Financial Analysis of Solar Power for Greensburg, Kansas

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Outline

- Some information on Greensburg
- Data used for analysis
- Examples of load and PV generation
- Results of PV alone
- Battery selection methodology
- Results

City of Greensburg

- Located in south-central Kansas.
- Hit by a massive EF 5 tornado on May 4, 2007.
- Since then the community has rebuilt as a model community for sustainable living while putting "green" in Greensburg.
- One observer described Greensburg as "a unique place where rural values meet global vision."
- Greensburg's electricity is 100% wind power.
- The restored community has a population of approximately 850 people.

Data Used

- Hourly load for 2019 to 2021
- Hourly solar irradiation for 2019 to 2021
- Technical and Financial

PV module ($\$/W$)	Inverter ($\$/W$)	Equipment ($\$/W$)
0.035	0.04	0.18
Overhead ($\$/W$)	O&M ($/kW)	Transformer ($)
0.1	15	150,000
Energy cost $\$/kWh$	Power cost ($\$/kW$)	Tax credit (%)
0.025	22	30
Initial battery ($\$/kWh$)	Replacement battery ($\$/kWh$)	Project lifetime
150	100	20 years
Labor ($\$/W$)	Discount rate	Battery roundtrip efficiency
0.1	0.08	0.9025
Inverter coefficient	Battery efficiency	Battery utilization
1.2	0.95	0.7

