Storage Performance and Reliability Foresight [30]. Testing of performance and functionality of customer-sited battery storage systems is also underway in a project called [31].
- **Security:** DER and energy storage cyber and physical security is important for customer data privacy, as well as for overall system safety and reliability. This is an evolving and important area of research [32], as energy storage and DERs may communicate bi-directionally with multiple, different local and system controllers and, in some cases, may be connected to the internet. As a result, the possibility for cyber intrusion must be considered carefully. Physical security and placement of these resources also should be carefully considered, because intentional or unintentional interaction with these assets may cause damage, safety, and/or reliability issues.

### *Safe and efficient interconnection of customer energy resources*

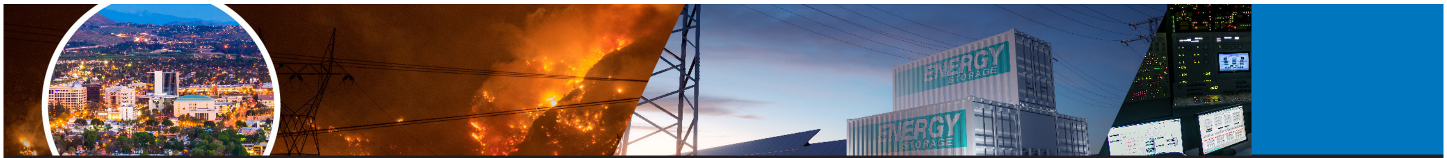
Deployment and interconnection of new types of DERs presents challenges for customers, local permitting authorities, and electric utilities, including:

- **Electrical safety for customers and utility personnel:** Proper training may be required to safely design and deploy local energy resource solutions to avoid electric shock, electrical fire hazards, or health impacts due to improper siting, connection, protection, or operation. Additionally, DER equipment should be listed compliant and certified to recognized standards (e.g., IEEE 1547) to ensure grid compatibility and grid protection, such as preventing back feed of power to the electric grid during outage (a potential utility worker safety issue).
- **Streamlined permitting:** Much of the research around deployment and interconnection of battery storage and DERs focuses on education and tools to support local Authorities Having Jurisdiction (AHJs) to understand key risks of these assets, to streamline permitting, and to promote common approaches. EPRI's interconnection taxonomy working group brings utilities, integrators, product manufacturers to a common table to converge on use case, control mode, and application terminology. This aims to level the playing field and standardize the goals and objectives of DER abilities to support wildfire and PSPS conditions. Streamlining permitting is projected to lower the time and cost of deployment and interconnection. A Department of Energy (DOE)-supported project, led by the Interstate Renewable Energy Council (IREC) and assisted by a team including EPRI, called BATRIES (Building A Technically Reliable Interconnection Evolution for Storage) [33], seeks to address deployment and interconnection issues with the development of technically informed toolkits. EPRI also has developed informational briefs to educate end customers on how to use battery storage systems in residential and C&I applications.

### *Improving investment and reliability through utility planning integration*

Beyond DER asset and deployment considerations, electric utilities may be challenged to incorporate DERs into power system planning to maximize benefits during normal ("blue sky") and emergency ("black sky") days, and to manage unintended impacts to power system power quality and reliability. Utility planning considerations include:

- **Customer adoption forecasting:** Customers are increasingly taking electric resilience into the own hands, and their choices to adopt and use resiliency resources may have great impacts on the broader power grid. To effectively plan for these changes, electric utilities need tools to objectively analyze customer behaviors and economic impacts. This new planning capability may help electric utilities optimize infrastructure investments, enhance reliability by utilizing excess capacity of customer energy resources, and manage any negative impacts. Current electric utility and end customer planning processes are largely independent, but this new area of planning may offer significant potential for increased collaboration and shared insights.




- **Utility tariff and program design:** The incorporation of novel utility program and tariff designs may help improve alignment in DER deployment and operation where it provides broader societal benefits. Continuing research into optimization and simulation tools, such as the open source DER Value Estimation Tool (DER-VET) [34], supports investigation and education into DER lifecycle costs and benefits to inform both customer and utility planning.
- **Equity and access considerations:** Certain customers and communities may have resilience needs which are difficult to meet due to cost or access to customer information/education. For example, utilities may need to challenge their business planning and actions to determine if they are deploying DERs with an eye towards equity or just targeting higher-income, more profitable populations. (EPRI has developed an equitable decarbonization white paper that outlines how energy efficiency programs may reach and benefit low-income households compared to higher income households.)
- **Utility transmission and distribution planning:** Power system planning traditionally has not considered limited energy resources like energy storage. Another potential issue is planning processes for high voltage transmission and low voltage distribution have been separately managed. These planning defaults may present challenges for coordinating T&D asset investment planning to assure reliability and affordability. Additionally, climate-driven wildfire scenarios are still evolving, which may drive development of new planning "worst-case" scenarios and targeted resilience investments. Several important efforts are ongoing to link power system planning tools with DER asset optimization and simulation to support decision-making. Strategic DER placement with microgrid controls is a golden opportunity to improve resilience. As part of a DOE project, EPRI has developed new resilience approaches termed Viability analysis of Isolated Power systems for Enhanced Resilience (VIPER), for distribution planning. The planning and interconnection approaches are documented in multiple reports. [23] [21] [24]

## *Operations for Resilience and Optimized Performance*

Customers and electric utilities are motivated to develop DER operational approaches to support multiple desired functions and benefits. These include a priority to ensure resilience functionality for targeted locations, while avoiding negative impacts to others. Also, to support overall economics of solutions, it is important to stack other value-enhancing operations where possible to offset the cost of resilience solutions. Additionally, when customers, electric utilities, and third parties are working together to craft multi-functional solutions, it is important to consider operations from a prioritized perspective that works from the perspective of the stakeholders so that solutions can maximize benefits while respecting the preferences of customers and asset owners.

