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SOLUTIONS THAT WORK

Microgrids are Magic

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REBUILD Conference

Resilient Grid-Connected Microgrids

Resilient

- Able to supply power to serve critical loads when the grid is inactive
- Able to recover functionality quickly and independently from outages

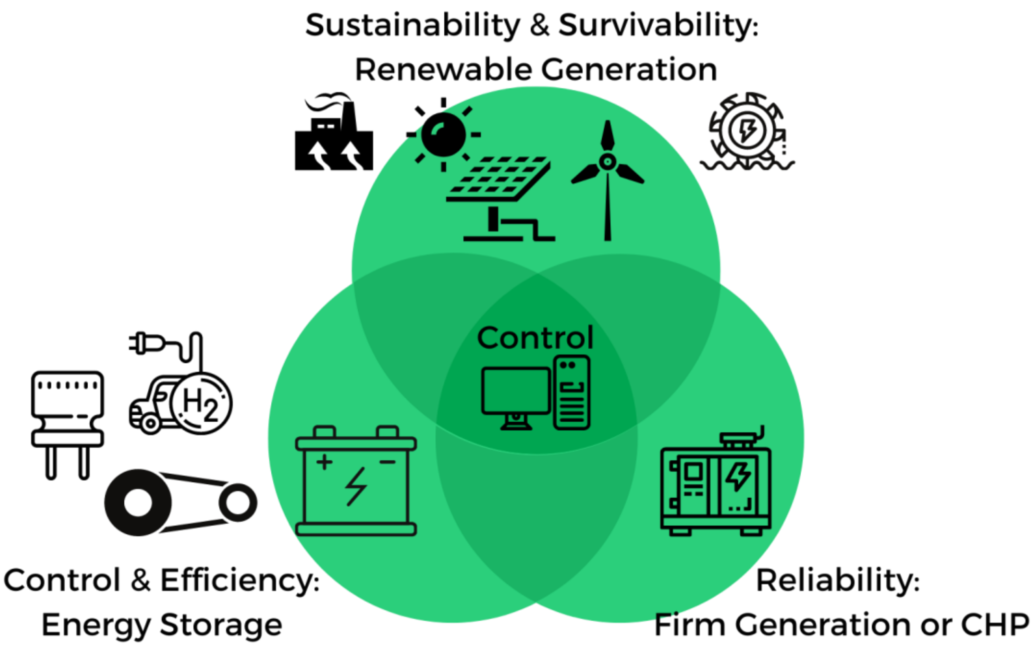
Grid-Connected

- Operates while the grid is active as an option to the grid
- Operational strategy determined by economics
- Economics driven by rate tariff, market participation opportunities, incentive programs

Microgrids

- A collection of energy generation and storage assets serving local loads
- Often contains renewable generation
- Non-dispatchable generation paired with storage
- Grid-forming capability

Microgrid Topology



BENEFITS

- Economic:
  - Provide utility savings during normal operation
  - Renewables can pay for themselves
- Resilience:
  - Extend survivability during outages at no net cost
  - Provide redundant sources of backup power to reduce risk
- Sustainability:
  - Meet sustainability / green energy goals with renewable / clean generation
- Equity:
  - Make local clean air, resilience, and revenues available to communities

How big should each element be?
How should the microgrid be operated to achieve these benefits?

2023 REBUILD CONFERENCE
THURSDAY, OCTOBER 12, 2023 | TQL STADIUM

The Likely Suspects: Solar + Storage

Solar PV

- Non-dispatchable:
  - The sun comes out → electrons flow → you save money
- Mature technology
- Siting:
  - Roof mount: penetrating attachment or ballasted
  - Ground mount
  - Carport / awning

Battery Energy Storage (BESS)

- A battery is a bucket

- Energy (kWh): Capacity of the bucket
- Power (kW): Fill/empty rate
- Must be commanded to work!
- Decisions:
  - How big of a bucket?
  - When to fill the bucket?
  - When to empty it?
- Energy we take out must be worth more than the energy we put in.

