SEEKING ENERGY INDEPENDENCE: CORPORATE MICROGRIDS IN CALIFORNIA

UCLA Institute of the Environment & Sustainability
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SUMMARY

Microgrids can serve a variety of purposes: keeping essential buildings online during natural disaster events, powering residential communities, or delivering energy to multiple customers. This paper focuses on corporate microgrids designed to power a single business entity. As microgrid installation expands, businesses will require resources to support their decisions on whether or not a microgrid system could optimally serve their energy needs. Generation technology, ownership/financing models, available incentives, and decision support tools are a suite of factors that should be considered prior to investment in a microgrid system. Each will be considered in turn in this report, and key findings include:

- Microgrid systems are commonly powered by either traditional fossil fuel generators, renewable energy resources (solar, wind, marine-based energy), or fuel cells (see "Types Of Microgrid Generation"), each of which have tradeoffs for system economics, sustainability, and resilience.
- A microgrid can be financed, owned, and operated by the primary energy user or by a third-party through a variety of ownership and financing contract types (see "Ownership and Financing").
- A number of state and national incentives and tax credit structures are currently in place that can be harnessed by microgrid developers to increase a project's economic feasibility (see "Incentives and Tax Credits").
- As microgrids become more popular, more tools are being made available to help make decisions and evaluate the benefits of different distributed power and storage investments (see "Analysis Tools").

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INTRO & CONTEXT

WHAT IS A MICROGRID?

In essence, a microgrid is a self-contained, small-scale grid system designed for local energy production, storage, and use. The National Renewable Energy Laboratory (NREL) defines a microgrid as "a group of interconnected loads (consumers of energy) and distributed energy resources that acts as a single controllable entity with respect to the grid."[1] Figure 1 illustrates this concept: distributed generation resources (such as combined heat and power - CHP, fuel cells, solar, and backup generators) and energy storage systems interact through a microgrid manager. Together they can operate as a standalone system to power facilities (the controllable load in the Figure) or connect to the main utility grid.

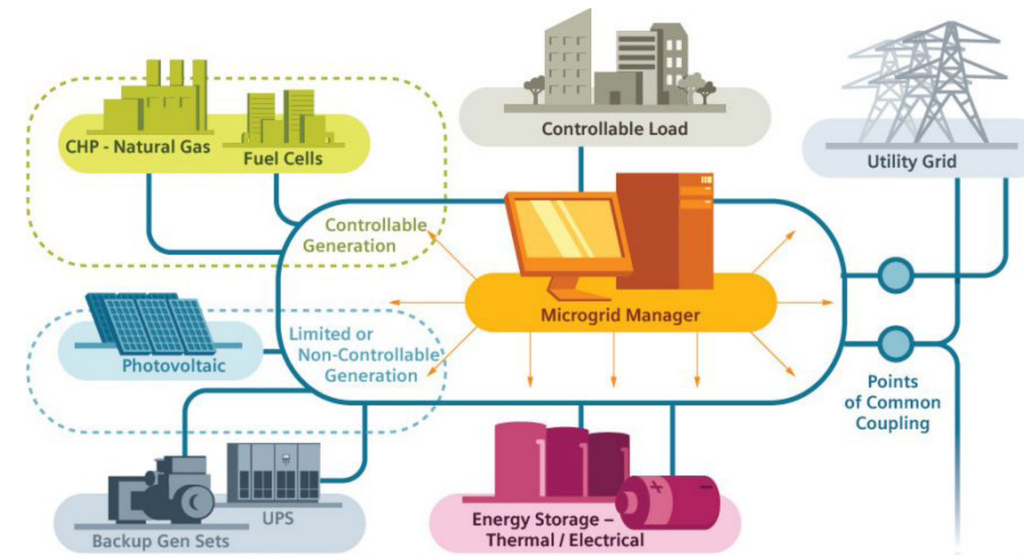


Figure 1: Diagram of a grid-connected microgrid system. Source: Siemens, Center for Climate and Energy Solutions

In 2016, microgrids accounted for a mere 0.15% of total electricity generation in the U.S. However, a substantial increase in microgrid capacity is expected in the near future. A 2020 Wood Mackenzie report found that more microgrids were installed in 2019 than in any year prior.[2] Further, the research firm Markets and Markets projects a dramatic increase in the microgrid market to $47.4B in 2025, up from $28.6B in 2020.[3]

U.S. microgrid development is particularly concentrated in Alaska, California, Georgia, Maryland, New York, Oklahoma, and Texas.[4] Within those states, California had the highest count of operational microgrid projects as of 2016 and a diverse energy source composition compared to states like New York, Georgia, Texas, and Oklahoma which were dominated by a single generation type (Figure 2).

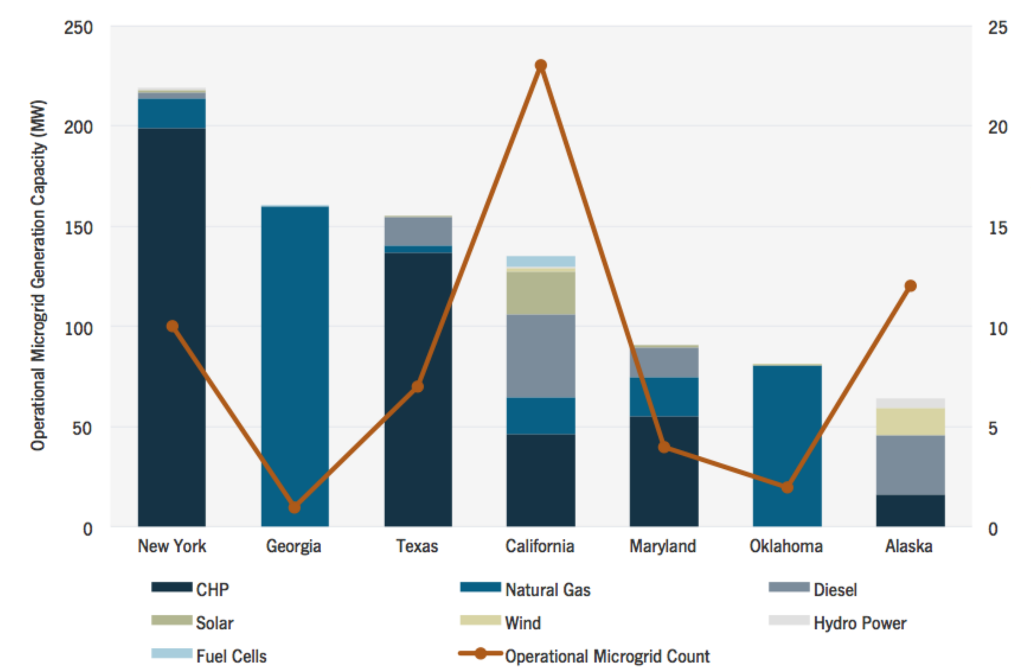


Figure 2: U.S. microgrid development across 7 states in 2016. Source: ILSR Mighty Microgrids Report

TYPES OF MICROGRID GENERATION

This section highlights the pros and cons of four of California's most common microgrid generation types (Figure 2 *above*): diesel & natural gas generator systems, combined heat and power (CHP), solar and storage, and fuel-cells. In addition, we provide examples of existing microgrids that are being used to power businesses and campuses in California.

DIESEL AND NATURAL GAS

Diesel and natural gas powered microgrids together make up a large portion of California's operational microgrid generation capacity. Diesel-based generation is particularly common for remote microgrid systems[5] and as dispatchable generation for temporary microgrid systems during blackouts or California's public safety power shutoff (PSPS) events.[6]

Diesel generators are popular for their low capital costs, high reliability, ability to come online quickly, sensitivity to load changes, and quick installation timelines.[7] However, diesel fuel costs are volatile and rising in comparison to renewable energy sources, which now have a lower levelized cost of electricity (LCOE).[8] In addition, diesel-based systems face criticism for their environmental impacts in terms of air pollution and carbon emissions.[9]

Natural gas generator systems offer many of the same benefits of diesel systems, but natural gas is a comparatively cleaner energy source.[10] In early 2020, Pacific Gas & Electric (PG&E) released a plan to explore the use of natural gas generators as an alternative to dispatchable diesel generators to power essential microgrids during PSPS events.[11] However, despite being 'cleaner' than diesel generation, natural gas generator systems still face criticism as being unsustainable (as it is still a fossil fuel) and therefore investments into natural gas systems can be seen as counterproductive to achieving zero-carbon goals.[12]

COMBINED HEAT AND POWER

As of 2016, Combined Heat and Power (CHP) microgrids were the most common microgrid type across the U.S. - composing 64% of operational and 56% of planned microgrid capacity.[13] CHP generation typically runs on natural gas supplied through existing, piped gas delivery infrastructure.[14] Additional fuel sources are represented in Figure 3 below.

