NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Economic Optimization of Microgrids and Energy Storage

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NELHA Energy Storage Conference

September 12, 2016

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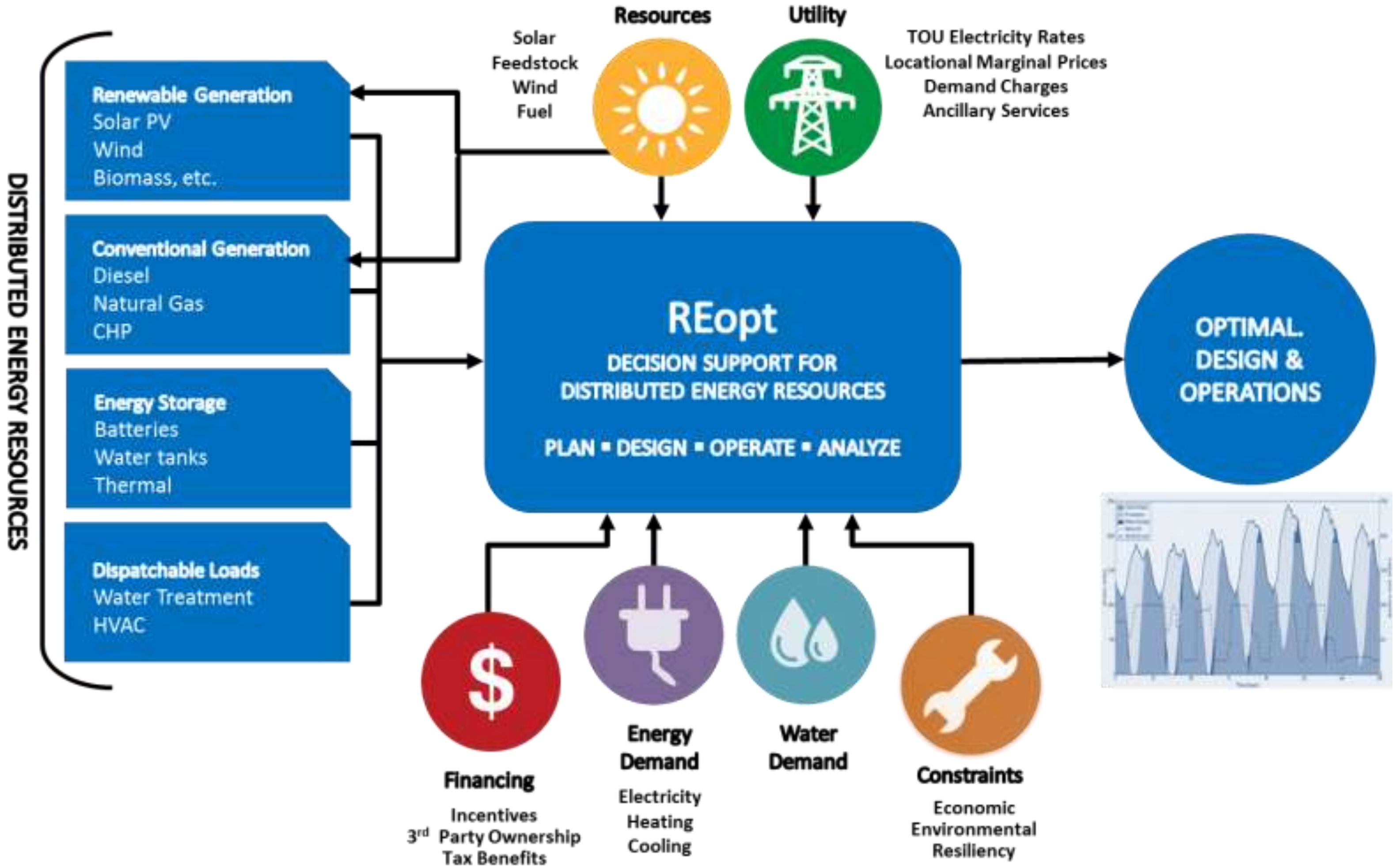
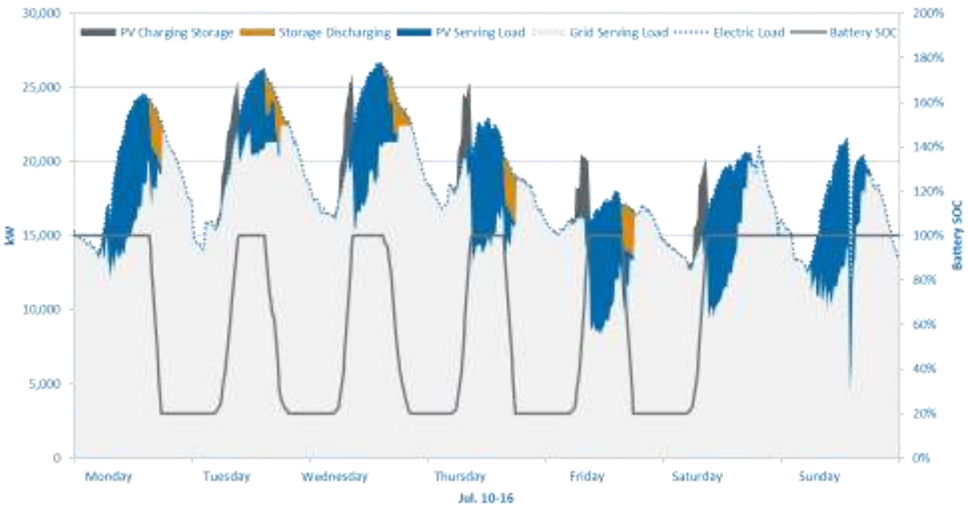
NREL’s REopt Microgrid Design Platform



