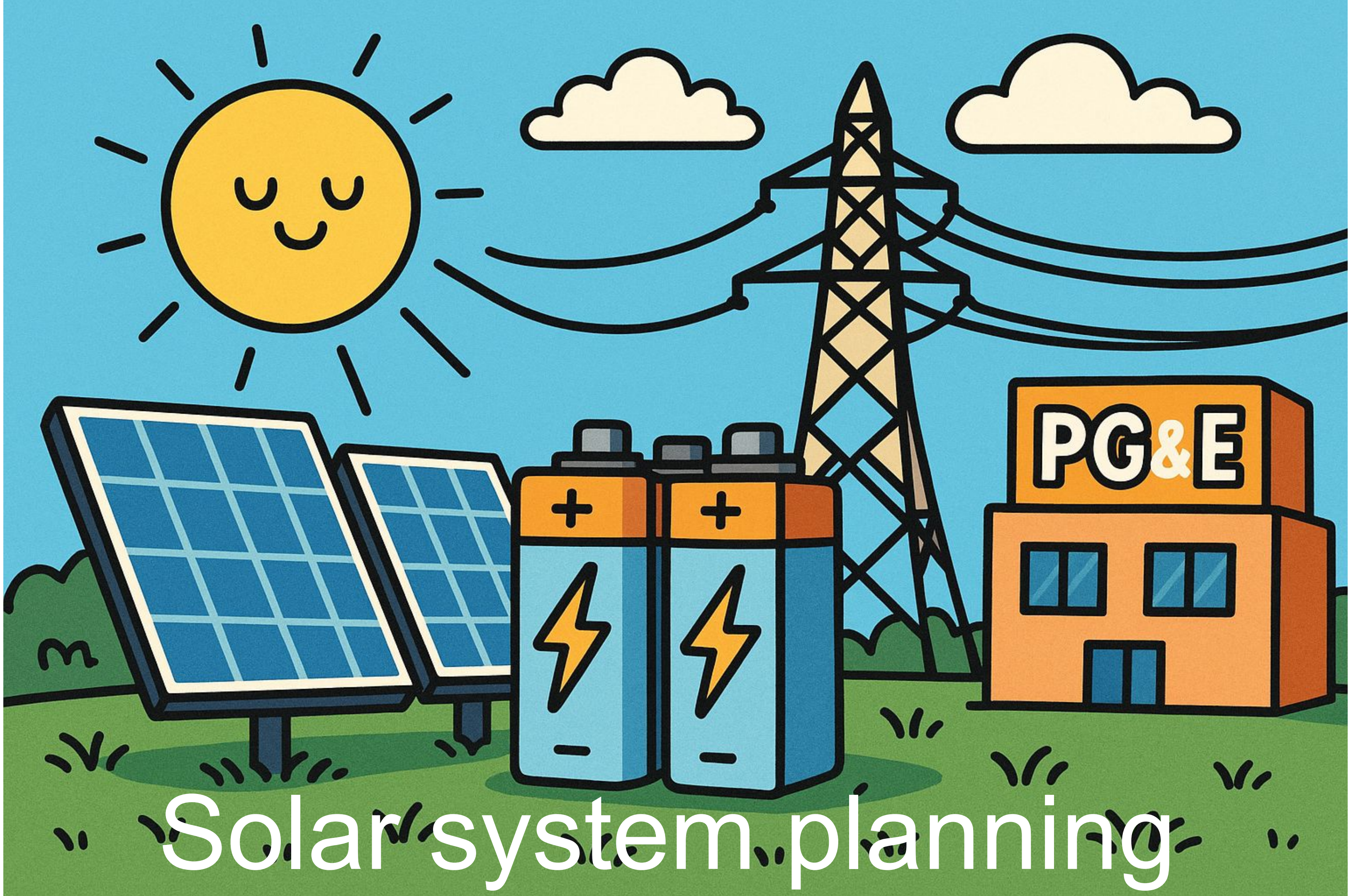


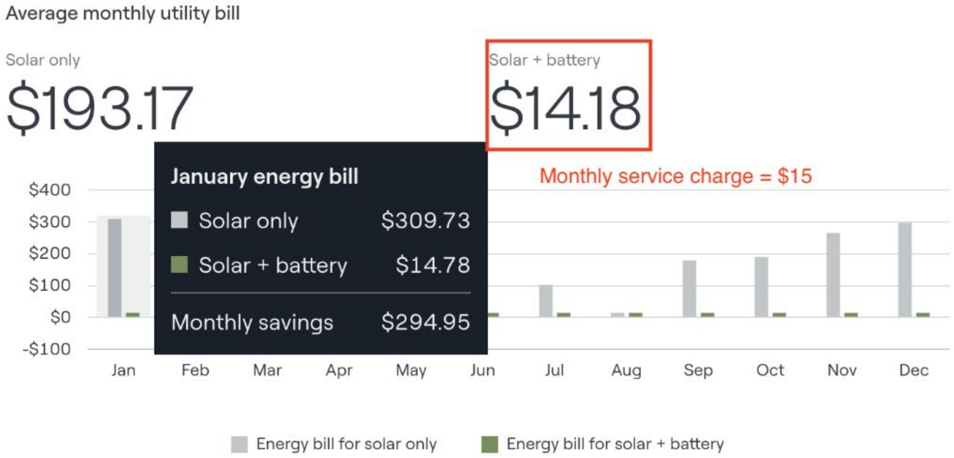
Solar system planning

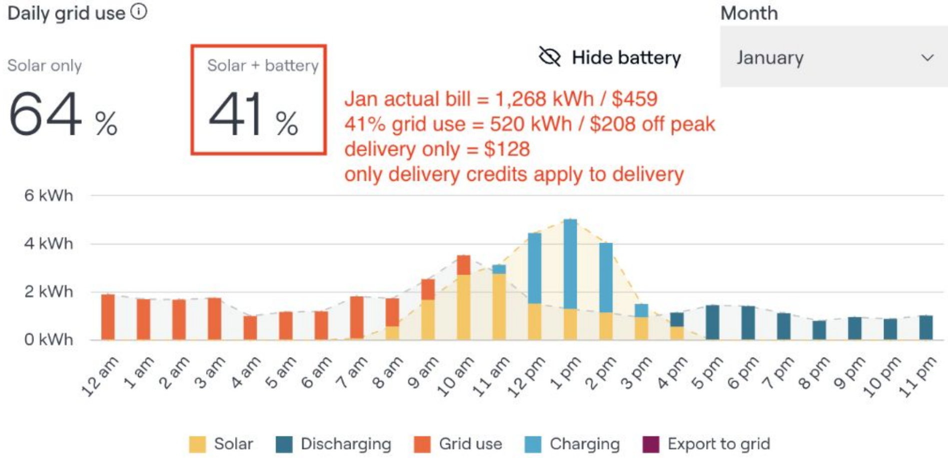
Solar company math

The quote from the solar company makes big claims, does not explain their methodology, and is internally inconsistent.

