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Energy Storage Peaker Plant Replacement: Battery/PV Sizing and Control

With Post-Optimization Cost Benefits Analysis

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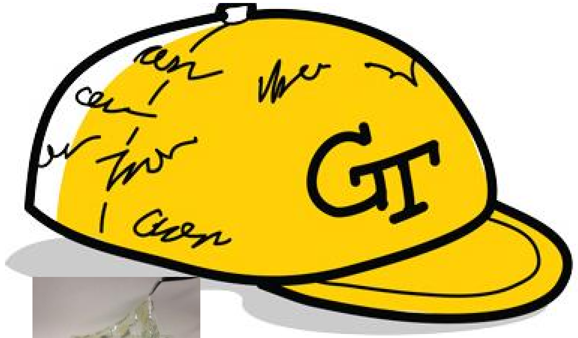
Outline

- My Background
- Peaker Plant Overview
- Case Study: PNM Reeves Power Generating Station
- Bilevel Optimization Problem of Sizing and Control
- Incorporation of Monetized Energy Justice Metrics
- Further Considerations
- Conclusion

Amanda West, PhD Student Summer Intern



U.S. AIR FORCE

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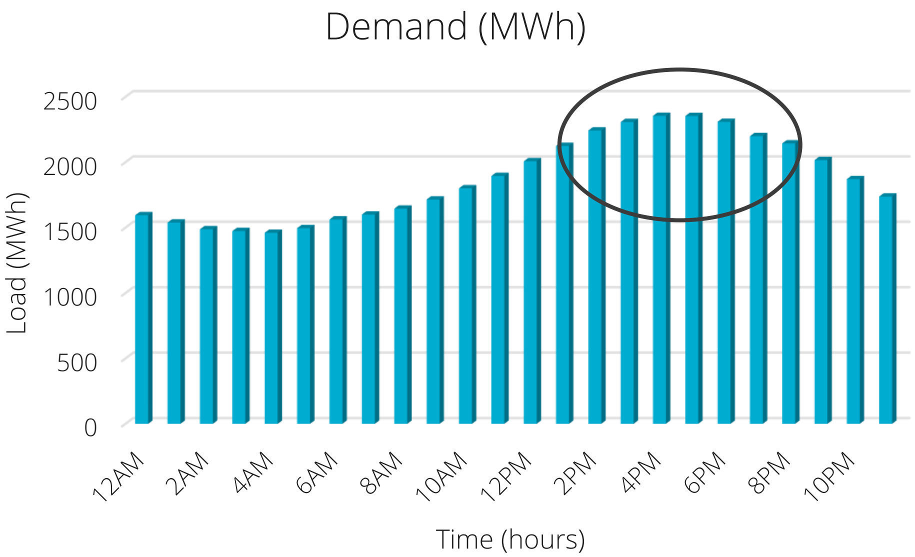
Energy Burden

