Value-of-resilience from Solar Microgrids

VOR123 Methodology

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Mission
To accelerate the transition to renewable energy and a modern grid through technical, policy, and project development expertise.

100% renewable energy end-game
• 25% local, interconnected within the distribution grid and facilitating resilience without dependence on the transmission grid.
• 75% remote, dependent on the transmission grid for serving loads.
Natural gas infrastructure is not resilient

- **Assertion:** Gas-driven generation is often claimed to be resilient.
- **Reality:** Gas infrastructure is not resilient and takes much longer to restore than electricity infrastructure.
- **Threats:** Gas infrastructure can be flat-out dangerous and is highly vulnerable to earthquakes, fires, landslides, and terrorism.

![2010 San Bruno Pipeline Explosion](image)

**Service Restoration Timeframes (M7.9 Earthquake)**

- Gas: 60% restoration takes 30 times longer than electricity.
- Electricity: 60% of customers restored in 3 days.

Source: The City and County of San Francisco Lifelines Study
Value-of-resilience (VOR) depends on tier of load

- Everyone understands there is significant value to resilience provided by indefinite renewables-driven backup power, especially for the most critical loads
  - But, nobody has quantified this value of unparalleled resilience.
  - Hence, there is a substantial economic gap for renewables-driven microgrids.
- The Clean Coalition aims to establish a standardized value-of-resilience (VOR) for critical, priority, and discretionary loads that will help everyone understand that premiums are appropriate for indefinite renewables-driven backup power to critical loads and almost constant backup power to priority loads, which yields a configuration that delivers backup power to all loads a lot of the time.
- The Clean Coalition’s VOR approach aims to standardize resilience values for three tiers of loads:
  - Tier 1 are mission-critical & life-sustaining loads and warrant 100% resilience. Tier 1 loads usually represent about 10% of the total load.
  - Tier 2 are priority loads that should be maintained as long as doing so does not threaten the ability to maintain Tier 1 loads. Tier 2 loads usually represent about 15% of the total load.
  - Tier 3 are discretionary loads make up the remaining loads, usually about 75% of the total load. Maintained when doing so does not threaten Tier 1 & 2 resilience.
Typical load tier resilience from a Solar Microgrid

Percentage of time online for Tier 1, 2, and 3 loads for a Solar Microgrid designed for the University of California Santa Barbara (UCSB) with enough solar to achieve net zero and enough energy storage capacity to hold 2 hours of the nameplate solar (200 kWh energy storage per 100 kW solar).

- **Tier 1** = Critical, life-sustaining load, ~10% of total load
- **Tier 2** = Priority load, ~15% of total load
- **Tier 3** = Discretionary load, ~75% of total load
A typical diesel generator is configured to maintain 25% of the normal load for two days. If diesel fuel cannot be resupplied within two days, goodbye. This is hardly a solution for increasingly necessary long-term resilience. In California, Solar Microgrids provide a vastly superior trifecta of economic, environmental, and resilience benefits.
VOR123 methodology yields a 25% typical adder

There are different VOR multipliers for each of the three load tiers. The following valuation ranges are typical for most sites:

- **Tier 1**: 100% resilience is worth 3 times the average price paid for electricity. In other words, indefinite energy resilience for critical loads is worth 3 times the average price paid for electricity. Given that the typical facility has a Tier 1 load that is about 10% of the total load, applying the 3x VOR Tier 1 multiplier warrants a 20% adder to the electricity bill.

- **Tier 2**: 80% resilience is worth 1.5 times the normal price paid for electricity. In other words, energy resilience that is provisioned at least 80% of the time for priority loads is worth 1.5 times the average price paid for electricity. Given that the typical facility has a Tier 2 load that is about 15% of the total load, applying the 1.5x VOR Tier 2 multiplier warrants a 7.5% adder to the electricity bill.

- **Tier 3**: Although a standard-size Solar Microgrid can provide backup power to Tier 3 loads a substantial percentage of the time, Tier 3 loads are by definition discretionary, and therefore, a Tier 3 VOR multiplier is negligible and assumed to be zero.