Combined heat and power systems, as their name entails, provide outputs in the form of both heat and electricity.[15] This system of dual outputs increases the efficiency of CHP generation by recapturing the heat output from electricity generation and putting it to use - resulting in 30-55% less greenhouse gas emissions per unit of energy compared to power plants or onsite boilers.[16] Increased fuel efficiency results in lowered operating costs for CHP systems.[17] In addition, CHP systems provide a reliable source of continuous electricity generation, with natural gas supply lines less likely to be affected by a natural disaster than power lines.[18]

CHP microgrids may not be appropriate in all situations — their viability in part rests on the existence of a suitable demand for the system's heat output at the facility.[19] Although efficient, CHP systems are less desirable for microgrid developers looking to move away from fossil fuel-based generation.[20] In addition, the capital costs to build and incorporate a new CHP microgrid system can be high.[21,22] While CHP systems can be more reliable than utility grid-based power, they are still reliant on fossil fuel pipelines and subject to fuel cost fluctuations.

CHP System Schematic

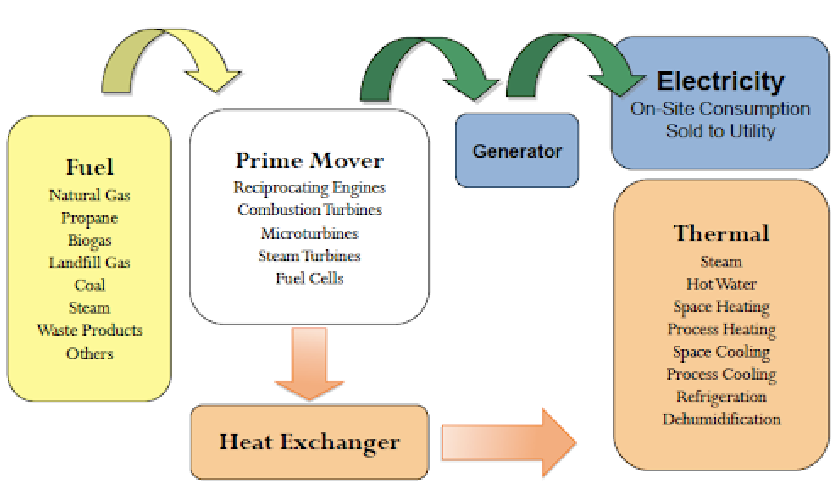


Figure 3: Diagram of CHP system components. Source: Efficient Energy Delivery System of the CHP-PV Based Microgrids

MICROGRID EXAMPLE: TECOGEN'S PHARMACEUTICAL CLIENT[23]

In 2017, Tecogen announced plans to install a 625kW combined heat and power (CHP) generation system to provide electricity, heating, and cooling to a California Bay Area-based pharmaceutical headquarters. Reliability was a key driver for this project. The pharmaceutical company's research activities require climate controlled environments and are sensitive to disruptions, making backup power critical. While normally fueled by natural gas, backup propane storage at the campus provides additional redundancy against natural gas supply interruptions to power the microgrid if necessary. The InVerde e+ generators installed for this project are highly efficient and emit very low levels of pollutants, exceeding California Air Resources Board regulatory standards for distributed energy generation.[24]

MICROGRID EXAMPLE: JSR MICRO MICROGRID[25]

Semiconductor materials manufacturer JSR Micro installed 11MW of Bloom Energy fuel cells at their corporate campus in 2018.[26] Investment in this microgrid system was motivated by electricity cost savings, reliability (avoiding outages is critical for precision manufacturing processes), and efforts to reduce the company's carbon footprint. Bloom's solid oxide fuel cells have lower carbon emissions than a conventional U.S. power plant and release almost no smog-forming particulate emissions due to their lack of combustion.

FUEL CELLS

Fuel cells are a popular electricity generation technology among retail business customers — a 2017 report cited a retailer (Home Depot) as the largest stationary fuel cell customer in the US.[27] Their appeal to businesses is based on sustainability benefits, emissions reductions, and cost-competitiveness with grid-produced electricity.[28]

A fuel cell generates electricity through an electrochemical reaction, rather than combustion, that releases very low levels of emissions depending on the fuel source used.[29] Fuel cells offer the benefit of constant, reliable electricity generated onsite.[30] Though most fuel cell systems operating today utilize piped natural gas,[31] the systems are capable of running on different fuels. In the future, fuel cell system sustainability may be increased through the use of renewable hydrogen[32] or other renewable fuel sources.

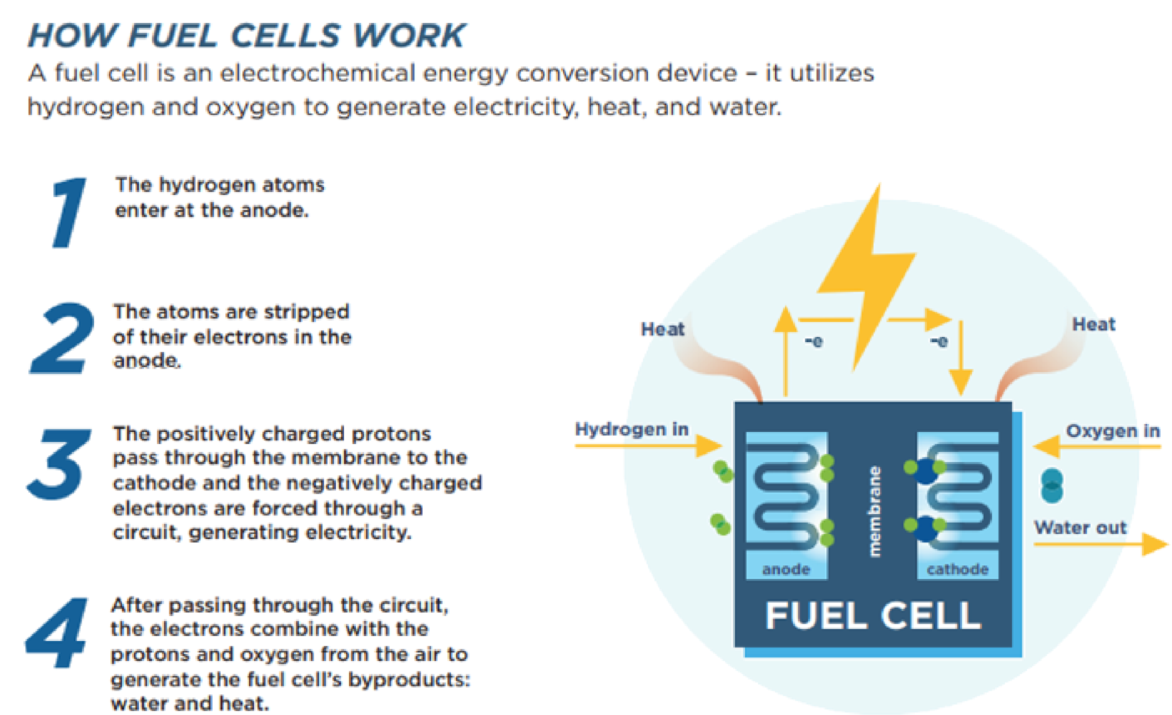


Figure 4: Diagram of a hydrogen powered fuel cell system. Source: FCHEA

SOLAR-POWER

Renewable-based microgrids harness the power of locally produced energy, including from onsite wind and solar-power installations. For the purposes of this report, we will focus on solar-powered microgrids given that solar is a widely available renewable energy resource in the state of California.[33] For an example of wind energy in a microgrid see the Inland Empire Utilities Agency's system.[34] While CHP microgrids dominate existing microgrid production capacity in the U.S., a 2018 IFC report found that solar-powered microgrids are on the rise, with planned capacity exceeding that of planned CHP capacity.[35]

Because solar energy production varies throughout a day, some form of energy storage is required in order to ensure a consistent flow of electricity within a microgrid system. Figure 5 provides an example of how energy output from a solar microgrid is

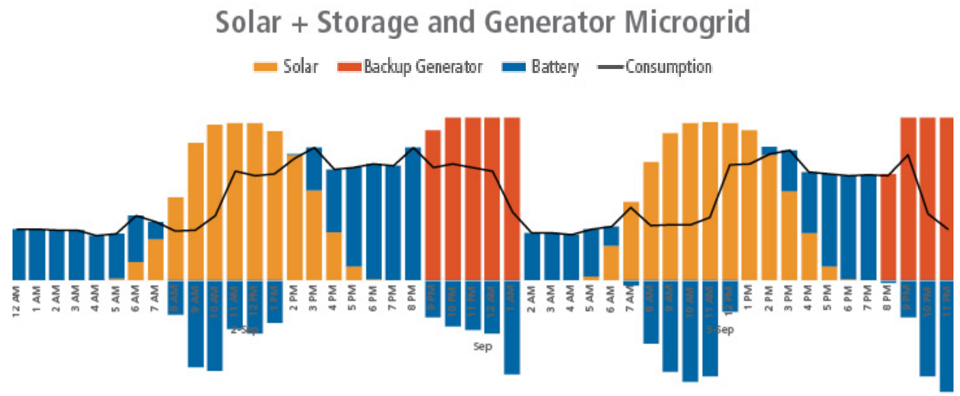


Figure 5: Load simulation for a solar+storage+generator microgrid. Source: EDF

maintained throughout the day with help from battery and generator inputs. In the future, storage systems may provide longer-term, seasonal stabilization of energy availability for solar-powered systems (see Hydrogen Storage).