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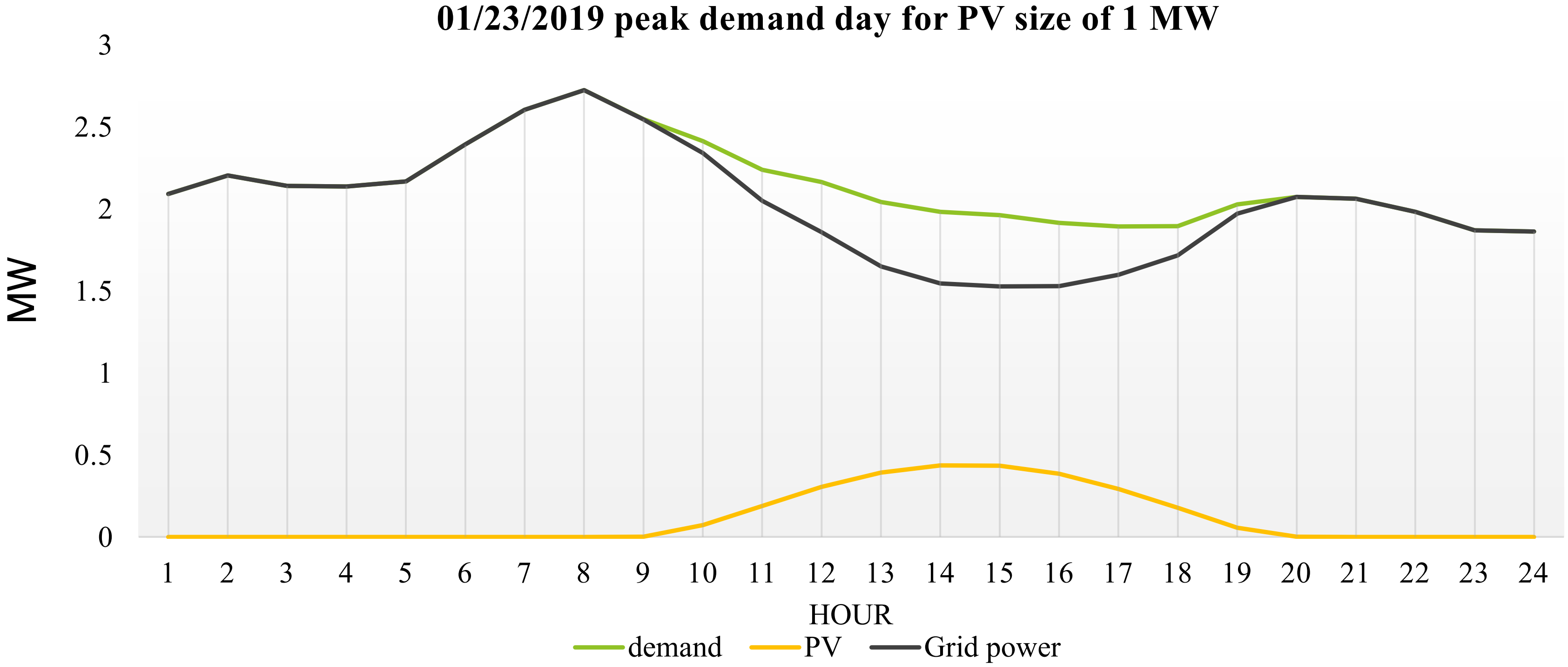
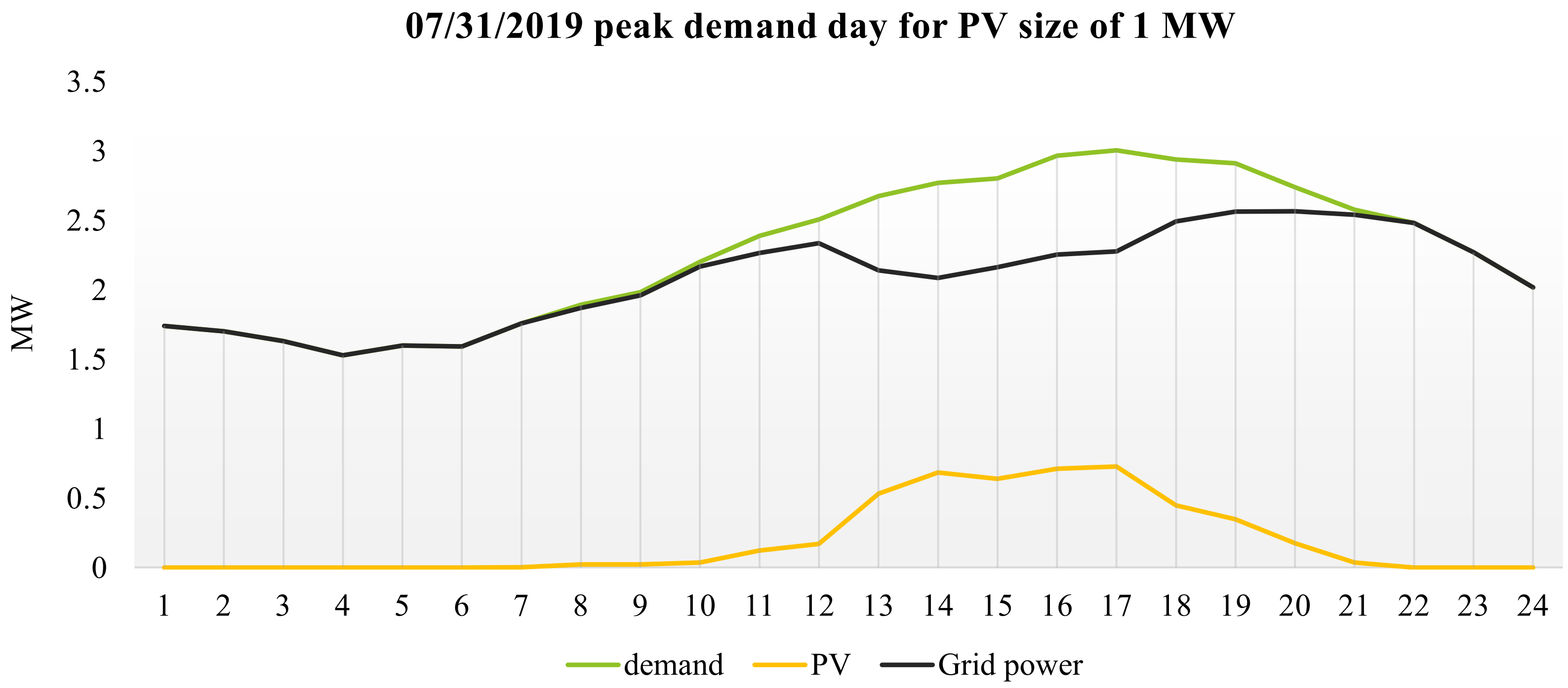
Example of Load and PV

