Microgrid Component Optimization for Resiliency Tool

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OUTLINE

- Microgrid Planning Process
- Context
- Challenges
- Description
- Example Results
- Use Cases
- Future Directions

MICROGRID PLANNING PROCESS

Determine Project Needs

- Critical loads
- Resiliency requirements

Assess Current Assets

- Existing equipment to be included in microgrid
- Available resources

Identify Restrictions

- Fuel storage
- Capital costs
- Space constraints
- Net-metering limits
- Resource mix

MCOR Tool

- Explore different system configurations that meet res. goals
- Determine resilience capabilities of existing systems

CONTEXT

- Army Directive 2017-07: Installation Energy and Water Security Policy
  - Tool development funded by the Army Reserve with additional support from OEI
  - Used to determine initial specs for 2 Army Reserve and 4 Army sites

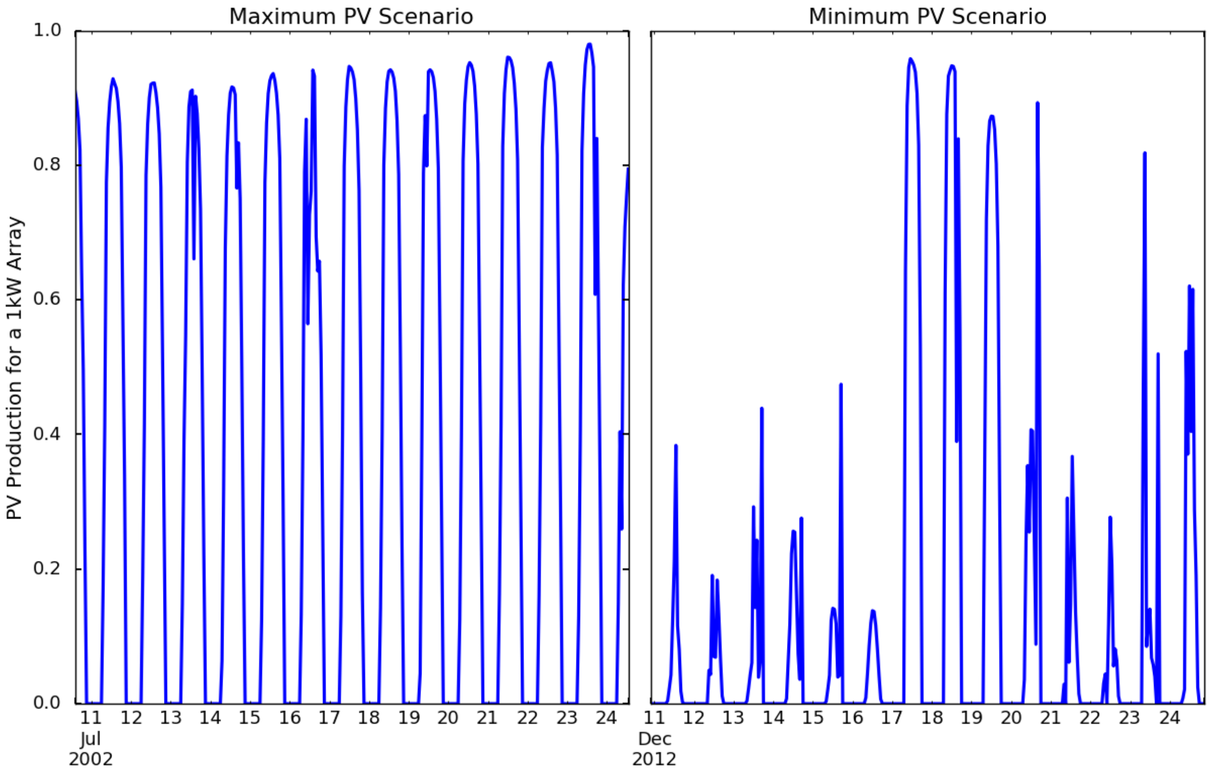
- Project Goals
  - Quickly size microgrid components (PV, batteries, generators) to meet resiliency goals
  - Quantify economic benefits of operating the microgrid year-round
  - Allow for integration and modeling of existing resources
  - Filter potential systems according to varying priorities (economics, fuel consumption, PV area limits)
  - Determine resiliency risk under varying conditions

CHALLENGES

- Existing tools non-optimal for project goals
  - Based on “typical” conditions
  - Design focused on economics
  - Dispatch strategies based on “perfect” foresight
  - Predicting battery economic benefits requires detailed market models

- Our approach:
  - Simulation based on meeting resiliency goals
  - Robust design accounting for varying weather outside of average conditions
  - Realistic operational strategy
  - Uncertainty estimates for output metrics
  - Modular algorithm design
  - Leverages other PNNL tools

