

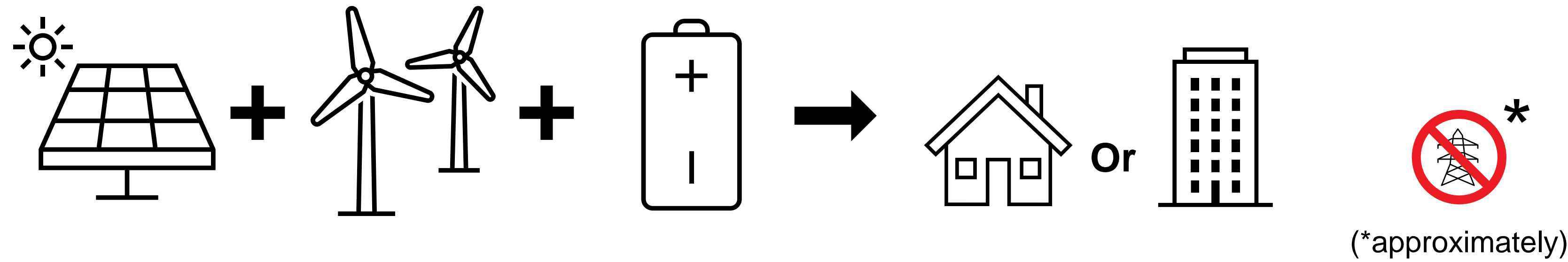
# Load-matching renewable plus storage system modeling in NREL SAM (2021.12.2r2)

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## Summary

- NREL SAM can model renewable energy systems with battery energy storage (ES) for load-matching. This can include off-grid systems (microgrids) or 24x7x365 "energy matching" scenarios, e.g., for corporations with sustainability goals beyond simple annual net zero [1, 2].
- SAM and HOMER (v2.68 "Legacy") can get similar results in optimizing PV+ES microgrids.
- There are a few ways to model load-matching PV+ES and **PV+Wind+ES** systems in SAM, including "hacks" to model PV+Wind+ES with parametric sizing.



## "Off-grid" PV+ES in SAM

Can be modeled two ways with distributed (BTM) energy storage models using either:

- Grid Outage feature (make 100% of load "critical" and all time steps have a grid outage)
- Grid power targets BTM battery dispatch option (with fixed 0 kW grid power target)

Here's an example with 2014 Birmingham AL weather and default SAM residential load:

Parametric analysis can optimize PV and ES size (here using Grid Outage feature):

*INPUTS*

SAM Grid Outage		PV capacity (kW):					
Annual Unmet Load		5	10	15	20	25	30
Battery Capacity (kWh):	20	33.13%	10.32%	5.85%	4.31%	3.49%	2.92%
	40	31.31%	4.65%	0.57%	0.22%	0.10%	0.04%
	60	30.91%	3.39%	0.05%	0.00%	0.00%	0.00%
	80	30.65%	2.81%	0.00%	0.00%	0.00%	0.00%
	100	30.42%	2.45%	0.00%	0.00%	0.00%	0.00%

*"OPTIMAL" FOR 0% OUTAGE CRITERIA*

Grid power target dispatch gives *slightly* different results:

SAM Grid Target		PV capacity (kW):					
Annual Unmet Load		5	10	15	20	25	30
Battery Capacity (kWh):	20	32.56%	11.10%	6.80%	5.16%	4.26%	3.64%
	40	30.41%	4.50%	0.66%	0.29%	0.14%	0.08%
	60	29.95%	3.12%	0.12%	0.02%	0.00%	0.00%
	80	29.70%	2.50%	0.00%	0.00%	0.00%	0.00%
	100	29.48%	2.11%	0.00%	0.00%	0.00%	0.00%