Solar-powered microgrids have the benefit of being clean energy-based, supporting sustainability efforts by moving away from carbon-based fuel systems.[36,37] Relying primarily on solar energy captured on-site builds resilience to outside fuel and electricity supply disruptions or price fluctuations that might impact other microgrids types reliant on fossil fuel-based generation.[38,39] Once the system is operational, electricity costs are very low compared to other systems as solar energy is captured free of charge.[40]

While there are many upsides to solar and storage microgrid systems, there are some challenges to consider. Solar and storage microgrid systems are complex and require regular maintenance and technical management.[41] Battery systems are costly, increasing the upfront investment required to construct a solar-powered microgrid system.[42] Further, a fossil fuel-based backup generator may still be required to supplement renewable energy production and keep the microgrid system online at night, seasonally, or during periods of bad weather.[43,44]

MICROGRID EXAMPLE: SANBAR SOLAR[45]

In 2018, Sandbar Solar began operation of a microgrid system composed of 59kW of solar panels, three Avalon flow batteries, and a 60kW natural gas generator. Cost savings was a key motivator for this microgrid. The headquarters was built on undeveloped land so building a microgrid allowed Sanbar to avoid utility connection costs and save on future electricity bills. In addition, the project serves as a demonstration for Sanbar's clients. The generator provides backup power during periods of cloudy weather (expected to run 200-300 hours per year). The project employs vanadium flow batteries designed to handle 100% daily charge/discharge cycles over a 30-year timeframe. The vanadium electrolyte is unique in that it retains 100% of its energy storage capacity rather than degrading over time.[46]

COMBINING MICROGRID TECHNOLOGIES

The microgrid generation technologies outlined above can be used in combination in order to uniquely satisfy customer energy needs and bolster a microgrid system's resilience.

MICROGRID EXAMPLE: UCSD[47]

The microgrid serving the University of California, San Diego's campus combines CHP, fuel cells, and solar generation. The microgrid offers the University electricity cost savings, reliability for its research activities, and supports University and statewide carbon reduction goals.[48] Currently, the microgrid accounts for 92% of the campus' annual energy use and there are plans to expand that system in the future to meet 100% of energy needs. UCSD's on-campus generation components include:[49]

- "30MW CHP plant, serving as the microgrid anchor
- 2.8MW biogas fuel cell, using anaerobic digestor gas (ADG) from wastewater treatment plant
- 1.2MW of solar PV panels distributed throughout the campus"

WHY INVEST IN MICROGRIDS?

In a 2018 report prepared for the California Energy Commission, Navigant Consulting surveyed a sample of microgrid users and asked them to rank the most valuable benefits obtained from their microgrid energy system.[50] The top three answers were renewable energy integration, resiliency, and bill savings/demand charge abatement.

Those top answers fall generally into the wider categories of economic, environmental, and resilience benefits which were identified as important drivers in the microgrid examples above. We explore each of these categories further in the sections that follow.

ECONOMIC BENEFITS

The capital requirements for a microgrid project can be high but in a well-designed system those investments pay off (we explore capital costs further in a later section). A 2018 assessment of several California microgrid projects found that expected payback periods on initial investments varied from 4 to 18 years.[51] The timeline for returns on investment depends on the characteristics of an individual project and available incentives.

Overall, microgrids offer savings by reducing the cost of utility electricity bills. Onsite generation can produce electricity at a lower cost than electricity purchased from the utility. Microgrids allow customers to save both by purchasing less electricity from the utility and by controlling when energy is purchased in order to maximize savings.[52] This kind of smart microgrid management can reduce a customer's utility bill-based time of use and demand charges.[53] During peak periods, when utilities charge higher rates, the microgrid owner can elect to draw power from the microgrid (see Figure 6). The same type of microgrid management can be used to smooth peaks in a customer's demand and effectively reduce demand charges on utility energy bills.[54] In addition, as we will explore later, utility net metering programs allow microgrid customers to sell excess power generated back to the grid for further bill savings.

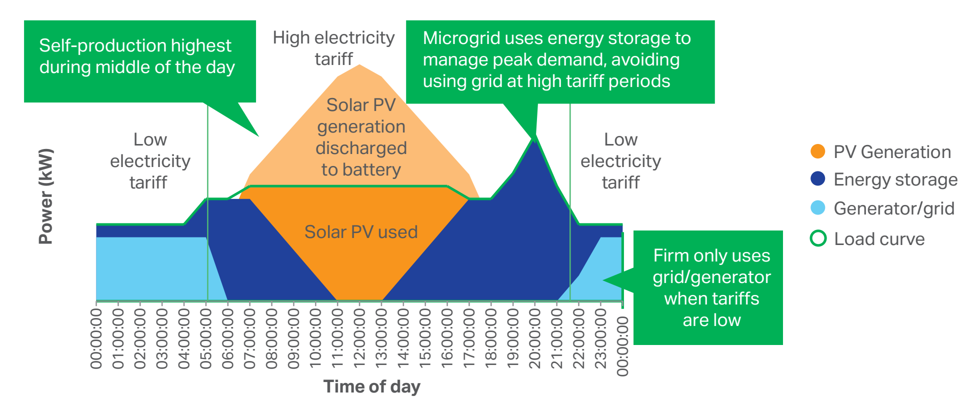


Figure 6: Diagram of the benefits of energy storage for mitigating peak demand energy charges. Source: Microgrids for commercial and industrial companies

RESILIENCE BENEFITS: MICROGRIDS & PUBLIC SAFETY POWER SHUTOFFS

Electric utility public safety power shutoffs (PSPS) across California are now common practice in efforts to reduce wildfires (see Figure 7 for state map of susceptibility). In October 2019, over 2 million customers were impacted by shutoffs.[55] Loss of power comes at a price for businesses— 2019 shutoffs cost Silicon Valley companies millions of dollars.[56]

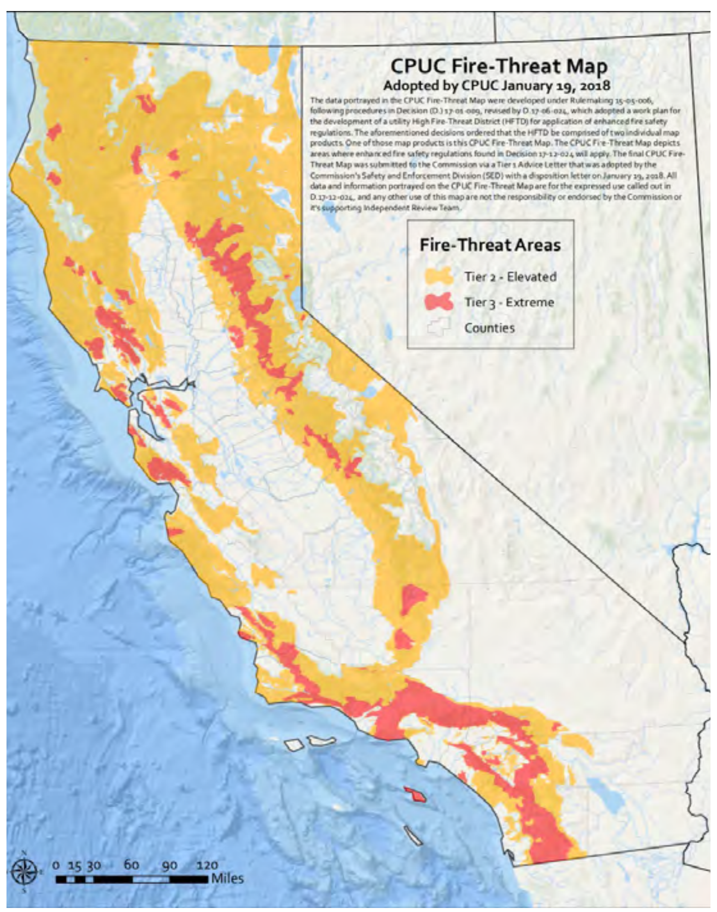


Figure 7: CPUC fire threat map 2018. Source: Fortis Telecom

In order to keep essential services online during planned outages, utilities and customers turn to dispatchable onsite electricity generation options. To date, this has generally meant diesel backup generators. However, utilities like PG&E are actively seeking cleaner alternatives for backup generation during shutoff events.[57] In December 2020, the California Public Utilities Commission (CPUC) proposed funding for clean energy microgrids to power utility substations during future fire seasons.[58]

Economic models from the Rocky Mountain Institute demonstrate a clear economic benefit of solar-plus-storage systems for customers affected by PSPS events. Their model found that if the 1 million customers impacted by shutoffs in 2019 had solar-plus-storage systems they would have had a combined economic benefit of $1.4B when accounting for value added to the grid.[59] Tellingly, the fire season in fall of 2020 saw a surge in demand for microgrid systems from commercial and residential customers across California.[60] The resilience value of microgrids, in terms of avoided economic losses, is generally customer specific.[61]

SUSTAINABILITY BENEFITS: FURTHERING NET-ZERO ENERGY GOALS

Microgrids help achieve carbon and energy goals through incorporation of zero emission energy sources, utilization of waste heat, reduction of transmission losses, as well as intelligent management of energy supply and demand to reduce a customer's overall carbon footprint.[62] Even when microgrids rely on natural gas-based generation, such as within combined heat and power (CHP) systems or fuel cells, the efficiency of power production and relatively clean nature of natural gas compared to other fuels can result in overall emissions benefits.[63] In a renewable powered microgrid, energy storage components enable effective capture and use of intermittent resources, such as wind or solar.[64]

