Resilient Renewable Energy Microgrids

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Overview

Why consider RE-battery-diesel hybrid microgrids for backup power?

Estimating economic savings

Quantifying the resiliency gain

Where will this work?
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Power Outages are Increasing

The United States has seen an increase in the number of high-impact, high-cost natural disasters—seven of the ten costliest storms in U.S. history have occurred in the last ten years.
Existing Backup Power Is Insufficient In Some Cases

On-site diesel fuel supplies typically only last 1-2 days

Regulatory requirements may limit on-site fuel storage

Diesel fuel re-supply is vulnerable

Disasters may damage fuel supply chain or fuel may be diverted to higher priority needs

Source: NREL Pix 24490
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Solar and Storage Costs are Falling

**Solar**

![Solar Cost Curve](image1.png)

Source: Lawrence Berkeley National Laboratory

**Storage**

![Storage Cost Curve](image2.png)

Source: Nature Energy
The Cable Industry is Striving to Lower Energy Consumption, Cut Energy Costs, and Reduce Dependence on the Grid

SCTE Energy 2020 Goals

- Reduce energy intensity by 15% year on year
- Reduce energy costs by 25% on a unit basis
- Reduce grid dependency by 10%
- Optimize technical facilities and datacenters footprint by 20%
Diesel generators alone provide resiliency. RE/storage/diesel hybrid microgrids provide resiliency + energy savings + cost savings.

Why consider RE microgrids?

The triple bottom line.
Case Study: Southern California Telecommunications Facility

Multi-use facility includes administrative offices, warehouse, production studio, technology center, customer service center, and hub site delivering cable services to surrounding community:

- Average load 150 kW, ranging from 120-250 kW; critical load 155 kW
- Annual energy use: 1400 MWh
- Annual energy cost: $250,000
- 300 kW of backup diesel generation

### Utility Rate Tariff

<table>
<thead>
<tr>
<th></th>
<th>Energy Charge ($/kWh)</th>
<th>Demand Charge ($/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed monthly charge</strong></td>
<td>$453.25/meter</td>
<td></td>
</tr>
<tr>
<td><strong>Facility demand charge</strong></td>
<td>$19.38/kW</td>
<td></td>
</tr>
<tr>
<td><strong>June-September</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noon-6 p.m., weekdays</td>
<td>0.15856</td>
<td>15.51</td>
</tr>
<tr>
<td>8 a.m.-noon, 6 p.m.-11 p.m., weekdays</td>
<td>0.12541</td>
<td>3.05</td>
</tr>
<tr>
<td>All other hours</td>
<td>0.10878</td>
<td>0</td>
</tr>
<tr>
<td><strong>October-May</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 a.m.-9 p.m., weekdays</td>
<td>0.12156</td>
<td>0</td>
</tr>
<tr>
<td>All other hours</td>
<td>0.1131</td>
<td>0</td>
</tr>
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</table>
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Modeling

**Resources**

- **Renewable Generation**
  - Solar PV
  - Wind
  - Biomass, etc.

- **Conventional Generation**
  - Electric Grid
  - Fuel Supply
  - Conventional Generators

- **Energy Storage**
  - Batteries
  - Thermal storage
  - Water tanks

- **Dispatchable Technologies**
  - Heating and Cooling
  - Water Treatment

- **Energy Conservation Measures** (via Open Studio)

**Goals**

- Minimize Cost
- Net Zero
- Resiliency

**Economics**

- Financial Parameters
- Technology Costs
- Incentives

**Utility Costs**

- Energy Charges
- Demand Charges
- Escalation Rate

**REopt**

*Energy Planning Platform*

*Techno-economic Optimization*

**Optimized Cost Solution**

- Technologies
  - Technology Mix
  - Technology Size

- Operations
  - Optimal Dispatch

- Project Economics
  - CapEx, OpEx
  - Net Present Value

**Technology Options**

- **Thermal Loads**
- **Electric Loads**
- **Water Demand**
# Assumptions

<table>
<thead>
<tr>
<th>Input</th>
<th>Assumption</th>
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<tbody>
<tr>
<td>Analysis period</td>
<td>25 years</td>
</tr>
<tr>
<td>Ownership model</td>
<td>Third-party owned</td>
</tr>
<tr>
<td>Site discount rate</td>
<td>7%</td>
</tr>
<tr>
<td>Developer discount rate</td>
<td>10%</td>
</tr>
<tr>
<td>Corporate tax rate</td>
<td>35%</td>
</tr>
<tr>
<td>General inflation rate</td>
<td>0.1% per National Institute of Standards and Technology (NIST)</td>
</tr>
<tr>
<td>Utility cost escalation rates</td>
<td>0.1% per NIST</td>
</tr>
<tr>
<td>Incentives</td>
<td>30% Federal ITC for PV and battery, 5-year MACRS depreciation, $0.36/kWh SGIP</td>
</tr>
<tr>
<td>Net metering limit</td>
<td>1 MW</td>
</tr>
<tr>
<td>PV capital cost</td>
<td>$2.13/kW</td>
</tr>
<tr>
<td>PV O&amp;M cost (includes 1 inverter replacement)</td>
<td>$0.02/W-year</td>
</tr>
<tr>
<td>Battery capital cost</td>
<td>$520/kWh plus $1000/kW</td>
</tr>
<tr>
<td>Battery replacement cost (year 10)</td>
<td>$200/kWh plus $200/kW</td>
</tr>
<tr>
<td>Solar resource</td>
<td>TMY2 solar data</td>
</tr>
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</table>
### Quantifying the Economic Benefit of Solar PV+Battery