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The Likely Suspects: CHP

- Combined Heat and Power
  - Fuel-based engine that harnesses heat offtake for maximum efficiency
  - Natural gas, propane, or bio-fuels
  - Reciprocating engine or gas turbine
- Works in symbiosis with solar+storage
- Appropriate for campuses
  - MIT – 21 MW
  - Miami University (Ohio) – 11.2 MW
  - Kent State – 12.3 MW
- Microturbines down to 65 kW

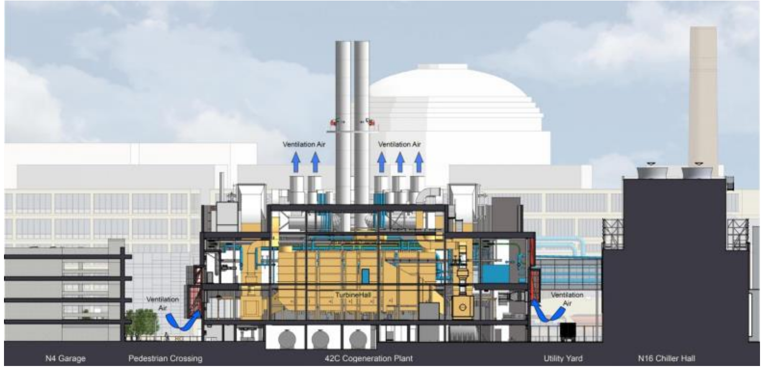


Image from Ellen Zweig

Microgrid Technologies

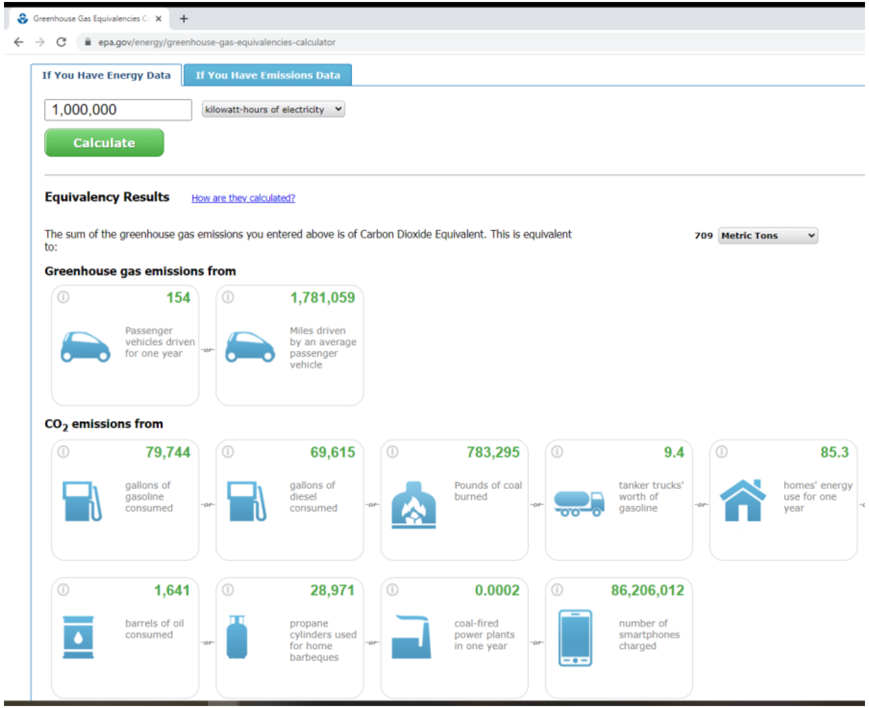
Loads	Renewable Generation	Energy Storage	Firm Generation	Control

