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

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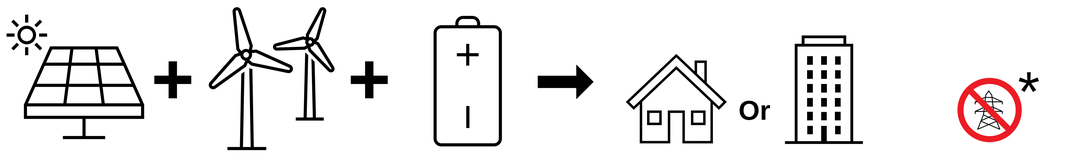
Summary

- 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.



(*approximately)

“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 Annual Unmet Load		PV capacity (kW): 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:

e.g.

SAM Grid Target Annual Unmet Load		PV capacity (kW): 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%

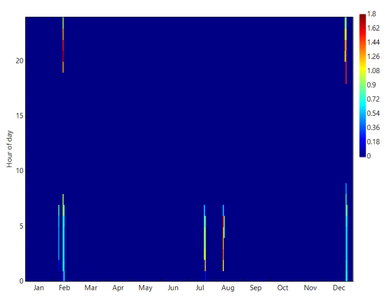
PV+ES in SAM vs. HOMER (Legacy)

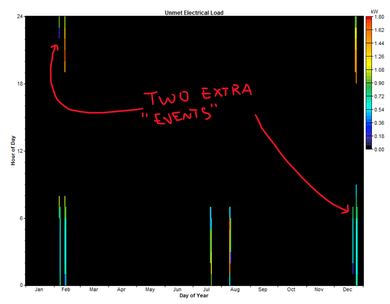
SAM can give very similar results to the "legacy" version of HOMER (v2.68) for off-grid PV plus battery system sizing.

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

HOMER Annual Unmet Load		PV capacity (kW): 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:

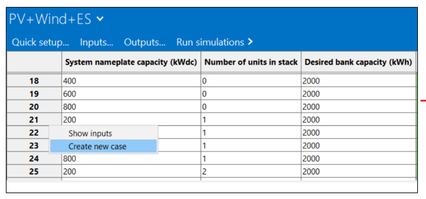
Multiple ways to get to 100%

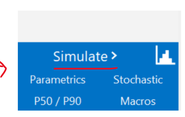
Cost and land constraints could easily be considered

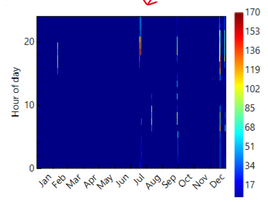
Input value ranges can be iterated on to “zoom in” on design space

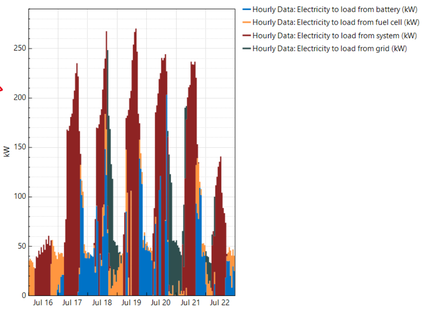
Specific cases can be explored: right click case number, “Create new case”, “Simulate”, and dive deep…

Battery Capacity (kWh)	SAM Annual Unmet Load	PV Capacity (kWdc) 200	400	600	800	Number of 250 kW Wind Turbines
	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

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References

[1] 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
[2] https://www.theverge.com/2022/6/9/23160508/corporate-renewable-energy-misleading-rec-power-purchase-climate
[3] 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