PV Production Under Varying Conditions

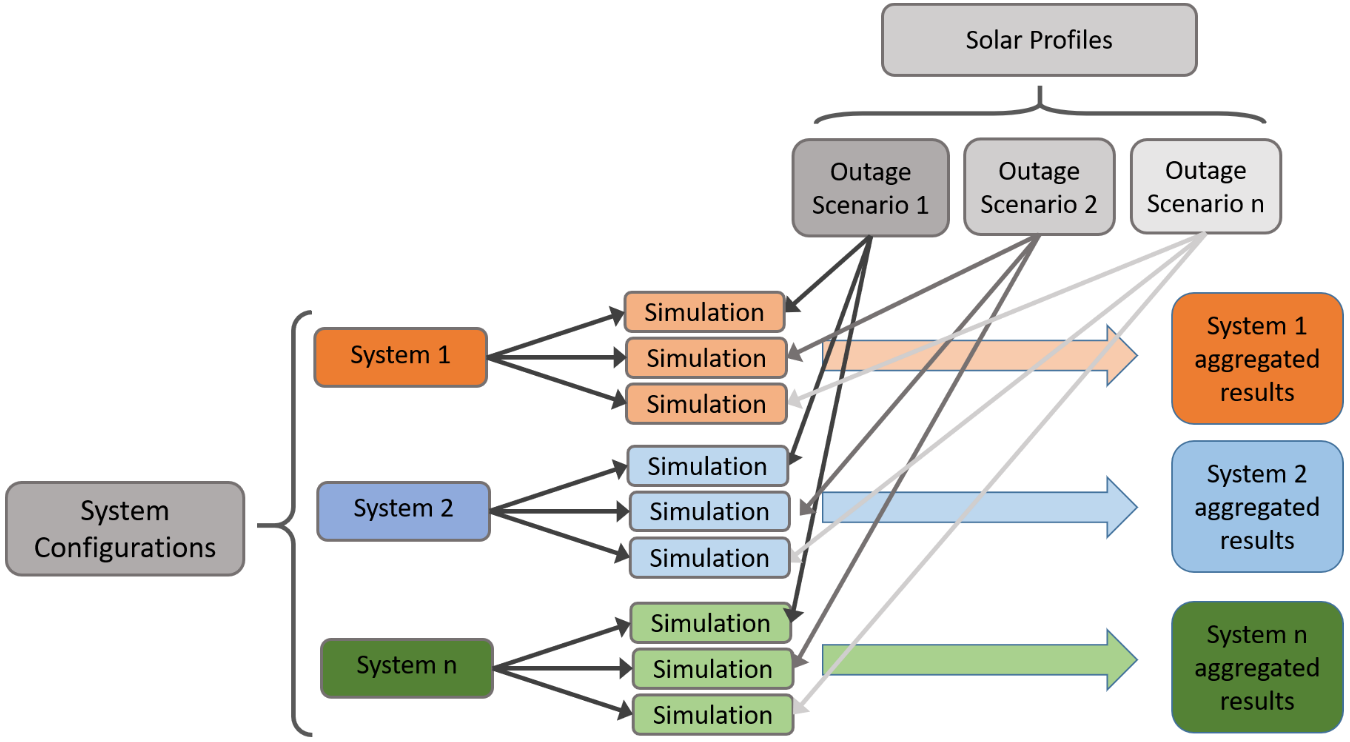


TOOL DESCRIPTION

- Tool specifications
  - Meets critical loads for a specified outage duration
  - Considers many different system configurations with different randomized outage scenarios
- Inputs:

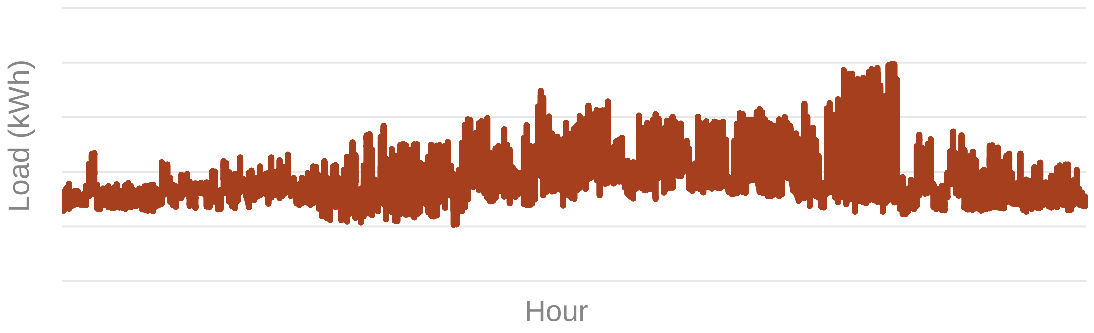
Required
  - Location
  - Resiliency goal
  - Annual hourly load profile
  - Utility rates

Optional
  - Existing equipment
  - PV orientation and parameters
  - Battery parameters
  - System constraints
  - Ranking criteria
  - Capital Costs