Response: “You gave me your hourly data so I can be accurate within my aurora program. My proposals include your hourly PGE data vs the hourly credits from PGE.”

System specs: 10.44 kW solar panels, 30 kWh battery

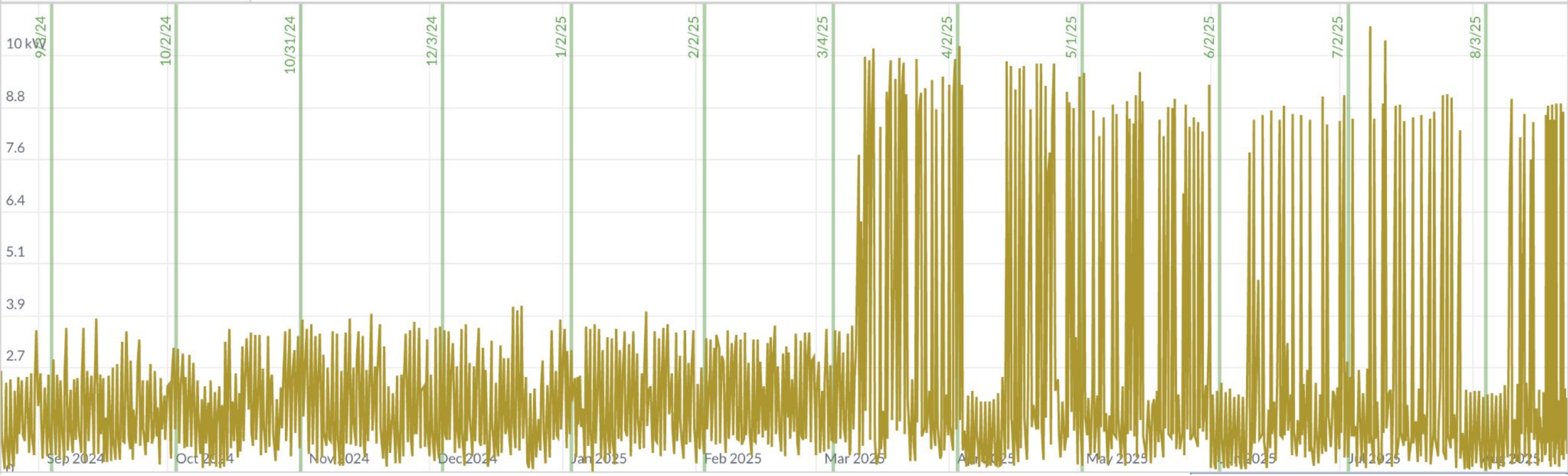




Setup

1 year of hourly interval data from PG&E

- Added EV charging in March

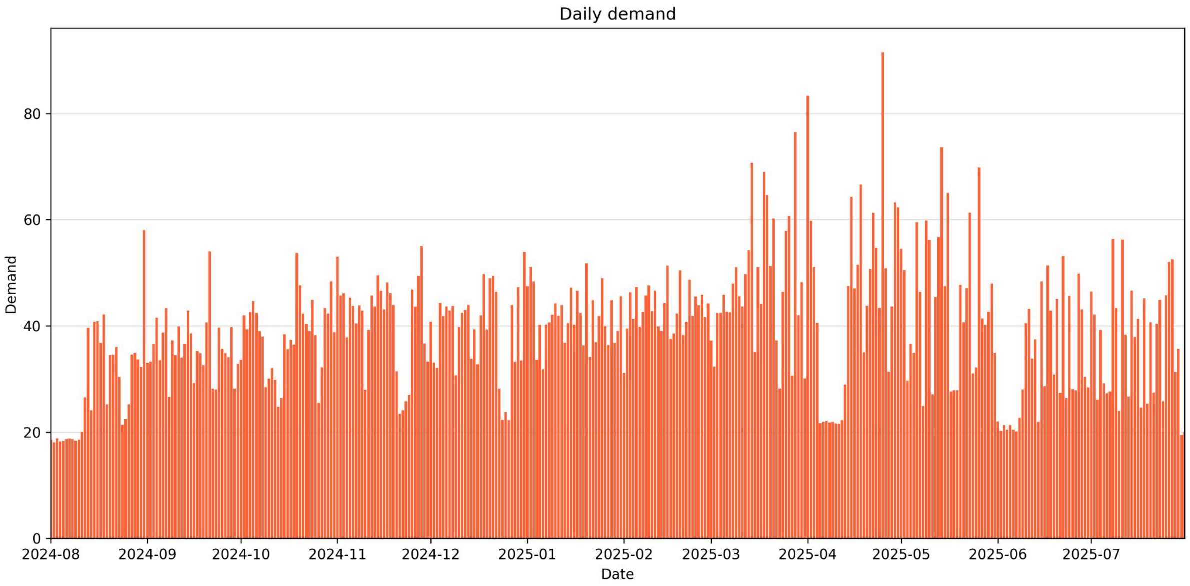


Load curve surgery

Copy 12-3am charging data to

- May -> Jan, Mar, Jun, Oct, Nov, Dec (winter)
- Apr -> Feb, Nov (winter)
- Jun -> Sep (summer)
- Jul -> Aug (summer)

Swap 12-3am / 12-3pm for EV charging when solar is available.