*e.g.*

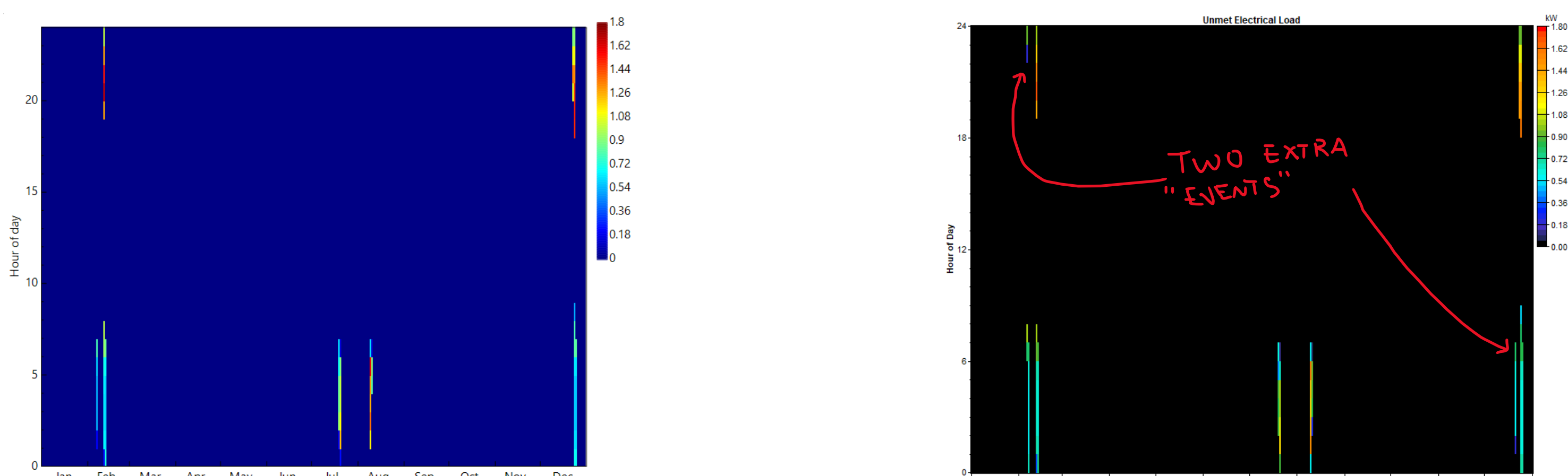
## PV+ES in SAM vs. HOMER (Legacy)

SAM can give very similar results to the "legacy" version of HOMER (v2.68) for off-grid PV plus battery system sizing.

Copying load and weather (GHI and  $T_{amb}$ ) from SAM, and a custom battery approximating Li-ion:

HOMER		PV capacity (kW):					
Annual Unmet Load		5	10	15	20	25	30
Battery Capacity (kWh):	20	33.79%	10.05%	5.14%	3.56%	2.74%	2.20%
	40	32.35%	5.05%	0.67%	0.22%	0.11%	0.05%
	60	31.92%	3.87%	0.09%	0.00%	0.00%	0.00%
	80	31.59%	3.27%	0.00%	0.00%	0.00%	0.00%
	100	31.25%	2.84%	0.00%	0.00%	0.00%	0.00%

Unmet load in SAM (Grid Outage) (*left*) and HOMER (*right*) for 15 kW PV, 40 kWh ES:



## PV+Wind+ES in SAM

SAM doesn't offer PV+Wind+ES models (yet), but there are workarounds:

- Generic-Battery model can import generation profiles from other open cases (e.g., setup a PV case, a second case for wind, and Generic-Battery as the third case that imports the wind and solar profiles) and then dispatch a battery.

### But what about using the parametric tool for sizing PV and wind?

- Use a Fuel Cell-PV-Battery case, where fuel cell dispatch is an imported wind profile:
    - Create a wind case, model a single "block\*" for the wind project, export hourly *System power generated (kW)*
    - Create a Fuel Cell case
    - Set fuel cell unit nameplate equal to the wind "block" size
    - Let the fuel cell run like a wind turbine:
      - remove Fuel Cell degradation, start/stop time limits, and ramp limits; set fuel cost to zero (if running financial analyses)
      - Fuel cell dispatch: use *Input dispatch* and paste in wind generation
    - Battery dispatch: use 0 kW grid power target (Grid Outage feature may not work right [3]).
  - Use the parametric tool to vary PV capacity, battery capacity, and Fuel Cell *Number of units in stack* (the number of wind "blocks")
  - Make sure to pick the right weather files for wind and solar: e.g., could be co-located with load or all spread out for a virtual "energy matching" project.
- \*capacity amt. by which wind project size can be increased or decreased, e.g., a single turbine.