Georgia Tech
Plasma and Dielectrics Lab

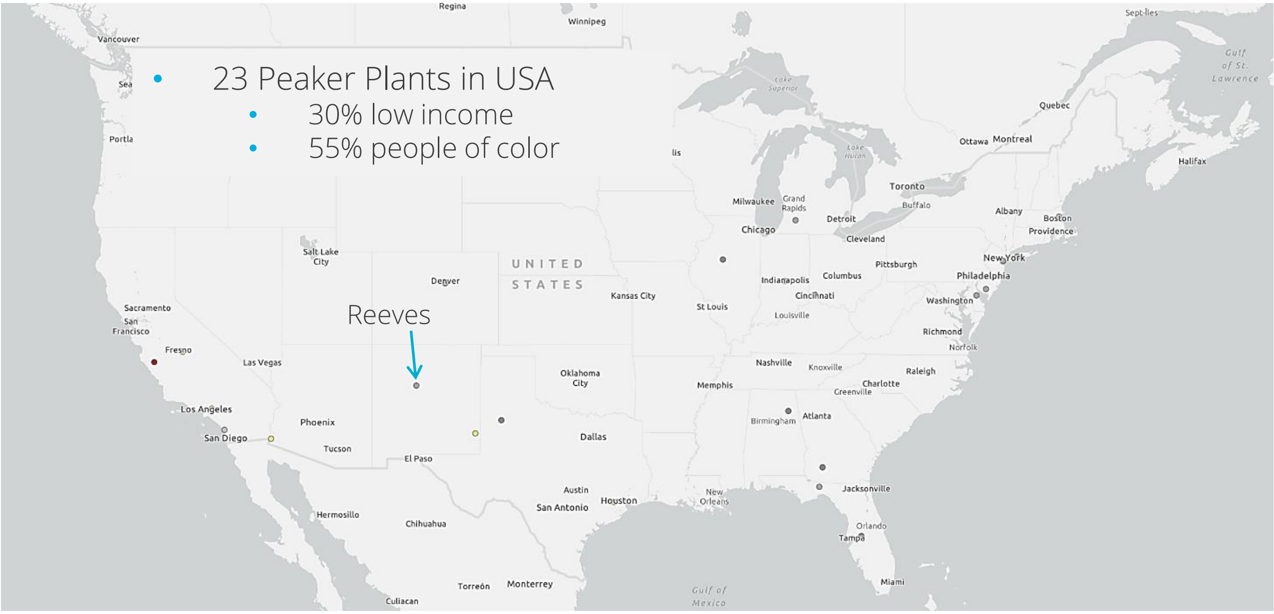
Sandia National Laboratories

Peaker Plant Overview

Peaker Plants: Power production outweigh health impacts?



From: EIA Hourly Electric Grid Monitor
https://www.eia.gov/electricity/gridmonitor/dashboard/electric_overview/balancing_authority/PNM



From: EPA Clean Air Markets Power Plants and Neighboring Communities
https://www.epa.gov/airmarkets/power-plants-and-neighboring-communities

- Peak Load Support
- Voltage Regulation
- Transmission Congestion Relief
  - 200 MW nameplate capacity
  - 10-15% capacity factor
  - NOx, CO_2, $PM_{2.5}$, or SO_2 greater than 0.01 tons/year

- 1,803,116 people within 3-mile radius
  - Preterm and very preterm birth
  - Hospitalization for asthma, acute respiratory infections, chronic obstructive pulmonary disease

Case Study: PNM Reeves Power Plant

Location:	Albuquerque NM
Maximum Power:	146 MW [1]
Age:	61 years [1]
Capacity Factor:	11.5% [2]
Population (3 miles):	63,227[2]
Expected retirement:	2030 [1]

[1] Phillips et al. “2020 integrated resource plan,” Public Service of New Mexico, Tech. Rep., 2020.
[2] Krieger et al. Energy Policy, 2016.

From: “PNM Reeves Power Plant 3/25/10” Article posted by n3mra on 01/14/14
https://menloservice.sandia.gov/https://westernghosttowns.wordpress.com/2014/01/13/pnm-reeves-power-plant-32510/

Reeves dispatch data for 2018 and 2019 was collected from public EPA Air Markets Program Data: https://ampd.epa.gov/ampd/

BESS+PV Sizing and BESS Control

Bilevel Optimization Problem of Sizing

Problem Statement: What combination of battery power, battery energy, and PV power capacity will match the peak load support service of a given peaker plant at minimum cost?

Peak Load Support

- Removed periods of continuous power output exceeding 10 hours per day*

Bilevel Optimization Problem

Top level Problem: Optimal Sizing

- Choose BESS+PV size to minimize capital cost

Bottom level problem: Optimal Control

- Dispatch BESS system to match peak load supply service
- Enforce physical constraints of the battery

* The analysis was performed based on duration limits of 4, 6, 8, 10, 12, 14, and 16 hours per day. A 10 hour per day limit was selected to represent peak load service.