Taken together, the Tier 1 and Tier 2 premiums for a standard load tiering situation yields an effective VOR of between 25% and 30%. Hence, the *Clean Coalition uses 25% as the typical VOR123 adder that a site should be willing to pay*, including for indefinite renewables-driven backup power to critical loads — along with renewables-driven backup for the rest of the loads for significant percentages of time.
Validating VOR123 – four confirming approaches

Importantly, the Clean Coalition has resolved on the general 25% premium figure after conducting numerous analytical approaches, including the following three primary methodologies:

1. **Cost-of-service (COS):** This is the cost that suppliers will charge in order to offer the Solar Microgrid VOR across the Tier 1, 2, and 3 loads (VOR123). As evidenced by a case study of the Santa Barbara Unified School District (SBUSD), a COS that reflects a 25% resilience adder is sufficient to attract economically viable Solar Microgrids at the larger school sites.

2. **Department of Energy (DOE) Multiplier:** The DOE researched VOR and determined that the overall value of critical load that is missed due to grid outages over an annual period is $117/kWh. While the Clean Coalition stages Solar Microgrids to provide indefinite solar-driven backup power to critical loads, and considers 30 consecutive days to be a proxy for indefinite, the Clean Coalition assumed a conservative annual cumulative outage time of 3 days for the DOE Multiplier VOR analysis. The SBUSD case study yielded an overall 30% VOR adder to the 2019 electricity spend, as indicated in the table below.

### DOE Multiplier results for SBUSD prototype schools

<table>
<thead>
<tr>
<th>Prototypical School</th>
<th>Average Tier 1 Load (kW)</th>
<th>Tier 1 kWh/year missed (72 hours/year)</th>
<th>VOR ($117/kWh)</th>
<th>Total 2019 electricity spend</th>
<th>DOE-derived VOR % of 2019 spend</th>
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<tr>
<td>Franklin ES</td>
<td>4.7</td>
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<td>$39,256</td>
<td>$70,000</td>
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<td>La Cumbre JHS</td>
<td>2.8</td>
<td>202</td>
<td>$23,587</td>
<td>$78,000</td>
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<tr>
<td>San Marcos HS</td>
<td>4.4</td>
<td>314</td>
<td>$36,729</td>
<td>$188,000</td>
<td>20%</td>
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<tr>
<td><strong>Totals</strong></td>
<td><strong>11.8</strong></td>
<td><strong>851</strong></td>
<td><strong>$99,572</strong></td>
<td><strong>$336,000</strong></td>
<td><strong>30%</strong></td>
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3. **Market-Based**: This is essentially the market price, where supply meets demand, and the Direct Relief Solar Microgrid provides a local case study. Direct Relief has deployed a 320 kW PV and 676 kWh BESS Solar Microgrid, and while the PV is purchased via a roughly breakeven PPA, the BESS is leased at an annual cost of $37,500. While the size of the Direct Relief BESS (676 kWh) is a bit smaller than the size of the San Marcos Solar Microgrid BESS (710 kWh), Direct Relief is paying a bit more ($37,500/year) than the DOE Multiplier would value the San Marcos BESS ($36,729/year, as shown in Table 2-2).
4. **Avoided Diesel Generator Cost**: This approach is analogous to the previous cost-of-service (COS) approach, except it calculates the adder needed for a diesel generator to fulfill the VOR123 level of resilience. For this calculation, we equate “indefinite backup” to 30 days, and assume such a grid outage occurs once per year, during which the loads need to be maintained according to the standard VOR123 profile. The result, for a diesel backup system sized for a 1 million kWh/year site in Santa Barbara, is a **21 % adder** to the electricity bill.