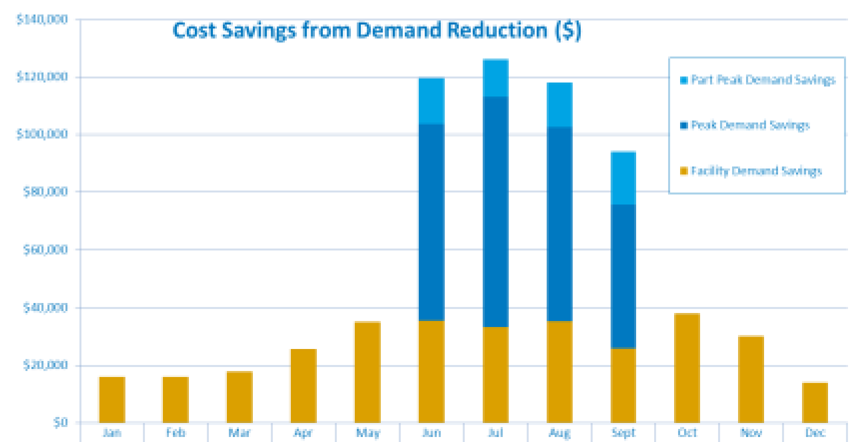
Plan: PV – BESS Sizing in Southern California

- Determine economically optimal PV + Battery system size
- Demand Reduction / Arbitrage
- Data
  - 15-minute electrical load
  - Southern California Edison (SCE) utility tariff (TOU-8)
- Result: Optimal PV + Battery size and resulting economic performance
- Battery is only economical when paired with PV at this site



Energy Charge			
Summer	on peak	12 pm - 6 pm	$0.09/kWh
Summer	mid peak	8 am - 12 pm; 6 pm - 11 pm	$0.06/kWh
Summer	off peak	11 pm - 8 am; weekends	$0.04/kWh
Winter	mid peak	8 am - 9 pm	$0.06/kWh
Winter	off peak	9 pm - 8 am; weekends	$0.04/kWh
Demand Charge			
Summer	on peak	12 pm - 6 pm	$14.60/kW
Summer	mid peak	8 am - 12 pm; 6 pm - 11 pm	$3.90/kW
Winter	all	any time	$0/kW
Facility Demand Charge[2]			$7.64/kW