OUTPUT METRICS

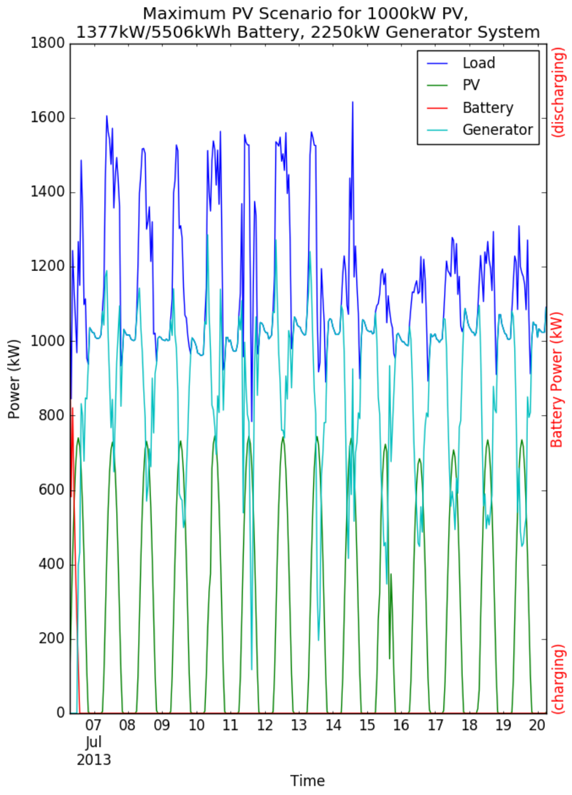
- Example site:
  - 14-day resiliency period
  - Existing 1MW PV array
- Generator sizing:
  - Typical - Average of all scenarios
  - Conservative - Worst-case scenario (largest generator, most fuel)

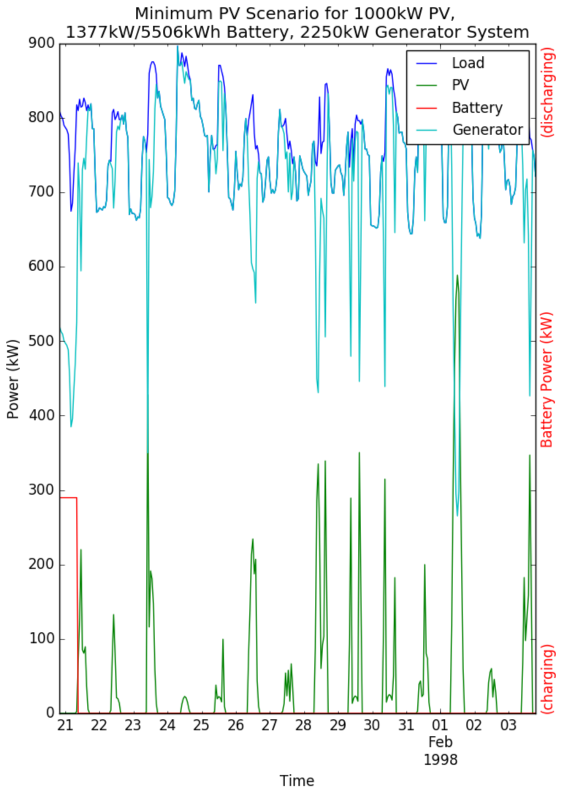


System	System Size			Generator Size (kW)		Capital cost ($)	% of Load Met by Each Component			Fuel Consumption (Gallons)	
	PV (kW)	Battery (kWh)	Battery (kW)	Typical	Conservative		PV	Battery	Gen.	Typical	Conservative
Current PV Equipment	1000	0	0	1530	2250	$1,187,895	15	0	85	20048	26180
Current Equip. with storage	1000	5506	1377	1527	2250	$4,608,744	15	1	84	19787	25950
System with Least Fuel	7350	22026	5506	907	2250	$28,840,539	41	38	21	5814	15786