<table>
<thead>
<tr>
<th>Site Load Inputs</th>
<th>Diesel Genset Size Check</th>
<th>Diesel Tank Capacity Check</th>
<th>Financials</th>
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<tbody>
<tr>
<td>Total Site Annual Load (kWh)</td>
<td>Diesel genset size (kW)</td>
<td>Diesel genset tank capacity (gallons)</td>
<td>Diesel Genset Depreciation Life (years)</td>
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<td>200</td>
<td>3,000</td>
<td>15</td>
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<td>Outage Duration (days)</td>
<td>Peak load (kW)</td>
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<td>Diesel Genset Capex</td>
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<tr>
<td>30</td>
<td>171</td>
<td></td>
<td>$350,000</td>
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<td>Number of outages/year</td>
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<td>Diesel Genset Opex ($/year)</td>
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<td>$14,694</td>
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<td>Diesel Genset Depreciated Capex ($/year)</td>
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<tr>
<td>Average Site Power (kW)</td>
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<td>Diesel Genset Total Yearly Cost</td>
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<td>Yearly cost of utility-purchased electricity</td>
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<td>Cost of Diesel Genset backup energy ($/kWh)</td>
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<td><strong>VOR123 Parameters</strong></td>
<td><strong>% adder of Diesel backup cost on top of</strong></td>
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<td>Tier 1 % of time</td>
<td>utility-purchased electricity**</td>
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<tr>
<td>100%</td>
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<td>Tier 2 % of time</td>
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</tr>
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<td>80%</td>
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<td></td>
<td></td>
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<tr>
<td>Tier 3 % of time</td>
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</tr>
<tr>
<td>30%</td>
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<tr>
<td>Tier 1 % of load</td>
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</tr>
<tr>
<td>10%</td>
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<td>Tier 2 % of load</td>
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<tr>
<td>15%</td>
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<tr>
<td>Tier 3 % of load</td>
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</tr>
<tr>
<td>75%</td>
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<td>TCLR (kWh)</td>
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<td>36,575</td>
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<table>
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<tr>
<td>Diesel Genset Depreciated Capex ($/year)</td>
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<tr>
<td>Diesel Genset Total Yearly Cost</td>
</tr>
<tr>
<td>Cost of Diesel Genset backup energy ($/kWh)</td>
</tr>
<tr>
<td>% adder of Diesel backup cost on top of utility-purchased electricity</td>
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## Diesel generator cost analysis

### Input Variables

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<table>
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<tbody>
<tr>
<td>Diesel Genset Size</td>
<td>kW</td>
</tr>
<tr>
<td>Diesel Tank Capacity</td>
<td>Gallons</td>
</tr>
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### Capex Costs

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<tr>
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<th>$/kW</th>
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<tr>
<td>Genset equipment cost</td>
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<tr>
<td>Genset &quot;Balance of Plant&quot;</td>
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<tr>
<td><strong>Variable Capex Subtotal</strong></td>
<td>$520</td>
<td></td>
</tr>
<tr>
<td>Structural design</td>
<td>$20,000</td>
<td></td>
</tr>
<tr>
<td>Installation</td>
<td>$25,000</td>
<td></td>
</tr>
<tr>
<td><strong>Fixed Capex Subtotal</strong></td>
<td>$45,000</td>
<td></td>
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<tr>
<td>Fuel tank cost</td>
<td>$/gal</td>
<td>$61</td>
</tr>
<tr>
<td>Fuel tank installation</td>
<td>$/gal</td>
<td>$6</td>
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<tr>
<td><strong>Fuel Tank Variable Subtotal</strong></td>
<td>$/gal</td>
<td>$67</td>
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### Opex Costs

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<tr>
<td>Fuel</td>
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<tr>
<td>Fuel cost</td>
<td>$/gal</td>
</tr>
<tr>
<td>Number of tanks burned per year</td>
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<tr>
<td>Maintenance</td>
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<td>Annual contract</td>
<td>$/year</td>
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<td>Annual parts</td>
<td>$/year</td>
</tr>
<tr>
<td>Monthly run time</td>
<td>Hours/month</td>
</tr>
<tr>
<td>Annual staff hours</td>
<td>Hours/year</td>
</tr>
<tr>
<td>Labor cost/hr</td>
<td>$/Hour</td>
</tr>
<tr>
<td>Labor cost</td>
<td>$/year</td>
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<tr>
<td><strong>Annual Maintenance Subtotal</strong></td>
<td>$/year</td>
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### Totals for given Genset Size

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>Total Genset CapEx</td>
<td>$</td>
</tr>
<tr>
<td>Total Genset OpEx</td>
<td>$/year</td>
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</table>
Diesel generator efficiency data