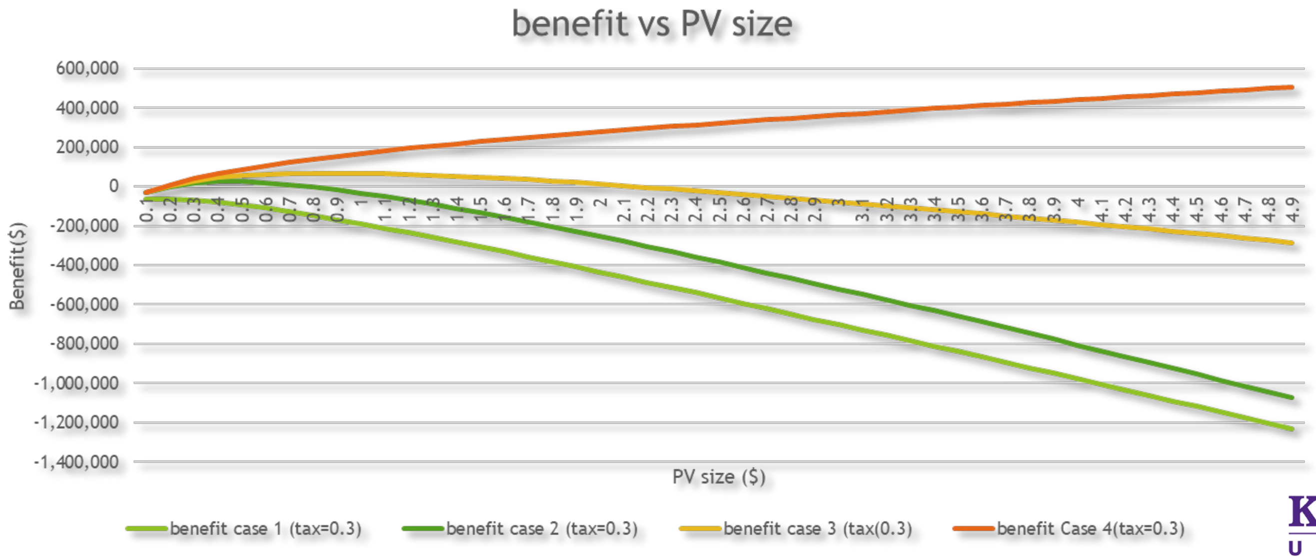




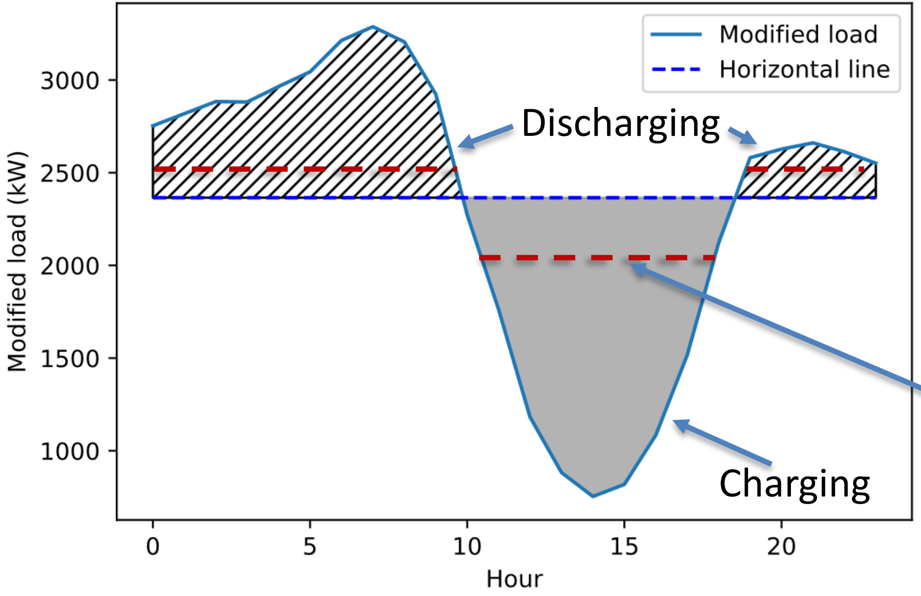
07/31/2019 peak demand day for PV size of 1 MW
MW
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
demand
PV
Grid power

Case	Energy cost (Cent/kWh)	Peak demand charge ($/kW)	Tax rebate (%)
Case 1	2.654	10.64	30
Case 2	2.5	22	30
Case 3	3.75	16.5	30
Case 4	5	11	30