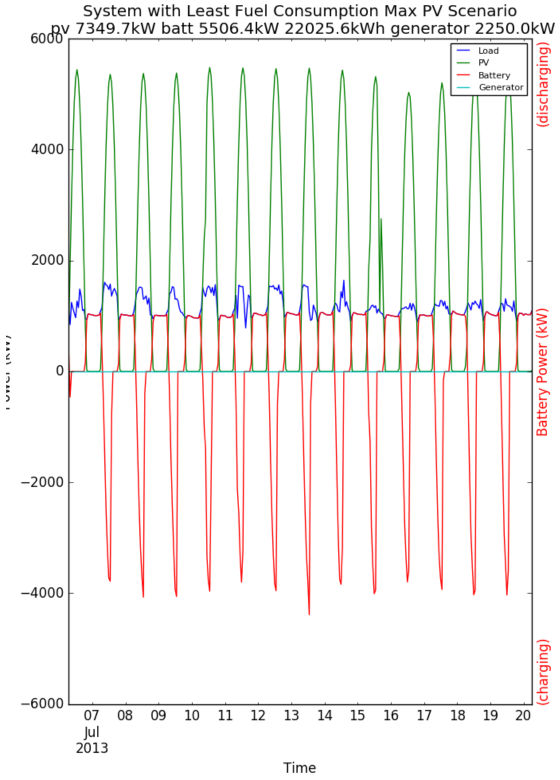
COMPARE SYSTEMS

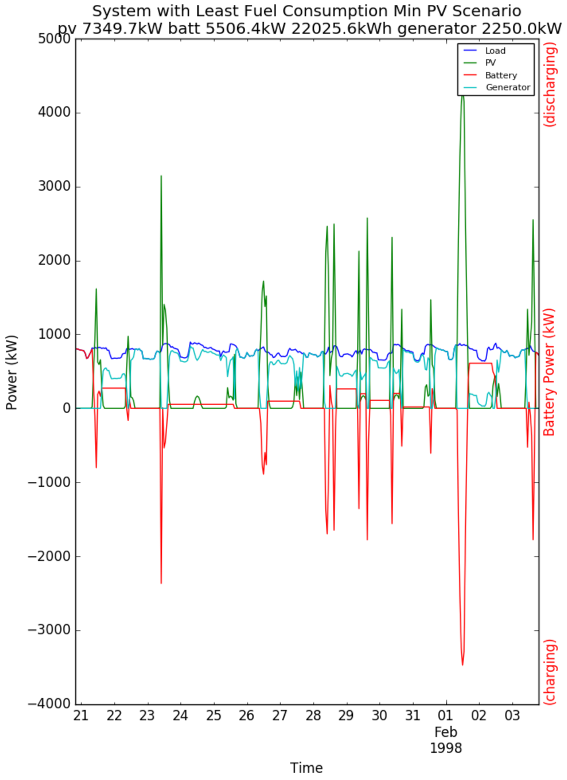
- Current PV system (1MW) with storage





- Add PV for better performance (7.3MW)