Bilevel Optimization Problem: Peak Load Support Sizing and Control

$$\min_{\mathbf{x}\in\mathbb{R}^{3n+4}} \quad C^{\text{MWh}}_{\text{BESS}} E_{\text{BESS}} + C^{\text{MW}}_{\text{BESS}} P_{\text{BESS}} + C^{\text{MW}}_{\text{PV}} P_{\text{PV}} \tag{1a}$$

Capital Cost

$$\text{s.t.} \quad \mathbf{p}^{-} + \mathbf{p}^{+} + P_{\text{PV}}\mathbf{p}_{\text{PV}} \geq \mathbf{p}_{\text{peak}} \tag{1b}$$

Peaker Power Matching

$$\mathbf{D}\varsigma = \mathbf{p}^{-} + \eta\mathbf{p}^{+} + p_{\text{sd}}[\mathbf{1}] \tag{1c}$$

Energy Reservoir Model

$$[\mathbf{0}] \leq \varsigma \leq E_{\text{BESS}}[\mathbf{1}] \tag{1d}$$

$$\mathbf{p}^{+} - \mathbf{p}^{-} \leq P_{\text{BESS}}[\mathbf{1}] \tag{1e}$$

Battery Management System Limits

$$\varsigma_{[0]} = \varsigma_{[n]} = E_{\text{BESS}} \tag{1f}$$

Initial and Final SoE

A 604MWh 125MW Battery and 108 MW of PV can effectively replace the Reeves power plant **peak load support capabilities** at minimum capital cost.

Control Optimization Problem from Unmodified Reeves Dispatch

Problem Statement: How well would the BESS+PV sized for <=10 hour periods preform when trying to match the unmodified Reeves dispatch power?

Optimization Problem

Control

- Dispatch BESS system to match total peaker plant service
- Enforce physical constraints of the battery

Control Optimization Problem from Unmodified Reeves Dispatch

$$\max_{\mathbf{y}\in\mathbb{R}^{3n+1}\times\{0,1\}^n} \sum \mathbf{g} \quad (1a)$$

Generation Boolean

s.t.

$$\mathbf{p}^- + \mathbf{p}^+ + P_{\text{PV}}\mathbf{p}_{\text{PV}} \geq \mathbf{p}_{\text{peak}}\mathbf{g} \quad (1b)$$

Peaker Power Matching

$$\mathbf{D}\varsigma = \mathbf{p}^- + \eta\mathbf{p}^+ + p_{\text{sd}}[\mathbf{1}] \quad (1c)$$