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<tr>
<th>Generator Size (kW)</th>
<th>1/4 Load (gal/hr)</th>
<th>1/2 Load (gal/hr)</th>
<th>3/4 Load (gal/hr)</th>
<th>Full Load (gal/hr)</th>
<th>1/4 load</th>
<th>1/2 load</th>
<th>3/4 load</th>
<th>full load</th>
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<td>20</td>
<td>0.6</td>
<td>0.9</td>
<td>1.3</td>
<td>1.6</td>
<td>0.120</td>
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<td>0.080</td>
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<td>9.1</td>
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<td>0.080</td>
<td>0.076</td>
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<td>0.072</td>
<td>0.069</td>
<td>0.071</td>
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</table>

Average over generator size (Gallons/kWh) | 0.101 | 0.081 | 0.076 | 0.075

Average over load (Gallons/kWh) | 0.083
Key VOR123 concepts
Although there are multiple potential Load Management configurations, the minimal functionality anticipated to be cost-effectively implemented is referred to as the Critical Load Panel (CLP) approach.

The CLP name reflects the requirement for a smart critical load panel that maintains Tier 1 loads indefinitely and toggles Tier 2 loads. In the CLP approach, Tier 3 loads will be toggled as a group by toggling power to the Main Service Board (MSB). Figure 9 illustrates the CLP approach for SMHS, with Tier 1 and Tier 2 loads being served by new dedicated wire runs that connect to a new smart critical load panel.
Batteries optimized for economics & resilience

Top owner reserve is often in place to absorb battery energy storage system (BESS) degradation over time, while still delivering the contracted daily cycling energy capacity.

SOCr = the minimum state-of-charge (SOC) that is reserved for provisioning resilience. The SOCr can be dynamic and/or resized to between 0% and 100% of the contracted BESS energy capacity. A lower SOCr facilitates BESS operations that optimize daily economic performance, while a higher SOCr facilitates the provisioning of greater resilience.

Bottom owner reserve is often required to meet BESS warranty requirements that are imposed by BESS vendors.

Contracted BESS energy capacity (kWh) that must be available for daily cycling over the contract duration for achieving specified economic & resilience performance.
SOCr dynamically minimized to maximize economics

5-day SOCr plot beginning Sat 12-Jan for San Marcos HS
Goleta Load Pocket (GLP) Community Microgrid case study
Goleta Load Pocket (GLP) and attaining resilience

The GLP is the perfect opportunity for a comprehensive Community Microgrid

• GLP spans 70 miles of California coastline, from Point Conception to Lake Casitas, encompassing the cities of Goleta, Santa Barbara (including Montecito), and Carpinteria.

• GLP is highly transmission-vulnerable and disaster-prone (fire, landslide, earthquake).

• **200 megawatts (MW) of solar and 400 megawatt-hours (MWh) of energy storage** will provide 100% protection to GLP against a complete transmission outage (“N-2 event”).
  - 200 MW of solar is equivalent to about 5 times the amount of solar currently deployed in the GLP and represents about 25% of the energy mix.
  - Multi-GWs of solar siting opportunity exists on commercial-scale built environments like parking lots, parking structures, and rooftops; and 200 MW represents about 7% of the technical siting potential.
  - Other resources like energy efficiency, demand response, and offshore wind can significantly reduce solar+storage requirements.
Goleta Substation serves eight 66kV feeders that in turn serve the entire GLP.
Target 66kV feeder at the core of the GLP

Legend
- 220 kV Transmission
- 66 kV Feeder #4311
- Substations
- 16kV Gladiola Feeder
- 16kV Gaucho Feeder
- 16kV Professor Feeder
- Tier 3 Fire Threat
- Tier 2 Fire Threat
- University of California Santa Barbara (UCSB)
- Santa Barbara Airport
- Sanitary or Water Districts
Target 66kV feeder serves critical GLP loads

Legend
- 220 kV Transmission
- 66 kV Feeder #4311
- Substations
- 16kV Gladiola Feeder
- 16kV Gaucho Feeder
- 16kV Professor Feeder
- University of California Santa Barbara
- Tier 3 Fire Threat
- Goleta Valley Cottage Hospital
- Fire Stations
- Direct Relief
- Deckers
- Sanitary or Water Districts
- Proposed 160-240 MWh Battery