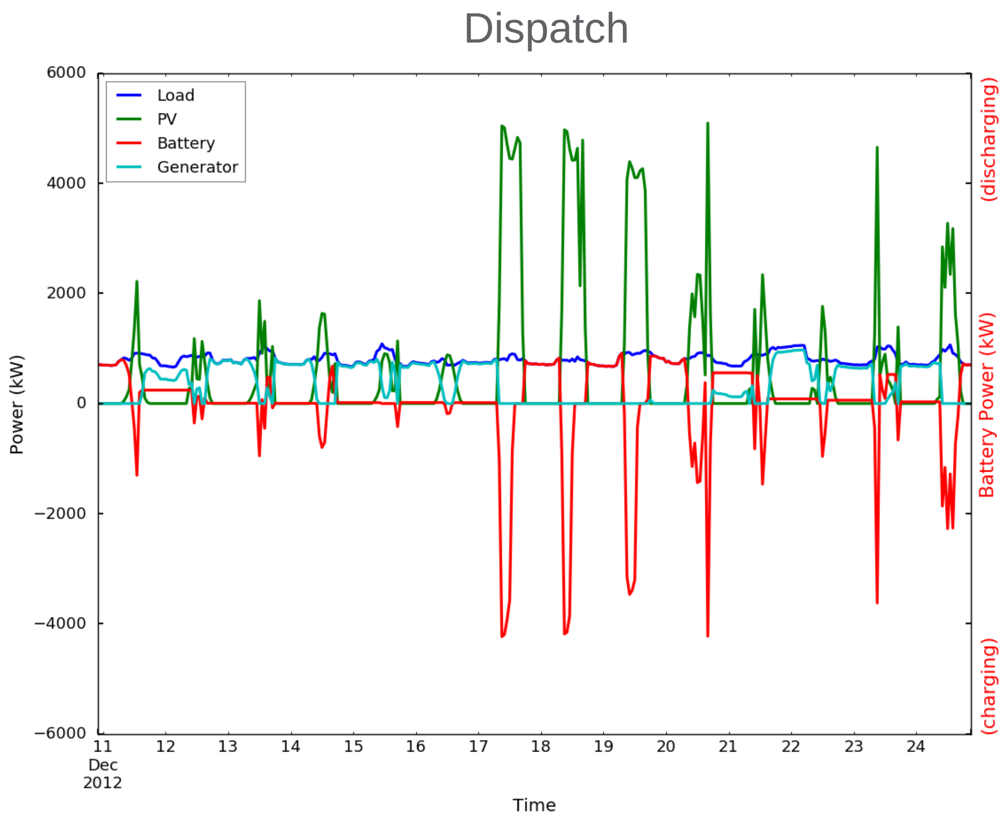




BATTERY MODEL

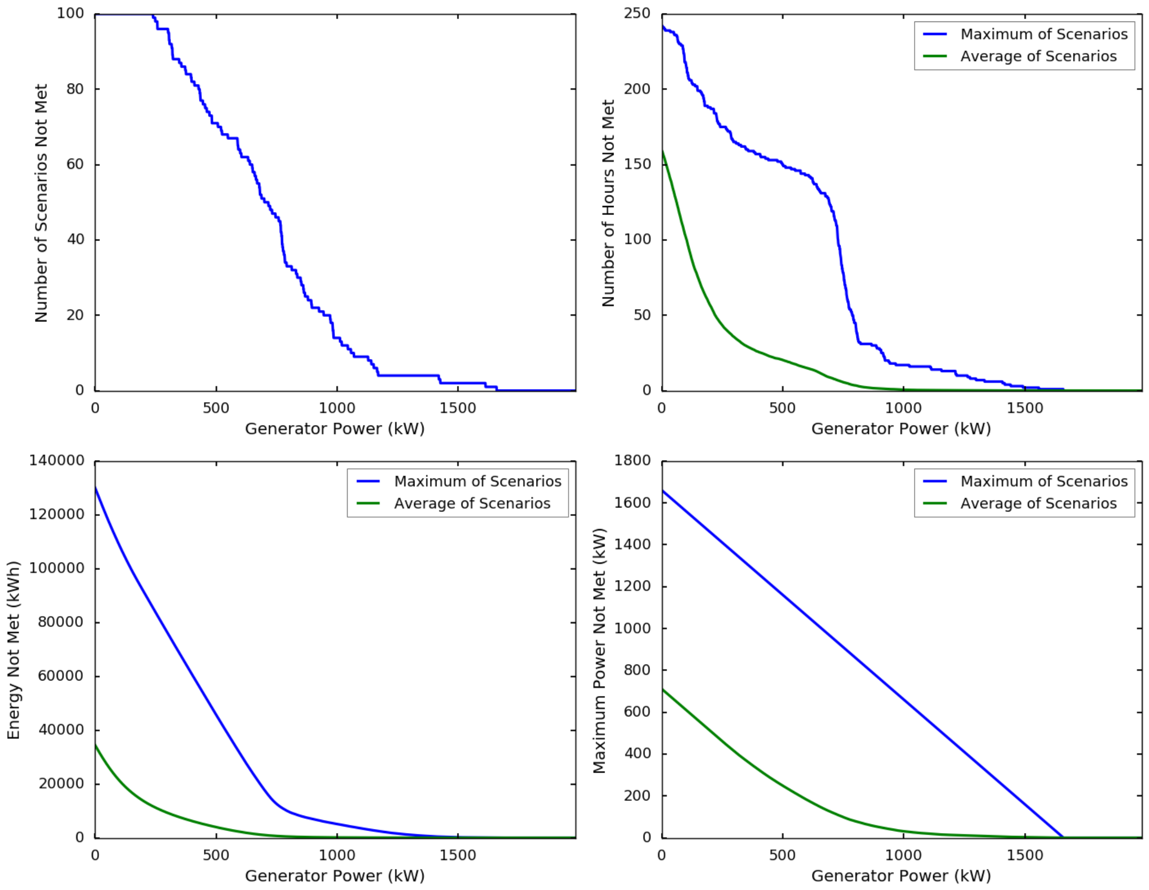
- Dispatch strategy:
  1. PV is dispatched to meet the load, with any excess used to charge the battery
  2. The battery is discharged such that it is at the minimum SOC at the end of the night
  3. The generator is sized to meet any un-met load

- Battery options:
  - Power/energy ratio
  - Initial, max, min SOC
  - Battery and inverter efficiencies