Energy Reservoir Model

$$[\mathbf{0}] \leq \varsigma \leq E_{\text{BESS}}[\mathbf{1}] \quad (1d)$$

$$\mathbf{p}^+ - \mathbf{p}^- \leq P_{\text{BESS}}[\mathbf{1}] \quad (1e)$$

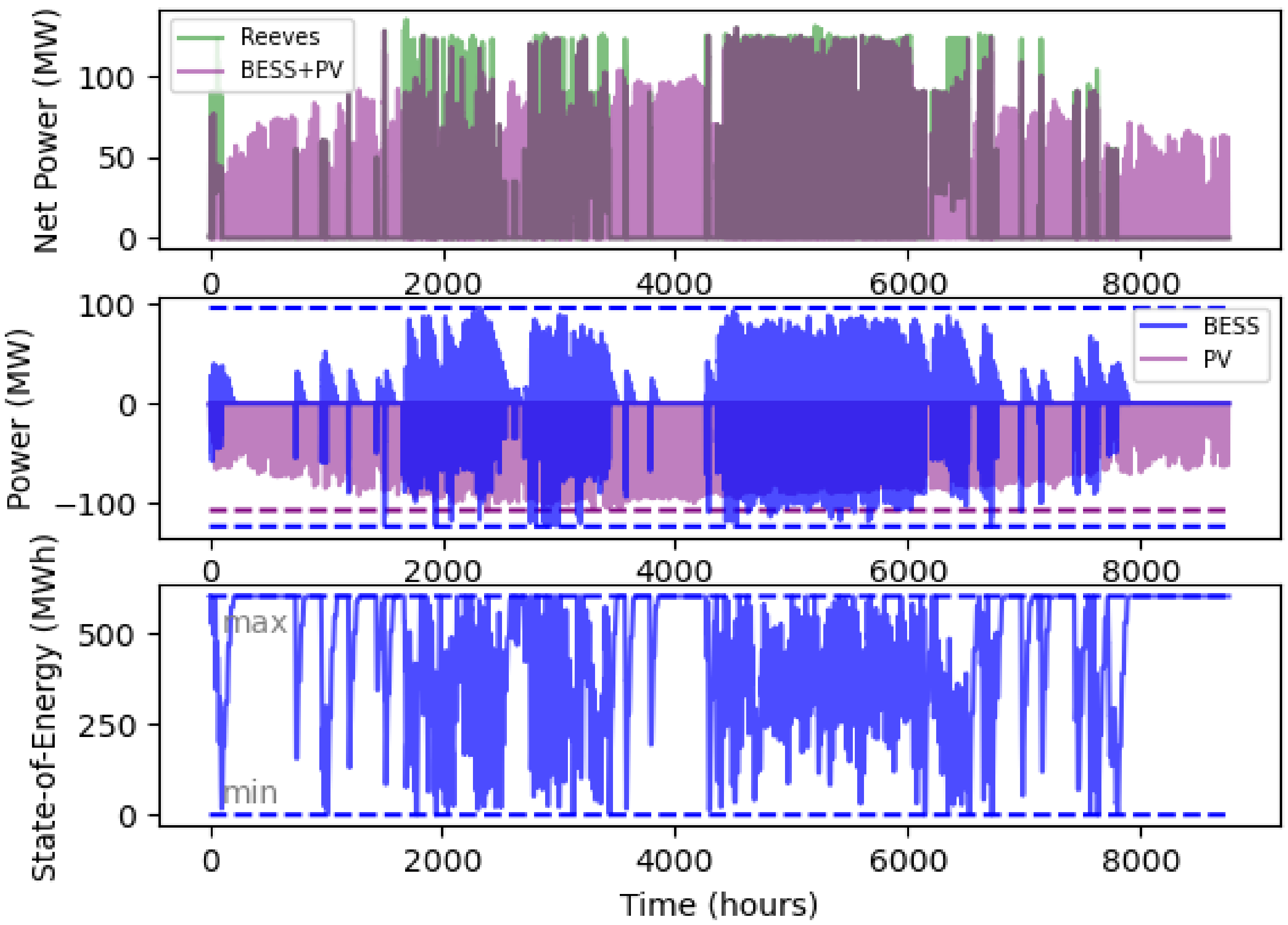
Battery Management System Limits

$$\varsigma_{[0]} = \varsigma_{[n]} = E_{\text{BESS}} \quad (1f)$$

Initial and Final SoE

Sizing Results to Match Reeves Peak Load Support Capability

EMS Profile: 2019



BESS+PV meets or exceed Reeves total generation 91% of the time (for both 2018 and 2019 data) and, by design, 100% of Reeves total generation of duration <10 hours per day.

Energy Justice Considerations

Monetize Associated Negative Heath Affects and Estimate Carbon Price

- EPA CO-Benefits Risk Assessment (COBRA)
  - Monetary value normalized to population of each county within US
  - NOx, $PM_{2.5}$, or SO_2 considered
- Near-term to net-zero carbon emissions (NT2NZ)
  - \$93/ton CO_2 (2018 USD)