## Results for a windy site in North Alabama, default SAM commercial load:

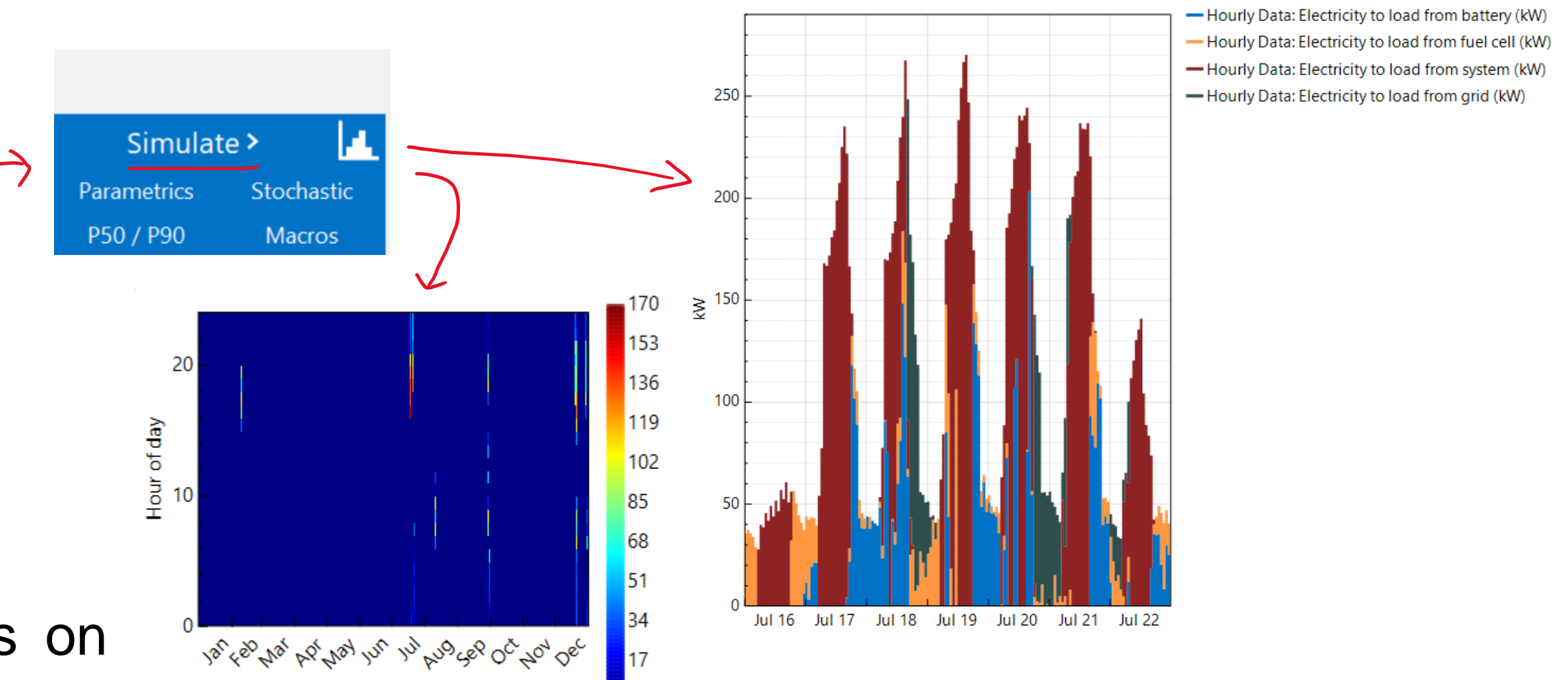
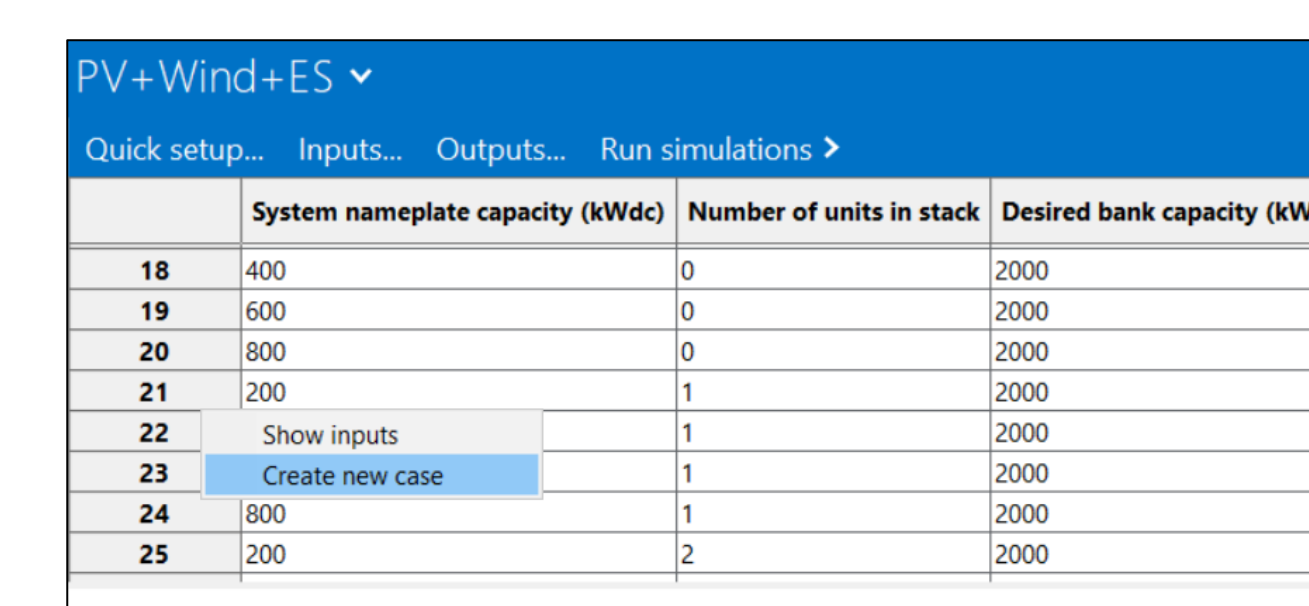
Multiple ways to get to 100%