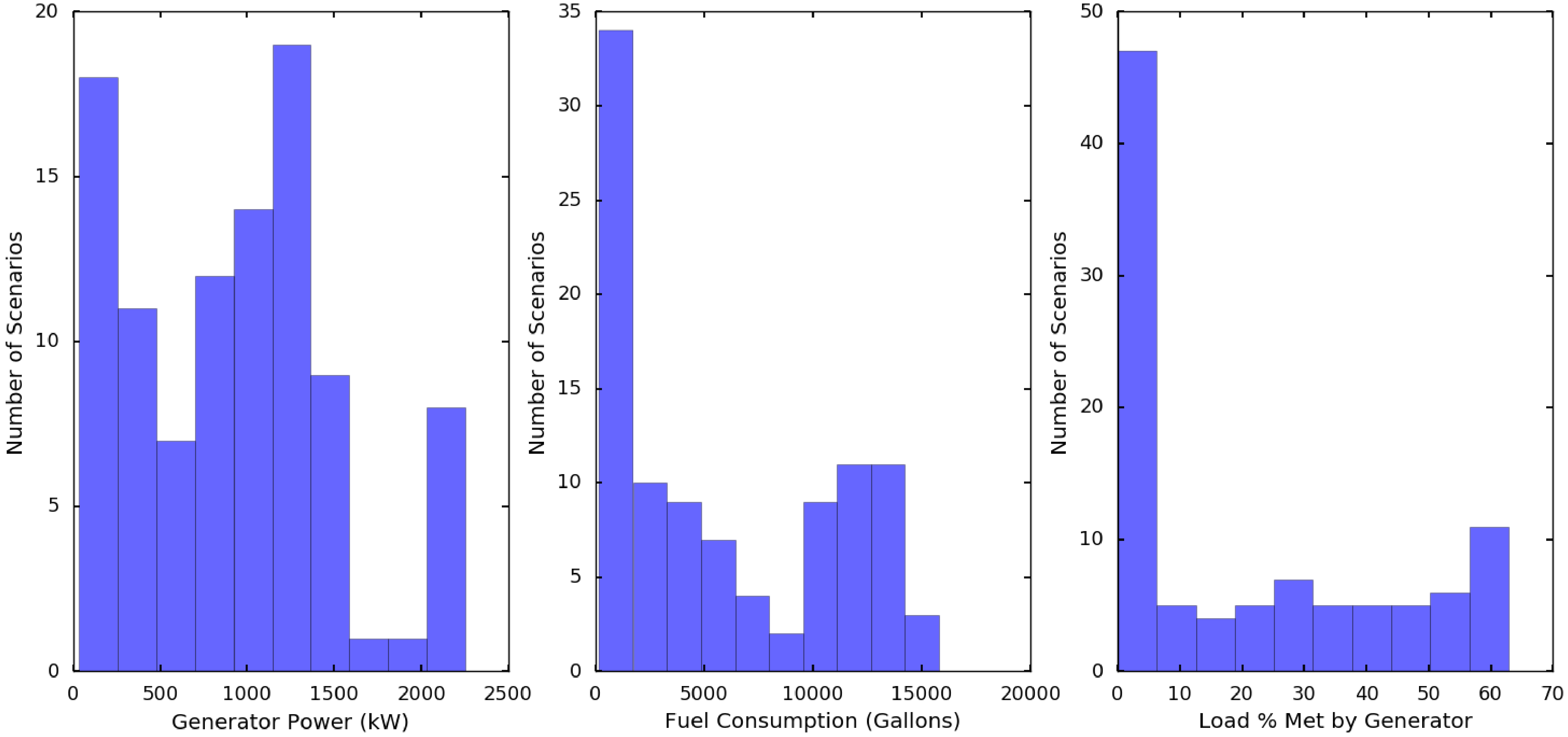
GENERATOR SIZING

- Sizing constraints:
  - All electrical load is met at each hour
  - Specified % buffer
  - Selected from list of diesel generators
  - Fuel consumption calculated based on a fuel efficiency function
- Includes smaller generator options with:
  - # scenarios not met
  - Average and max # hours not met
  - Average and max kWh not met
  - Average and max peak kW not met
  - Average and max fuel consumption
  - Capital cost reduction