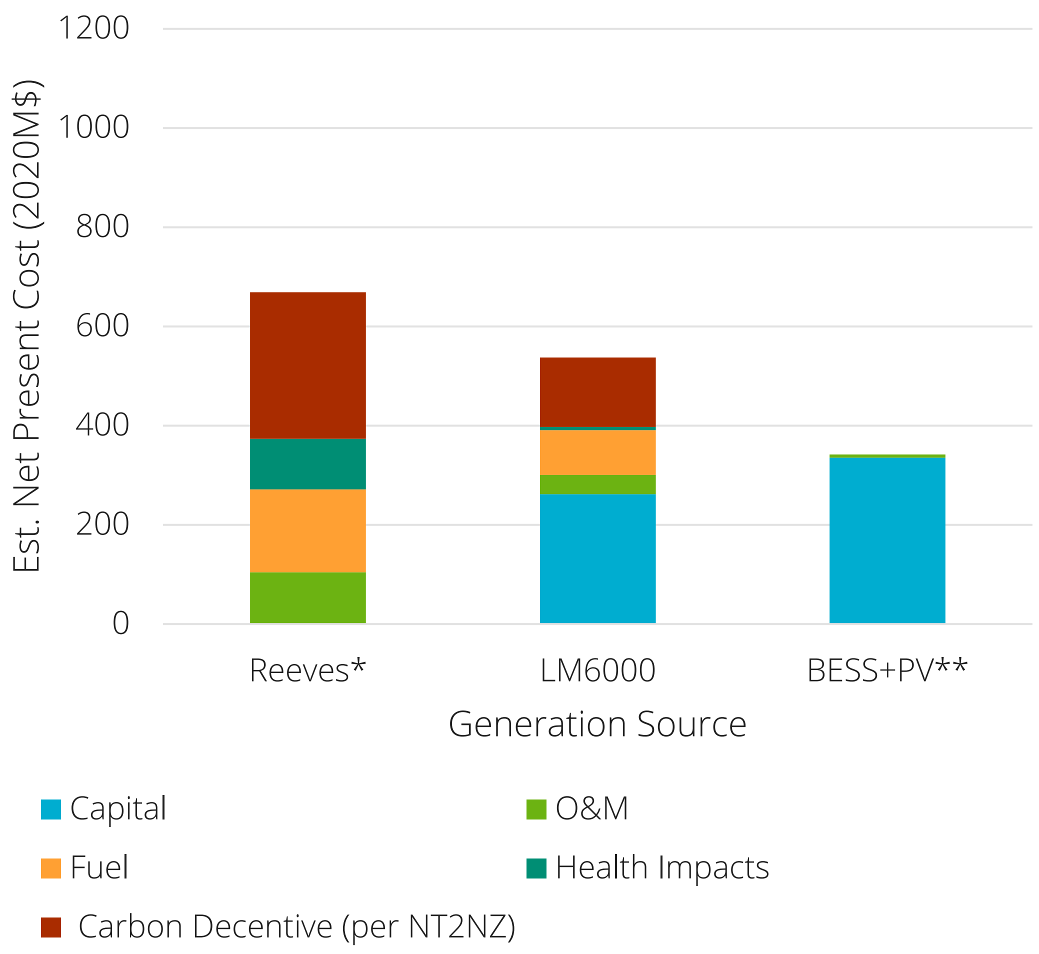
    Kaufman et al. *Nature Climate Change* 2020

