Spring 5-19-2023

Community Microgrids as an Equitable Climate Resilience and Adaptation Strategy in California

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This Master's Project

Community Microgrids as an Equitable Climate Resilience and Adaptation Strategy in California

by

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is submitted in partial fulfillment of the requirements
for the degree of:

Master of Science
in
Environmental Management

at the

University of San Francisco

Submitted:

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Savanna Smith 5/11/2023

Received:

5-15-2023

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Advisor Signature Date

Abstract

Climate change summons more extreme and frequent weather events that threaten communities' access to power. Without power, businesses lose revenue, essential services are limited, people are exposed to extreme temperatures, and lives are lost. California has adopted microgrids as a solution to costly power outages, electrification needs, and renewable energy goals. This work evaluates the adoption of microgrids as an equitable climate resilience and adaptation strategy through a geospatial analysis of California's resilience investment needs, a case study analysis of 9 existing tribal and rural microgrids, and a gap analysis of California and federal policies and incentive programs. Programs like Electric Program Investment Charge demonstrates that it is possible to identify and prioritize environmental justice (EJ) areas. It is recommended that California expands incentives and technical assistance to EJ communities. Additionally, this work found that Rule 218 is a major barrier to microgrid adoption. It is recommended to first modify the rule to allow community-owned microgrids under the own-use doctrine and second to exempt microgrids from public utility status to mobilize innovation and commercialization, aligned with SB 1339's goals. Furthermore, the current utility model impedes progress towards climate adaptation. Investor-owned utilities have failed to provide reliable electricity and prevent wildfires. This work recommends shifting to a performance-based utility model that rewards resilience and reliability. Other actions that are needed to mobilize equitable microgrid adoption include raising high-voltage network rates for industrial users and investing in workforce development. Mobilizing microgrids through these actions equips California for equitable climate resilience and adaptation.

1. Introduction

This work evaluates California's adoption of microgrids as an equitable climate resilience and adaptation strategy. Microgrids are adopted globally to improve electric reliability, create community resilience in the face of weather extremes, and deploy more renewable energy sources. California has incentives for microgrid technology and in several cases explicitly targets funding to vulnerable and under-resourced communities. This type of investment is a crucial tool for restoring equity to communities facing disproportionate impacts of climate change. This work evaluates high-risk areas, existing tribal and rural microgrids, and performs a gap analysis of the policies and incentives to ensure California can effectively and efficiently mobilize equitable microgrid adoption.

Anthropogenic climate change summons more frequent and severe weather events, like earthquakes, fires, and floods (WMO, 2011). These severe events lead to power outages that limit emergency services, water treatment, food storage, and gas distribution. In 2017, Hurricane Maria resulted in a 11-month electricity outage for 1.5 million people, the largest blackout in United States (US) history (Campbell, 2018). Hurricane Ida's heavy rain, winds, and floods cut power for 1.2 million customers across eight states (EIA, 2021). In early 2023, an ice storm caused massive power outages across Texas, which was once considered rare and is now becoming more prevalent: between 2020 and 2021 the Department of Energy logged 60 major weather-related power outages in Texas (Brady, 2023). Notably in 2021, winter storms took out power during below-freezing days for millions of Texans, causing lost lives and infrastructure damages (Mills, 2022). Without power, communities are unable to protect themselves from extremely hot or cold temperatures, which can be life-threatening. Outages caused by weather-extremes are an increasingly widespread issue. Between 2011 and 2021, weather-induced outages across the nation increased 78 percent compared to the previous decade (Brady, 2023). Thus, it is crucial that governments ensure access to energy in face of a changing climate, especially for the most vulnerable of communities.

These examples illustrate that the central grid has been ill-equipped to resist or quickly recover from disruptions. For this reason, local governments are identifying strategies that limit power outage frequency and their impacts. One solution is implementing microgrids, which the US Department of Energy (DOE) Microgrid Exchange group defines as follows:

A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts 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 or island-mode (Ton, 2012).

As shown in Figure 1, microgrids can be managed and isolated to maintain electricity during disturbances. By maintaining electricity, adverse health and economic impacts may be avoided, especially for Environmental Justice (EJ) communities.

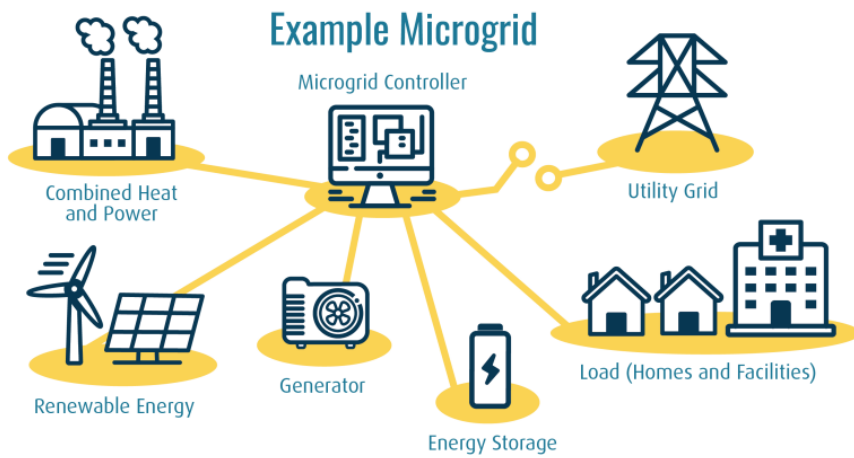


Figure 1: Microgrids are made up of energy generation, storage, users, a microgrid controller, and a detachable connection to the central grid (Rickerson, 2022)

On December 20th, 2022, President Biden signed the Community Disaster Resilience Zones Act to designate resilience zones impacting disadvantaged communities most at-risk to natural hazards (The White House, 2022a). These identified areas will have access to federal funds that help reduce impacts caused by climate change and natural hazards. The Biden Administration announced a goal for 40 percent of certain federal investments to go to disadvantaged communities overburdened by pollution (The White House, 2022b). Access to reliable energy in an ever-electrifying society is a fundamental need. However, nascent microgrid policies and incentive programs are largely inaccessible to lower-income communities because they require complex grant-writing expertise and only fund a fraction of the cost. Thus, policies and incentives need to be modified and expanded so that EJ communities can realize full benefits from microgrids.

2. Research Questions

This work aims to address: how can California ensure equitable adoption of microgrids for climate resilience? To answer this, this work 1) identifies environmental justice areas at risk to climate extremes and unreliable electricity 2) evaluates existing tribal and rural microgrids, and 3) analyzes microgrid adoption under current policies and incentives. This work concludes with recommendations to improve and expand policies and incentive programs to ensure equitable adoption of microgrids.

3. Methodology

This work first performs a geospatial analysis of communities across California that face risk to extreme weather, poverty, social vulnerability, and unreliable connection. Second, this work evaluates case studies of tribal and rural communities that have adopted microgrids to help rebound from extreme weather events and frequent blackouts. Third, this work performs a gap analysis, which includes expert interviews. These approaches help identify ways to continue, expand, or modify current practices and policies for equitable microgrids adoption.

3.1 Data Sources

This work leverages per capita income in the United States by county (Esri, 2022), the poverty index map layer of the 2016-2020 American Community Survey (ACS) data from the U.S. Census Bureau (Berry, 2022), tribal census tracts (Esri, 2023a), and the FEMA Risk Index by county (Esri, 2023b). This work also includes tracked power outages from the California Governor's Office of Emergency Services (OES, 2022). Outage data comes from Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), Sacramento Municipal Utility District (SMUD), and Los Angeles Water & Power (LAWP).

3.2 FEMA Risk Index

The National Risk Index illustrates the expected impact natural hazards have on communities, for 18 hazard types, listed in Table 6 in the appendix. There are three components to the Risk Index: the expected annual loss (EAL) from hazards, a community’s social vulnerability make-up, and a community’s resilience score.

EAL is a composite of building value, population loss dollar equivalence (every ten injuries or one death is treated as a loss of $7.6 million), and agricultural value, multiplied by annualized frequency and historic loss ratio (Zuzak, 2022).

The social vulnerability is estimated using the Social Vulnerability Index (SoVI) developed by the University of South Carolina's Hazards and Vulnerability Research Institute (HVRI). SoVI comprises 29 socioeconomic variables, like median age, ethnicity, per capita income, population with English as a second language, average household occupancy, median gross rent, and percent of people in poverty (HVRI, 2013).

The community resilience is estimated using HVRI's 49 Baseline Resilience Indicators for Communities (BRIC) at the county level. These attributes, as detailed in Table 7 in the appendix, span a community's economic assets, their social connectivity, natural resources and environmental conditions, infrastructure and housing, institutional ability, and community capacity (HVRI, 2021). The Risk Index provides a holistic picture of a community's ability to be resilient to climate-related power outages.

3.3 Case Studies

The case studies consist of nine California community microgrids selected from the DOE's database of microgrid deployments (DOE, 2022a). Information was collected from interviews, government documents, web publications, and energy news. For each case study, this work considers the county's Risk Index and the community's explicit resilience goals. It also considers reliability issues such as limited, damaged, or difficult to service transmission lines. It assesses other community goals, like wildfire prevention, lower utility bills, renewables, energy storage research, and energy independence. For a given community, motivating factors were only included if they were explicitly mentioned in the literature. Thus, there may be more energy goals and microgrid motivations outside of the ones listed.

3.4 Policy Analysis

Regulations are compared across year established, dollars committed, microgrids committed, whether there is an explicit EJ component, and any key conflicts. There are other programs and policies that were out of scope for this study. This study excluded energy bills and programs that do not explicitly mention microgrids. Also excluded were technical assistance programs, like SB

774's technical assistance program (SB 779, 2019), Title 26's Energy Storage Technology and Microgrid Assistance program (42 USC 17233), and Title 42's CHP Technical Assistance Partnership (DOE, 2023) since these are newer programs with limited data on their contribution to microgrid deployment. Environmental compliance regulations were also out of scope. This is because microgrid projects are sometimes exempted from the California Environmental Quality Act reporting requirements (CEQA, 2022). This work focused on state policies, utility programs, state resilience funds, and federal programs that policy experts identified as major incentives or limitations to microgrid deployment.

4. Literature Review

This section discusses microgrid benefits, barriers and opportunities, and communities that stand to benefit the most from microgrids.

4.1 Microgrid Benefits

Community microgrids complement central transmission lines by providing backup power during planned or emergency outages, facilitating integration and control of renewables, adding electric capacity and efficiency, and providing ancillary services that the central grid lacks.

Microgrids provide backup power for disaster shelters and critical facilities during weather-related outages. Maintaining reliable power allows resilience to natural hazards. Resilience is defined as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through adaptable and holistic planning and technical solutions", according to the National Renewable Energy Laboratory (NREL) (Hotchkiss, 2019). Local and state governments have turned to microgrids as a solution for maintaining power during extreme weather events. Following Hurricane Sandy in 2012, states including Connecticut, Maryland, Massachusetts, New Jersey, and New York launched several programs for addressing resilience to hurricanes and severe storms (Rickerson, 2022). Following Hurricane Maria in 2017, the DOE recommended microgrids for enhanced resilience in Puerto Rico (Jeffers, 2018). Similarly, Rhode Island and Wisconsin adopted microgrid resilience programs through their State Energy Office (Carley, 2021). More leaders are recognizing microgrids as a solution for maintaining power when faced with fires, floods, storms, and more.

Microgrids can also maintain reliable power during public safety planned shutoffs (PSPS), which are outages that prevent wildfires (Lindh, 2021). This current system is under-performing. In 2018, PG&E shut off power to at-risk areas in California to prevent wildfires, which was met with customer backlash. To prevent a similar backlash during 2019's fire season, PG&E decided not to shut off risk areas. This led to the Campfire, which killed 86 people (Trabish, 2020). Subsequently, customers bailed PG&E out from bankruptcy. As shown in Figure 2, wildfires have caused property loss valued at $1.7 billion per year between 2009 and 2019 (CESER, 2021). Governor Gavin Newsom issued a State Emergency in 2020, which aimed to expedite clean energy projects to ensure resilience to wildfires in 2022 and beyond (OOGGN, 2021). California has seen pay-offs of microgrid investments. For example, the Redwood Coast Airport microgrid stayed online during earthquakes and flooding in January 2023 (Hitchens, 2023) and the Pacific Union College in Angwin stayed online during PG&E's PSPS events (St. Clair, 2019).