Daily usage pattern

- 33 kWh off peak
- 4 kWh part peak
- 6 kWh peak

= 10 kWh part peak + peak

43 kWh daily

76% of usage and 65% of cost is off peak.

period	use %	cost %	cost $
summer off peak	21%	18%	1,825
summer part peak	2%	3%	324
summer peak	4%	6%	607
winter off peak	55%	47%	4,726
winter part peak	7%	10%	984
winter peak	10%	16%	1,654

Estimating solar output

Get solar output estimates from https://www.renewables.ninja

> Renewables.ninja allows you to run simulations of the hourly power output from wind and solar power plants located anywhere in the world. We have built this tool to help make scientific-quality weather and energy data available to a wider community.

- 10 kW system size
- San Jose, CA
- = 16,962 annual kWh
- higher than solar company estimate: 16,680 kWh for 10.44 kW system

Solar production

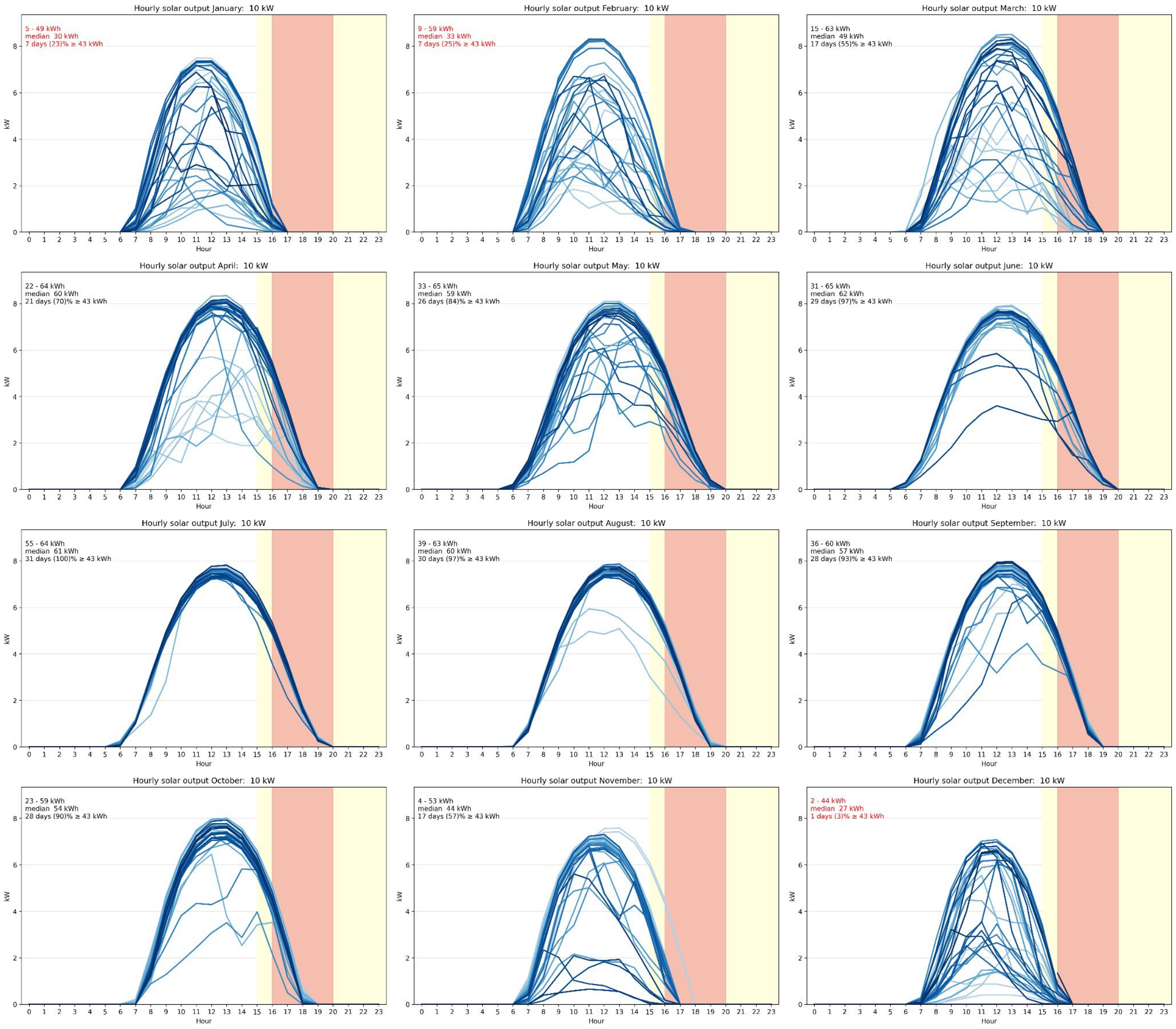
Chart one line per day

Jun-Sep have ideal curves: almost no clouds

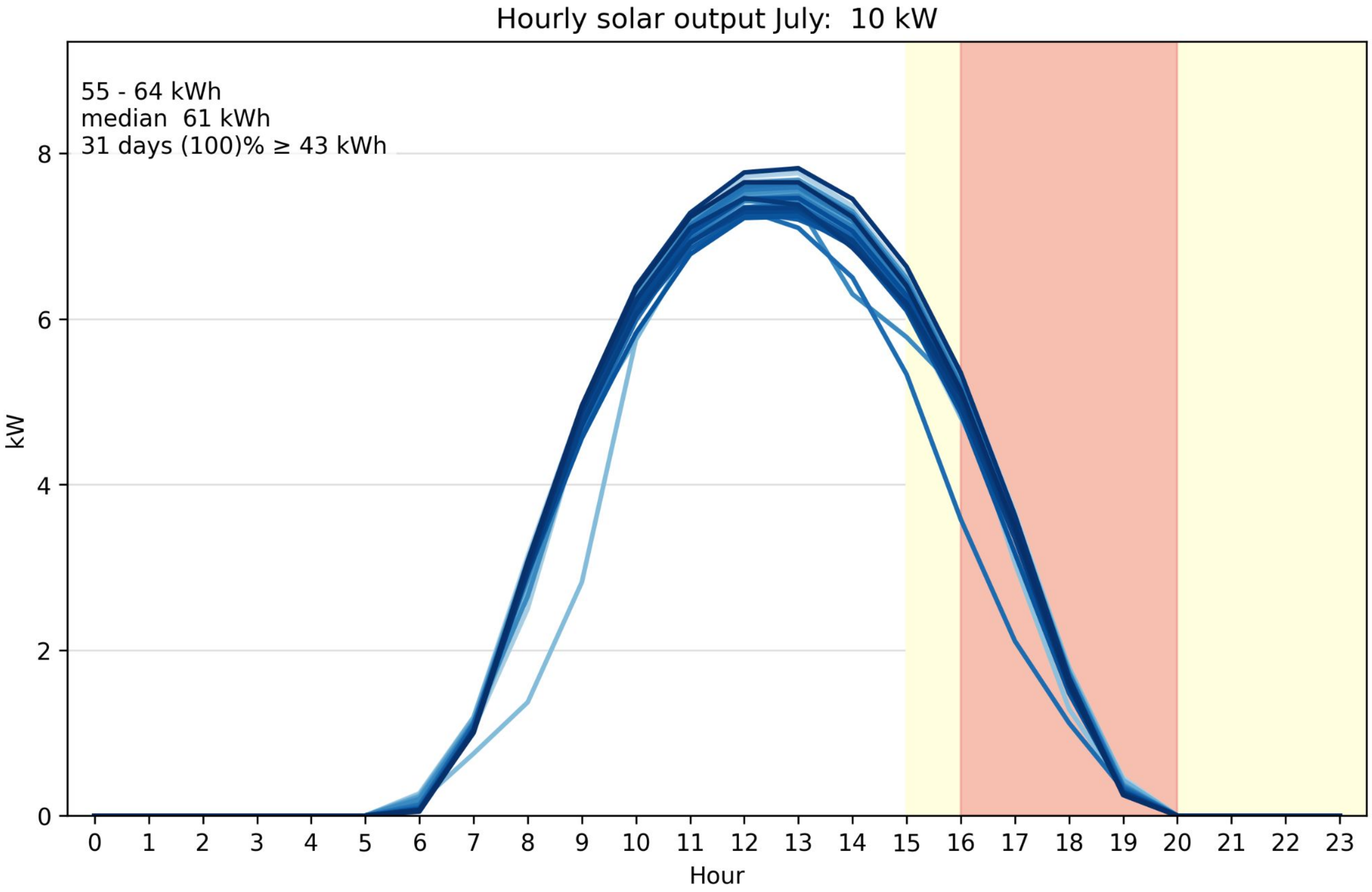
Other months: highly variable

Dec, Jan, Feb don't have enough generation available to cover demand: shorter day, more cloudy days