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Solar PV Size</td>
<td>845 kW</td>
</tr>
<tr>
<td>Battery Size</td>
<td>155 kW, 172 kWh</td>
</tr>
<tr>
<td>Developer Cost</td>
<td>$2,450,000</td>
</tr>
<tr>
<td>Annual O&amp;M</td>
<td>$16,900 /yr</td>
</tr>
<tr>
<td>% Renewable Energy</td>
<td>91%</td>
</tr>
<tr>
<td>Year 1 Savings</td>
<td>$42,000</td>
</tr>
<tr>
<td>Net Present Value</td>
<td>$519,000</td>
</tr>
<tr>
<td>Lifecycle Savings</td>
<td>18%</td>
</tr>
</tbody>
</table>

$a.$ Includes PV, BESS, and site electrical work, BEFORE incentives are applied.

#### Demand Charge Savings

- **Peak**
- **Part Peak**
- **Off peak**
- **Facility Demand Charges**

<table>
<thead>
<tr>
<th>Month</th>
<th>Peak</th>
<th>Part Peak</th>
<th>Off peak</th>
<th>Facility Demand Charges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>$500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb</td>
<td>$1,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td>$1,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td>$2,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>$2,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td>$3,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul</td>
<td>$3,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>$4,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep</td>
<td>$4,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>$5,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>$5,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>$6,000</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
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Example Day

Peak demand without solar+battery

Peak demand with solar+battery

50 kW reduction in peak
Quantifying the Resiliency Benefit of Solar+Storage

Quantifying the Resiliency Benefit of RE+Storage

![Graph showing the probability of surviving an outage vs. the length of the outage. The graph compares Diesel Only to Solar+Storage. The x-axis represents the length of the outage in days, ranging from 1 to 6. The y-axis represents the probability of surviving the outage in percentage, ranging from 0% to 100%. The graph shows a significant decrease in the probability of surviving the outage as the length of the outage increases. The Diesel Only option has a much steeper decline compared to the Solar+Storage option.]
Quantifying the Resiliency Benefit of RE+Storage

![Graph showing the probability of surviving an outage for different lengths of outage with Diesel Only option highlighted.]

- Probabilty of Surviving Outage [%]
- Length of Outage [Days]

Diesel Only
Quantifying the Resiliency Benefit of RE+Storage

- Solar+Storage+Diesel
- Diesel Only

Probability of Surviving Outage [%]

Length of Outage [Days]

Quantifying the Resiliency Benefit of Solar+Storage
Quantifying the Resiliency Benefit of Solar+Storage

Quantifying the Resiliency Benefit of RE+Storage

1.8-Day Net Resiliency Gain
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How it Works

Solar PV allows generator to turn off during daytime hours, extending diesel fuel supply.

Battery provides backup during transition from diesel to solar and during cloudy times.

After diesel fuel is exhausted, PV+battery can support daytime loads indefinitely.
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The Cost of Resiliency

Grid-connected system saves $519,000 over project life, but provides 0 added resiliency.

The microgrid system saves only $104,000 over the project life ($415,000 less), but provides an extra 1.8 days resilience plus indefinite daytime power.

Is an extra 1.8 days resiliency worth $415,000?

<table>
<thead>
<tr>
<th>Description</th>
<th>Grid-Connected</th>
<th>Microgrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV+Battery Installed Cost (before incentives)</td>
<td>$2,451,000</td>
<td>$2,451,000</td>
</tr>
<tr>
<td>Added Microgrid Cost</td>
<td>$0</td>
<td>$415,000</td>
</tr>
<tr>
<td>Total Installed Cost</td>
<td>$2,451,000</td>
<td>$2,866,000</td>
</tr>
<tr>
<td>Net Present Value</td>
<td>$519,000</td>
<td>$104,000</td>
</tr>
<tr>
<td>Added Resiliency (days)</td>
<td>0</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Key Findings

At this site, integrating solar PV + battery with existing diesel generators provides $104,000 cost savings, 91% utility energy savings, and 1.8 days added resiliency.

After diesel fuel supplies are exhausted, the site could continue to operate critical loads indefinitely during daytime hours when solar resource is sufficient using just PV+battery.

Business interruption cost is not included in the economic analysis, but should be considered in the investment decision.
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Where Else Will this Work?

Utility rate tariff, incentives, technology costs, and solar resource drive solar PV + battery economic viability.

Sites with higher energy and demand rates (i.e California, New York, Hawaii)

Sites with good solar and storage incentives (i.e. California, New Jersey, Hawaii, Massachusetts)

Sites that place a high value on resiliency
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The analysis is based on projections, estimates or assumptions made on a best-effort basis, based upon expectations of current and future conditions at the time they were developed. The analysis was prepared with information available at the time the analysis was conducted. Analysis results could be different if new information becomes available and is incorporated. This analysis is a starting point for additional research and consideration of investment options. Other factors that can inform decision-making are not considered here. The analysis results are not intended to be the sole basis of investment, policy, or regulatory decisions.

This analysis was conducted using the NREL REopt Model (http://reopt.nrel.gov). REopt is a techno-economic decision support model that identifies the cost-optimal set of energy technologies and dispatch strategy to meet site energy requirements at minimum lifecycle cost, based on physical characteristics of the site and assumptions about energy technology costs and electricity and fuel prices.