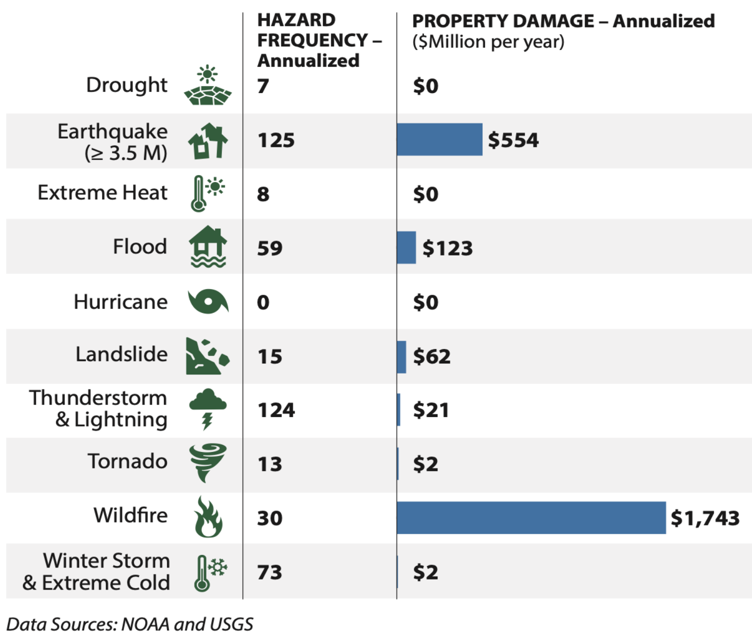


Figure 2: California's annualized frequency of and property damage caused by natural hazards from 2009 to 2019 (CESER, 2019).

Second, microgrids help increase available capacity for electrification goals. For example, California aims to ban the sale of internal combustion vehicles by 2035 (CARB, 2022b). Increasing the number of electric vehicles (EVs) is necessary to meet net zero goals but puts a substantial strain on the grid. More grid infrastructure is required to support the added load from electrification initiatives, like EVs, in California (CEC, 2019). Several are turning to microgrids as a solution. For example, the Peninsula Advanced Energy Community (PAEC) solar microgrid aims to use power management that reduces peak demand by 25 megawatts (MW) and add 46 level 2 electric vehicle chargers across San Mateo County (Wasko, 2019). Microgrids are one way to add capacity and support for EVs and other electrification goals.

Third, microgrids are often designed with renewable energy and control components, which provide dynamic responsiveness to renewables' generation intermittency (Saini, 2021). Microgrids can provide ancillary services to the central grid, including local management of net load variations, ramping, frequency regulation, and load following (Majzoobi, 2017). Microgrids offer these services to optimize the utilization of assets and operate efficiently, which are fundamental to the clean energy transition. Expanding renewable generation and improving control of those power sources can displace fossil fuels. Lowering fossil fuels aligns with California and federal strategies. The Biden-Harris administration targets net zero by 2050 (Biden, 2021) and California targets net zero by 2045 (CARB, 2022a). Adoption of renewable energy has historically been limited due to the high cost, however, the Rocky Mountain Institute (RMI) reports that clean energy portfolios, consisting of solar, wind, and storage, are now a better investment than both new and existing natural gas plants (Shwisberg, 2021). This does not include 2022's Inflation Reductive Act (IRA), which provides incentives that drive down the cost of renewables further. Thus, renewable microgrid projects are a way to meet state, local, and federal targets.

Figure 3: Energy challenges microgrids help address.

As summarized in Figure 3, microgrids help address several energy challenges, including reduced risk of power-outages from climate-extremes and fire prevention measures, added capacity that supports electrification, and increased amount and control of renewables. For these reasons, microgrids are of continued importance in California not only to the energy needs of communities, but also for health and safety.

4.2 Microgrid Barriers & Opportunities

Community microgrids have been met with resistance in part because they are expensive and have unclear benefits to customers. Microgrids are also limited by external threats like labor shortage issues and societal reliance on fossil-fuel powered solutions.

First, one of the biggest problems is cost. In community microgrids, generation is the largest cost at 54%, followed by energy storage at 15% (Giraldez, 2018). Generation costs often come from retrofitting legacy generators. Another cost in community microgrids involves islanding, since the system needs "medium-voltage switchgear, supervisory control, and data acquisition systems" (Giraldez, 2018). An alternative energy resilience solution is grid hardening, which involves upgrading overhead power lines threatened by snow, wind, and other environmental hazards. In July 2021, PG&E proposed undergrounding 10,000 miles of distribution lines to reduce the risk of causing wildfires, an effort that would take multiple years and cost up to $40 billion (Rickerson, 2022). This demonstrates that microgrid alternatives are also expensive.

Second, regulators may reject microgrid projects when the benefits are unclear to ratepayers. This occurred in Maryland when Maryland Public Service Commission denied a proposed microgrid due to "uneven benefits to ratepayers" (Maryland PSC, 2015). All customers' rates will go up to fund the project, but only one community receives the microgrid project. However, some communities experience lower energy reliability or resilience. Public Utility Commissions and State Energy Offices have not been able to prioritize resilience investments without metrics that quantify the societal impacts from power disruptions. Similarly, utility companies have often excluded high-impact but low-probability events when measuring reliability for customers because they are difficult to model (Nateghi, 2016). Clark (2022) and Wechtel (2022) argue for Willingness to Pay (WTP) and Value of Lost Load (WoLL) approaches to social equity resilience valuation. However, there is limited data applied through a social equity resilience model.

Third, there are gaps in the labor force for renewable energy. For example, NREL (2022) found that 68% of wind energy employers reported difficulty in finding qualified applicants.

Labor and employment attorney Bernice Diaz commented that “there will likely be a shortage of apprentices, especially if this generation continues to steer away from skilled trade jobs” (DiGangi, 2023). This provides a gap and economic opportunity to grow the workforce in distributed energy resources.

The fourth issue is the proliferate use of fossil fuels for backup power**.** In just three years, the number of nonresidential backup generators increased 34% in the Bay Area Air Quality Management District and 22% in the South Coast Air Quality Management District (Moss, 2020). Across five air quality districts, 89% of the total 24,503 backup generators are diesel powered (Moss, 2020). IOUs deployed temporary diesel-based microgrids in 2021 to meet reliability needs and avoid PSPSs (CPUC, 2021b). California is acting fast to get people reliable power, but these quick and dirty fossil-fuel solutions perpetuate the problems of climate change.

4.3 Environmental Justice

An EJ community has households predominantly made-up of persons of color, Native Americans, Hispanics, or people below the poverty line. An EJ community is disproportionately burdened by climate change and may experience “a significantly reduced quality of life relative to comparative communities” (Welsch, 1997).

This reduced quality of life extends to energy needs. According to the American Council for an Energy-Efficient Economy (ACEEE), an EJ household pays a more significant share of their income on their energy bills, which heightens economic hardship (Somberg, 2020). Notably, “tribes have a really unfair disadvantage in terms of what they’re charged”, Maggie Tallmadge from Navajo Power comments, “tribes want to stand alone and control their energy use” (Cohn, 2022b). Director of the Office of Indian Energy, Kevin Frost, comments that “power is the nexus for everything, not just within Indian country or Alaska communities, but in society at large. You can't have economic development, you can't have financial growth, you can't offer economic growth, jobs, all those other things without a power source” (Dozier, 2019). More tribes across California engage in distributed energy projects to promote economic growth and independence.

In addition to economic impacts, energy has health impacts to EJ communities. Gas peaker plants are a traditional way to meet energy demand peaks. Gas peaker plants, which are high polluters, are also disproportionately located in EJ communities (Krieger, 2016), threatening them with more health and environmental hazards, which include asthma risks and pollution-related deaths. Gas peaker plants sit idle most of the time, which is expensive, inefficient, and has health impacts. Opting for renewables rather than gas plants is estimated to avoid 152 to 346 deaths across the US each year (Krieger, 2016).

In 2019, Governor Gavin Newsom issued an executive order to recognize the harm inflicted on native tribes across California (N-19-19, 2019). With funding from the Infrastructure Investment and Jobs Act, the DOE (2021) is consulting federally recognized tribes to develop 60 new programs to ensure investment has a positive impact for the communities. Microgrids can help address economic and health hardships faced by EJ communities.

5. High Risk Regions

This section compares reliability and social vulnerability across California, analyzing for disparities in opportunities for microgrid investments.

5.1 Public Shutoff Risk

Data from California Office of Energy Security (OES), shows numerous planned and unplanned power outage events already in the first four months of 2023, shown in Figure 4.

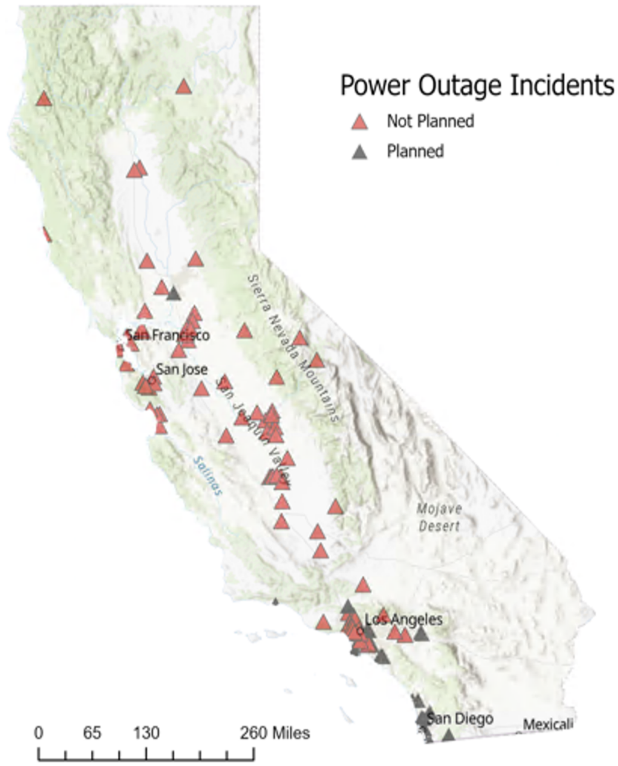


Figure 4: Cumulative California Power Shut Offs from February to March 2023 (OES, 2022).

Planned outages are for maintenance or to reduce the risk of debris during storms igniting on energized lines. Unplanned outages occur when trees or high winds damage the lines. These power outages have affected anywhere from 2 to over 1000 customers, shown in Figure 5. Of the total 94 outages in this period, about 15% impacted more than 25 customers.

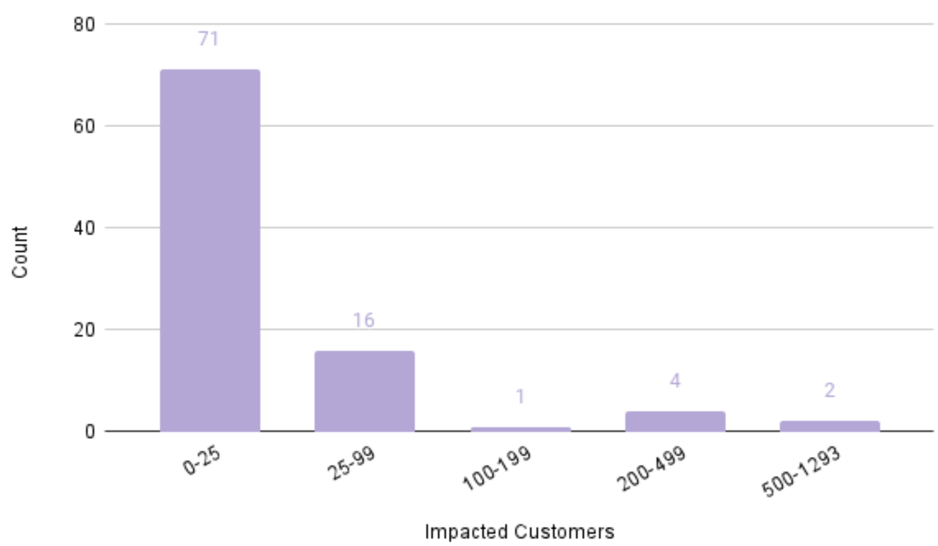


Figure 5: Number of customers impacted by 2023 shut-offs in California.

Outages have lasted between two hours and two weeks, shown in Figure 6. Fifty-two percent of the outages impacted customers for more than 10 hours. Even outages that last a couple hours can expose people to extreme temperatures, spoil food, or limit essential services.