Benefit (PW) = Energy Bill Reduction + Demand Bill Reduction – Net Cost



Battery Operation with Grid



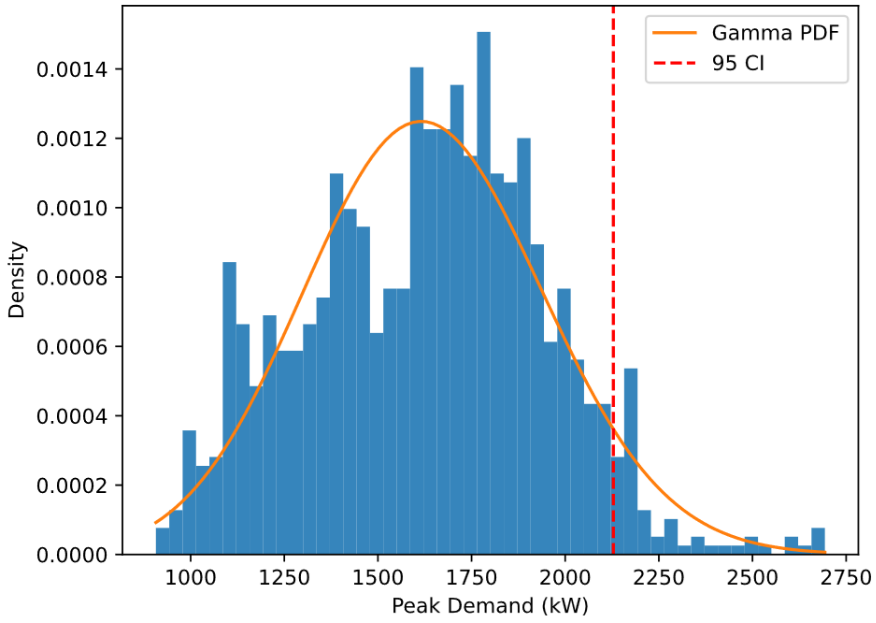
Battery fully charged and discharged in 24 hours

Smaller Battery

Discharging Area = Charging Area*Battery Roundtrip Efficiency

Battery Size = Charging Area*Charging Efficiency/Battery Utilization Factor

Peak Load Distribution



PV Size = 2000 kW

Battery = 4000 kWh

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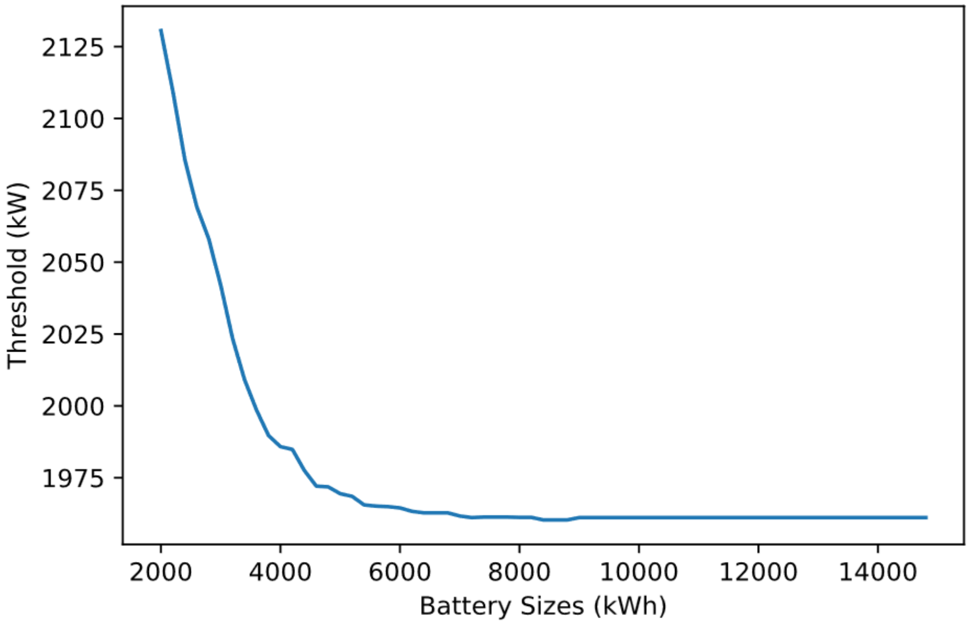
Peak Load Threshold