Summer: June-September; Winter: October-May

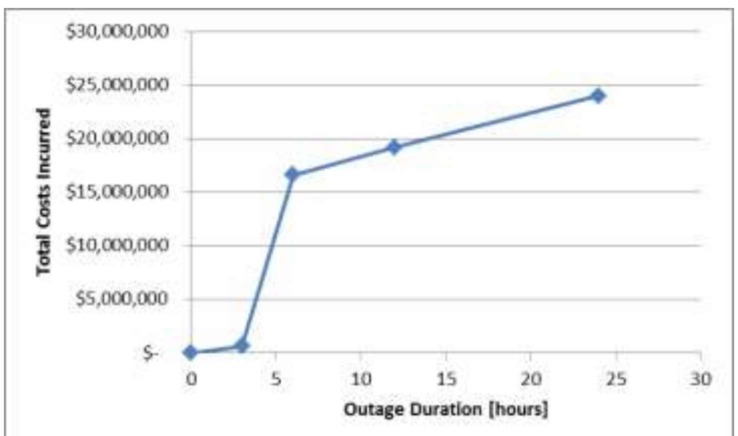


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Part Peak Demand Savings	$0	$0	$0	$0	$0	$15,992	$13,048	$15,382	$18,274	$0	$0	$0
Peak Demand Savings	$0	$0	$0	$0	$0	$68,045	$79,821	$67,414	$49,738	$0	$0	$0
Facility Demand Savings	$16,109	$16,107	$17,857	$25,724	$35,177	$35,607	$33,262	$35,277	$26,027	$37,966	$30,089	$14,160

Design: PV-BESS-Diesel Microgrid for NELHA

- Determine economically optimal sizes for hybrid microgrid
- Applications
  - Resiliency
  - Demand Charge Reduction
  - Energy Arbitrage

Energy Charge	$0.36 / kWh
Demand Charge	$10.25 / kW



Customer Damage Function

- Model chooses to incur losses or design system capable of sustaining outage
- Ran 480 outages of random start and random duration scenarios for two meters.
- Adding PV and battery to generators resulted in about $2.5 million of additional value over 25 years.

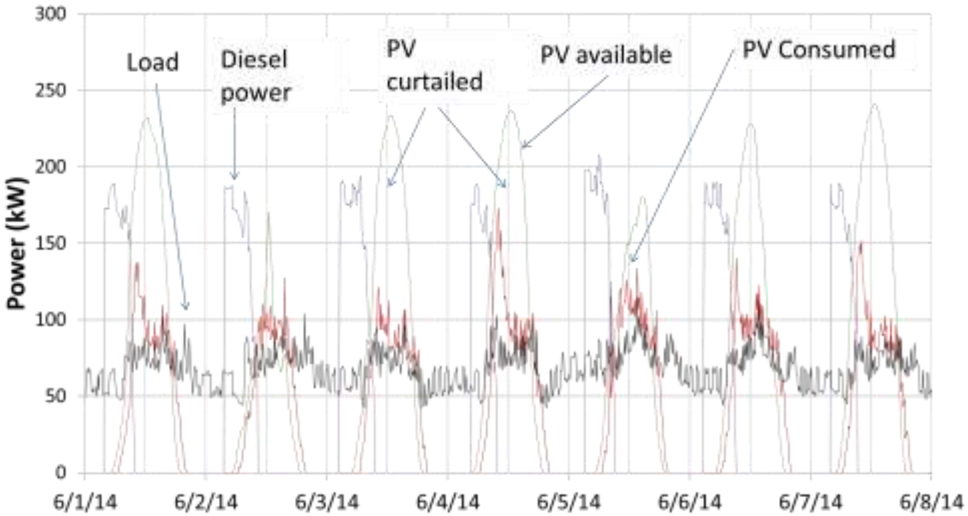
NELHA Results– 55 Pump Station

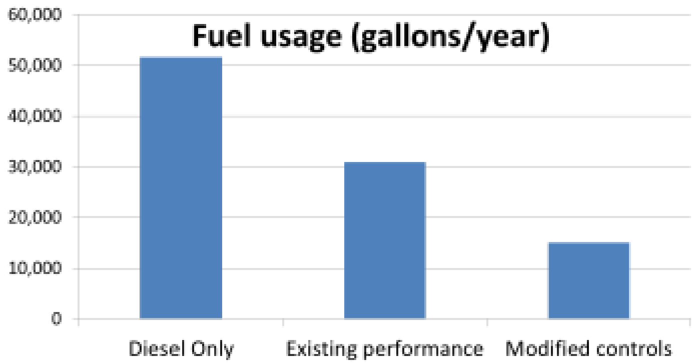
	Base Cases	Renewable Energy Cases	Value of RE
No Outages	**No outages, utility only** Life-cycle cost: $12,501,082	**RE installed without generator** PV: 646 kW, Battery: 134kWh/70 kW Life-cycle cost: $11,101,400	Net Present Value $1,399,682
Outages	**Utility, with generator to sustain outages** Generator: 391 kW Life-cycle cost: $12,730,100	**RE installed with generator** PV: 646 kW, Battery: 134 kWh/70 kW, Generator: 391 kW Life-cycle cost: $11,330,300	Net Present Value $1,399,800