In the last year, businesses increasingly committed to net-zero goals. Key announcements came from the U.S. utility sector,[65] investment groups,[66] and the World Business Council on Sustainable Development,[67] among others. These commitments are complemented by Amazon and Global Optimism's Climate Pledge, which as of February 2021 had 53 signatories.[68,69]

In addition, California has its own net-zero goals, pursuing overall carbon neutrality, including from electricity systems, by 2045.[70] The state's zero net energy goals aim for onsite renewable energy production to equal or exceed consumption in new buildings.[71] The California Energy Commission (CEC) has recognized the opportunity for microgrids to support achievement of the state's goals, and is actively developing policies to promote further microgrid investments.[72]

BENEFITS IN PRACTICE: ALPHA OMEGA WINERY PROJECT[73]

The Alpha Omega Winery in Napa, California built a microgrid with 400kW of solar panels, complemented with 100kW of saltwater energy storage batteries. While only in operation for about five years, the microgrid investment has already delivered quantified economic and environmental returns. Onsite solar electricity production and demand management lessens utility-bought energy use during peak times, reducing the winery's monthly electricity bill from $15,000 to $1,000 per month. Environmentally, the winery's carbon footprint was reduced by 960,750 lbs of CO_2 per year with the integration of solar energy production. Finally, although not quantified, the project delivered resilience benefits to the winery as well, providing a source of backup power described as "important for the winery's operations."

OWNERSHIP AND FINANCING

HOW MUCH DO MICROGRIDS COST?

The cost associated with microgrid development varies by location and microgrid type. A Navigant Consulting survey of nine California microgrids revealed an average unit cost[74] of around $3.5M/MW, just under the average cost of other North American microgrids included in the survey.[75] A national survey of microgrids by NREL compiled cost information from 80 different systems across the U.S., finding a mean unit cost for campus/institutional microgrids of $3.3M/MW (Table 1).[76]

Segment	IQR	Mean
Campus/ Institutional	$4,936,109 - $2,472,849	$3,338,666
Commercial/ Industrial	$5,353,825 - $3,399,162	$4,079,428
Community	$3,334,788 - $1,430,805	$2,119,908
Utility	$3,219,804 - $2,323,800	$2,548,080

Table 1: Microgrid costs from NREL Survey, market segment IQR and mean normalized microgrid costs in $/MW. Replicated from: NREL Microgrid Cost Study

As microgrid technologies continue to develop and scale up, their cost is expected to decline. Figure 8 predicts that the cost of energy from solar and storage systems will fall below grid energy costs for California, Hawaii, and Texas by around 2025. Note that the actual price of solar-plus-storage systems has already seen dramatic declines in recent years (Figure 8).

Even with future cost reductions, microgrids require significant amounts of capital investment as well as operation and maintenance costs. The following sections explore ownership and financing models for microgrids that can make microgrid systems economically feasible under a variety of financial scenarios.

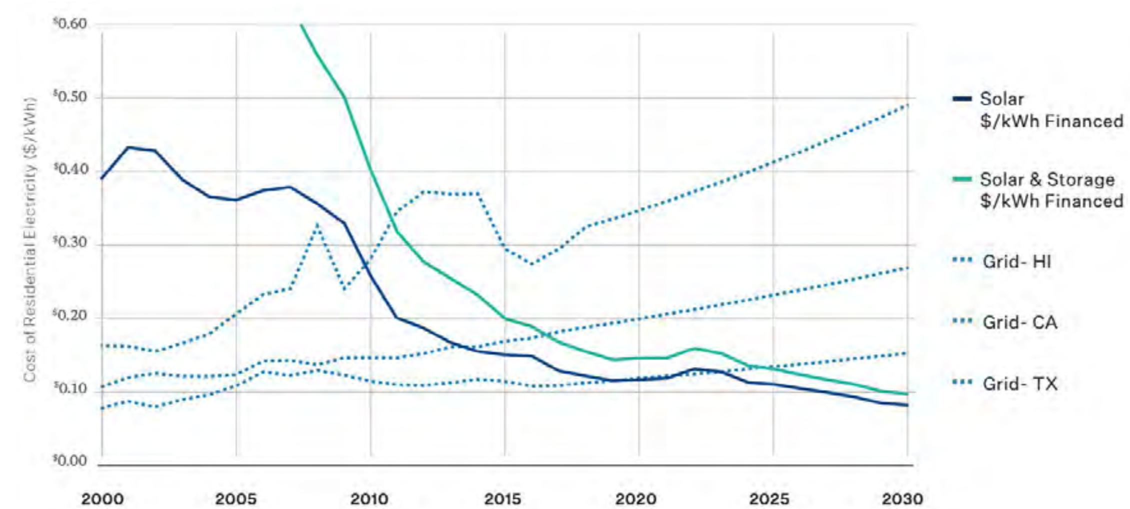


Figure 8: Actual and predicted costs of solar and batteries compared to utility grid rates in Hawaii (HI), California (CA), and Texas (TX). Source: NARUC

FINANCING & OWNERSHIP OPTIONS

Ownership of microgrids can take several forms. The three primary modalities of microgrid ownership are:[77]

- **Direct ownership**: The microgrid user finances, builds, owns, operates, and maintains the microgrid.
  Pros: high return; Cons: high risk
- **Joint ownership**: The microgrid user owns and finances the microgrid, but development and operation is delegated to a third-party.
  Pros: medium risk; Cons: medium return
- **Third-party ownership**: A third-party finances, develops, operates, manages, and owns the microgrid system.
  Pros: low risk; Cons: low return

Ownership models can be complicated, with different third-parties involved at different stages of a microgrid's development. Figure 9 demonstrates a few ways that different third-parties might interact with a customer to provide microgrid energy services. Third-parties involved in microgrid development can include independent power producers (IPPs), developers, engineering, procurement and construction contractors (EPCs), service companies, infrastructure funds, and engineering service providers (Engs).[78]

Microgrids can be financed upfront by a customer or procured through another financing model. Financial mechanisms used to support microgrid development include power purchase agreements, leases, energy savings performance contracts, and energy as a service contracts. The sections below provide summaries of each of these mechanisms and a case study of implementation.

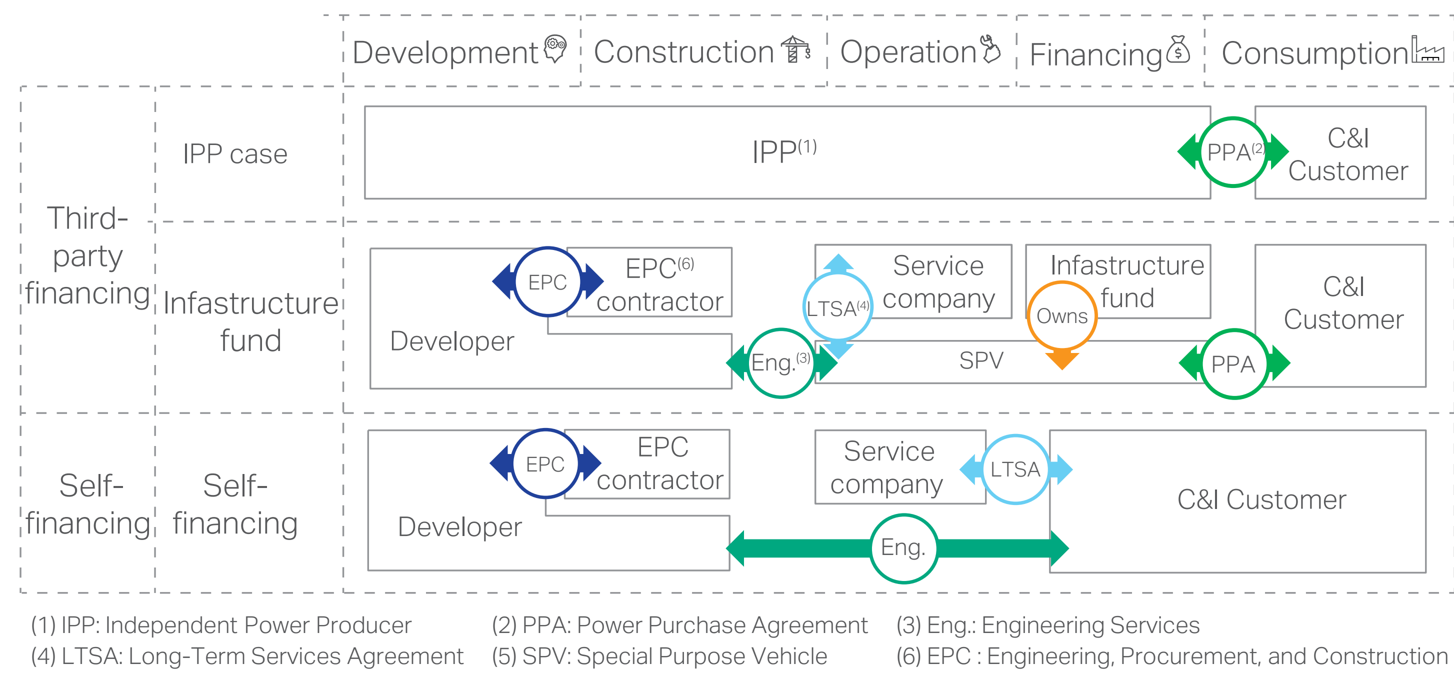


Figure 9: Schematic of major microgrid ownership structures. Source: WBCSD

POWER PURCHASE AGREEMENTS

One model whereby a third-party can provide microgrid-based energy for a customer without upfront customer financing is through a Power Purchase Agreement (PPA). A PPA allows a third-party developer to own or lease a microgrid and retain responsibility for microgrid operation and management. The third-party recoups the cost of the initial investment and continued microgrid operation through customer payments for power. Customers only pay for the power that is produced, typically at a rate lower than utility provided power, so risks are largely shifted to the third-party operator.[79] A PPA is generally medium-term, lasting between 10 and 25 years. At the end of the agreement, the customer can decide whether they want to generate a new agreement, have the system removed, or purchase the system from the third-party.[80] The electricity rate structure for a customer is locked in at the beginning of a PPA contract and often includes escalators, whereby the cost of electricity increases over the duration of the agreement.[81,82]