Proposed 160-240 MWh Battery
Direct Relief
Vegas Substation
Isla Vista Substation
Fire Station # 17
SB Airport
Fire Station # 8
Goleta Sanitary District
Target 66kV feeder grid area block diagram

Goleta Substation (220-to-66kV)

Goleta Substation has eight feeders, all 66kV, that serve the entire GLP

Isla Vista Substation (66-to-16kV)

66kV distribution feeder #4311 with multiple branches

Tier 2 & 3 facilities

160+ MWh battery

Diagram Elements
- 66 kV Distribution Feeder #4311
- 16 kV Gladiola Feeder
- 16 kV Gaucho Feeder
- 16 kV Professor Feeder

Planned 160-240 MWh Battery

Grid isolation switch (open, closed)

Smart meter switch (open, closed)

66kV underground interconnection

Direct Relief + Solar Microgrid

SBA (runway lights & ATC)

SBA (Main Terminal)

Goleta Sanitary District

UCSB + Solar

Deckers + Solar Microgrid

Fire Station #8

Fire Station #17

Vegas Substation (66-to-16kV)

Tier 2 & 3 facilities

Deckers + Solar Microgrid

SBA (runway lights & ATC)

SBA (Main Terminal)

Goleta Sanitary District
Santa Barbara Unified School District (SBUSD) case study
The entire Santa Barbara region is surrounded by extreme fire risk (earthquake & landslide risk too) and is extremely vulnerable to electricity grid outages. The SBUSD is a major school district that increasingly recognizes the value-of-resilience (VOR) and has embraced the Clean Coalition’s vision to implement Solar Microgrids at a number of its key schools and other critical facilities. SMHS is in the middle of the extensive SBUSD service area.
Six SBUSD Solar Microgrid sites

- Dos Pueblos High School
- San Marcos High School
- La Cumbre Junior High School
- District Food Warehouse & District Office
- Santa Barbara High School
Guaranteed SBUSD bill savings and free VOR

Lifetime (28-year) Bill Savings and Added Value of Resiliency

- Expected Financial Savings (Nominal $): $7.78 million
- Added Value of Resiliency (Nominal $): $6.47 million
- Future Value Streams

Making Clean Local Energy Accessible Now
San Marcos High School (SMHS) case study
SMHS is vulnerable to distribution outages too
San Marcos High School (SMHS)

- SMHS is a large public high school serving 2,000+ students in grades 9 through 12.
- Red Cross designated facility.
- School features include:
  - Array of classroom buildings
  - Large pool
  - Gymnasium
  - Football stadium
  - Multiple baseball fields
  - Cafeteria
  - Outdoor Greek theater
  - Auditorium
  - Numerous tennis & basketball courts
- Craig Lewis in the Class of 1981.
The SMHS Solar Microgrid is intended to enable the school to operate independently during grid outages of any duration with **indefinite resilience for the most critical loads** and **resilience for all loads for significant percentages of time**.

- **Solar**
  - 725 kWp
  - Solar is entirely in the form of solar parking canopies
  - Net Zero Energy (NZE) is exceeded at 101%

- **Battery Energy Storage System (BESS)**
  - 700 kWh energy capacity
  - 350 kW power capacity

- **Critical (Tier 1) loads**
  - Food service refrigerators & freezers, maintained indefinitely
  - 4.36 kW of average load
  - 3.44% of total average load

- **Priority (Tier 2) loads**
  - Gym lights and Main Distribution Frame, maintained at least 80% of the time
  - 4.32 kW of average load
  - 3.41% of total average load
### SBUSD 2019 electricity costs & breakeven values

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<th>Site Name</th>
<th>2019 Cost &amp; Values (¢/kWh)</th>
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<td>La Colina JHS</td>
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### SBUSD 2020 costs & PPA estimates

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**Notes**

- Analyses estimated Power Purchase Agreement (PPA) pricing for three Load Management configurations, assuming 25-year PPAs starting in 2020 with 3% SCE electricity cost escalators.
- Solar Microgrid PPA prices in green are less than breakeven values, including 25% VOR123 adder.
- SCE raised its electricity costs by about 7% in 2019 and is proposing similar increases in each of the next three years.