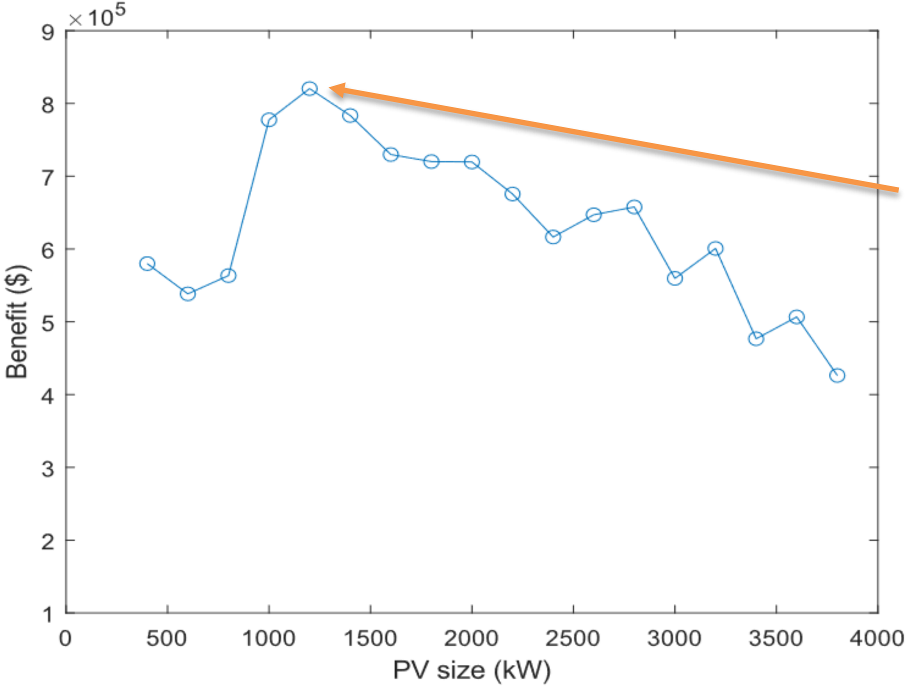


PV Size = 2000 kW

Optimal PV/Battery Sizes

PV size (kW)	400	800	1200	1600	2000	2400	2800	3200	3600
Battery size (kWh)	6200	5000	3200	4400	4600	5400	4600	4200	4400
Threshold (kW)	2167	2090	2078	1995	1971	1952	1958	1955	1931

Present Worth of Benefit



Best Option

PV Size = 1200 kW

Battery = 3200 kWh

Benefit = Energy Bill Reduction + Demand Bill Reduction – Net Cost

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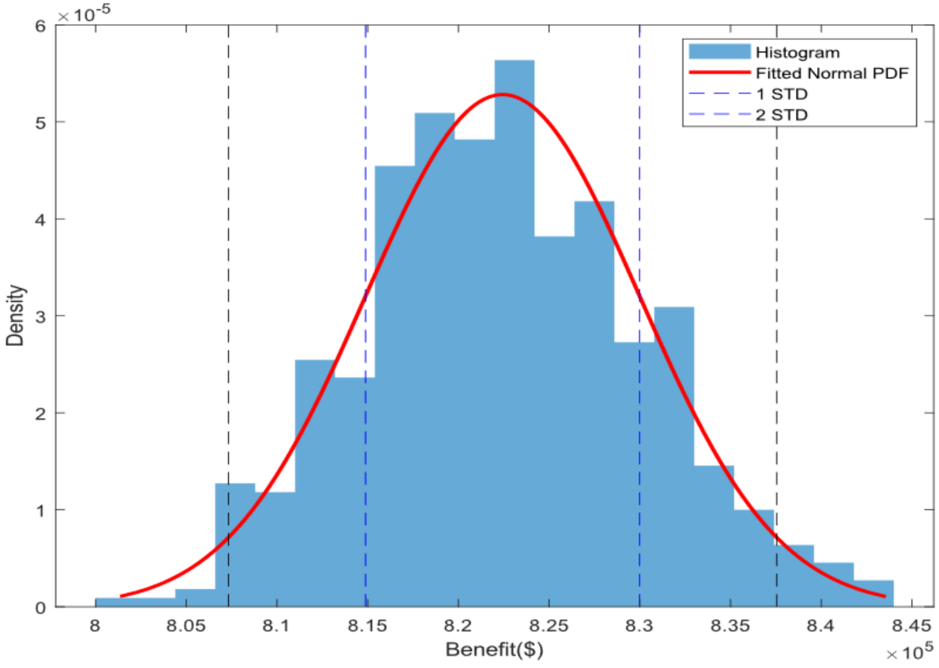
Results (Present Worth)

	Without PV-battery	With PV	With PV-battery
Energy cost ($)	3,788,907	3,337,719	3,365,366
Peak cost ($)	6,913,926	6,539,467	5,166,301
Equipment cost ($)	0	1,016,013	1,350,792
Benefit ($)	-	-190,366	820,373

PV Size = 1200 kW
Battery = 3200 kWh
Benefit of $83539/yr
Payback Period of 6 years

20-Year Monte Carlo Analysis



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Conclusions

- If the peak load does not coincide with peak PV hours, PV alone does not help in reducing demand charges.
- PV combined with battery gives positive results.
- The proposed statistical method is valuable for determining the best battery and PV size combination for planning new installations. It works only with real data.

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