Case Study: Gridscape Solutions & the City of Fremont, California[83,84]
In order to provide reliable electricity supply to fire stations, the City of Fremont entered into a PPA with Gridscape Solutions to supply power through solar and storage microgrid systems. Gridscape's projections indicate that, combined, the microgrid systems will save the city over $200,000 in bill savings over 10 years.[85]

- **System Cost**: $2.4M
- **Capital Financing**: $1.8M from the California Energy Commission
- **PPA**: Gridscape Solutions paid the remainder of the required initial investment which will be recouped through PPA payments

LEASES

A leasing structure reduces the upfront capital investment required for microgrid development. A third-party finances and owns all or part of the microgrid system and leases it to the customer over a defined lease period. Meanwhile, the customer retains responsibility for operation and maintenance of the microgrid.

Unlike PPA payments which are based on the amount of energy consumed, lease payments are standard and independent of energy usage over a period of time.[86] As with PPAs, leasing agreements can include price escalators that increase payments over time.[87] However, leasing agreements tend to have shorter contract terms.[88]

Case Study: Alpha Omega Winery[89]
In 2016, Alpha Omega began installation of a 500kW microgrid system to provide electricity to its Napa, California winery. The leasing contract was developed so that lease payments were lower than the winery's utility energy costs. After the 7 year lease term, Alpha Omega will fully own the microgrid system.

- **System cost**: $1.1M
- **Financing**: 7-year lease from Blue Sky Utility, $180,000 in Self-Generation Incentive Program funding (SGIP, discussed further in a later section)

ENERGY SAVINGS PERFORMANCE CONTRACTS

Another financing option offering no upfront capital from a microgrid customer is an Energy Savings Performance Contract (ESPC). Through this contract, a third-party develops and owns the microgrid and recovers their investment in the customer's monthly energy savings. The system is designed so that the energy savings effectively cover the costs of upfront capital investments.[91] The number of energy service companies offering energy storage and grid services is on the rise.[92] A toolkit centered around ESPC contracts for federal developers is available from the Department of Energy. This budget-neutral approach is utilized mainly by government entities looking to make large-scale efficiency upgrades.[93]

Case Study: Air base in Japan[90]
In January, 2021 Schneider Electric announced an energy saving performance contract with the U.S. Air Force to develop a 10MW CHP plant with microgrid controls at Yokota Air Base in Japan. The project includes work to enhance the efficiency of over 450 buildings on the base to reduce overall energy demand.

- **Contract Cost**: $403M ($167M in implementation costs, 21 years of operation and maintenance)
- **Financing**: Funded with energy savings guaranteed by Schneider Electric over 25-year contract

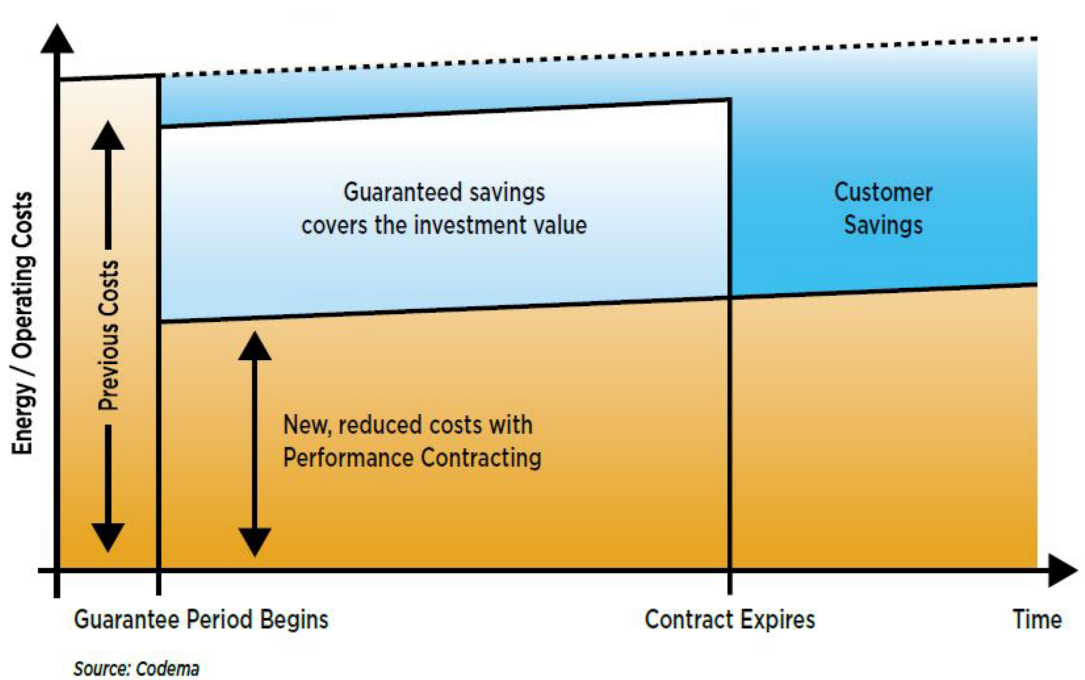


Figure 10: Diagram of ESPC funding model. Source: SD Sustainability

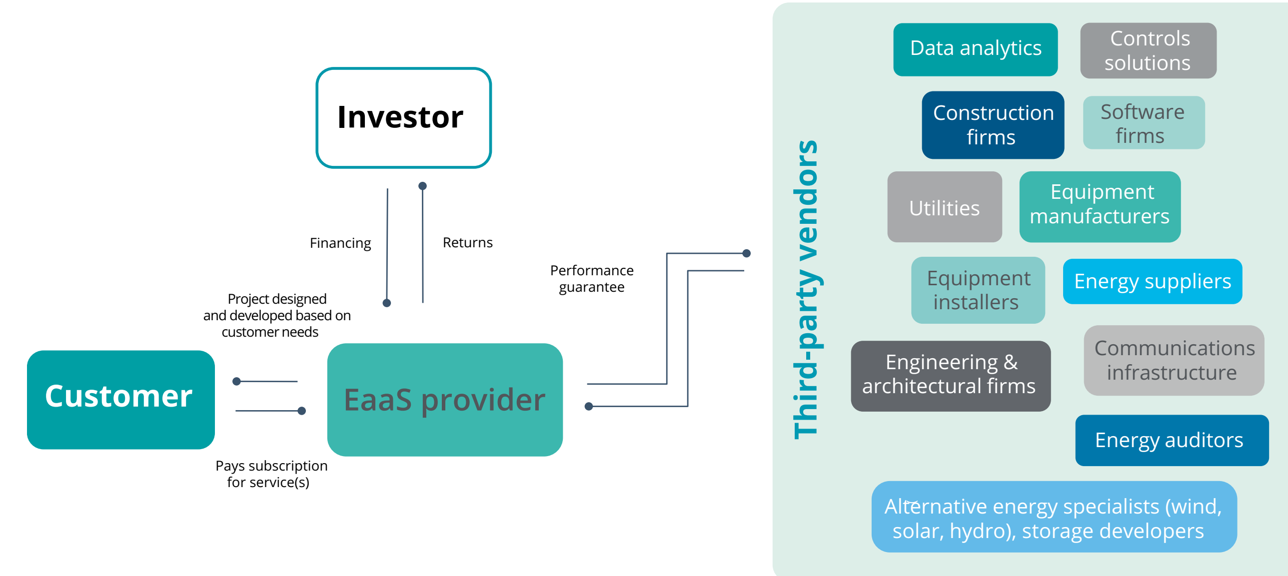


Figure 11: How an Energy as a Service contract works. Source: Deloitte

ENERGY AS A SERVICE

Energy as a Service (EaaS) financing is one of the most popular microgrid financing models in the U.S., composing around 25% of financing available for microgrids.[94] EaaS contracts involve no upfront financing and, as a pay-for-performance solution, infrastructure and efficiency costs can be paid for through realised energy savings.[95] In addition, EaaS projects are designed to have immediate positive operating income, lending customers savings compared to their previous utility-energy bills.[96] The Energy as a Service provider takes responsibility for ownership, software, analytics, and operations and maintenance of the microgrid system, allowing customers to benefit from the systems without having to take on microgrid system responsibility themselves.[97] A schematic describing the different ways third-parties might interact within an Energy as a Service structure is included below. Note that the experience for the customer is streamlined — they only need to interact with the Energy as a Service provider (Figure 11). Energy as a Service contracts may take the form of other no upfront-cost finance models, such as PPAs or leases.[98] Energy as a Service contracts are used more for complex, multi-measure infrastructure projects as compared to PPA contracts, which are commonly used to finance solar installations and involve direct or indirect purchase of power from a generating entity.[99,100]

Provider Example: AlphaStruxure
Started in 2019, AlphaStruxure is a joint venture by The Carlyle Group and Schneider Electric.[101] The company's Energy as a Service model provides microgrid services to customers at no upfront cost. Rather, the customer enters into a long-term agreement with AlphaStruxure in exchange for financing, installation, and management of a microgrid system. AlphaStruxure's offering also includes electric vehicle integration (e.g., EV chargers, bus fleets).