- **Enabling resilience functionality:** For microgrids to work as effective resilience solutions, multiple resources and control layers must work in concert with one another. At the device level, DERs with inverters that are capability of grid-forming, without a reference generator to follow, are an important research area.
  At the microgrid level, controllers are increasingly expected to provide seamless backup, or islanding, and resynchronization without human intervention which requires fast and intelligent response to disruptions. It is also challenging to support operations for long duration outages, when microgrids consist of a combination of variable resources and limited energy resources. Extending outage cover can be accomplished through careful operations of DER, as well as prioritization of loads, using, for example, intelligent circuit breaker technologies [35] and customer interfaces.
  In the case of community microgrids, coordination with electric utility assets is required to enable backup power for larger groups of customers. This includes communication and coordination with utility field assets, such as protection and voltage regulation devices. It also includes Supervisory Control and Data Acquisition (SCADA) and Automated Distribution Management Systems (ADMS) integration to support situational awareness and control at the enterprise level of the electric utility. EPRI is leading two large DOE-funded research project called SOLAr Critical infrastructure Energization System (SOLACE) and Solar Energy CommUnity Resilience (SECURE) which are demonstrations of two different approaches to this challenging integration. In the SOLACE project, the research team is working to demonstrate a centralized approach to operating a community microgrid, focused on pre-event planning to energize a pre-define zone of the grid in case of outage. In contrast, the SECURE project takes a de-centralized autonomous approach to coordinate utility field assets from the level of a distribution substation ADMS. These two related demonstrations are expected to generate important results to inform the pros and cons of these approaches.

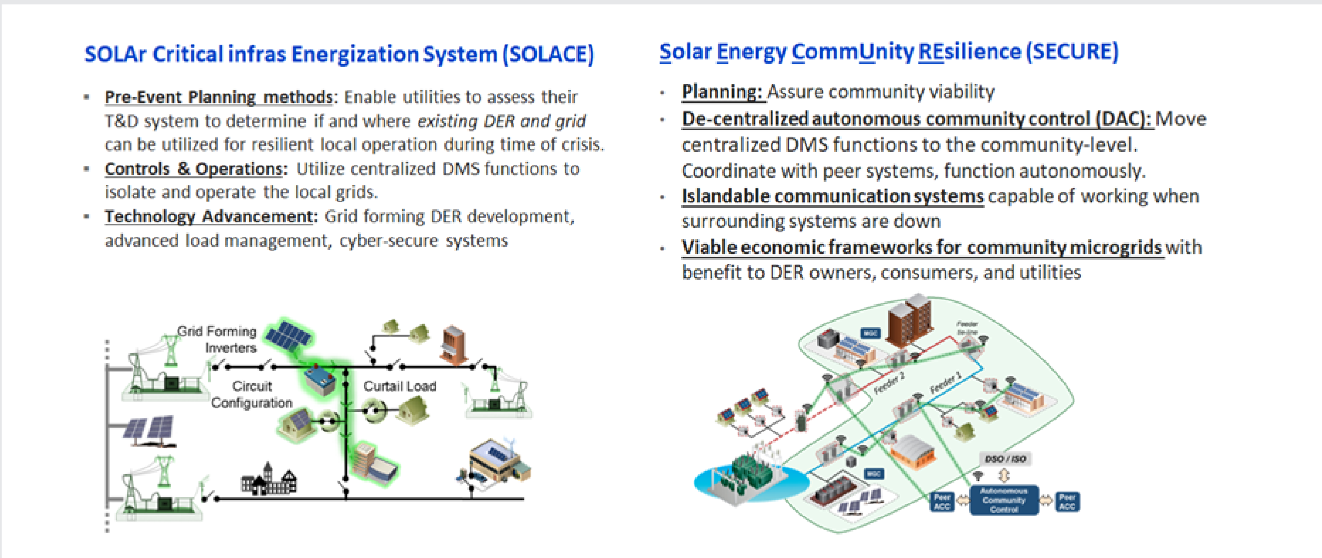
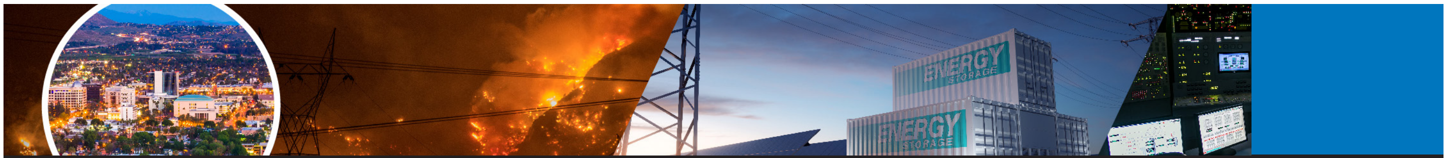