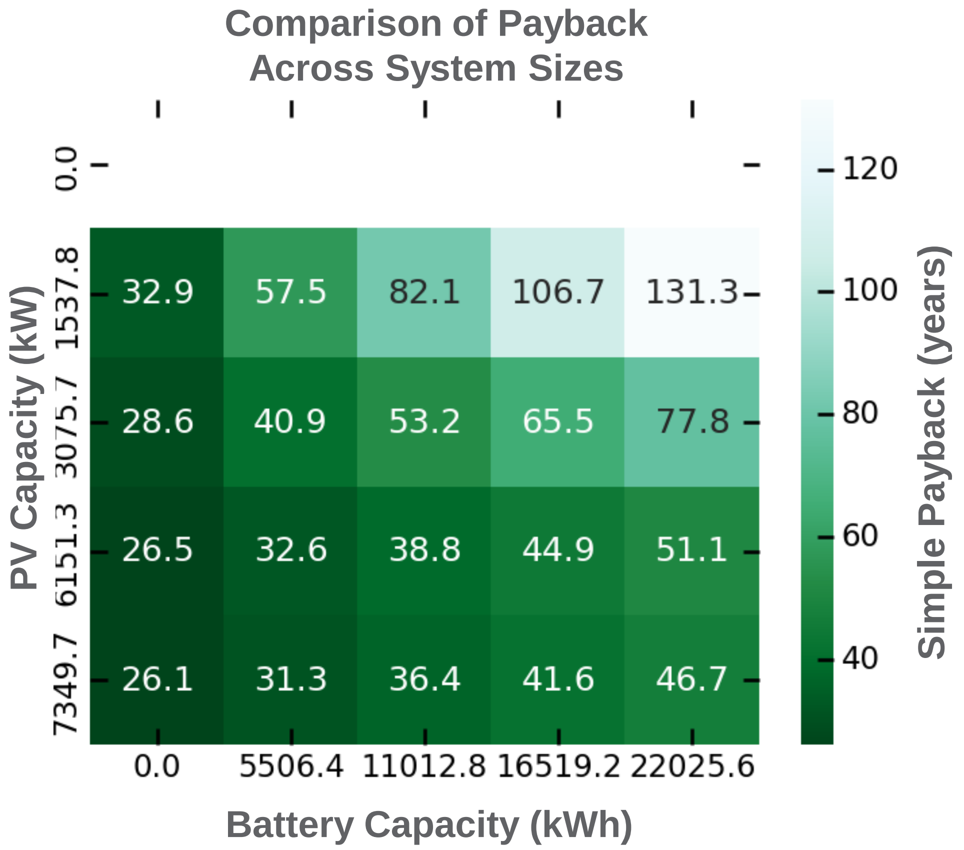


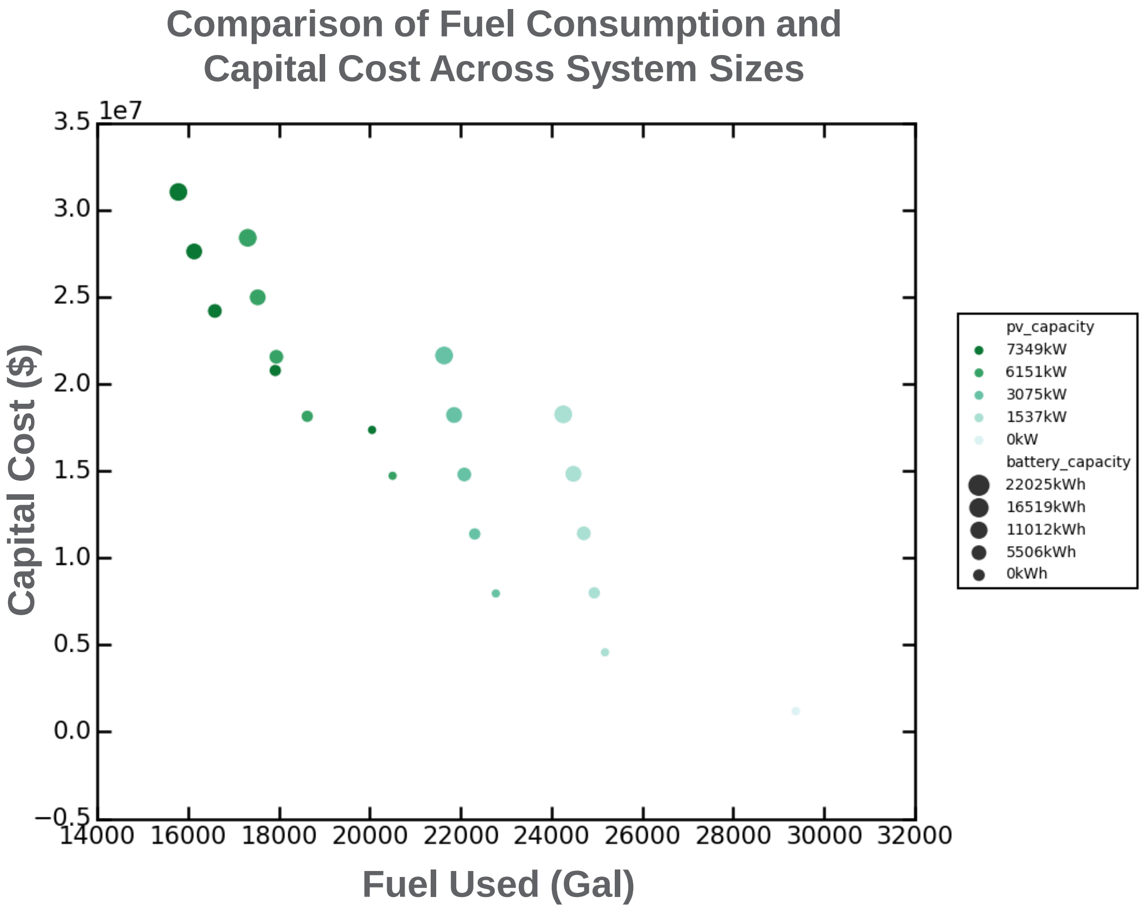
GENERATOR PERFORMANCE

Generator Power and Fuel Consumption Distributions



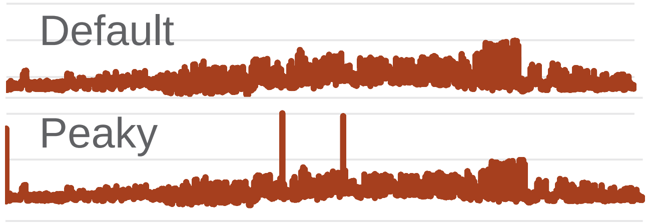
METRIC TRADE-OFF





SENSITIVITY TO INPUTS

- Load profile
  - Total annual load impacts PV and battery system sizes (largest cost component)
  - Peak load drives generator sizing and fuel consumption
- Resiliency goal and number of scenarios:
  - Generator sizing constrained by worst-case scenario
  - Allows for decreased risk



	Default load profile	'Peaky' load profile
Total Cost	$28.84M	$28.89M
Conservative Generator	2250kW	3280kW

	2-week period	1-day period
Average Generator	907kW	199kW
Conservative Generator	2250kW	2050kW

USE CASES

- Find systems that meet known requirements
- Cost/benefit analysis of different critical loads and generator sizes
- Cost/benefit of including different resources
- Assess resiliency capabilities of existing equipment
- Determine fuel requirements for potential outages
- Quantify risk/uncertainty for different system configurations

Source: PNNL

Pacific Northwest NATIONAL LABORATORY

FUTURE DIRECTIONS

- Current status of tool: internal, command-line tool, requires Python/scripting knowledge
- Future vision: Graphical User Interface - allowing any user to run the tool independently
- Additional capabilities:
  - Redundant dispatch of multiple generators
  - Demand charge savings
  - Improved sizing algorithm
  - More advanced battery discharge algorithm
  - Payback calculation based on year-round battery operation
  - More complex pricing options
- Integration with other PNNL tools to optimize operational strategy
- Include new generation sources?