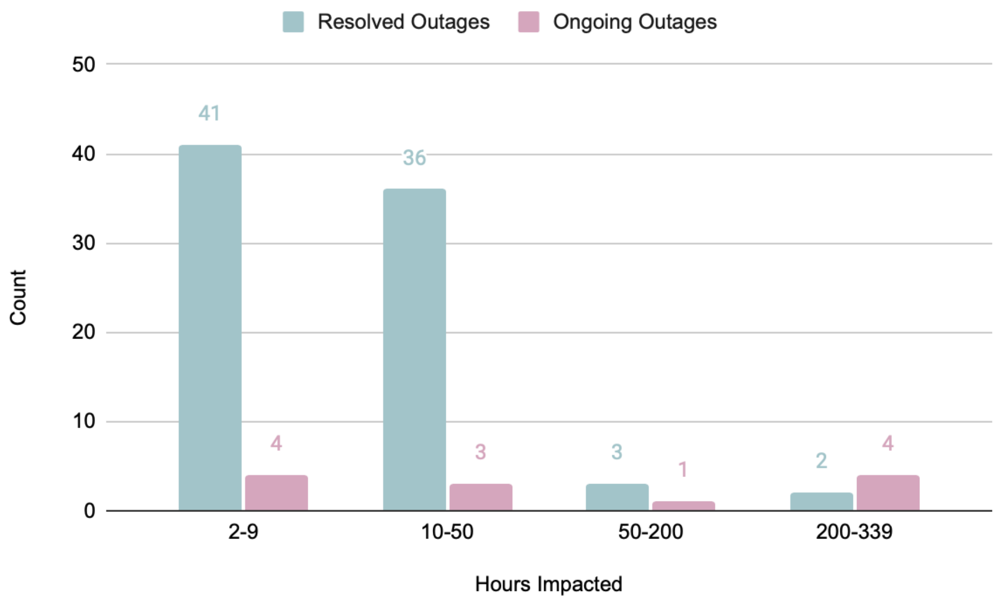


Figure 6: Number of hours customers were impacted by 2023 shut-offs in California.

The impacts of 2023's flooding, snow, and windstorms on transmission lines have left businesses and households across California without power. There is a need across California to advance reliable energy with microgrid projects.

5.2 Funding Distribution

Already, there has been investment in microgrids across the state. Figure 7 shows microgrid installations and low-income census tracts, which are based on whether the tract "has a poverty rate of at least 20 percent" or if the "median income is less than 80 percent of the statewide median" (Berry, 2022). The figure indicates that there are 47 out of 90 microgrids, or approximately 52%, located in areas of greater wealth.

Figure 7: Microgrid installations across low-income communities in California.

A microgrid's impact on a low-income community also depends on the use-case. For example, a microgrid in the middle of a low-income area may serve a military-base, instead of the broader community members. Figure 8 shows that 10% of California's microgrids serve military bases. Nearly 19% or 17 out of 90 total are commercial microgrids. There are 41 microgrids that serve public needs like for hospitals, the community, public institutions, schools, and water treatment facilities, which together make up approximately 45% of the total. The "other" category includes the San Diego Zoo microgrid, the Lion's Club wilderness camp microgrid, and SCE Gem Dam microgrid.

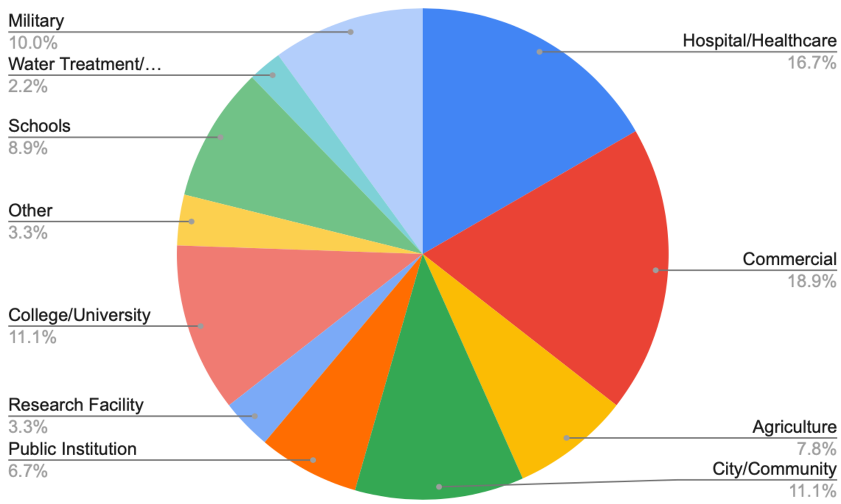


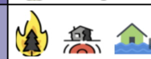
Figure 8: Application type for 90 microgrids in California

Distributed energy projects have historically been challenging to implement in EJ areas. One issue is that circuits within EJ communities have less hosting capacity for energy components like solar photovoltaics (Brockway, 2021). This lack of upgraded energy infrastructure is just one-way communities are under-resourced. Several barriers like operability, capital costs, and misaligned policy have prevented progress in achieving the full benefits microgrids offer for community resilience and California's renewable energy goals. In recent years, investment programs, discussed in Section 7. Microgrid Policies, have incentivized microgrid developments in under-resourced areas and this trend must continue.

5.3 FEMA Risk Areas

Table 1 shows the breakdown of the FEMA Risk Index across six counties. The Risk Index has the EAL according to each hazard type, the social vulnerability, and the community resilience. This provides a more equitable approach compared to just assessing natural threat hazard. For example, Marin County has a relatively high EAL, but their population has less social vulnerability and high community resilience. The other counties are subject to similar levels of EAL but lack the same level of wealth and resources to mitigate the risks. Thus, microgrid projects should be prioritized in areas that are subject to high risk, high social vulnerability, and low community resilience.

Table 1: Breakdown of National Risk Index (FEMA, 2023) for counties with community microgrid projects

County	Expected Annual Loss	Social Vulnerability	Community Resilience	Hazard Types
Riverside	$1,190,667,489	Very High	Relatively Low	
San Bernardino	$1,137,542,458	Very High	Relatively Moderate	
San Diego	$799,862,388	Relatively High	Very Low	
Humboldt	$118,015,867	Very High	Relatively Moderate	
Marin	$122,042,805	Relatively Low	Very High	
Colusa	$71,260,808	Relatively High	Relatively Low	
Del Norte	$18,494,927	Very High	Relatively Low	
Mariposa	$14,763,212	Very High	Relatively Low	

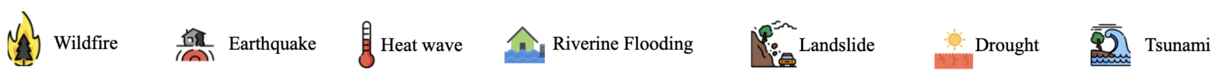


Figure 9 shows that tribes are majorly located in areas with high National Risk Index scores across California. This means the areas are subject to large risk to natural hazards, have high social vulnerability, and low community resilience resources. These areas are especially vulnerable to planned and unplanned power shutoffs. They are likely to experience more frequent shut offs due to increased risk of natural hazards. Additionally, there may be less redundancy in power resources that make these areas less robust to power shut-offs. This was exemplified in Borrego Springs microgrid, since the community was only connected by one major line to the grid. If something happens to this one line, the rest of the system is impacted. Natural hazards like fires, floods, and earthquakes are damaging enough to communities. With the added electric reliability and robustness to extremes that microgrids provide, these communities can be resilient to growing climate extremes.

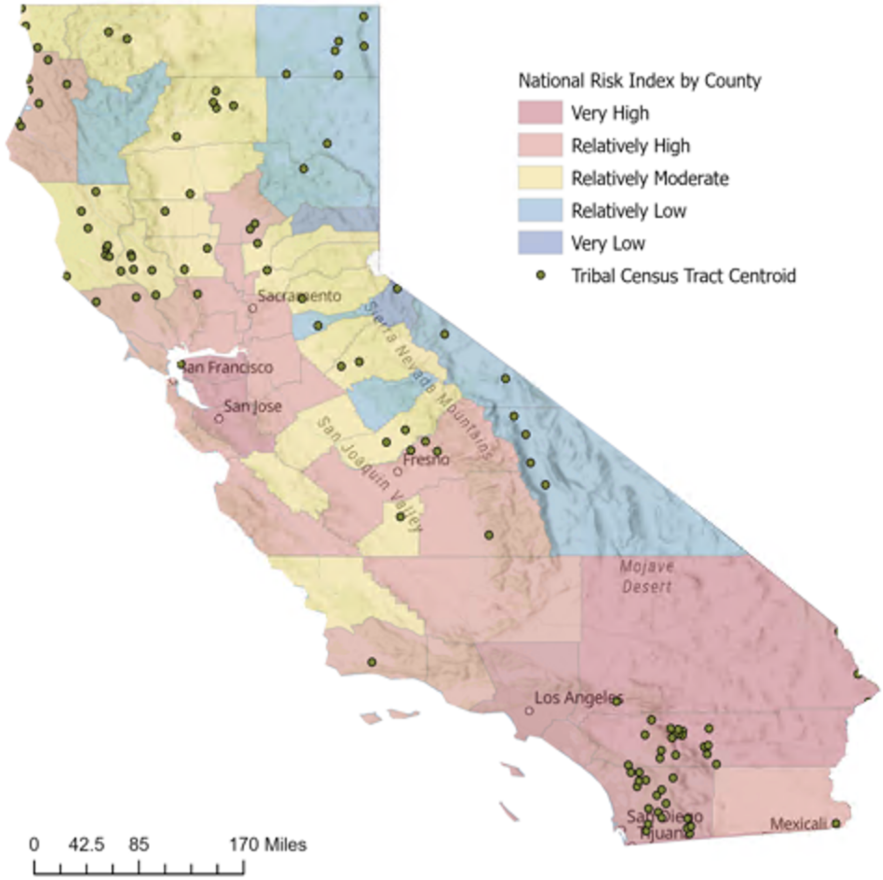


Figure 9: Natural Risk Index by county and California tribal areas

6. California Community Microgrids

This section evaluates each sampled community microgrid, listed in Table 2. Often these areas have less connection points to the central grid, making them more vulnerable to reliability issues. Figure 10 shows the transmission lines: Chemehuevi Reservation has two, Colusa Rancheria has one, Yurok Reservation has one, and the remaining have none. Note that the Yurok Reservation is larger geographically than the other tribes, so a zoomed-out aspect ratio was used to view the entire area. Figure 10 also shows the county Risk Index where the sampled microgrid projects reside. While Blue Lake Rancheria is at relatively moderate risk, the remaining territories face relatively or very high risk. The combination of high Risk Index and low grid connectivity lower the community's resilience to climate change. Each subsection details the motivating factors behind each project, the funding sources, and the current challenges.

Table 2: Sampled microgrid projects, their counties, and affiliated tribes

Microgrid	County	Affiliated Tribe
Anza Electric	Riverside	Santa Rosa Band of Cahuilla Indians
Blue Lake	Humboldt	Blue Lake Rancheria
Borrego Springs	San Diego	None
Briceburg	Mariposa	None
Chemehuevi	San Bernardino	Chemehuevi Reservation
Colusa	Colusa	Colusa Rancheria
Rohnerville	Humboldt	Bear River Band of the Rohnerville Rancheria
Viejas	San Diego	Viejas Band of Kumeyaay Indians
Yurok	Humboldt and Del Norte	Yurok People

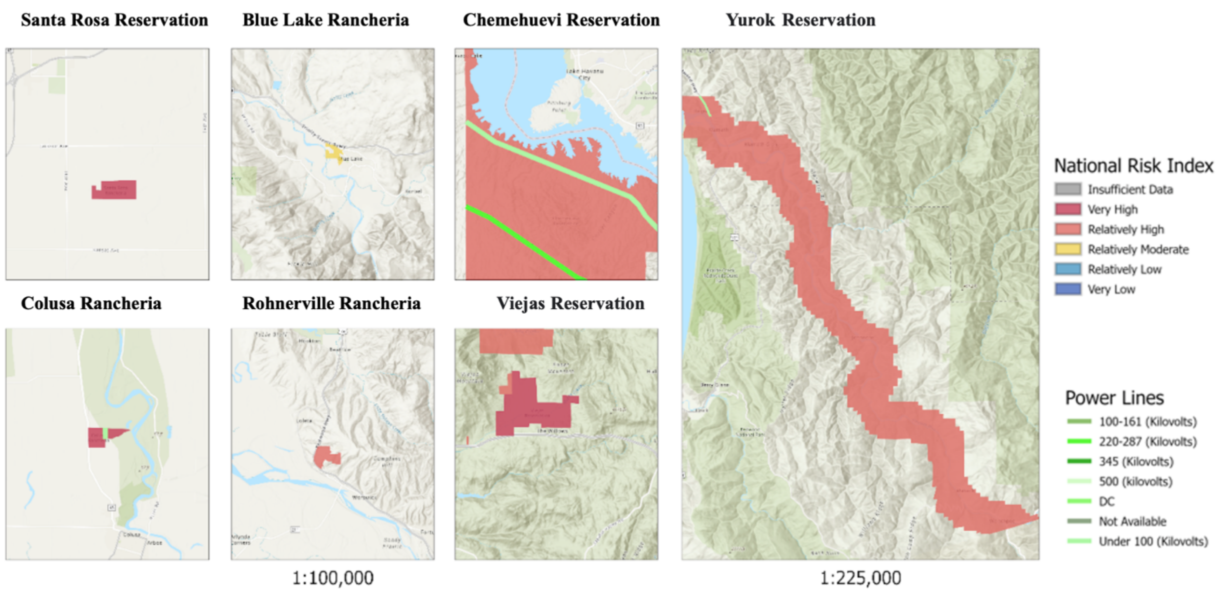


Figure 10: Transmission Power Lines and National Risk Index on sampled tribal lands with microgrid projects

6.1 Anza Electric Cooperative

Anza Electric Cooperative (AEC) services 10,000 customers, 94% of which are residential and 6% are small commercial. The service area is 550 square miles located within Riverside County. As shown in Table 1, Riverside has the highest EAL among the sampled counties, with high social vulnerability, and low community resilience. Riverside has a relatively high risk of earthquakes, heat waves, and riverine flooding and a very high risk of wildfires (FEMA, 2023).