• HVAC
• Refrigeration
• Lighting/plug loads
• Communications / IT
• EV charging
	• Electricity
	  • Solar PV
	  • Wind
	  • Geothermal
	  • Hydro
	• Heat
	  • Solar thermal
	  • Geothermal
		• Batteries
		  • Lithium Ion
		  • NiMH
		  • Lead Acid
		  • Flow
		  • Advanced Chemistries
		• Fuel Cells / Hydrogen
		• Supercapacitors
		• Mechanical
		  • Flywheels
		  • Gravity tower
		  • Pumped hydro
		• V2B / V2G (future)
			• Generators
			  • Diesel
			  • Natural Gas
			  • Alternative fuel / biofuel
			• Combined heat and power (CHP)
			• Biodigesters
				• Building Management System (BMS)
				• Energy Management System (EMS)
				• Islanding control
				• Economic dispatch control
				• Distributed Energy Resource Management System (DERMS)

Sustainability

Sustainability Performance

- Step 1: Understand where your power comes from and how “green” your local grid is
- For renewable generation GHG offset: use EPA Greenhouse Gas Equivalencies Calculator
  https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
- Natural gas or biomass CHP requires careful analysis
- Consider local air quality
- Consider the system boundaries
  - Industrial processes
  - Employee or client commute / transportation
  - Normal operations or islanded operations



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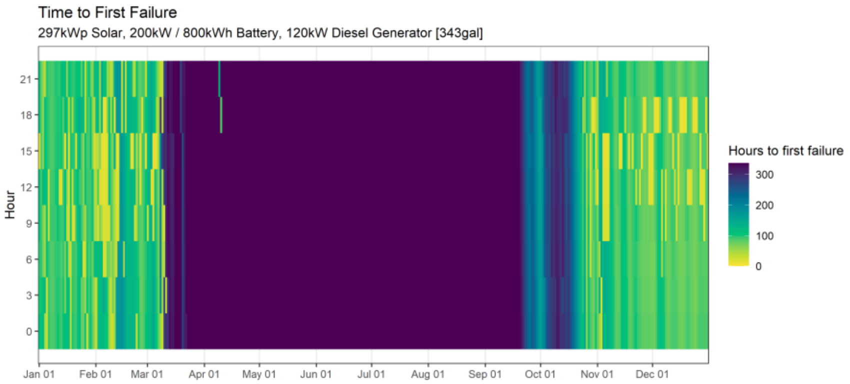
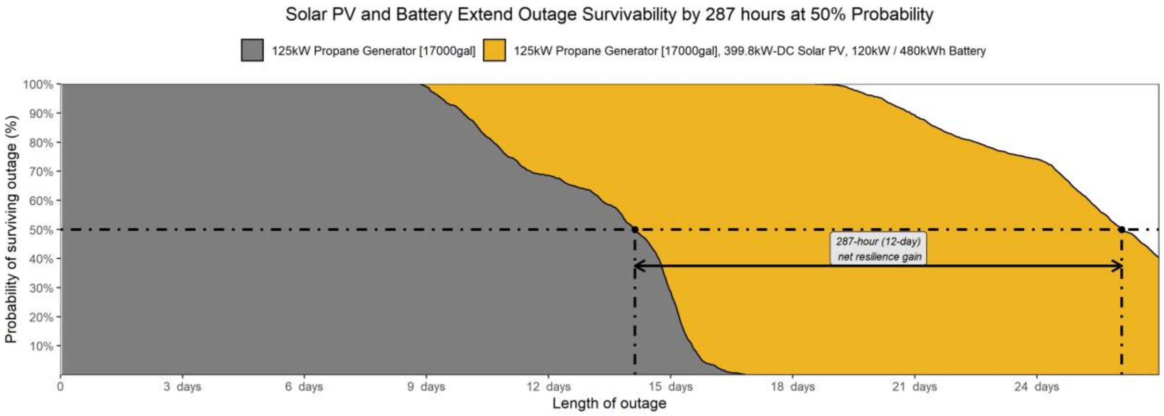
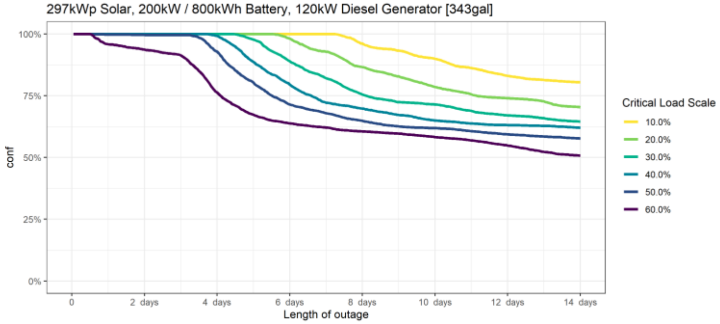
Resilience