Cost and land constraints could easily be considered

Input value ranges can be iterated on to "zoom in" on design space

Specific cases can be explored: right click case number, "Create new case", "Simulate", and dive deep...

SAM Annual Unmet Load	PV Capacity (kWdc)				Number of 250 kW Wind Turbines
	200	400	600	800	
1000	56.62%	26.29%	15.71%	11.86%	0
2000	56.08%	21.78%	9.04%	5.05%	
3000	56.02%	19.10%	6.57%	3.09%	
4000	55.97%	17.71%	5.20%	2.07%	
1000	17.29%	5.46%	2.26%	1.25%	1
2000	14.07%	3.51%	0.90%	0.29%	
3000	12.15%	2.31%	0.37%	0.07%	
4000	10.83%	1.55%	0.14%	0.00%	
1000	9.71%	2.40%	0.98%	0.52%	2
2000	7.02%	1.07%	0.28%	0.05%	
3000	5.28%	0.53%	0.05%	0.00%	
4000	4.03%	0.26%	0.00%	0.00%	
1000	5.87%	1.46%	0.56%	0.28%	3
2000	3.45%	0.51%	0.13%	0.03%	
3000	2.18%	0.12%	0.00%	0.00%	
4000	1.35%	0.00%	0.00%	0.00%	



## Acknowledgements

Thanks to Paul Gilman and others on the SAM team for help and ideas.

## References

- <https://www.bloomberg.com/press-releases/2022-03-07/constellation-launches-sustainability-partnership-with-microsoft-featuring-24-7-365-real-time-carbon-free-energy-matching>
- <https://www.theverge.com/2022/6/9/23160508/corporate-renewable-energy-misleading-rec-power-purchase-climate>
- At least in 2021.12.2 revision 2, see: <https://github.com/NREL/SAM/issues/1130>

Files, details, and more screenshots at:

<https://github.com/williamhobbs/PVPMC-2022>