Prior to the microgrid, the area was fully dependent on SCE lines for importing power. Importing power is challenging in Riverside's high desert, at 4,000 feet in elevation, and rough winter conditions. A new transmission line would cost AEC more than its total value (Cohn, 2021). In 2017, AEC was shut down twice by SCE because of fire threats, once over 10 days during the hottest time of year (Cohn, 2021).

The Santa Rosa Solar project was awarded a $2 million grant provided by the California Community Services Department because some of the solar energy went to tribal and low-income households (NRECA, 2020). The Santa Rosa Solar project is a 1 MW array owned and maintained by AEC and located on the land owned by the Santa Rosa Band of Cahuilla Indians, which receive financial offsets through virtual net metering.

6.2 Blue Lake Rancheria Microgrid

Blue Lake Rancheria (BLR) is in Humboldt County, an area at risk to earthquakes and landslides, moderate social vulnerability, and low community resilience, as shown in Table 1. Landslides can make roads impassable to emergency vehicles. Further, communications were frequently impacted by damage to non-redundant cables (Henderson 2014). BLR is connected to the utility grid by a 70 MW transmission line, leaving no room for error to frequent storms, floods, wildfires, earthquakes, and tsunamis. On April 11, 2011, thousands of Humboldt County residents self-evacuated to higher grounds, finding shelter at BLR when a tsunami was expected to follow the Fukushima earthquake.

In 2016, BLR members installed a 500-kilowatt solar array microgrid, in collaboration with the Schatz Energy Research Center and the Humboldt State University, funded through a grant from the California Energy Commission (CEC) (EIA, 2022). Today, BLR is a certified Red Cross shelter-in-place site and a nationally recognized Climate Action Champion. The microgrid generates 420 kilowatts of electricity from solar PV to power the tribal offices and meeting rooms, casino, emergency facilities, and hotel. In 2018, the microgrid saved 200 tons of CO_2 equivalent, $160,000 in annual electricity costs, and increased clean energy jobs by ten percent (CEC, 2019). In addition to jobs, the microgrid helps teach students about battery storage and renewable energy.

The microgrid has also demonstrated resilience benefits. In 2019, BLR successfully shared electricity from its microgrid with approximately a tenth of the Humboldt population during a wildfire-related utility power shutoff (EIA, 2022). For some county residents, the microgrid's sustained power can be life-saving. It was estimated that the microgrid saved four lives by powering necessary medical devices (Maloney, 2019). Saving lives is a powerful demonstration of the benefit this microgrid has provided. To put it in context of economics using the FEMA EAL, this equates to a $30.4 million saved. The microgrid provides community resilience for not only Blue Lake Rancheria, but the broader Humboldt area. It also mobilizes increases power reliability, expands research ventures, and creates job opportunities.

6.3 Borrego Springs Microgrid

Borrego Springs is a remote desert town located in San Diego County, which suffers the third highest EAL, a high social vulnerability, and low community resilience, according to Table 1.

Borrego Springs is served by just one utility transmission line. That line was taken down during a wildfire in 2007. The community responded by developing a microgrid, which can maintain power to critical facilities in the summer when temperatures exceed 110 degrees Fahrenheit (Climate Interactive, 2019). The population has many seniors, amplifying the health impact of power outages (Climate Interactive, 2019). Andrew Moradpour, Senior Distributed Energy Resources Engineer at SDG&E explains that extensive research goes into selecting a microgrid site. In Borrego, Moradpour says, "there's only one transmission line that feeds them, so it was a perfect candidate for a microgrid". Borrego also has a large customer base hosting PV solar, several commercial solar farms, and large-scale agricultural operations (Moradpour, 2023).

In 2015, SDG&E won a grant to expand the microgrid and connect it with a nearby solar farm (Climate Interactive, 2019). As a result, the Borrego microgrid boasts an abundance of solar, with excess sent to the California Independent System Operator (CAISO) market. The next challenge was storing the excess energy locally. In 2019, SDG&E won a $4.5 million SETO federal grant to upgrade the Borrego Springs microgrid to 100% renewable energy through long duration hydrogen and lithium-ion energy storage technology (Nanda, 2022). SDG&E aims to meet the 100% renewable target by 2045. Moradpour explains that if they were to do this transition in a shorter span, such as in 5 years, "we would have to plead our case to the CPUC in the next GRC filing, which may impact customer rates" (Moradpour, 2023). Instead, the project is expected to have net benefit spread over a 20-year period.

Moradpour supports SDG&E's GRC filing for 2022 to 2024 and he says that CPUC interveners scrutinize each capital proposal. To further expand the Borrego Springs microgrid, SDG&E must provide qualitative and quantitative justification of the environmental and reliability improvement. An example of how Borrego Springs microgrid is already championing improved reliability for the community was when the microgrid supported 3,000 customers for 10 days in February 2023, during transmission line maintenance. The microgrid provides redundant and offline power for Borrego Springs and enables the community's 100% renewable energy goals.

6.4 Briceburg Microgrid

This entirely remote microgrid serves five customer meters, including a visitor center, a telecommunications facility, and a transportation facility, to provide electricity in a high fire risk area. Briceburg is in Mariposa County, which, among the sampled counties, has the lowest EAL show in Table 1. This is likely because there is a smaller population and less infrastructure. Mariposa has a very high social vulnerability and relatively low community resilience.

The Briceburg area's rugged terrain makes it challenging to service and rebuild transmission lines. The microgrid permanently replaced 1.4 miles of line destroyed in a 2019 fire (Cohn, 2022a). This provides electric reliability and reduced wildfire risk.

PG&E financed the project, BoxPower implemented the solar power system, and New Sun Road provided the remote performance management and control system (Goldbach, 2023). Microgrids and accompanying control technology can ease the burden of servicing and repairing electric systems in remote and hard-to-navigate areas. PG&E identified an additional 20 wildfire risk areas they aim to target with similar systems (Cohn, 2022a). The microgrid serves as an improvement to wildfire prevention and power reliability and exemplifies innovative capabilities driving distributed energy resources.

6.5 Chemehuevi Community Center Microgrid

San Bernardino has the second highest EAL, at over a billion dollars, very high social vulnerability, and relatively moderate community resilience, shown in Table 1. Natural hazards include wildfires, earthquakes, and riverine flooding. The microgrid enables resilience to such natural hazards since it is in the tribe's emergency response center.

The microgrid also addresses power reliability needs: according to SCE's reliability report, the Chemehuevi community center experiences an above-average number and duration of power interruptions (UC Riverside, 2021).

The project was funded by a $2.6 million grant from the California Energy Commission's Electric Program Investment Charge (EPIC) Program. The microgrid serves as a battery management research partnership with the University of California Riverside's Southern California Research Initiative for Solar Energy (SC-RISE). Additionally, GRID-Alternatives offers vocational training for Chemehuevi tribal members (GRID Alternatives, 2022). The microgrid provides increased reliability, community resilience, research partnerships, and job opportunities.

5.6 Colusa Casino Microgrid

Colusa county has an EAL of over 71 million dollars, relatively high social vulnerability, relatively low community resilience, and is subject to drought conditions (Table 1). The Colusa Indian Community Council owns and operates an islanded microgrid. The microgrid supplies power to the Colusa Casino Resort, administration buildings, wastewater treatment plants, a wellness center, 30 houses, a daycare, the mechanic, irrigation pumps, and a sewer lift station (Humphrey, 2019). The microgrid thus can provide redundant and reliable power that serve their community and economic needs.

What started as a cogeneration power plant expanded in 2019, when the DOE funded the development of a solar photovoltaic (PV) carport canopy in the Colusa Casino Resort parking lot (OIE, 2019a) and system improvements (OIE, 2019b). In 2020, Colusa received an Energy Technology Deployment on Tribal Lands grant from the Office of Indian Energy. The fund covers the advanced net-metering infrastructure to automate power supply to tribal households and street lighting (OIE, 2020). In 2022, the DOE awarded the Colusa tribe $517,200 to expand its cogeneration power plant and microgrid to serve seven new homes as part of a $9 million national investment in tribal energy security and resilience (DOE, 2022b). The microgrid is expected to save the Colusa tribe $9,381,420 and reduce CO_2 emissions by about 10,000 tons over 30-years (Humphrey, 2019).

6.7 Rohnerville Rancheria Microgrid

Rohnerville Rancheria is in in Humboldt County, an area with moderate social vulnerability and low community resilience (Table 1). In 2015, the Bear River Band of the Rohnerville Rancheria installed California's first tribal microgrid, which consisted of solar, wind, and storage (EIA, 2022). The microgrid consists of 100kW of solar photovoltaic panels and twenty Zefr wind turbines that power the Tish Non Community Center.

Mr. Barry Brenard, Tribal Council member, commented that the project "demonstrates our respect for natural resources, self-reliance and Tribal Sovereignty" (Business Wire, 2015). The microgrid provides reliable power for the building operations when there is a power outage.

The tribe self-financed the $400,000 microgrid and contracted JLM Energy for implementation. The project is expected to have a 10-year return on investment period with projected energy savings for the next 20 years (Clean Energy Group, 2015). The microgrid will help the tribe reduce their peak demand, thus lowering the charges they pay to utilities. By concentrating the energy management within the community, they expand job opportunities within the tribe. This in turn helps the Tish Non Tribe accelerate tribal sovereignty through energy independence.

6.8 Viejas Tribe of Kumeyaay Indian

The Viejas Tribe is in San Diego County, which has high EAL, high social vulnerability, and low community resilience, shown in Table 1. The California Energy Commission (CEC) awarded $31 million for a backup renewable energy storage system for the Viejas Tribe of Kumeyaay Indians (CEC, 2022a). This is funded through California's Long-Duration Energy Storage Program (Cohn, 2022b), which is the largest funding source for all the sampled microgrids, shown in Figure 11 and is one of the largest state grants that benefits tribes. The project will be developed by Indian Energy LLC, a private Native American-owned microgrid developer. Through this project, researchers will evaluate the feasibility of a long-duration energy storage system that does not use lithium batteries and provides up to 10 hours of power. John Christman, Viejas Band of Kumeyaay Indians chairman comments, "we recognize our responsibility to lead by example in lessening our burden on the electric grid, and it is our sincere hope that the demonstrated financial and environmental merits of this project will serve as a repeatable model for others" (Invinity Energy Systems, 2022). More benefits, in addition to advanced research and electric reliability, should become clear as this new project develops..