Resilience Performance

- Resilience is stochastic
  - Outage time and duration is a random event
  - Conditions at the site (load / weather) also have a probabilistic variation
- Resilience measured by duration + confidence
- “Time to first failure” is the main metric
- Load shedding is a powerful tool





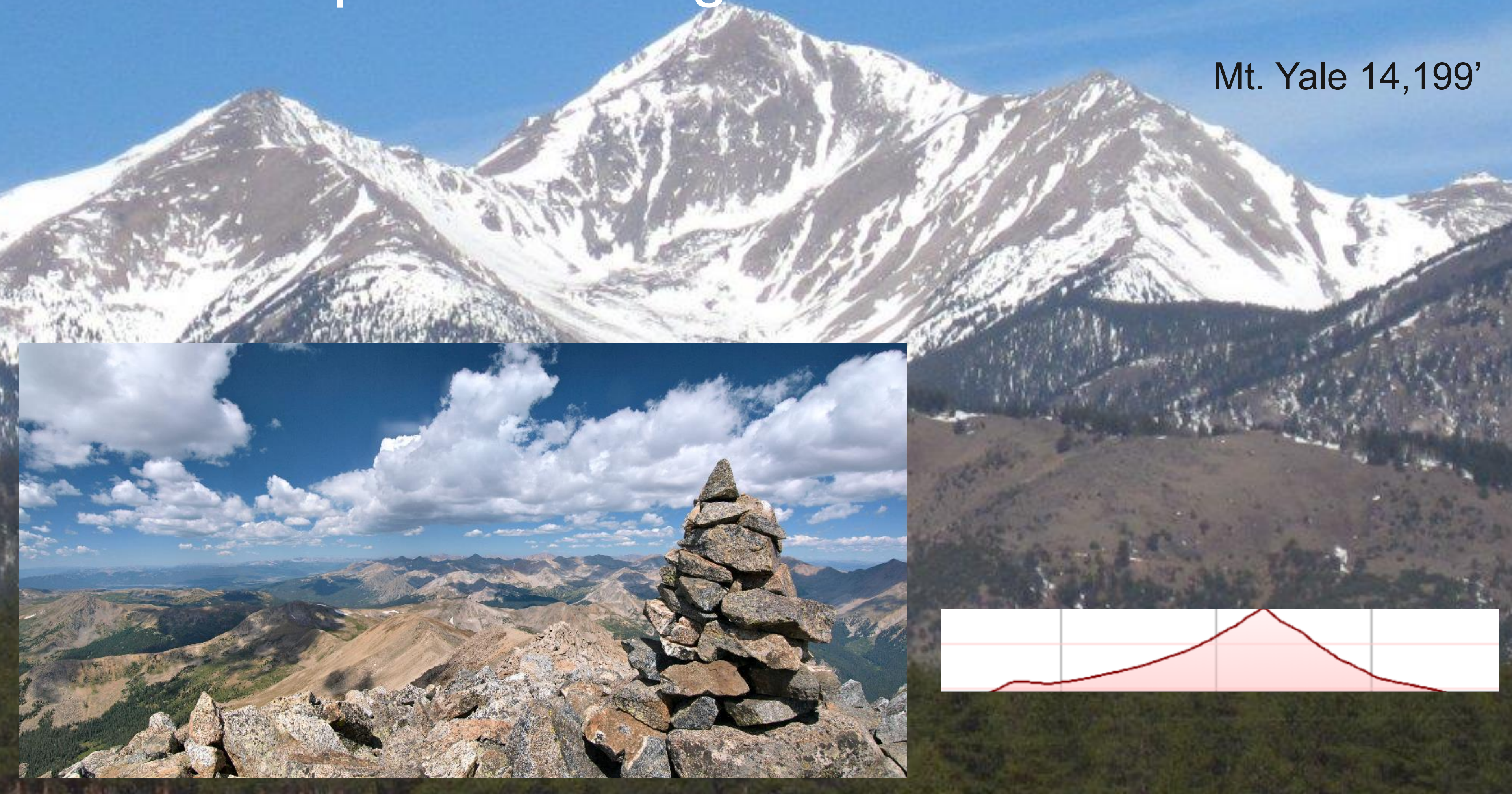


Economics

The Likely Suspects: Revenue Streams

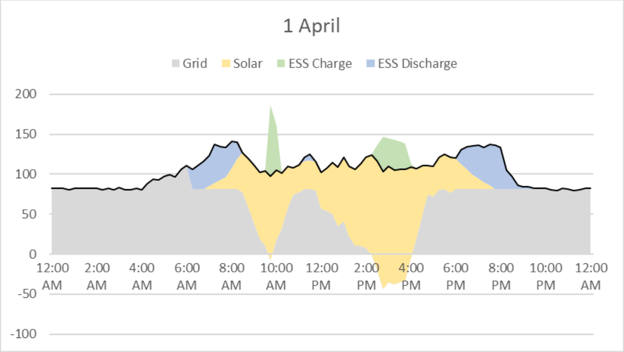
- **Load Management**
  - Manual
  - Programmable HVAC