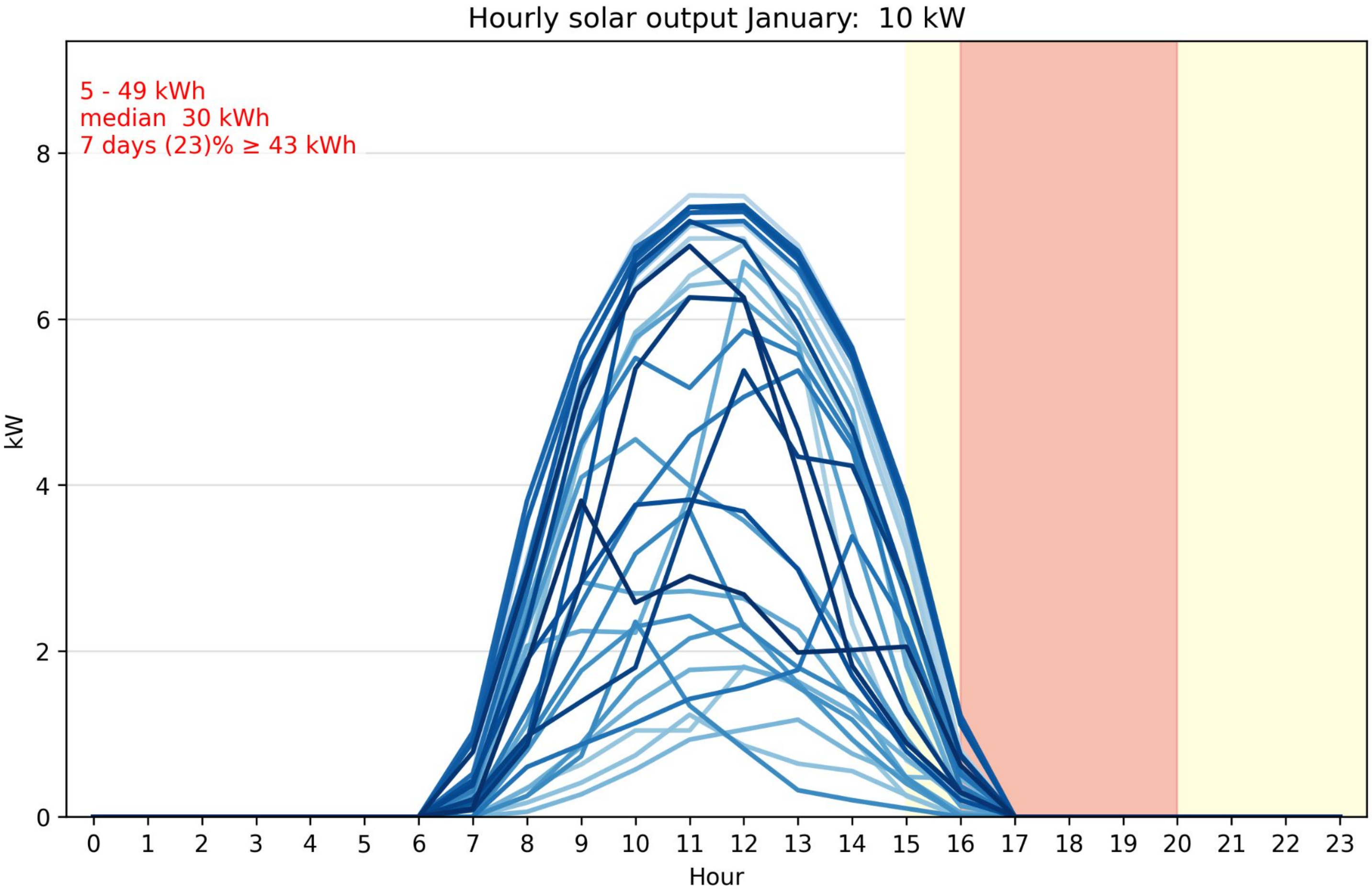
Average is not useful outside of summer



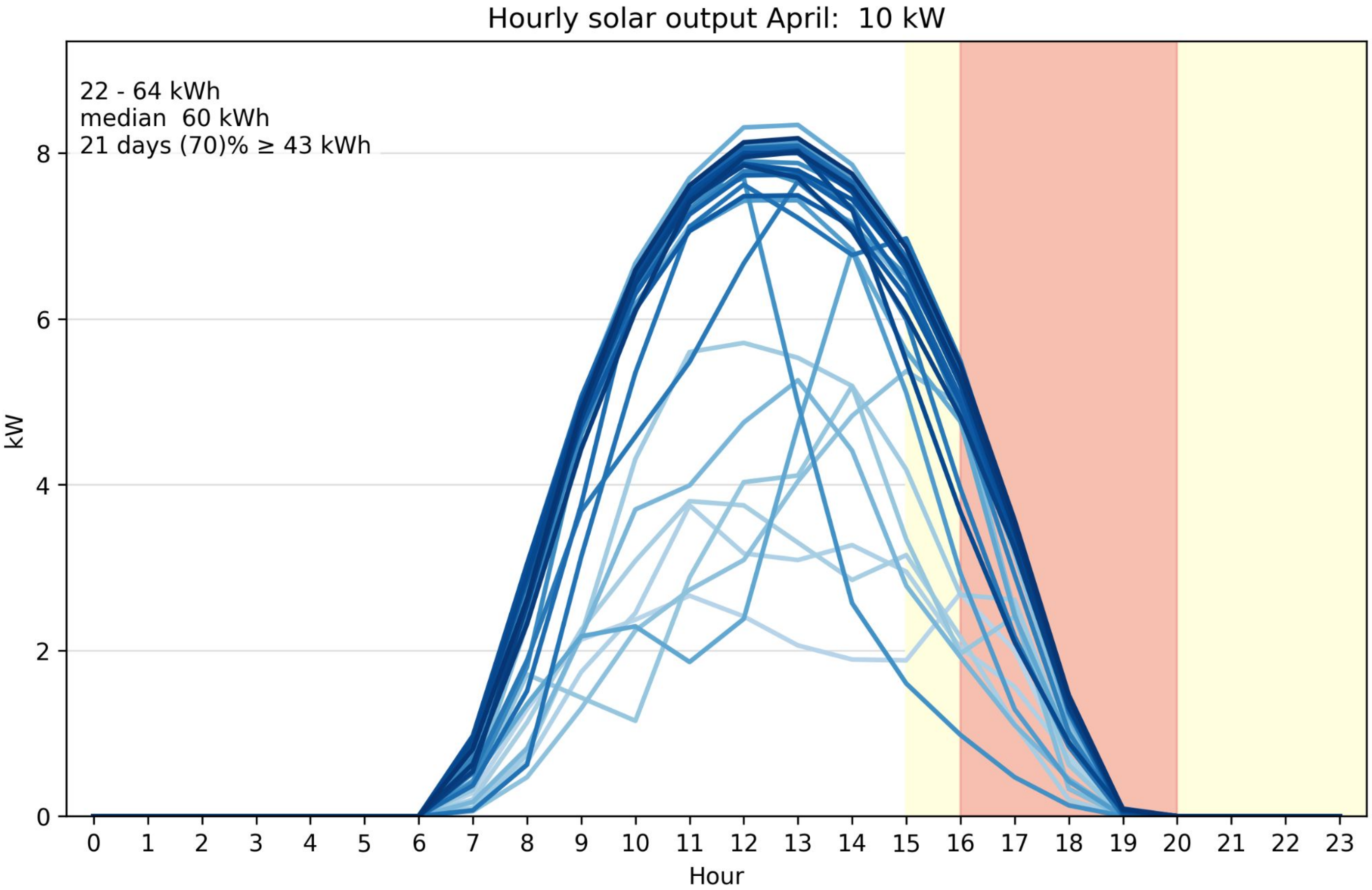
In July, every day meets demand then and mostly charges a 30 kWh battery.



January: only 7 days have enough solar to meet demand.



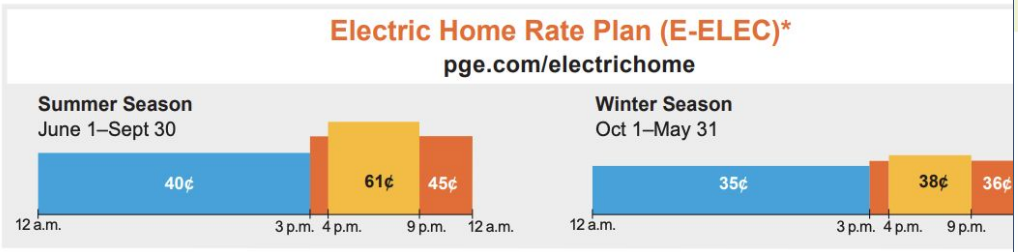
April usually has more solar than demand, and can sometimes charge more than half of a 30 kWh battery.