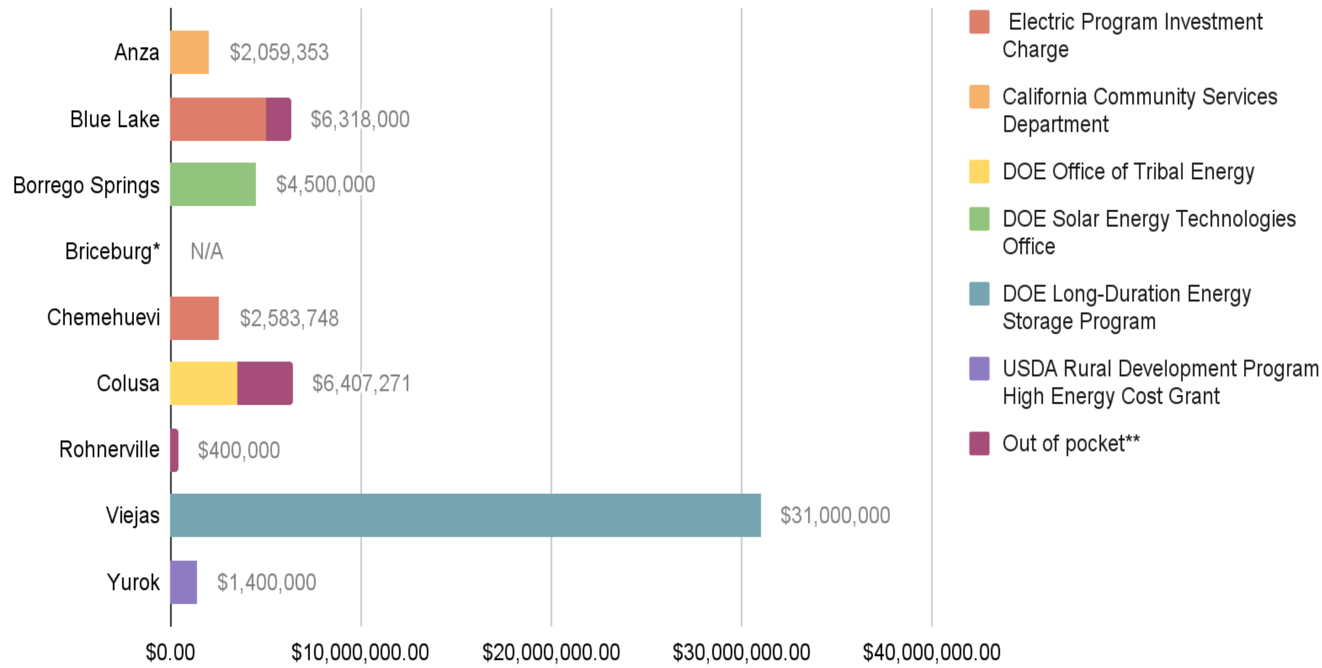


Figure 11: Dollars contributing to microgrid projects
** Data not available on Briceburg; privately funded by PG&E*
*** Includes publicly available costs and grant-matching across project collaborators.*

6.9 Yurok Tribe Microgrid

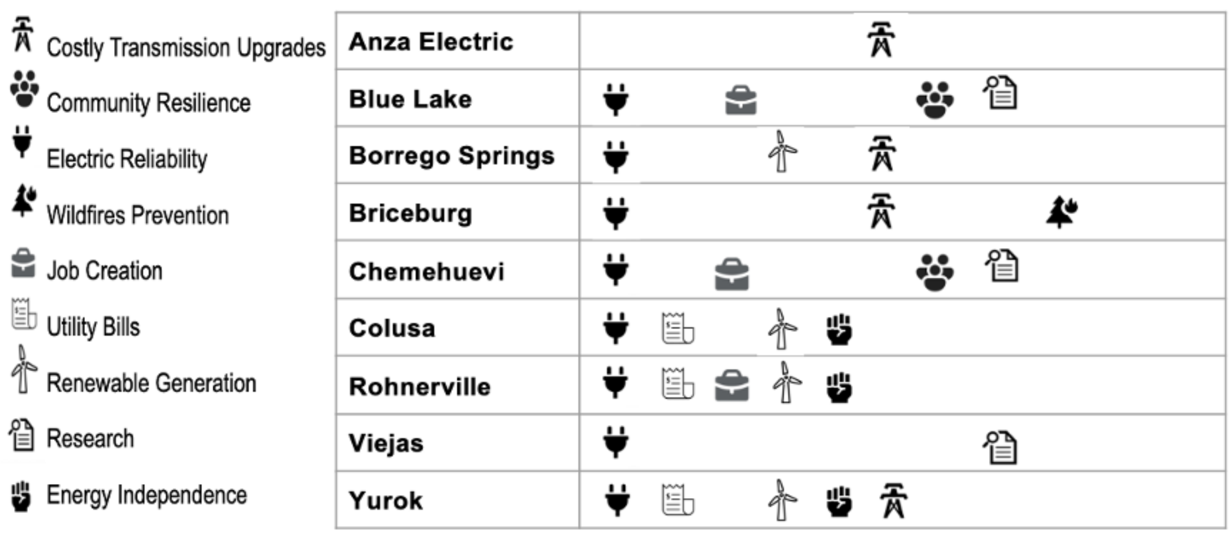
The Yurok Tribe is located across Humboldt and Del Norte counties. Sections 6.2 Blue Lake Rancheria Microgridand 6.7 Rohnerville Rancheria Microgriddescribe Humboldt County's risk. Del Norte has a high tsunami risk, very high social vulnerability, relatively low community resilience, and low EAL, likely due to the remote and sparsely populated area.

Electricity is unreliable or nonexistent in the Upper Reservation (Zoellick, 2020). The Upper Reservation is also more expensive to service, aggravating the problem of poverty that already exists and further stifling economic development. To bring new service to the Upper Reservation, the tribal government extended lines to the Village of Wautec in 2018 (Zoellick, 2020). The tribe prefers off-grid resources for the remaining unserviced areas, which includes 128 homes, one-third of which are tribal members, because it avoids expensive extensions of power lines (Zoellick, 2020).

The microgrid is a collaboration with the Schatz Energy Research Center at Cal Poly Humboldt. The project was awarded a $1.4 million grant from the US Department of Agriculture (USDA) (Yurok Tribe, 2022). While this is the smallest awarded grant listed in Figure 11, it demonstrates the project developer's resourcefulness in seeking financing options.

The Yurok Tribe's Energy Vision Statement is "to make sure all Tribal members living within the Yurok ancestral territory have access to reliable, affordable, modern, cost-effective energy services. In addition, the Tribe seeks an energy program that promotes energy self-sufficiency, environmental sustainability, use of local renewable resources, and job creation and economic opportunity for Tribal members" (Zoellick, 2020). The microgrid enables these cost savings, improved connectivity and reliability, expanded renewables, job creation, and tribal energy independence.

Table 3: Sampled California communities were motivated by related factors to develop microgrid projects.



As summarized in Table 3, the sampled microgrids have common motivations to reduce energy costs, increase electric reliability, promote community resilience, expand job opportunities, lower utility bills, expand renewable energy generation, avoid costly transmission upgrades and repairs, and mobilize tribal energy independence. California must prioritize distributed energy resources in historically under-resourced areas, like the tribal and rural areas discussed. Next, this work analyzes policies that impede or enable further investment of microgrids for community resilience.

7. Microgrid Policies

While microgrids are not new in concept, they are undergoing ongoing discussion and workshops on resilience, metering, tariffs, ownership schemes, and more. This section highlights several initiatives that incentivize or limit microgrid adoption. As shown in Table 4, EPIC, established by R.11-10-003, has been the most effective program for adapting microgrids and doing so equitably. Progress is limited for programs that are new or are not advertised to microgrid developers. The CPUC has contradicting policies that both incentivize and limit microgrids, as discussed in Section 7.1. Most investment has been through IOU-lead microgrids, as discussed in Section 7.2. More recently, California has allocated state funds for resilience projects like microgrids, discussed in Section 7.3. Federal policies and investment are discussed in Section 7.4.

Table 4: State and federal bills and their impact on microgrid investments

Program or Rule Name	**Bill**	**Year**	**Microgrids committed**	**Dollars committed**	**EJ target**	**Key Issues**
			California Policy			
Over the fence rule	CPUC 218	1951	N/A	N/A	N/A	186 Cal. 162
Micro-utility statute	CPUC 2780	2004	0	N/A	No	CPUC has never authorized a micro-utility
Commercialization of microgrids	SB 1339	2018	N/A	N/A	Yes	Reworked utility rules; addresses cost-shifting issues; conflicts with 218
Resiliency and Microgrids Working Group	R.19-09-009	2020	N/A	N/A	Yes	Cost responsibility waiver conflicts with 1339's cost shifting rule
			Investor-Owned Utility Programs			
Self-Generation Incentive Program	D.20-01-021	2012	5	$900M	No	Limited to households

Program or Rule Name	Bill	Year	Microgrids committed	Dollars committed	EJ target	Key Issues
Electric Program Investment Charge	R.11-10-003	2020	16	$130M+ annually	Yes	Conflicting opinions on whether IOUs should administer EPIC
Community Microgrid Enablement Program	D.20-06-017	2021	1*	$82.2M total	Yes	First year only funded distribution upgrades
Microgrid Incentive Program	AB 1325	2021	0	$200M	Yes	CPUC approved 1 year and 4 months late
Equity Initiatives and Clean Energy Access Grant Program	AB 179	2022	0	$30M	No	Projects must be in an IOU serviced area; This has been an under-advertised program so far
			State Resilience Funds			
Climate Catalyst Revolving Fund	SB 1258	2020	0	N/A	N/A	IBank lacks technical expertise
Community Resilience Centers	SB 155	2021	0	$125M	Yes	Program is under-advertised with limited technical assistance
Demand Side Grid Support Program	AB 205	2022	0	$200M		
Distributed Electricity Backup Assets (DEBA)	AB 205	2022	0	$700M over five years	N/A	Program is under-advertised and is out of cycle with related programs.
Emergency services funds	AB 1567	2023	0	$75M per project	N/A	Could conflict with 218B
			Federal Programs			
Pre hazard mitigation grant	AB 1659	2020	0	$200M	N/A	Program is under-advertised

Program or Rule Name	Bill	Year	Microgrids committed	Dollars committed	EJ target	Key Issues
Indian tribal energy resource	T.25-3502	2021-2023	1	$50M	Yes	
Inflation Reduction Act	S. 243	2021	0	$16M	Yes	
Building Resilient Infrastructure and Communities grant program	PL 100-707	2022	0	N/A	Yes	

7.1 California Policy

7.1.1 Over the Fence Rule

Every policy expert interviewed cited Rule 218, the “over the fence” rule, as an impediment to microgrid progress. Clean Coalition policy expert, Ben Schwartz, explains that the rule states that “energy shall not be sent over public thoroughfares, unless the entity that does so becomes a public utility. Becoming a public utility means you would need to shoulder the same burdens and responsibilities that PG&E and other IOUs do, which isn’t realistic” (Schwartz, 2022). This rule prevents someone from reselling energy to their neighbors at a higher price. This rule did not anticipate the issues this would cause for microgrids, since sharing energy is a feature of microgrids during an emergency. Schwartz argues that Rule 218 B lacked foresight since “distribution level resources were not cost-competitive, not effective, and were never considered to be the future. The past has always been about long-distance power lines, remote generation, and load centers”. Schwartz muses, “the future is local. The future is bidirectional. The future is democratized market access”. A localized energy distribution system inherently clashes with the current financial and regulatory system. There have been several situations where microgrid developers and advocates are blocked by Rule 218.

Frank Lindh has been a practicing energy and public utilities lawyer for over 35 years. Lindh formally was a general counsel member of the California Public Utilities Commission (CPUC), principal natural gas regulatory lawyer for PG&E, and appellate attorney for the Federal Energy Regulatory Commission. Frank Lindh represented Google when their proposed microgrid was rejected because the company is not a public utility under Rule 218. Lindh argues that there is a "longstanding principle of California law that a private enterprise supplying electricity, steam, water, or sewer services to tenants, and in some instances to third-parties on nearby parcels of land, can do so as a private, contractual matter. In undertaking such activities, the supplier does not necessarily become a public utility subject to the Commission's regulatory jurisdiction" (Lindh, 2020). One example of this is Story v. Richardson, in which a LA office building owner supplied electricity and steam to his tenants. The Supreme Court decided that Story's business was not a public utility since "public utility status attaches only if the service provider dedicates its property to public use, as distinct from providing service only privately to select individuals such as tenants" (186 Cal. 162, 1921). By precedent, CPUC should respect this decision when applied to microgrid projects. However, Rule 218 continues to impede microgrid projects like Google' surrounding the problem of public utility status.