  - Motion sensing
  - Building Management Systems (BMS)
- **Energy offset**
  - Solar or CHP generates kWh of energy
  - You don’t buy those kWh from the utility
- **Peak Shaving**
  - Demand charges: $/kW calculated on the peak power demand of the month
  - May be more complicated
  - How does peak shaving work?

How does peak shaving work?

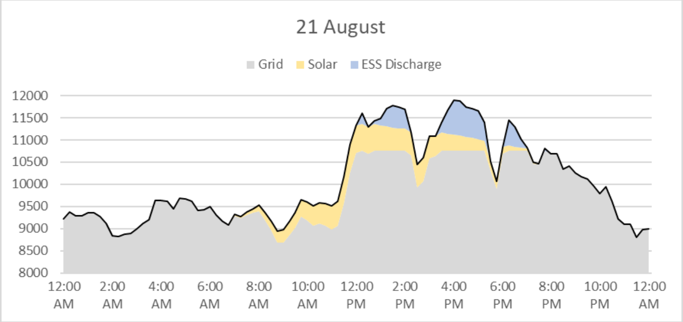


Peak Shaving Examples

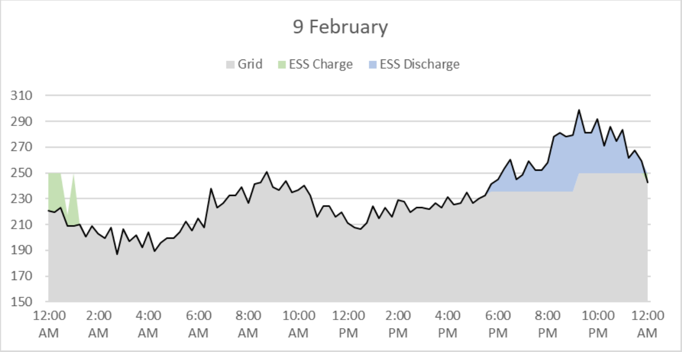
Community Center in the Pacific Northwest