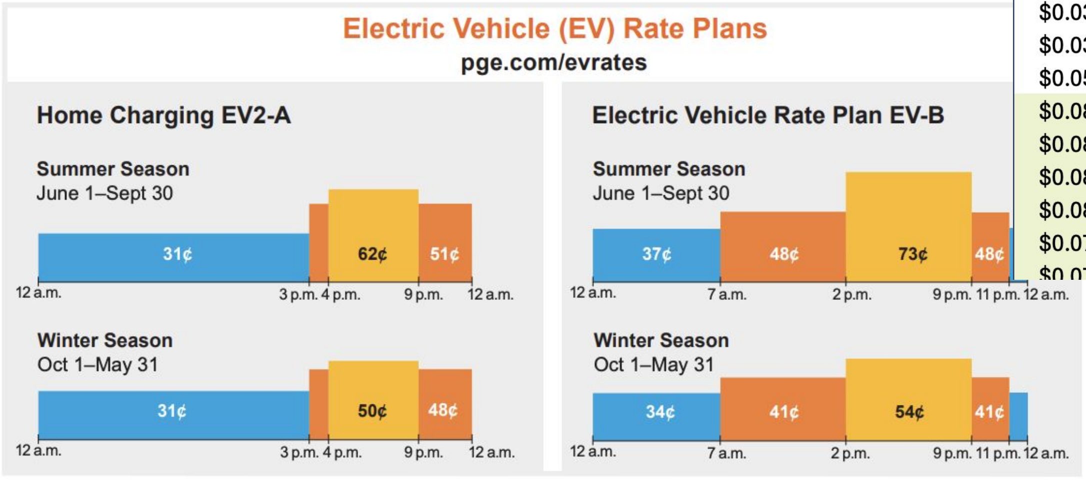


Grid costs

35-40¢ kWh off peak

36-61¢ kWh peak/part peak





June		July			
Produced	Delivered	Produced	Delivered		
$0.07852	$0.00075	$0.07473	$0.00071		
$0.07337	$0.00070	$0.07127	$0.00067		
$0.07268	$0.00069	$0.06752	$0.00063		
$0.07529	$0.00071	$0.06621	$0.00062		
$0.07383	$0.00070	$0.06540	$0.00061		
$0.07667	$0.00073	$0.06661	$0.00063		
$0.07504	$0.00071	$0.07040	$0.00067		
$0.07049	$0.00069	$0.06461	$0.00063		
$0.05487	$0.00058	$0.05969	$0.00063	[illegible]	[illegible]
$0.04449	$0.00052	$0.05132	$0.00059	$0.06218	$0.00071
$0.04135	$0.00052	$0.05400	$0.00063	$0.06226	$0.00072
$0.04034	$0.00059	$0.05246	$0.00067	$0.06145	$0.00076
$0.03882	$0.00065	$0.05193	$0.00069	$0.06059	$0.00080
$0.04334	$0.00074	$0.04916	$0.00068	$0.06071	$0.00084
$0.03992	$0.00088	$0.04522	$0.00082	$0.06154	$0.00106
$0.03733	$0.00107	$0.04911	$0.00110	$0.06462	$0.00138
$0.03618	$0.08798	$0.05079	$0.08579	$0.07626	$0.08096
$0.05069	$0.17827	$0.06280	$0.25738	$0.66147	$0.16364
$0.08480	$0.18219	$0.09141	$0.26637	$0.68795	$0.24457
$0.08322	$0.17885	$0.09787	$0.34781	$0.79492	$0.23911
$0.08626	$0.08946	$0.10352	$0.17201	$0.90727	$0.08156
$0.08087	$0.00137	$0.08649	$0.00167	$0.71849	$0.00181
$0.07461	$0.00097	$0.07906	$0.00114	$0.69841	$0.00123
$0.07359	$0.00073	$0.07349	$0.00075	$0.08707	$0.00087

Below is the table of values for t
Bonus Credit based on custome

	Residential $/kWh
2023	$0.022
2024	$0.018
2025	$0.013
2026	$0.009
2027	$0.004

Credits based on value to the grid. Published for 20 years; guaranteed for 9 years. Generation and delivery **credited separately**.

Methodology

Label TOU periods according to tariff rules:

- 3-4pm, 9pm-12am part peak
- 4-9pm peak
- 12am-3pm off peak

Load hourly solar output model

Create flow model for each period

- timestamp, demand, solar_generation
- start_battery_level, end_battery_level
- from_solar, from_battery, from_grid, to_battery, to_grid

In winter, use battery in off peak if it's at least 10 kWh: might need all daily solar production to offset peak usage.

In summer, let battery go lower (2 kWh) since it will likely refill.

Flow model

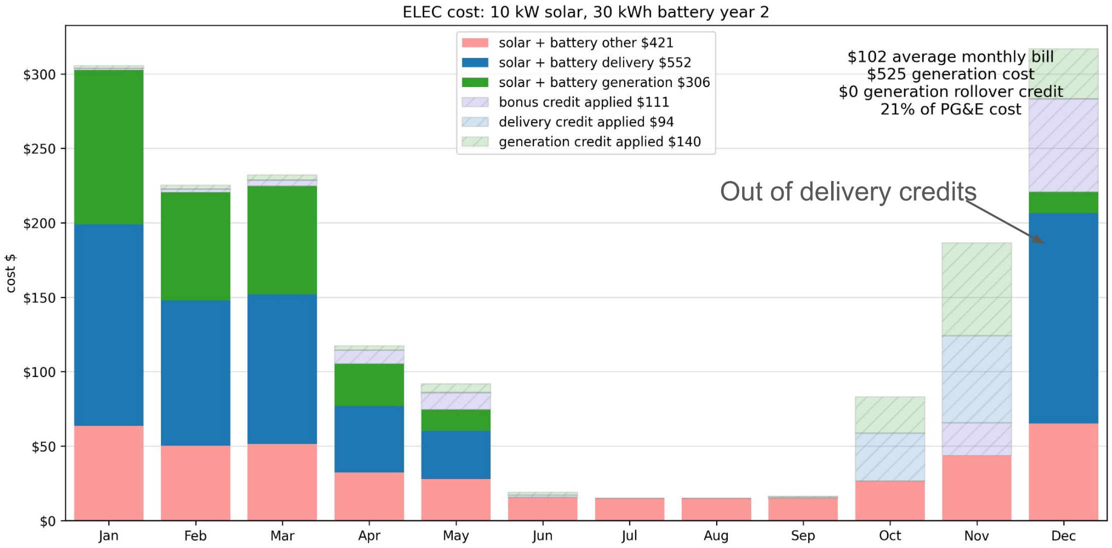
All periods	
Use all available solar generation for demand (from_solar).	
peak and part peak	**off peak**
Use all available battery (from_battery)	Draw from battery, maintaining minimum battery level (from_battery)
All periods	
Draw from grid (from_grid)	
If excess (solar_generation > from_solar), charge battery to capacity (to_battery)	
Export remainder (to_grid).	