- PV-BESS is economically viable in grid-connected operation
- Diesel only case, and Diesel-PV-BESS case can both meet 100% of simulated outages
- Diesel-PV-BESS case can presumably sustain longer outages than diesel-only case given a limited supply of diesel fuel onsite
- **Installing renewable energy with generators adds resiliency and value to the system**

Analyze: Alcatraz Island

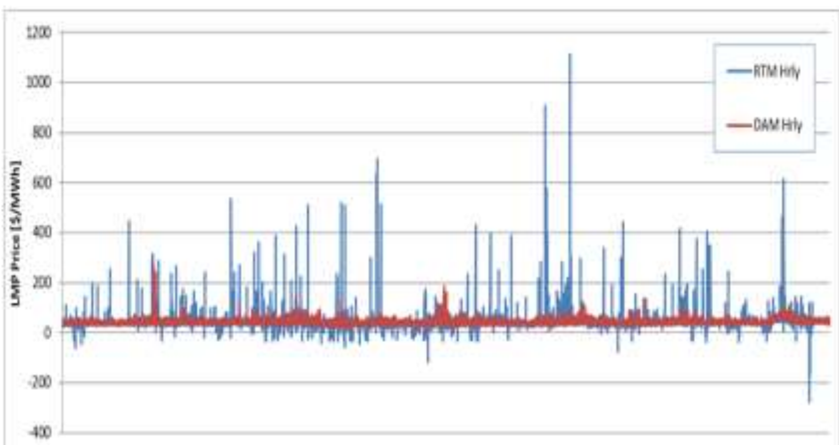
- PV-Battery-Diesel island microgrid installed 2012
  - Two 220 kW-DC diesel generators
  - 305 kW-DC solar PV
  - 1920 kWh lead acid batteries
- Optimized control strategy using REopt platform
  - “Cycle charging” results in curtailed PV, increased battery wear
  - Recommend “Load following”
- Revised control strategy saves 15,000 gallons of fuel annually
  - Cost savings of $115,000 / year (diesel fuel and battery wear)



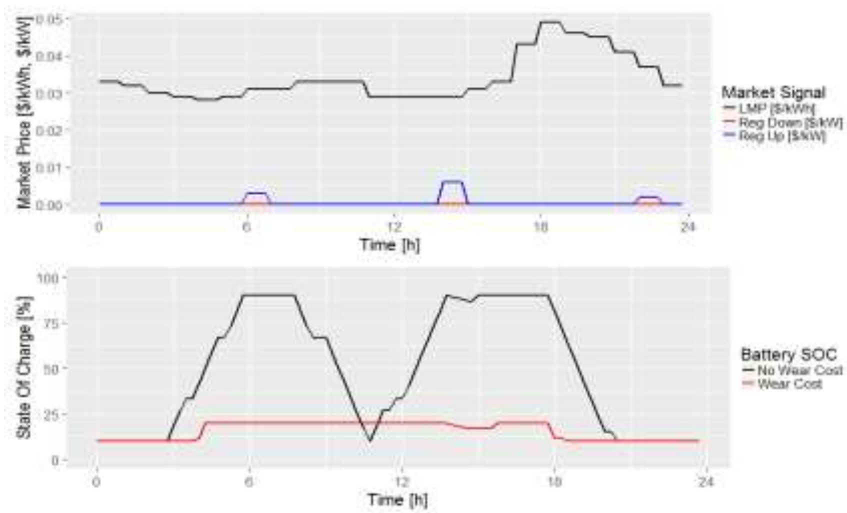


Operate: Utility Scale BESS in California

- Battery to be installed on feeder in California with high PV penetration
  - T&D Deferral
  - PV smoothing
  - LMP arbitrage
  - Frequency Regulation
- T&D deferral and PV smoothing given priority in optimization model
  - Determined optimal market participation strategy for arbitrage and AS
- Determined optimal participation in markets leads to $30-$80 / day net of degradation



Operation of the BESS for April 21st and 22nd(above). Relevant pricing data (below).



LMP and AS market pricing for a single day (above). Economically optimal BESS dispatch with and without battery degradation (below).

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