INCENTIVES &TAX CREDITS

The microgrid sector is rapidly changing, as are the policies and incentives surrounding it. While we provide an overview of available incentives in this section, consult with your local ordinances to obtain the most up-to-date information on relevant policies.

The availability of state and federal incentives and tax credits can play a key role in the economic feasibility of a microgrid project. A 2018 publication explored incentives and tax credits available for campus microgrids in California.[102] The programs identified by the researchers are included in Table 2.

In the below sections, we define each of these financial incentives and offer resources to obtain further information. In addition, we include information on new incentive programs expected with the implementation of California's microgrid legislation.

Name	Implementing Sector	Category	Incentive Type	Amount
Business Energy Investment Tax Credit	Federal	Financial incentive	Corporate tax credit	30% for solar systems
Modified Accelerated Cost-Recovery System	Federal	Financial incentive	Corporate depreciation	5-year accelerated depreciation
Property Tax Exclusion for Solar Energy Systems	California	Financial incentive	Property tax incentive	100% of system value
Net Energy Metering	California	Regulatory policy	Net metering	Excess generation solar at retail TOU rate
Self-Generation Incentive Program	California	Financial incentive	Rebate program	$0.22/Wh for advanced energy storage, $1.00/W for fuel cells

Table 2: Incentives and tax credits related to microgrid technologies in California. Reproduced from: Hau, V.B., et al. (2018)

BUSINESS ENERGY INVESTMENT TAX CREDIT[103]

This federal incentive operates as a corporate tax credit available to commercial, industrial, investor-owned utility, cooperative utilities, and agricultural sector development across a range of eligible technologies. Projects must meet size requirements to qualify:

- Small wind turbines: 100kW or less
- Fuel cells: 0.5kW or greater
- Microturbines: 2MW or less
- CHP: 50MW or less

The table below includes the value of investment tax credits available by technology based on the first year of construction as detailed in a Taxpayer Certainty and Disaster Tax Relief Act of 2020 extension. Maximum incentives are detailed for fuel cells ($1,500 per 0.5 kW), microturbines ($200 per kW), and small wind turbines depending on the service start date.[104]

For more information on this tax credit, visit DSIRE's incentive overview and relevant IRS form instructions. A summary guide of the Investment Tax Credit focused on commercial solar photovoltaics is available from the Department of Energy.

Technology	Dec 2020	Dec 2021	Dec 2022	Dec 2023	Dec 2024	Dec 2025	Future Years
PV, Solar Water Heating, Solar Space Heating/ Cooling, Solar Process Heat	26%	26%	26%	22%	22%	22%	10%
Hybrid Solar Lighting, Fuel Cells, Small Wind, Waste Energy Recovery	26%	26%	26%	22%	N/A	N/A	N/A
Geothermal Heat Pumps, Microturbines, Combine Heat and Power Systems	10%	10%	10%	10%	N/A	N/A	N/A
Geothermal Electric	10%	10%	10%	10%	10%	10%	10%
Large Wind	18%	18%	N/A	N/A	N/A	N/A	N/A

Table 3: Investment tax credit value by technology per year. Reproduced from: DSIRE

MODIFIED ACCELERATED COST RECOVERY SYSTEM

A federal financial incentive, the Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments into "certain property through depreciation reductions."[105] A number of renewable energy technologies are eligible for the program, including:

- a variety of solar-electric and solar-thermal technologies
- fuel cells and microturbines
- geothermal electric
- direct-use geothermal and geothermal heat pumps
- small wind (100kW or less)
- combined heat and power (CHP)

The MACRS offers investors some market certainty to encourage investments in solar and energy sectors.[106] More information on eligibility and the current status of this incentive is available on DSIRE and the IRS website.

PROPERTY TAX EXCLUSION FOR SOLAR ENERGY SYSTEMS

Typically, a valued physical investment into a property results in an increase in the property's base year value assessment. Higher property assessments generally translate to higher property tax payments.[107] The California tax code includes a new construction exclusion that allows installation of a qualifying solar energy system without a resulting increase or decrease in the assessment of the property. Qualifying active solar energy systems include:[108]

- Domestic, recreational, therapeutic, or service water heating
- Space conditioning (heating/ cooling systems)
- Production of electricity
- Process heat
- Solar mechanical energy

For more information on this exclusion and relevant requirements, see the California State Board of Equalization website.

NET ENERGY METERING

California's Net Energy Metering program allows "customers who generate their own energy ('customer-generators') to serve their energy needs directly onsite and to receive a financial credit on their electric bills for any surplus energy fed back to their utility". Eligible generation types include: small solar, wind, biogas, and fuel cells. More information on the current Net Energy Metering structure and eligibility requirements is available on the CPUC website.

SELF-GENERATION INCENTIVE PROGRAM[109]

California Public Utilities Commission's Self-Generation Incentive Program (SGIP) supports the development of existing, new, and emerging distributed energy resources. The incentive provides rebates for technologies installed on the customer side of the meter, including "wind turbines, waste heat to power technologies, pressure reduction turbines, internal combustion engines, microturbines, gas turbines, fuel cells, and advanced energy storage systems." As of January 2021, authorized SGIP incentives through 2024 totaled $813M with 88% of funds designated for energy storage investments and the remaining 12% for investments in generation.[110] The energy storage incentive structure as of January 2021 is outlined in the Table below. More details on the SGIP program and up to date incentive rate information can be found on the CPUC website and the SGIP online application database.

	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Large Storage (>10 kW)	$0.50	$0.40	$0.35	$0.30	$0.25	N/A	N/A
Large Storage Claiming ITC	$0.36	$0.29	$0.25	$0.22	$0.18	N/A	N/A
Residential Storage (<=10 kW)	$0.50	$0.40	$0.35	$0.30	$0.25	$0.20	$0.15

Table 4: Energy storage incentives per watt-hour (Wh). Reproduced from: SGIP Handbook

NEW DEVELOPMENTS IN CALIFORNIA: SB 1339

In September, 2018 the Governor of California approved Senate Bill 1339 requiring the California Public Utilities Commission (CPUC) to take actions to promote the commercialization of microgrids throughout the state.[111] Implementation of the bill is moving along 3 tracks:

- Track 1: Focused on short term deployment of resiliency strategies in Spring and Summer 2020 to prepare for the 2020 wildfire season.
- Track 2: Focused on broader policy goals around microgrid development, including the topics layed out in the original bill: "developing standards, protocols, guidelines, methods, rates, and tariffs to support and reduce barriers to microgrid deployment statewide, while prioritizing system, public, and worker safety, and avoiding cost shifts between ratepayers."
- Track 3: Focused on ongoing implementation and future resiliency needs.

In January 2021, the CPUC made a decision for Track 2 that "adopts microgrid rates, tariffs, and rules for large investor-owned electrical corporations."[112] Within that decision, the CPUC outlined new financial support for microgrid development, including:

- **Microgrid Incentive Program:** A statewide program jointly developed by the utilities in support of vulnerable communities most impacted by grid outages. The program's $200M budget will fund clean energy microgrids for these communities while testing new technologies and regulatory approaches.
- **Microgrid Tariff:** Each of California's large, investor-owned utilities (SCE, PG&E, and SDG&E) were tasked with the development of "a renewable microgrid tariff that prevents cost shifting for their territories." Tariff development is intended to create revenue for microgrid systems[113] by compensating microgrid owners for grid services provided, such as increased resilience.[114]

Once active, these developments may further enable microgrid development and financial feasibility. Up-to-date information on the implementation of SB1339 can be found on the CPUC website.

ANALYSIS TOOLS

There are a number of publicly available or fee-based tools available for microgrid project assessment and planning. Users can input customized data and energy objectives and receive microgrid investment guidance (an example of one model's inputs and outputs is provided in the Figure 12 below). Two of the programs listed in Table 5, the DER-VET Tool and mVSO Energy Modeling Software, incorporate available incentives/tax rebates to enable users to take advantage of related financial benefits.

The chart to the right includes an overview of the tools most frequently encountered during the research for this report. Many of these are publicly available and free to use (or have free versions available). Note that this is not an exhaustive list of tools available.