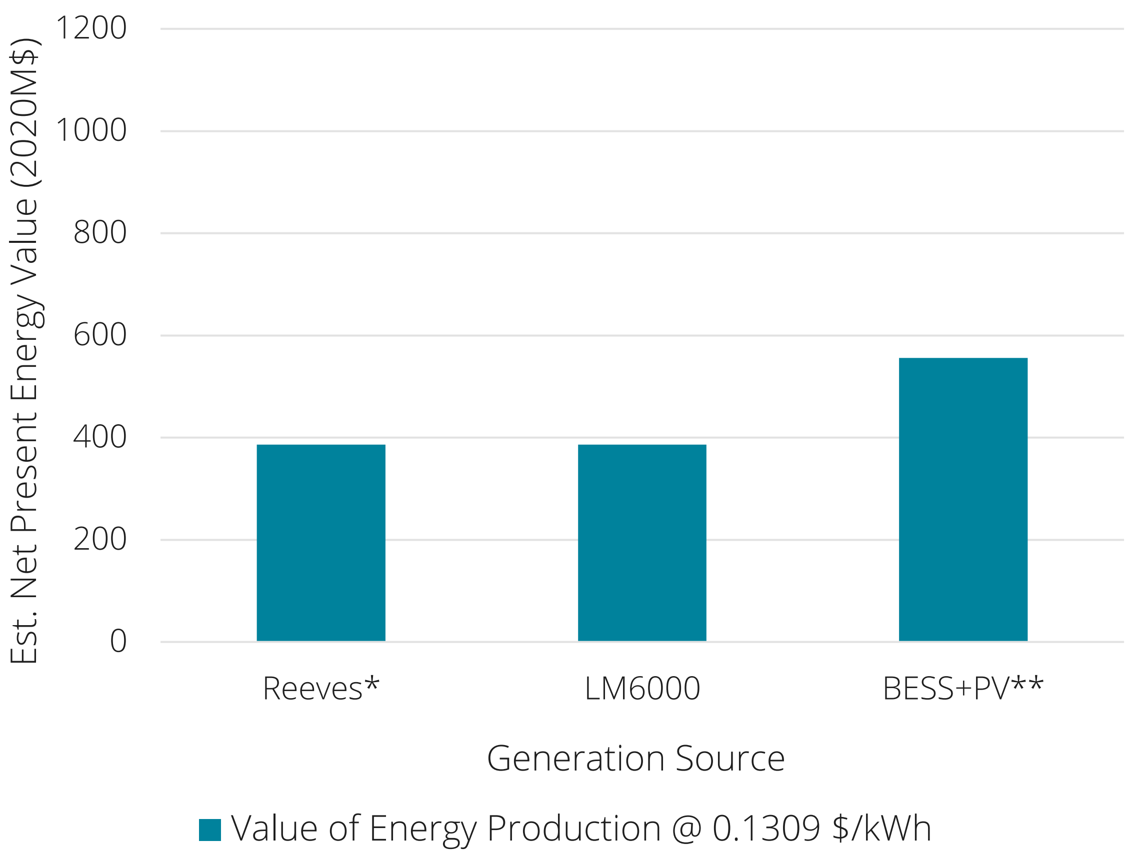
Emissions 2019

	NOx (tons/yr)	CO_2 (tons/yr)	SO_2 (tons/yr)	$PM_{2.5}$(tons/yr)
Reeves	285.4	142626	0.743	8.73
New CT	22.9	89292	0	0
BESS+PV	0	0	0	0

COBRA
Co-Benefits Risk Assessment
Health Impacts Screening and Mapping Tool

Cost Benefits Analysis





Further Research

More Considerations

- Assess Grid Level Integration
  - Improve Optimization Model
    - Voltage support
    - Transmission constraints/support
  - Include population equity comparison using a modified statistical measurement of inequity
- Cost Benefits Analysis Improvement
  - Consider more health factors of the population within a 3-mile radius

Conclusions

- 1,803,116 people in the US live in 3 mile radius of a peaker plant
  - Exposed to pollutants associated with negative health outcomes
    - Preterm birth, hospitalization due to asthma, acute respiratory infections, chronic obstructive pulmonary disease
- A 604MWh 125W Battery and 108 MW of PV system can meet or exceed the Reeves total power output 91% of the time
- In lieu of a globally recognized social cost of carbon, the NT2NZ price of carbon is used to address PNM's target to net zero carbon emissions by 2040
- BESS+PV is less costly and could provide more revenue than continuing using an old peaker plant or replacing the peaker plant with a new combustion turbine
- Monetized health factors can provide a useful metric for planners to assess renewable energy resource economic viability by reducing customers health costs

Thank you David Rosewater, Babu Chalamala, and Sharon Ruiz for a wonderful summer!