*Figure 3. Overview of Community Microgrid Demonstration Approaches*

- **Optimizing economics with grid services support:** DER can provide significant benefits to customer and utility management, beyond usage for resilience. Due to the current cost of these solutions, it is particularly important to maximum their additional benefits to support cost-effective solution development. In order to accomplish this, sophisticated intelligence is required for operational controllers to predict future value, plan dispatch of energy storage to ensure availability, and to coordinate large groups of heterogeneous assets, potentially with multiple owners and operating use cases. These capabilities may reside on a Distributed Energy Resources Management System (DERMS) [36], and the definition and demonstration of requirements are a significant research focus, to coordinate operations between independent DER, microgrids, ADMS/SCADA, and transmission-level controllers. At the transmission level, the focus shifts to virtual power plants (VPP) which are responsible to aggregate larger capacities of DER to address generation or transmission power flow objectives. Due to the new federal regulation known as FERC Order 2222 [37], system operators at the regional level are now working to update power market operations to be able to effectively harness the potential of thousands to millions of new DER assets for improving bulk power system reliability, efficiency, and economics.
- **Navigating asset owner operational constraint:** Due to the large number of potential use cases, it is important to understand the operational constraints of the underlying DER assets and the needs or preferences of their owners. Community microgrids introduce numerous scenarios and different owners who need to consent to using their resources in ways that support the greater good. Operation of customer DER by the electric utility may result in the customer asset to be unavailable when they need it for their primary objective. For example, if an EV is used for a V2G application it could be in a discharged state when its owner needs to drive somewhere. In addition, extra use of owner assets may result in additional wear and tear and reduced life, so these impacts need to be considered. Operational controllers are a rich area of research, and the associated economics of different parties can be evaluated through simulation utilizing software tools like DER-VET.
- **Integration of Mobile Energy Assets:** The introduction of energy assets on wheels, either through the use of vehicle-to-grid (V2G) or truck-hauled batteries or generators, introduces another level of opportunity and complexity. These resources move energy from one site to another without relying upon the power system. The result is the potential to support certain customers or communities which may or may not have local assets. However,



this requires plug-and-play interconnections and integration into control schemes. An EPRI project funded under California Energy Commission's MObile Renewable BackUp Generators (MORBUGs) initiative will demonstrate a hybrid hydrogen fuel cell and battery system on wheels to evaluate the challenges and opportunities for this application.

## Conclusion

This paper has introduced wildfire challenges of California and similar climates around the world. It has introduced the challenge of electric power infrastructure and the potential for its ignition of wildfires, and the mitigation of proactive de-energization during weather conditions that present higher risk. The associated outages for communities, which may last in excess of a day, may enhance risk to public safety during emergencies.

The opportunity for DER as a solution to wildfire induced outages was introduced, along with the various forms and use cases that can be considered. However, the application of these solutions is still nascent, and research and demonstration efforts at EPRI and others may help to accelerate solutions to unlock the full value of emerging technologies and integration approaches.

EPRI has conducted research to help energy providers prevent and prepare for wildfires and increase resiliency to these events. For more information on EPRI's holistic approach to wildfire research and application, click here or contact wildfire@epri.com.

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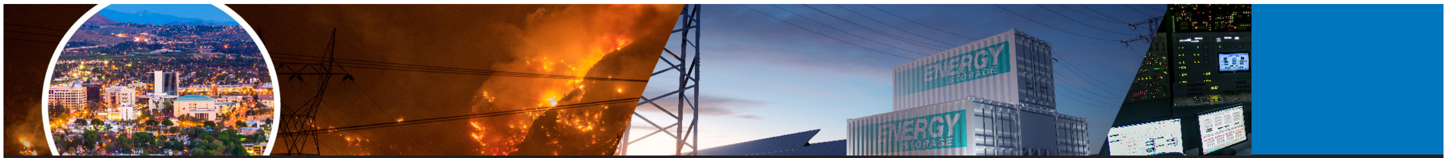


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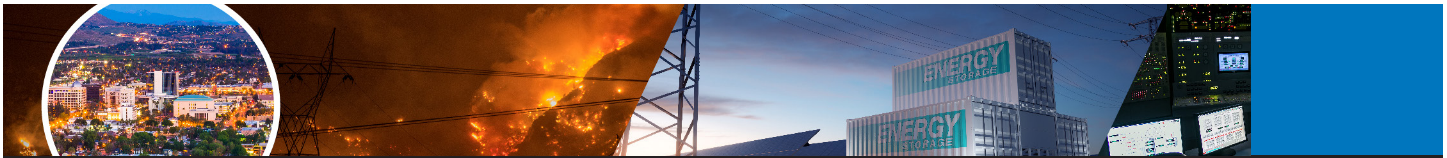


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