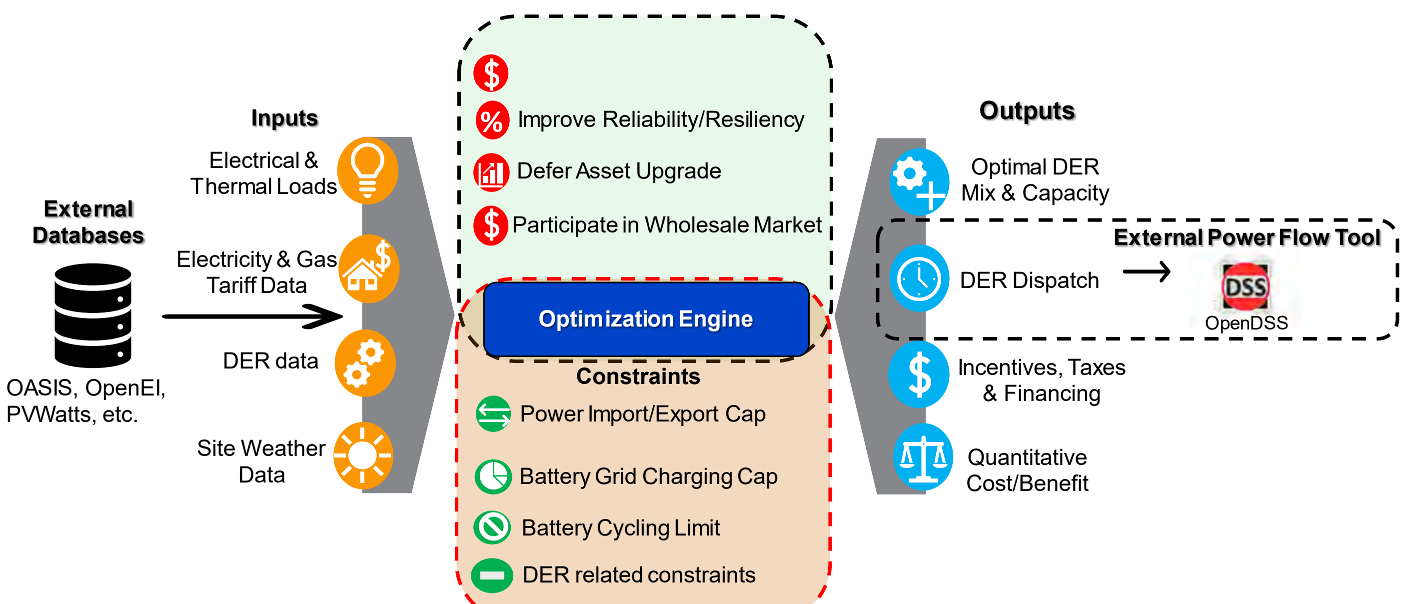


Figure 12: DER-VET optimization framework. Source: DER-VET.com

Tool Name	Developer	Inputs	Outputs	Intended Users	Availability
Distributed Energy Resource Value Estimation Tool (DER-VET)	Electric Power Research Institute, funded by California Energy Commission	Electrical and thermal loads, electricity & gas tariff data, DER data, site weather data	Optimal DER Mix & Capacity, DER Dispatch, Incentives, Taxes & Financing, Quantitative Cost/ Benefit	Grid planners and technology developers	Publicly available, free to use
Distributed Energy Resources Customer Adoption Model (DER-CAM)	Lawrence Berkeley National Lab	Building end-use load data, Electricity and gas tariffs, DER technology data, Site weather	Optimal DER capacities, optimal DER operations schedule	Site-owner	Publicly available, free to use
Microgrid Design Toolkit	Sandia National Laboratories	System objectives: cost, performance, reliability	Evaluate design alternatives, assess cost, performance and reliability tradeoffs	Microgrid designers	Publicly available, free to use
REopt: Renewable Energy Integration and Optimization	National Renewable Energy Laboratory (NREL)	• Drivers (energy costs and revenue, economics, resilience and environmental goals), • Generation Technology Options, Loads	• Technologies (Technology Mix and Size), • Operations (Optimal Dispatch Strategy), • Project Economics (Optimal Dispatch Strategy)	NREL Researchers, Commercial Building Managers	Lite version free to use, full version requires consultation with NREL
Hybrid Optimization of Multiple Energy Resources (HOMER)	HOMER Energy (originated from NREL)	Daily load profiles, resources, c omponents	• Optimal system configurations • Fuel consumption • Energy flows • Net present cost •LCOE • Capital, O&M costs[115]	Microgrid system designers	Quickstart version available for free (in beta), HOMER PRO is fee-based
mVSO (microgrid Value Stream Optimizer) Energy Modeling Software	CleanSpark	Consumption data	• Financial metrics: IRR, Payback, Incentives, estimated Cost Breakdown • Energy: Complete Annual System Operational Profile	Solar developers, battery suppliers, and energy performance contractors[116]	Fee-based service

Table 5: Common tools to aid in microgrid development. Information derived from project websites, linked in Table.

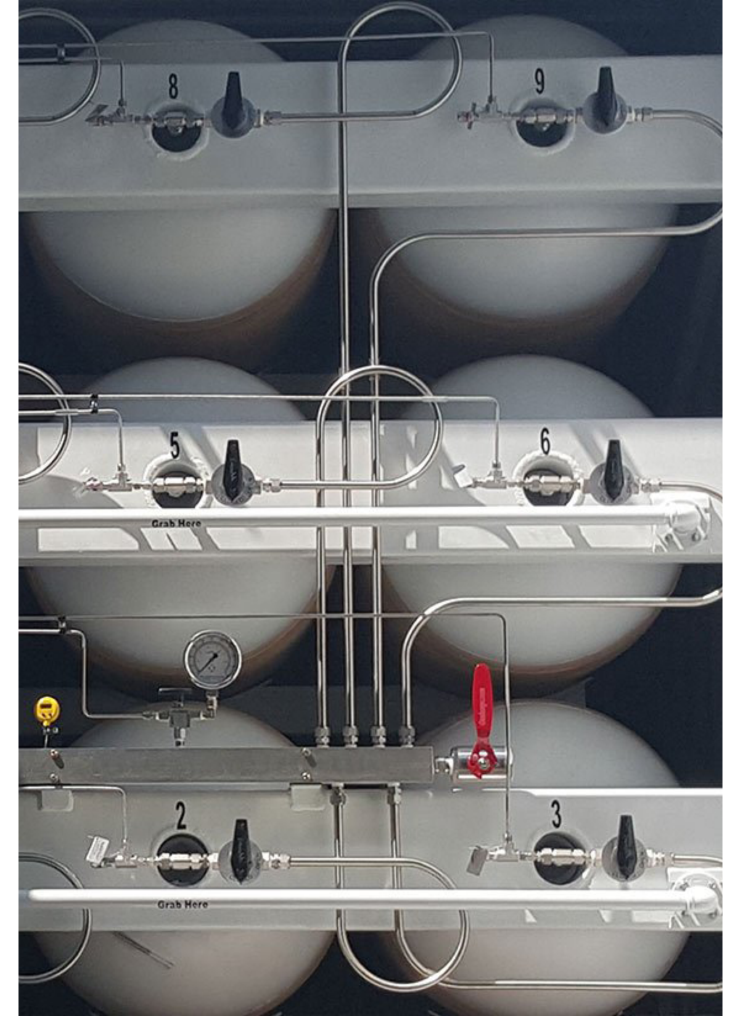
WHAT'S NEXT FOR MICROGRIDS?

The microgrid sector is rapidly developing and expanding. This report provides a surface level examination of different microgrid technologies, financing and ownership models, incentive policies, and analysis tools for decision makers. However, there is a wealth of information available on microgrids beyond what is included in this report for interested readers to explore.

Businesses located in California should continue to track the implementation of SB1339 and resulting microgrid-enabling incentives and policies. At the federal level, proposals for microgrid funding have recently been introduced as a part of larger climate legislation, although it remains to be seen whether they will be adopted.[117] In addition, there are several technological developments on the horizons for microgrids worth following, a few of which we describe below.