Manufacturing Facility in the Midwest



Hotel in Southern California



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Economic Performance

Revenue Streams

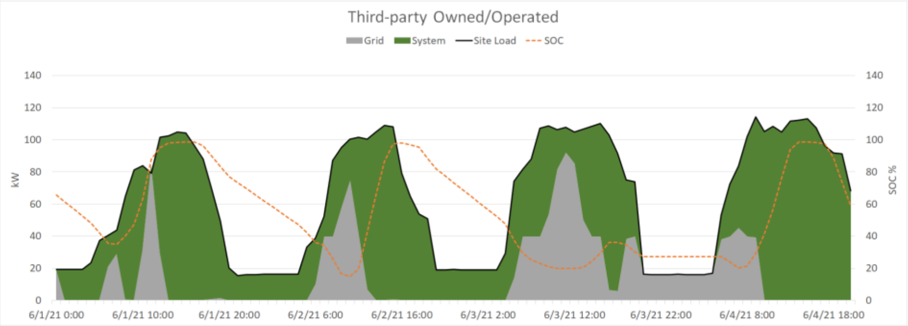
- Energy offset
- Energy arbitrage (time-shifting)
- Peak shaving
  (demand charge reduction)
- Coincident demand reduction
- Compensation programs that replace net-metering
  (e.g. MA SMART, NY Value Stack)
- Demand response
- Wholesale market participation (FERC 2222)
- Frequency regulation and other ancillary services

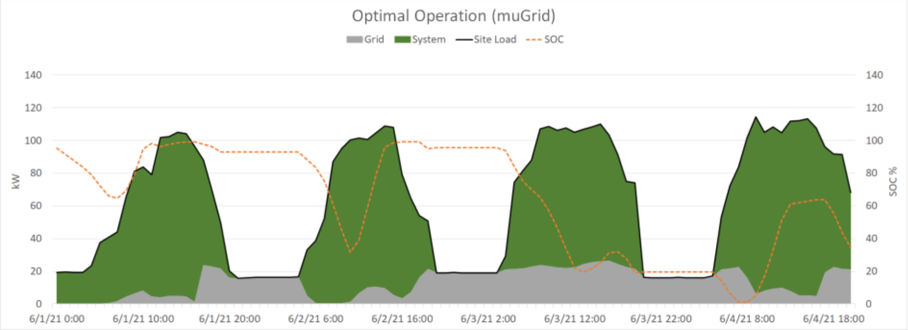
- Mathematical optimization based on historical data guides system design
  - Every time there was a decision to be made there was an optimal thing you could have done
- Operating strategy against multiple stacked revenue streams requires intelligent control
  - Simple rules-based control is insufficient
  - AI/Machine learning for prediction combined with mathematical optimization is the best approach
  - Intelligent control for microgrids is still nascent
- PJM-specific considerations
  - Capacity Payment program
  - Frequency regulation market – but not for behind-the-meter

Intelligent Dispatch Example

- Actual commercial site with operating resilient solar + battery storage
- Revenue streams are peak shaving and energy arbitrage
- Owner/operator using simple set-point control
- muGrid recommends optimized control to intelligently determine demand targets

	Utility Bill	Savings
No System	$5,250	$0
As Operated	$5,375	-$125
Intelligent Dispatch	$4,575	$675





Unintelligent control cost the site $800 this month, 17% more than they should have paid

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Financing Considerations

Financing Mechanisms

- Cash
- Debt Financing
- Third-party ownership / ESPC
  - Flip structure
  - Power purchase agreements (PPA): common for solar, trouble for energy storage
  - Energy savings agreements or microgrid-as-a-service more likely to align objectives for storage and microgrids

- Need tax appetite to be able to take most incentives
  - Investment Tax Credit (ITC)
  - Depreciation (MACRS)
  - State-level incentives as tax credits
- Batteries must be charged from solar to take ITC
- Non-taxable entities may consider third-party ownership structures to monetize tax benefits
- Grant funding (OPM)

Energy finance speaks the same language as real estate finance

Designing Microgrids

- Choose a priority: economics or resilience
    - Resilience and economics are often competing priorities
- Hire an expert
    - Microgrid interactions are complex and require modeling for design and operations
- Insist on intelligent dispatch control
- Contemplate load adjustments first
    - Energy efficiency or building automation
- Refine resilience requirements

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Thank you!

Please contact us anytime

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