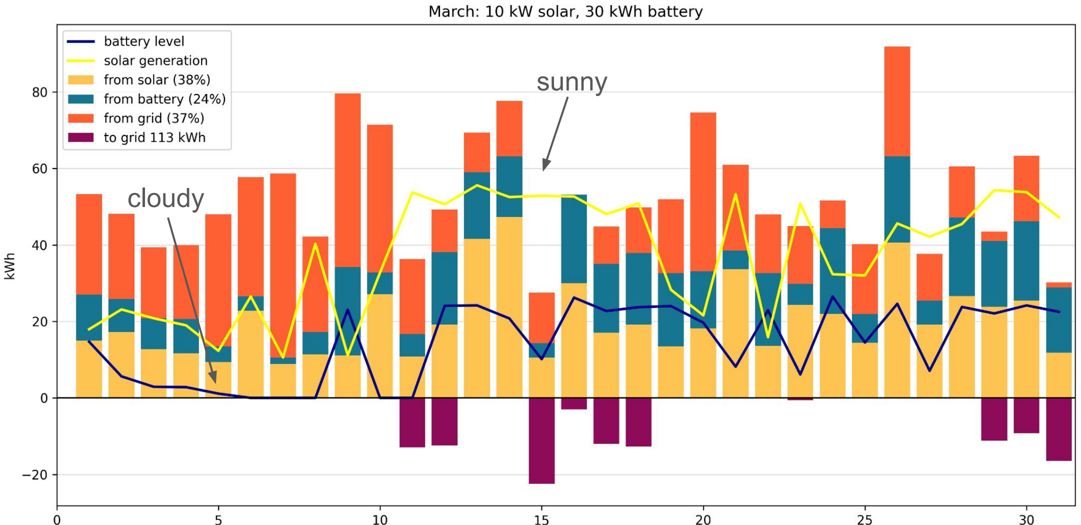
Calculate costs

Rate = per-kWh cost from period and tariff

Calculate credits for generation and delivery based on variable hourly values. Excess credits roll over to the next year.

- Generation cost
- Generation credit
- Delivery cost
- Delivery credit





Spreadsheet version

Timestamp	period	demand	solar_generation	start_battery_lev	end_battery_leve	from_solar	from_battery	from_grid	to_battery	to_grid	cr
8/4 7:00	summer off peak	0.98	0.00	21.54	20.56	0.00	0.98	0.00	0.00	0.00	
8/4 8:00	summer off peak	1.03	0.00	20.56	19.52	0.00	1.03	0.00	0.00	0.00	
8/4 9:00	summer off peak	1.14	0.00	19.52	18.39	0.00	1.14	0.00	0.00	0.00	
8/4 10:00	summer off peak	2.06	6.21	18.39	22.54	2.06	0.00	0.00	4.15	0.00	
8/4 11:00	summer off peak	1.05	7.10	22.54	28.58	1.05	0.00	0.00	6.05	0.00	
8/4 12:00	summer off peak	8.58	7.54	28.58	27.54	7.54	1.04	0.00	0.00	0.00	
8/4 13:00	summer off peak	6.46	7.54	27.54	28.62	6.46	0.00	0.00	1.08	0.00	
8/4 14:00	summer off peak	0.98	7.15	28.62	30.00	0.98	0.00	0.00	1.38	4.79	
8/4 15:00	summer part peak	0.94	6.36	30.00	30.00	0.94	0.00	0.00	0.00	5.42	
8/4 16:00	summer peak	1.01	5.12	30.00	30.00	1.01	0.00	0.00	0.00	4.11	
8/4 17:00	summer peak	0.91	3.48	30.00	30.00	0.91	0.00	0.00	0.00	2.57	
8/4 18:00	summer peak	0.36	1.63	30.00	30.00	0.36	0.00	0.00	0.00	1.27	
8/4 19:00	summer peak	0.40	0.25	30.00	29.85	0.25	0.15	0.00	0.00	0.00	
8/4 20:00	summer peak	0.42	0.00	29.85	29.43	0.00	0.42	0.00	0.00	0.00	