HYDROGEN STORAGE DEVELOPMENT

Long term storage solutions for solar-powered microgrids, such as hydrogen production, can harness excess solar energy produced in the summer when the sun is shining. When solar generation dips in the winter, hydrogen fuel cells can dispense that stored energy.[118] Economical hydrogen storage integration into microgrids is seen as the 'missing puzzle piece' that will enable renewable microgrid systems to realize their full



generation potential through long-term energy storage.[119] Seasonal hydrogen storage technologies may be cost effective as soon as 2050.[120] Hydrogen energy storage works best for long term storage needs (capturing solar energy in the summer to use in the winter) compared to short-term, overnight storage where batteries remain more cost effective.[121] Once generated, hydrogen fuels may be readily utilized within existing fuel cell systems; in 2019 Bloom Energy announced that existing fuel cells running on natural gas can be upgraded in situ to utilize renewable hydrogen fuel sources in the future.[122]

One microgrid project in California is already working to incorporate seasonal hydrogen storage into its system. The microgrid at Stone Edge Farm in Northern California was developed as a demonstration project and laboratory to test out different microgrid technologies. The project aims to develop a resilient, environmentally sustainable microgrid that enables cost savings — although economic considerations are secondary to the demonstration purpose.[123]

Hela Technologies is currently working to develop seasonal energy storage within the microgrid utilizing a hydrogen system (the images to the left depict hydrogen infrastructure installed at the farm).[124] The system will collect rainwater and use power from installed solar panels to transform the water into stored hydrogen fuel.[125]

ELECTRIC VEHICLE INTEGRATION

Electric vehicle charging can be integrated into a microgrid and serve a more active role in system management than other electricity draws. "Smart charging" management allows electric vehicle charging to occur at optimal times within a microgrid system, in order to avoid large peaks in energy use[126] (see Figure 13). For example, the microgrid at EDF Renewables Corporate Campus includes electric vehicle charging stations whose load is managed adaptively to reduce energy and demand charges.[127] The Powerflex Adaptive Load technology used in the EDF project to manage EV loads has been implemented in a number of other electric vehicle charging systems across the state.[128]

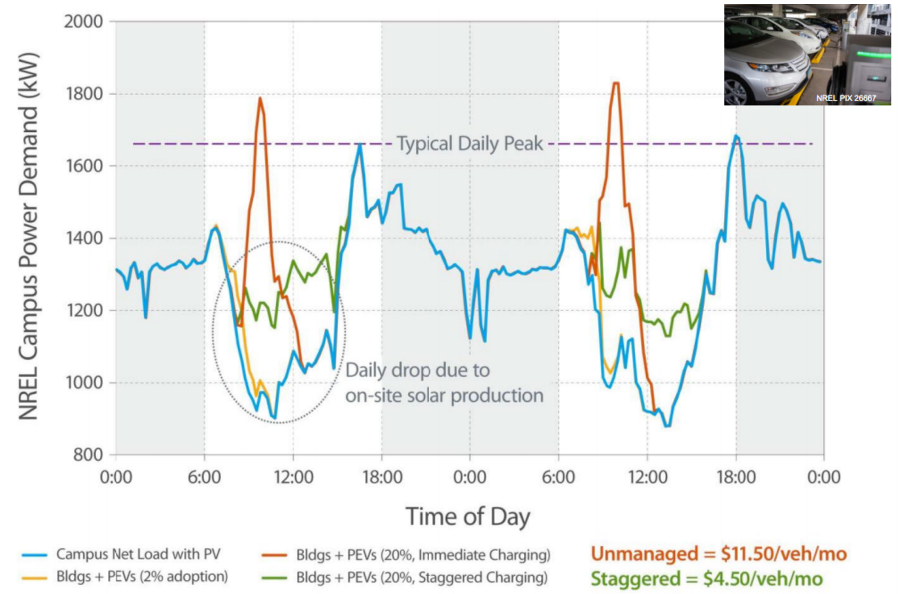


Figure 13: Integrating electric vehicle charging with renewable energy production. Source: ILSR

Going one step further, vehicle-to-grid (V2G) integration involves bidirectional electric vehicle chargers that allow a microgrid system to utilize the battery storage of the connected electric vehicles.[129] The connected batteries provide load balancing services to the microgrid.[130] This is especially useful in microgrids powered by intermittent renewable resources, such as solar energy.[131]

However, there are concerns around the effect of V2G integration on electrical vehicle battery life.[132] Batteries are often characterized by a certain cycle life - or the number of charging cycles a battery can perform before its performance declines beyond functionality.[133] V2G use of EV battery storage increases the number of charging cycles on connected vehicle batteries, potentially decreasing their longevity. Acknowledging this issue, researchers have demonstrated the potential for optimized V2G systems that reduce negative battery-life outcomes and can even expand vehicle battery capacities.[134] At UCLA, the Smart Grid Energy Research Center is currently building a platform for smart grid integration of electric vehicles that includes research into V2G power flow opportunities.[135]

SECOND-USE BATTERIES

California has a growing electric vehicle market expanding towards a statewide goal of 5 million zero emissions vehicles on the road by 2030.[136] The batteries of these vehicles represent a potential source for microgrid storage: when vehicle batteries degrade to around 75% of their original capacity, the owners may choose to obtain a new battery or vehicle. However, that remaining battery capacity is still useful and could potentially be utilized within a microgrid system.[137] In July 2020, the California Energy Commission awarded a grant to ReJoule and CleanSpark to develop donated, used EV battery systems from Ford into solar-plus-storage systems. The systems will be piloted at an artist's studio in Los Angeles and a housing and training center in Santa Ana.[138]

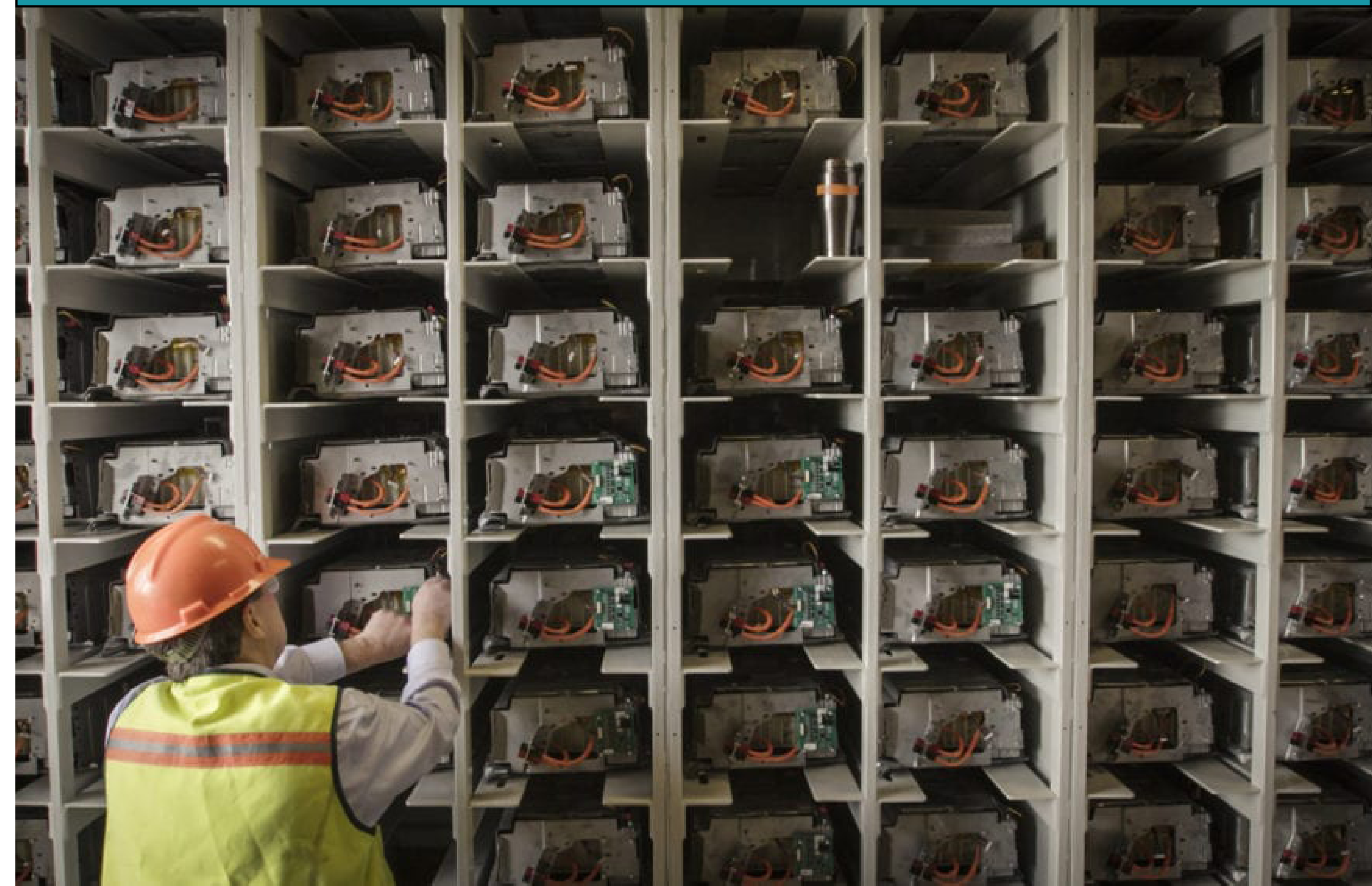


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IMAGE ATTRIBUTIONS BY SECTION

Summary
Solar panels installation at the Alpha Omega Winery. Photo from Alpha Omega project press release

Types of Microgrid Generation
InVerde e+ generator. Photo from Tecogen

Bloom Fuel Cells at JSR Micro. Photo from Bloom Case Study

Sanbar Solar Microgrid Installation (2). Photos from Sanbar Solar

Solar installation on UCSD parking structure. Photo from UCSD News

Ownership and Financing
Microgrid system at Alpha Omega Winery. Photo from Alpha Omega project press release

Conclusion
Renewable hydrogen infrastructire at Stone Edge Farm (2). Photos from Stone Edge Farm's gallery

Wall of electric vehicle batteries. Photo from Autofutures