ACKNOWLEDGEMENTS

- U.S. Army Reserve - Installation Management Directorate
- U.S. Army - Office of Energy Initiatives

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Thank you

SIZING COMPONENTS

- PV sizes:
  - $Max\ capacity = (L + eff)/PV$
  - $Net\ zero = L/PV$
  - $0.5 \times Net\ zero$
  - $0.25 \times Net\ zero$
  - 0
- Battery sizes:

  ($Battery\ power = capacity \times PER$ for all sizes)
  - $Max\ capacity = MNL/RTE$
  - $0.75 \times Max\ capacity$
  - $0.5 \times Max\ capacity$
  - $0.25 \times Max\ capacity$
  - 0

L: $Total\ annual\ load$

PV: $Total\ annual\ PV\ generated\ by\ 1kW\ system$

RTE: $Roundtrip\ efficiency$

MNL: $Maximum\ nightly\ load$

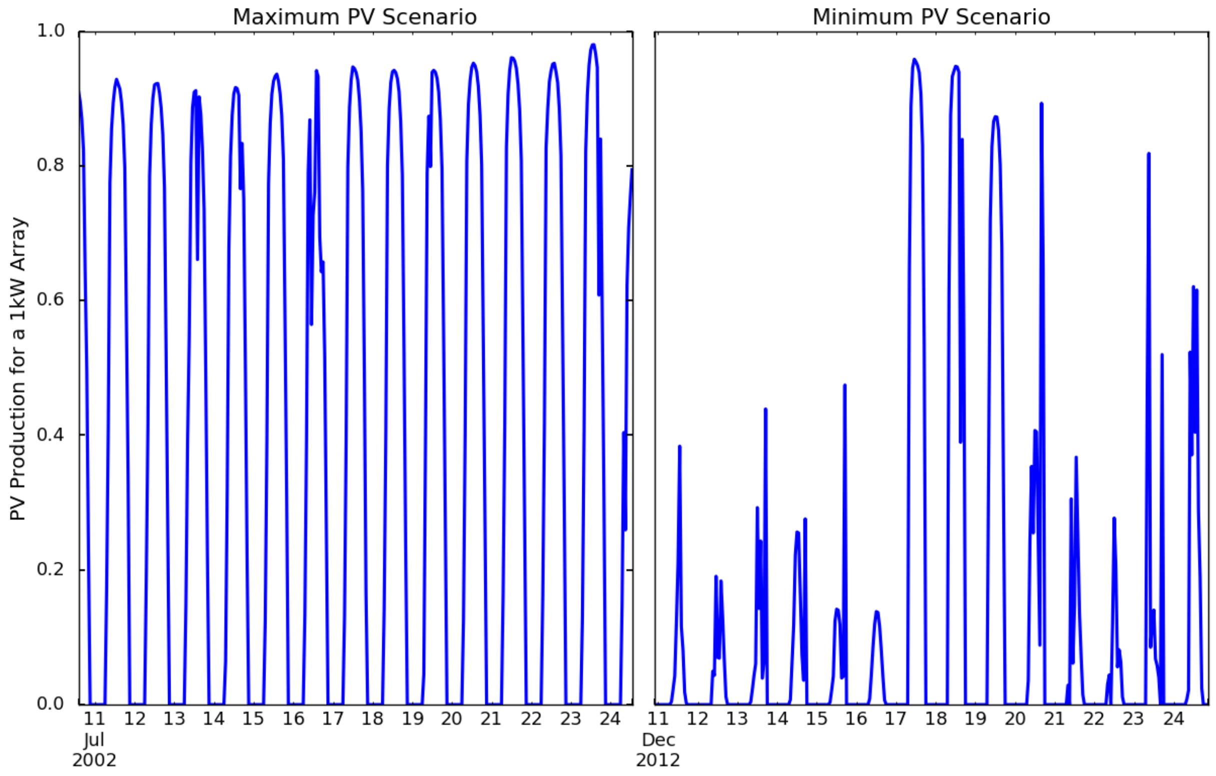
PER: $power\ to\ energy\ ratio$

eff: $Efficiency\ losses\ from\ charging\ battery$

$eff = excess\ PV\ from\ NZ * (1 - RTE)$

ALTERNATIVE SOLAR PROFILES

- Generates a suite of solar and temperature profiles based on historical NREL data
- Randomized profiles allow for a large range of solar conditions to be simulated
- Allows users to be confident that results encompass any "worst-case scenario" weather situations



PV MODEL

- Based on the publicly available pvlib code library, developed at Sandia National Laboratories as part of the PV Performance Modeling Collaborative
- Panel and inverter performance details are based on published test data from the California Energy Commission
- System options:
  - Tilt
  - Azimuth
  - Panel, inverter models
  - String configuration
  - Racking type
  - Albedo
  - Losses