As another example, Tony Brunello, founder of Gridworks and a partner at California Strategies, represents companies and tribes that develop distributed energy projects. Brunello explains that 218 is a major barrier for most of his clients, including, for example, a tribal project that leverages hydropower generation matched with batteries (Brunello, 2023). Microgrids make sense from a technology standpoint for this use-case, but they need to get approval from PG&E, their incumbent utility. Brunello explains, "utilities have really pushed back on microgrids because it doesn't allow transparency into the system behind the meter. They don't know when someone's turning it off or on and creates disruptions of capacity at different substations, etc. It takes away from their business since other folks are doing their job for them" (Brunello, 2023). This issue of public utility status may prevent projects that are in a community's best interest. The tribe wants to provide reliable power to help their residents. In this case, the tribe will go to the CPUC to change their current energy services, but Brunello urges California to adopt a broader solution.

Communities across California face high utility bills and unreliable electricity as storms increase. Additionally, many facilities have diesel generators to compact reliability issues, which goes against California's clean energy goals. Ultimately, Rule 218 limits microgrids to IOU-controlled projects. This can conflict with newer goals that explicitly incentivize microgrids, discussed next.

7.1.2 Senate Bill No. 1339

In 2018, Senate Bill 1339 (SB 1339) called on the CPUC to "facilitate the commercialization of microgrids for distribution customers of large electrical corporations" (California Legislature, 2018). This included rule-makings to remove barriers to microgrid commercialization.

For example, the CPUC directed SCE to modify its Rule 2 by eliminating examples of unique amenities, to make it clear that microgrid control systems are permissible under the rule (CPUC, 2021b). Additionally, the CPUC ordered that IOUs will develop a Microgrid Incentive Program to support vulnerable populations impacted by power shutoffs, discussed in Section 7.2.2.

As part of SB 1339, IOUs are required to submit their plan to transition diesel backups to clean energy generation. The California Energy Commission (CEC) expressed concern about diesel generators and held a workshop to discuss clean energy alternatives in January 2021 (CEC, 2021). IOUs were instructed to create a well-defined route for diverse technologies to achieve electrical isolation during a broad grid outage. These technologies include built-in remote disconnect switches commonly present in smart meters and other technologies that support disconnection of electricity during a more extensive grid outage (ESH&D, 2020).

The CPUC ordered modifications to PG&E and SCE's Rule 18 and SDG&E's Rule 19 to allow microgrids to provide critical services to customers located on adjacent properties (CPUC, 2021b). This attempts to address Rule 218 by allowing public agencies to provide electrical service to critical facilities on adjacent properties, without becoming a public utility subject to CPUC regulation (ESH&D, 2021). Schwartz comments that the new rule "finally allowed critical facilities to share power and island in emergency situations, but only if they are next store neighbors and owned by different agencies. For example, a fire dept next to a library. There are very few situations where those are next to each other" (Schwartz, 2022). While these changes address some of the problems with Rule 218, gaps remain.

Microgrids are expensive, complex, and time-consuming to design and implement, which SB 1339 is meant to address. According to Schwartz (2022), microgrids can take 24 to 36 months, without factoring in permitting and interconnection. To create a viable market for microgrids, Schwartz explains, "you need a determinant process that, whether you are a company, like Google or Microsoft, a local government, or a church agency, you should be able to navigate that process and quickly and effectively determine whether a community microgrid is the right solution and how to go about doing that. The fact that there's no easy way to get the process started, shows that a lot of progress is still needed" (Schwartz, 2022).

There are barriers to construction and operation of microgrids by third-party companies. As Lindh emphasizes, "by formalizing the rules to support and streamline the establishment of campus-style microgrid configurations, the Commission will provide multiple benefits aligned with the objectives of SB 1339" (Lindh, 2020). Third-parties have their own money to invest in expensive microgrid projects. California's legal barriers prevent widespread commercialization of microgrids, limiting progress in support of SB 1339.

7.1.3 Resiliency and Microgrids Working Group

Senate Bill 1339 was born out of a larger ongoing resilience and microgrid proceeding, the Resiliency and Microgrids Working Group (RMWG), created by Decision 21-01-018. RMWG has ongoing workshops and discussions about issues like policy reform, multi-customer microgrid tariffs, grid stability, standby charges, and resilience valuation.

Some RMWG members advocate for change to Rule 218, noting that "today's technology allows for seamless coordination of DER in a way that was not foreseen decades ago, when Section 218 was written" (CPUC, 2021a). Additionally, the CPUC requires IOUs to establish microgrid tariffs for each of their service territories. Through this, microgrid projects must meet the IOU's net metering requirements and the tariff cannot serve as a revenue stream for the microgrid owners. Another topic under debate is whether microgrids should be exempt from cost-responsibility surcharges (CPUC, 2021b). However, this goes against SB 1339's prohibition against cost shifting (CPUC, 2021a). Section 7.1.6 Cost-shiftingdiscusses the cost-shift concept in detail. Tony Brunello urges pay for these systems that are fair to everyone, since "already, rates are going up and utilities are charging too much", he explains (Brunello, 2023). Lower-income households already spend a much larger percentage of their income on electricity (Borenstein, 2021). RMWG is workshopping ideas to finance microgrids in a fair way.

7.1.4 Micro-utility Statue

Rule 218 defines a micro-utilities statute that exempts energy systems from public utility status if they serve communities with fewer than 2,000 customers (2780 CPUC Ch. 5.5). However, a micro-utility has never been approved. In 2022, Sunnova Energy's micro-utility proposal was rejected on the basis that the entity would avoid utility codes and regulations. However, Sunnova was trying to leverage an existing statute, not avoid regulation. Cameron Brooks, executive director of advocacy group Think Microgrid, argues that “the commission is saying that there needs to be rules put in place for this kind of microgrid, but they are the ones who refuse to create those rules. They say that there should be more information, but they refuse to create a forum to present that same information” (Wood, 2023). Brooks argues that this ruling has limited progress towards improved electric reliability: “communities want microgrids, and attempting to limit new market entrants and innovative solutions like those proposed by Sunnova is counter to the spirit of California's climate goals and tech innovation roots” (Wood, 2023). The micro-utility statue can enable further microgrid adoption, providing EJ communities with clean and reliable energy.

7.1.5 High-Voltage Industrial Users

Kevin Bell, principal at Convergence Research LLC, exposes another conflict for microgrids that arises between high-voltage electricity users and low and medium electricity users. Industrial customers only use high-voltage electricity and typically do not pay for low and medium-voltage electricity (Lazar, 2011). All other customers, residential and commercial, pay for both, as Bell explains, “right now, the cost of that high-voltage transmission network and the high cost of new high-voltage infrastructure, assumes that all customers, large and small, are using that network equally” (Bell, 2023). However, distributed energy resources, like microgrids, do not use the high-voltage distribution network. Bell’s argument is that with the shift to distributed resources, low and medium-voltage customers should pay less for high-voltage electricity, especially since “the current cost of that network in California is about $30 per megawatt hour, but it’s about to go up sharply” (Bell, 2023). However, as Bell points out, industrial customers have political influence that may limit savings for residential and commercial customers. It is likely too early to tell how this will play out, since the high-voltage network will remain important for the foreseeable future.

7.1.6 Cost-shifting

The CPUC’s Net Energy Metering (NEM) rooftop solar program exemplifies the cost-shift problem. NEM customers generate their own electricity and prior to the 2022 ruling, they did not pay for critical programs, like new transmission lines or wildfire mitigations, that are funded through utility retail rates. Cal Advocates explains that "customers without rooftop solar pay higher rates to compensate for the gap in funding" (Marcus, 2022). Thus, if wealthy customers are more likely to adopt rooftop solar, then costs are shifted onto low-income communities. This exacerbates issues by limiting access to clean, affordable, and reliable energy for EJ households.

The cost-shift argument also proliferates in microgrid investment discussions. However, with proper subsidies and incentives that lower costs for low-income communities, cost-shifting can be avoided. In fact, the cost-shift problem uncovers a flaw in the utility cost structure that is slowing distributed renewable energy progress. Allie Detrio is the Chief Strategist at Reimagine Power, where she represents the Microgrid Resources Coalition and the Bioenergy Association of California. She was the recipient of California Solar & Storage Association's (CSSA) 2018 Most Valuable Player Award and was instrumental in passing SB 1339. Detrio argues that rates are not going up because of microgrids or other local energy solutions, but because the old model rewards utility shareholders for building more large infrastructure. Thus, a fundamental counter-argument to the cost-shift argument is that less large, centralized infrastructure saves costs for ratepayers. CSSA (2021) points out that "if everyone in California suddenly consumed half as much electricity on hot summer days when the sun is shining brightest and the grid most stressed, costs for everyone would come down thanks to supply and demand economics. Further, the grid itself could be smaller and require less infrastructure if everyone used half as much energy, saving everyone money". The more California electrifies, the more electric infrastructure is needed. However, if more distributed generation can cover the added demand, costs are leveled.

In addition to this conceptual flaw, CCSA identified flaws in the actual cost-shift calculation. For example, IOUs estimated rooftop solar as having 9-years of benefit, rather than their warrantied 25 years (CSSA, 2021). Similarly, rooftop solar adopters were weighted equally when earlier adopters bore a much greater cost. These assumptions inflate the costs customers bear today and in the future. Additionally, the cost-shifting argument does not account for the 35% care discount for low-income households in California (Detrio, 2023).

Cost-shift arguments do not account for other intrinsic benefits of distributed energy resources, such as land conservation, since microgrids can be built amongst the built-environment, reliability, since microgrids provide robust and redundant power compared to transmission lines, especially in rough terrain, and speed of adoption for components like rooftop solar since “500 megawatts (size of a power plant) are built on rooftops across California every six months – much faster than can be achieved when building large projects in the desert” (CSSA, 2021).

The cost-shift argument would result in policies that thwart $4 billion in economic activity and 65,000 jobs (CSSA, 2021). Whereas distributed energy is saving communities money. For example, rooftop solar enabled CAISO to cancel $2.6 billion for grid infrastructure in 2018 (CAISO, 2018). A study found that “by 2030, bundled residential rates are forecasted to be approximately 12 percent, 10 percent, and 20 percent higher” for PG&E, SCE, and SDG&E, respectively, which outpaces inflation (Sieren-Smith, 2021). Some of this increase is from increasing wildfire mitigation costs. Investments into local and resilient infrastructure, like microgrids, may serve as a more cost-effective wildfire prevention strategy. It is estimated that increasing local energy will save Americans $473 billion over the course of 30 years (Clack, 2020). Investments must target EJ communities to limit harmful economic and health impacts from unreliable and dirty power.

7.2 Investor-Owned Utility Programs

7.2.1 Community Microgrid Enablement Program

For 2020 to 2022, PG&E was awarded a budget for the Community Microgrid Enablement Program (CMEP), which is meant to help power critical facilities during outages. During those two years, CMEP supported the Redwood Coast Airport Microgrid (RCAM), which was in prior development since 2016. RCAM effectively served as a pilot project that shaped the CMEP and developed the Community Microgrid Enablement Tariff (PG&E, 2022). Andrea Schumer, Resilience Coordinator at PG&E comments on the benefit of a separate program and tariff, “if a customer outside the high fire threat district or an area prone to outages as is required for CMEP eligibility wants to build a microgrid, and they’re well-funded, they can do it and still come to us for support and we can help with it through the tariff” (Schumer, 2023). Prior to the tariff, this was not possible, unless the entity was eligible through CMEP. Schumer comments that “now, it’s been a very fantastic way for us to learn from customers who are building them out, not necessarily just for resilience, but for grid innovation and to further the installation of distributed energy resources” (Schumer, 2023).

A challenge faced is the cost of microgrids. These 5 to 20-megawatt systems can require a lot of generating resources, batteries, and consulting, which make the project expensive (Schumer, 2023). Another challenge is in selecting a microgrid site, since microgrids may have unequal benefits to customers. This creates a challenge when selecting, prioritizing, and justifying projects to fund. Schumer shared that they were getting several requests from sites outside of high fire threat districts. Starting in October 2021, “we can support these projects, even outside of high-fire threat districts, in urban areas, where they want to build a community microgrid and they need our utility support, our technical expertise, and grid planning” (Schumer, 2023). Thus, the program is evolving in response to community needs.

Continued program funding was approved April 6, 2023. In this next cycle, PG&E requested $5.5 million a year for 2023-2026 to conduct microgrid islanding studies and $60 million in capital funding for infrastructure upgrades to enable islanding (Cohn, 2023). CMEP and the accompanying tariff helps support microgrid integration with the larger grid.

7.2.2 Electric Program Investment Charge

The Electric Program Investment Charge (EPIC) program funds investor-owned utilities (IOUs), like PG&E, SGE, and SDG&E to develop emergency energy technologies like combined heat and power, commercialized microgrids, bioenergy, advanced energy storage, and others across California.

EPIC allocates 25% of funds to disadvantaged communities and 10% for low-income communities, to prioritize equal access to advanced energy technologies and resources. In 2019, during an engagement workshop, the low-income housing program Self-Help Enterprises collected feedback from low-income, tribal, and disadvantaged communities that was incorporated into EPIC’s evaluation criteria (ACEEE, 2019). The scoring criteria includes how well a project benefits a community, how well it engages the community, and health impacts. The Empower Innovation workshop allows local governments, community groups, and tribes to network to form grant funding partnerships. A Civic Spark member is responsible for interfacing with disadvantaged and low-income communities. EPIC also participates in the Disadvantaged Community Advisory Group (ACEEE, 2019). These activities highlight efforts to get feedback from the community. Figure 12 shows the EPIC project sites located disadvantaged communities, low-income communities, and sites benefitting native tribes.

EPIC funded the Redwood Coast Airport microgrid (RCAM), for example. Marc Marshall, principal engineer at Schatz Energy Research Center explained how RCAM has maintained electricity during environmental hazards: “RCAM picked up seamlessly when power went out in the county following the earthquake, and despite the outage occurring at more or less the worst possible hour of the year — just after evening peak battery discharge, the second shortest day of the year and one day before the winter solstice, with bad weather — it ran smoothly for nearly 15 hours” (Doherty, 2023). This shows how distributed energy investment programs, like EPIC can restore reliability and provide resilience to communities during climate-extremes.

A potential gap is that EPIC is awarded only to IOUs. In the case of RCAM, all its electricity is moved through PG&E. Redwood Coast Energy Authority (RCEA) is the community choice provider that generates the electricity for RCAM. RCEA pays 13¢ per kWh for generation, whereas PG&E will only pay RCEA 6.2¢ per kWh. Thus, the project would not be fiscally possible without a grant from the CEC (Doherty, 2023). D.20-08-042 renewed the EPIC Program through 2030. In the renewal decision, there was a debate about whether to maintain IOUs as the program administrator. BAC recommended that the CEC be the sole administrator and Cal Advocates argued that the utilities were not effectively tracking benefits metrics (R 19-10-005, 2020). Tracking benefit metrics is crucial for understanding the cost-benefit of resilience investments. For example, Evergreen Economics (2017) found that every EPIC project will likely provide ratepayer benefits. Thus, the concern with ratepayer benefits can be weighed against broader issues of reliability and resilience.

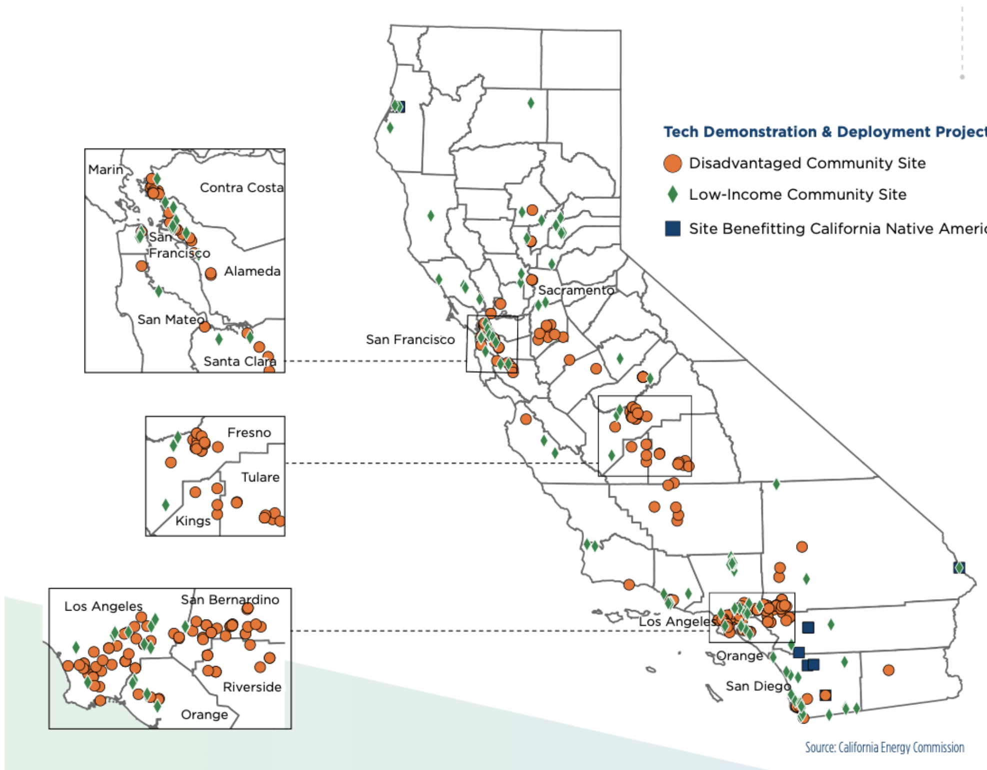


Figure 12: EPIC projects in under-resourced communities from 2021 Annual Report (CEC, 2022b).

7.2.3 Microgrid Incentive Program

The Microgrid Incentive Program (MIP) aims to promote resiliency for disadvantaged vulnerable communities. Compared to CMEP, MIP is a competitive bid process that funds the entire microgrid rather than just the distribution upgrades. MIP prioritizes EJ communities, adding electric reliability and community resilience to detrimental climate-caused blackouts. However, Clean Coalition's Ben Schwartz works on the Microgrid Incentive Program and discloses that "the program has been slow and onerous". The program was just approved in April 2023, one year and four months after SB 1339 ordered the program to be approved.

Figure 13 shows PG&E's program eligibility from its proposed implementation plan. Eligibility points are awarded based on low-income customers, medically vulnerable customers, critical facilities, community resilience services like disaster shelters, areas in high fire threat districts of 2 or 3, the worst performing reliability circuits from Utility Electric Reliability Reports, areas impacted by PSPS events, island duration, clean energy installments, and if the project displaces an existing fossil fuel emergency generator for a critical facility.

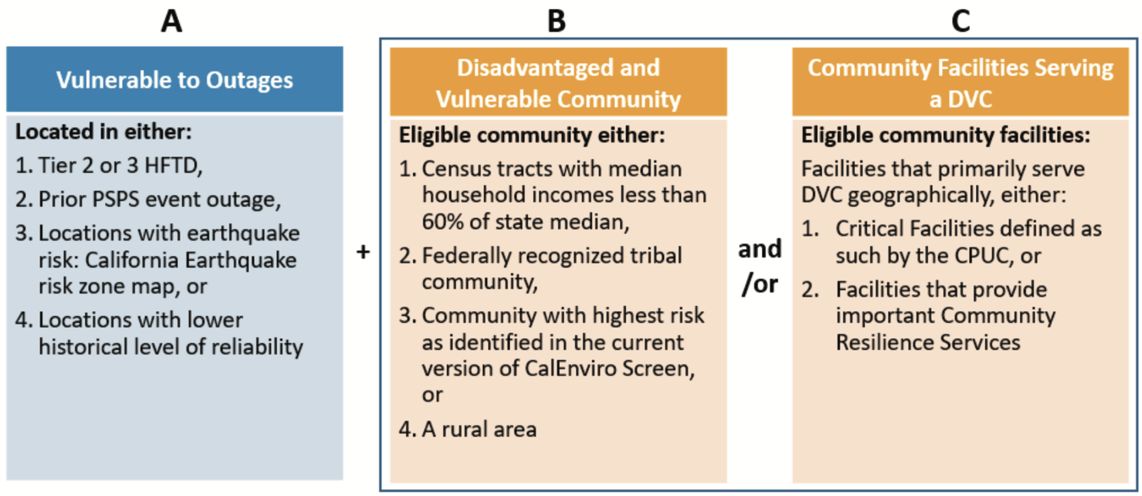


Figure 13: PG&E's MIP Implementation Plan eligibility structure (PG&E, 2021)

Reclaim our Power (ROP) urges developers to work with EJ community groups when creating projects to better understand needs (PG&E, 2021). The Community of Topanga mentioned that unincorporated areas like theirs need technical assistance in writing grants (PG&E, 2021). For example, they would need help in coordinating the MIP funding with the Self-Generation Incentive Program (SGIP), discussed in the next section. The Community of Topanga urges PG&E to move away from "a one size fits all scorecard" and offer different requirements for disadvantaged communities (PG&E, 2021). The scoring prioritization system may add complexity to both the application and reviewal process but is also a crucial step in fairly assessing community needs. Addressing these concerns enables wider participation in the MIP.

7.3.4 Self Generation Incentive Program

The Self-Generation Incentive Program (SGIP) incentivizes distributed energy resources through rebates (Ageto Energy, 2021). In decision 20-01-021, CPUC authorized $166 million to be collected from ratepayers to fund SGIP from 2020 to 2024. SGIP directed funds to the following microgrids: Blue Lake Rancheria, Redwood Coast Airport, Verdant, Hill Canyon Treatment Plant, and Soboba Casino Resort. In addition to offsetting the cost of microgrid installation, SGIP impacts the overall market by driving down the cost of storage and renewables. According to Age to Energy (2021), "SGIP can improve the ROI of a microgrid energy storage project and can mean power resilience, an extremely valuable or even lifesaving aspect of a system".

SB 851 changes SGIP language to “households” instead of “customers” and expands equity requirements. Under existing law, SGIP is required to allocate 70% of funds for low-income residents. SB 851 would require that CPUC adopt an equity award structure, technology guidelines, and a block grant structure to support that allocation, specifically geared towards tribes, community-based or local service providers, and CCAs (CPUC, 2020).

Further, AB 179 initiated the Equity Initiatives and Clean Energy Access (EICEA) grant program to provide technical assistance for project development, which increases the chances of SGIP and MIP acceptances (CPUC, 2023).

7.3 State Resilience Funds

7.3.1 Climate Catalyst Revolving Loan Fund

SB 1258 establishes the Climate Catalyst Revolving loan fund, which allots $49 million in low-interest loans for carbon technology, including microgrids (IBank, 2023). The program is proposed through California Infrastructure and Economic Development Bank (IBank), which was established in 1994 to finance general-purpose public and private projects, with a focus on climate impacts. The premise is that private capital complemented by public sector funding is essential to help new markets: “public revolving loan funds like Climate Catalyst can leverage 3-8X in private investment, providing a great public benefit in a time of challenged budgets” (IBank, 2023). The benefit of a revolving fund over a grant is that the fund replenishes when the loan is repaid, versus a grant program that needs to receive ongoing political support to renew. Additionally, administration overhead costs are covered through interest earnings for the fund, whereas a grant needs additional funding. Gabriel Petek from the Legislative Analyst’s Office rejected the Climate Catalyst loan on the basis that not enough projects are appropriate for this type of financing. Petek (2020) argues that emerging technologies need to be researched and proved out, which is better funded with grants, he argues.

7.3.2 Community Resilience Centers

As part of SB 155, California's Strategic Growth Council allocated $85 million for the Community Resilience Center (CRC) program that will offer refuge and various aid during climate-related hazards or other crises. The fund will be granted to “stakeholders such as tribes, nonprofit organizations, community-based organizations, schools, and local government agencies” (SGC, 2022).

7.3.3 Demand Side Grid Support Program

AB 205 initiated the Demand Side Grid Support Program (DSGS) program supported under the Strategic Reliability Reserve (SRR), which provides $200 million for load reduction, demand response, and backup generation during extreme events (CEC, 2023b). DSGS focuses on municipal and public power utilities regulated by the CEC instead of IOUs. DSGS enables public power utilities to “get paid for units of load reduction” when there is an emergency outage (Cohn, 2022c). The program has been underutilized by the microgrid community. This can first be mitigated by clarifying the program eligibility. The CEC Vice Chair Siva Gunda explains that the program excludes IOUs and CCAs since they have access to state funds and other state load reduction state programs (Paulson, 2022). Clarifying and engaging with qualifying microgrid developers is crucial, since this program can lower microgrid costs overall.

7.3.4 Distributed Electricity Backup Assets

AB 205 also allocated $1 billion towards resilience, based upon Newsom's $8-billion energy budget (No. 1694 [12]). Among other initiatives, AB 205 formed the CEC administered Distributed Electricity Backup Assets (DEBA) program (CEC, 2023a). The state allocates $550 million to fund clean technologies, which explicitly includes microgrids. DEBA leverages a general fund instead of IOU-based funding to relieve ratepayers from increased utility bills (Cal DOF, 2022). DEBA is under development and has not awarded funding to any projects yet.

7.3.5 Emergency Services Funds

AB 1567 is a grant program introduced in February 2023 to help finance zero-emission microgrids that power critical infrastructure. This bill would require OES to develop state recovery frameworks and provide technical assistance for California's catastrophe recovery plans aligned with FEMA’s guidelines across economic, health, social services, and infrastructure. The bill is behind since the original requirement was to complete the recovery frameworks by January 15, 2023 (AB 1567).

7.4 Federal Incentives

7.4.1 Building Resilient Infrastructure and Communities

The Stafford Act, Section 203, FEMA (42 U.S.C. §§ 5121-5207) authorized the Building Resilient Infrastructure and Communities grant program to fund hazard mitigation projects, beginning in 1988 and renewed in 2019. Section 203 also establishes a pre hazard mitigation grant program, which includes funding for microgrids. The program is developed by the OES and the Department of Forestry and Fire Protection. These programs provide federal funding for projects that prevent damage caused by natural hazards.

7.4.2 Inflation Reduction Act

In addition to numerous renewable energy and storage incentives, the Inflation Reduction Act (IRA) established a 30% tax credit for microgrid technologies, which was retained from the Build Back Better plan and the Microgrid Act. Jana Gerber from Schneider Electric argues that the IRA brings financial incentives surrounding non-transmission alternatives that will influence utilities and microgrid companies to collaborate (Hitchens, 2022). One incentive is the allocation of $16 million for the Local Energy Action Program (LEAP) for clean energy projects for low-income communities.

Additionally, the IRA enables partnerships between microgrid developers and tribes. Before the IRA, tribes were unable to monetize tax credits because they are a tax-exempt entity. The IRA now allows tribes and other tax-exempt entities to receive direct payment or transfer credits. This enables participation in distributed energy projects like microgrids. Furthermore, the IRA’s investment tax credit (ITC) exceeds 30% when applied within EJ communities (Cohn, 2022b). Thus, projects are incentivized to prioritize EJ communities, which are historically ignored.

The IRA ensures long-term certainty of tax credit support for renewables and storage, which accelerates the advancement of microgrids. This advancement is encouraged to take place in EJ communities, through the IRA’s financial and regulatory measures.

7.4.3 Tribal Energy Projects

Title 25 Section 3502 authorizes a program that funds tribal energy projects through the Department of the Interior which will issue an estimated 10 to 25 awards each between $100 thousand and $5 million for the 2022 and 2023 budgets (25 USC 3502). Already the Office of Indian Energy Invested in 210 tribal energy projects between 2010 and 2022, which amounted to over $120 million. Of these projects, only one microgrid has been funded so far nationally: the Rincon San Luiseño Band of Mission Indians, deployed in 2020.

8. Policy Recommendations

8.1 Expand Equitable Funding

Microgrid financing must not leave behind low-income communities. To do this, California can expand incentives to lower the up-front costs of microgrid adoption, such as through grants and government backed loans. These programs should target and prioritize EJ communities. Table 5 provides recommended near-term communities that can take advantage of DOE's funding for tribal energy projects. Funding entities can engage each tribe in conversation about their needs and interests. While federal and state funding is available, communities do not always know or have the resources to participate. Advocate groups can help socialize opportunities and fund technical assistance for project scoping.

The same screening process can be done for other communities across California, prioritizing regions with high EAL, high social vulnerability, and low community resilience. High EAL comes from natural hazards like earthquakes, flooding, and wildfires. As seen with the flooding and snowstorms across the state in winter 2022-2023, weather events are varying and intensifying, having destructive impacts on infrastructure and human well-being. Social vulnerability evaluation can be supplemented or paired with CalEnviroScreen (OEHHA, 2023), which EPIC already uses for identifying EJ communities. Community resilience includes factors like shelters available, evacuation routes, natural flood buffers, mitigation spending, and access to physicians. A full list of resilience indicators is shown in the Appendix, in Table 7. This work recommends adding at-risk electric lines as an indicator. The Briceburg and Anza microgrids are serviced by just one utility line, which was a reason for them to adopt microgrids. This lack of redundancy makes communities vulnerable to costly outages that make it harder for the community to be resilient in a climate-changing world.

Table 5: Tribes by county with a high Risk Index (FEMA, 2023).

County Name	**Tribe Name & Tract**
Humboldt	Big Lagoon 0240 Trinidad 4275 Table Bluff 4095 Hoopa Valley 1490
Butte	Berry Creek 0200 Moore Town 2340
Sonoma	Stewarts Point 3985 Dry Creek 0955
Yolo	Rumsey 3265
Contra Costa	Lytton 2075
Santa Barbara	Santa Ynez 3540
Fresno	Table Mountain 4110 Big Sandy 0265 Cold Springs 0720
Tulare	Tule River 4300
San Bernardino	San Manuel 3445
Riverside	Morongo 2360 Soboba 3870 Agua Caliente 0020 Augustine 0125 Cabazon 0415 Torres Martinez 4255 29 Palms 4375 Pechanga 2745
San Diego	Pala 2635 Pauma & Yuima 2715 Rincon 3165 La Jolla 1850 San Pasqual 3460 Santa Ysabel 3550 Mesa Grande 2190 Barona 0155 Inaja & Cosmit 1560 Capitan Grande 0495 Sycuan 4090 Jamul 1670 Ewiiaapaayp 1065 Manzanita 2115 La Posta 1895

	Campo 0450 Los Coyotes 1995
Imperial	Fort Yuma 1280

8.2 Incorporate Resilience into the Utility Model

Historically, IOUs have not been incentivized to provide reliable and resilient services. This culminated to major wildfires, public backlash, and the need to bail-out PG&E from bankruptcy. Regulation must address the inconsistencies between the utility regulatory model and public needs for reliability, resilience, and decarbonization. Allie Detrio (2023) argues for a performance-based regulatory model where profit is based on the quality of the service provided. Quality of service includes resilience, which the CPUC's microgrid proceedings prioritizes: "quantifying resilience value is critical for investment decision making, rate-making and emergency planning as we address the vulnerability and changing nature of our energy system" (CPUC, 2020).

Resilience and reliability should be central to how IOUs are compensated and to the cost-benefit analysis of funding decisions. Policy makers can pass SB 833, which requires CPUC to develop a publicly available tool that helps local governments analyze cost-benefits of microgrids. The tool would be a community planning website that helps local governments weigh the costs of microgrids against their resilience benefits. Meanwhile, a microgrid tariff can be developed to compensate services provided to the central grid at times of need, like when the grid is strained or when there are outage risks. This restructured, performance-based utility model, would allow microgrids to provide resilience and reliability benefits that communities across California need. Resilience initiatives must address economic growth and community needs, centered around environmental justice, to ensure vulnerable communities do not bear the burden of climate-extremes.

8.3 Evaluate High-Voltage Charges

Since IOUs are concerned with increased rates for low-income communities, they should consider saving costs for those customers in a way that does not slow distributed renewable energy progress. This may mean more fairly distributing costs of the high-voltage network to their primary users, industrial customers. More research is needed to determine the extent the high-voltage network will be used by residential and commercial customers in the decarbonized future. Reduced costs to residential and small business customers would free up allocation for microgrid projects, instead, which are needed in the face of climate extremes and net-zero goals.

8.4 Modify Rule 218

Rule 218 should be rewritten to clarify what entities qualify as a public utility. There have been several exemptions to the rule as technology advances, including qualifying cogeneration facilities in 1984 (SB 1773), independent solar energy producers in 2008, and EV charging stations in 2020 (Detrio, 2023). Microgrids are modern technology that help advance net zero goals and thus should be exempted in a modified Rule 218. This could be done by limiting a microgrid's customer base, like what is stated in the micro-utility statute. Detrio argues that loosening the regulations on what is considered a public utility enables the private market to "spur more innovation and technological advancement and bring down the cost for everyone" (Detrio, 2023). Ultimately, this change would expand microgrid adoption in alignment with SB 1339.

8.5 Clarify Own-Use Doctrine

The CPUC must also clarify the "own-use doctrine" used in Rule 218 and SB 1339. The idea is that utility service providers that sell or distribute electricity for the community's own use and not for sale to others are not considered a public utility (CPUC, 2021). Other states interpret the own-use doctrine differently than California does. For example, some states allow home-owner associations and shopping centers to provide electric services to their communities, since they are not selling it to the public (Detrio, 2023). Rewriting the own-use doctrine language to include community-owned microgrids enables residents to have control over their electric infrastructure. Communities would remain connected to the central grid and have added resilience to weather extremes and accelerated adoption of renewables.

Expanding public ownership options also help address cost-shift issues. Several entities, including Cal Advocates, recommend charging electricity customers a fixed charge based on their annual income (Marcus, 2022). While this might mitigate cost-shift concerns, IOUs are not the appropriate entity to provide income data to. Publicly owned structures are more aligned with this approach. This work does not promote or oppose the income-based structure: future work would need to assess this. This work recommends a public-ownership approach if the income-based structure is ever implemented. California can support community-ownership through changes to the own-use doctrine. These changes would enable communities to implement microgrids for improved reliability and community resilience planning.

8.6 Invest in Workforce Development

California can invest in workforce development through tribal training programs, engagement with IBEW, and community college apprenticeship programs. Tribal programs can model and expand on the GRID Alternatives program, which provide tribes with solar installation training, energy efficiency workshops, and K-12 renewable energy education (GRID Alternatives, 2022). This provides communities with skillsets that align with a decarbonized future.

Additionally, California can provide outreach and training for electric workers who feel threatened by the changing industry. As former mayor of San Jose, Sam Liccardo puts it, “if somebody can persuade IBEW that they’ll get all the microgrid jobs so they’ll back off their opposition, I suspect that would help” (Liccardo, 2023). IBEW’s labor force have the baseline skillsets for working on microgrids. Additional material on safety, control, and component communications could be covered in a couple training workshops. Community colleges can fill remaining labor gaps, by incorporating industry knowledge into specialized training programs (DiGangi, 2023). Microgrids and other distributed energy resources create job opportunities across California. Job training and outreach is essential to alleviate workforce shortages and temper political opposition.

9. Conclusion

California is currently trapped in a cycle of weather-induced outages and diesel-powered backups, which contribute to the tumultuous climate that causes these power outages in the first place. Microgrids, instead provide reliable backup power that accelerate the transition to clean energy. There have been several cases of success for tribal and rural community microgrid projects across California. However, there is a lot more work to be done. Progress has been slow due to competing interests across IOUs, IBEW, industrial energy users, and the needs of communities. The CPUC has the responsibility to manage these conflicting interests, with the public’s needs and justice at the forefront. The CPUC should modify Rule 218 to allow community-owned microgrids under the own-use doctrine. They also should exempt limitedsized microgrids from public utility status to mobilize innovation and commercialization, aligned with SB 1339's goals. Furthermore, the CPUC can promote a performance-based utility model that rewards resilience and reliability. California should invest in workforce training to equip electric workers and tribes with the skillset to mobilize the decarbonized future. With these actions, microgrids and other localized energy resources provide EJ communities with climate adaptation, resilience, and economic growth.

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10. Appendix

Table 6: Natural Hazards leveraged to compute FEMA's Risk Index (Zuzak, 2022)

FEMA Natural Hazards		
avalanche	heat wave	strong wind
coastal flooding	hurricane	tornado
cold wave	ice storm	Tsunami
drought	landslide	volcanic activity
earthquake	lightning	wildfire
hail	riverine flooding	winter weather

Table 7: Baseline Resilience Indicators for Communities (HRVI, 2021)

Economic/Financial	Human Well-Being/Cultural/Social	Environmental/Natural
Homeownership	educational attainment equality	local food supplies
employment rate	pre-retirement age	natural flood buffers
racial/ethnic income inequality	personal transportation access	energy use
non-dependence on tourism	communication capacity	perviousness
employment	English language competency	water stress
gender income inequality	non-special needs populations	
business size	health insurance	
large retail with regional/national distribution	mental health support	
	food security	
federal employment	access to physicians	
Infrastructure/Housing	**Institutional/Governance**	**Community Capacity**
sturdier housing types	mitigation spending	volunteerism
temporary housing availability	flood insurance coverage	religious affiliation
medical care capacity	governance performance regimes	attachment to place
evacuation routes	jurisdictional fragmentation	political engagement
housing stock construction quality	disaster aid experience	citizen disaster training
temporary shelter availability	local disaster training	civic organizations
school restoration potential	population stability	
industrial re-supply potential	nuclear accident planning	
high-speed internet infrastructure	crop insurance coverage	