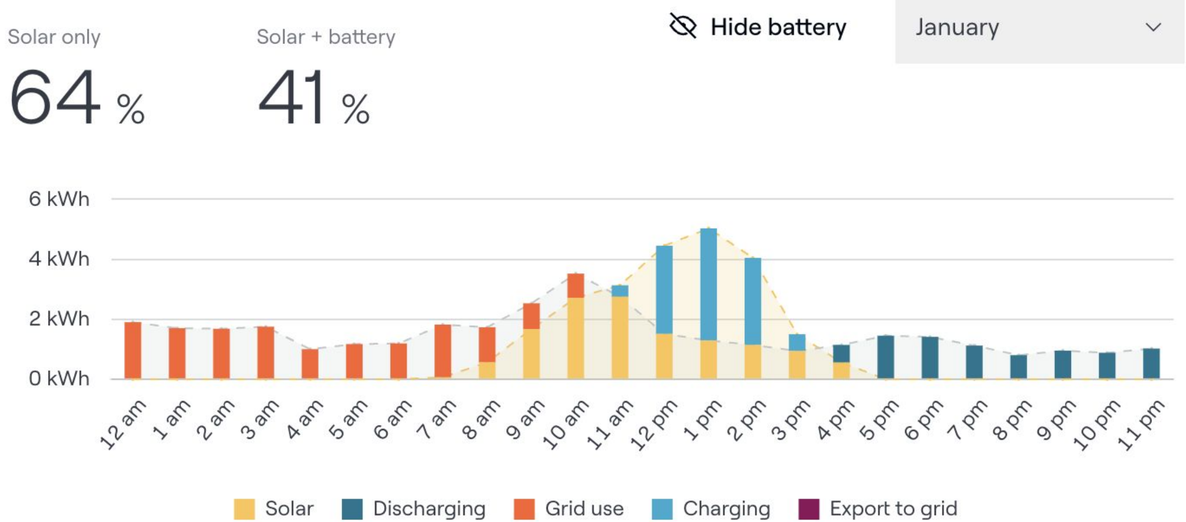
Hourly averages are misleading

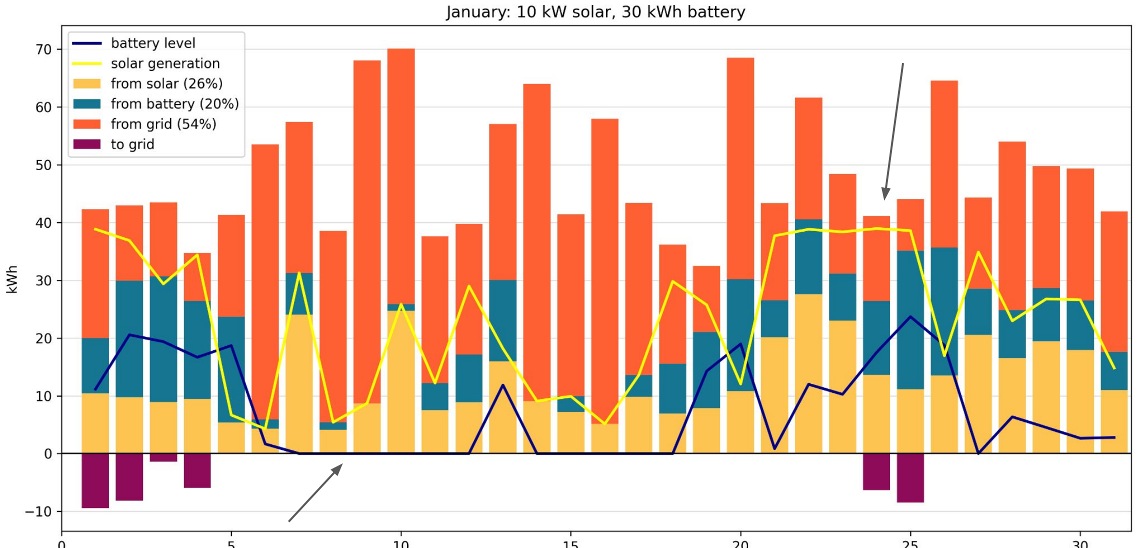
Quote: "most typical day of the selected month"

No such thing in rainy/cloudy season.

Runs of cloudy weather will drain the battery.

Runs of sunny weather will fill the battery, creating exports.



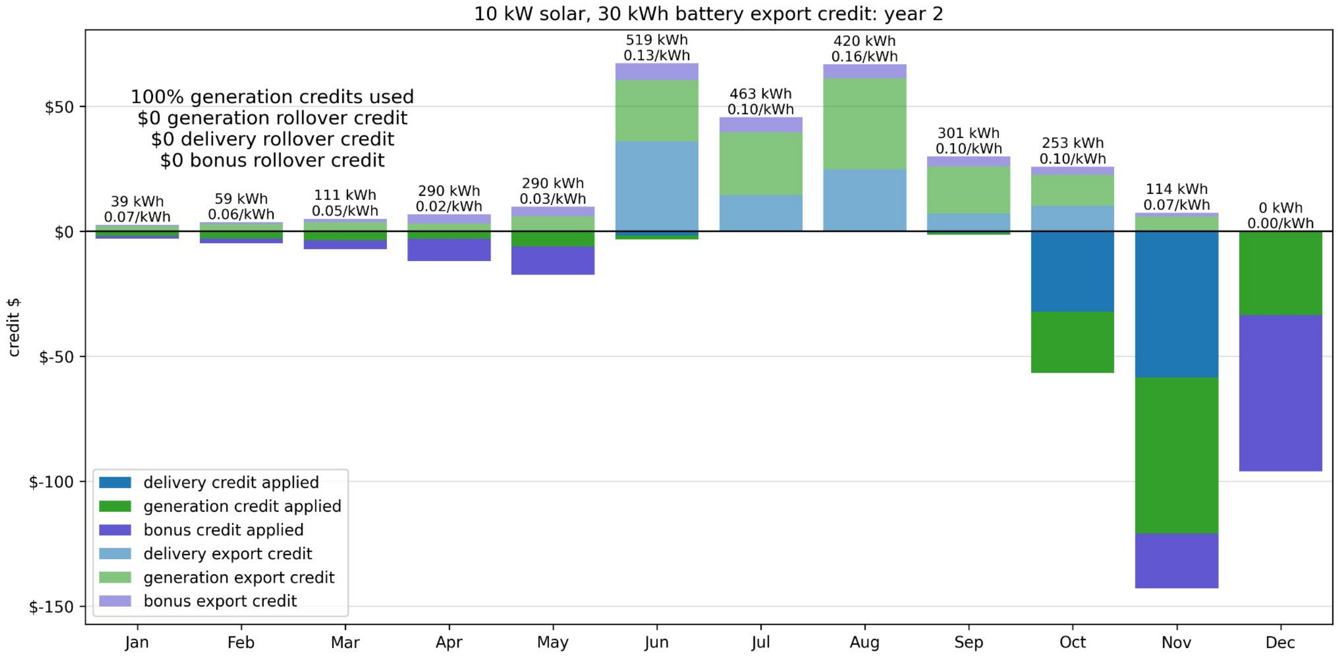


Export credits from summer do not offset winter use

Export credits are based on value to grid. Highest value is during peak periods / lower solar production. Weekend rates are sometimes 0 but rates do not vary by weekday/weekend.

Delivery credits offset delivery charges (⅔ of bill); generation credits offset generation charges. Credits do not apply to other charges (5.7¢/kWh) or monthly service charge ($15).

Average credit is 4-5¢/kWh: 11% of off peak rate. Sell 1 kWh for 4¢ in July, buy for 35¢ in January.

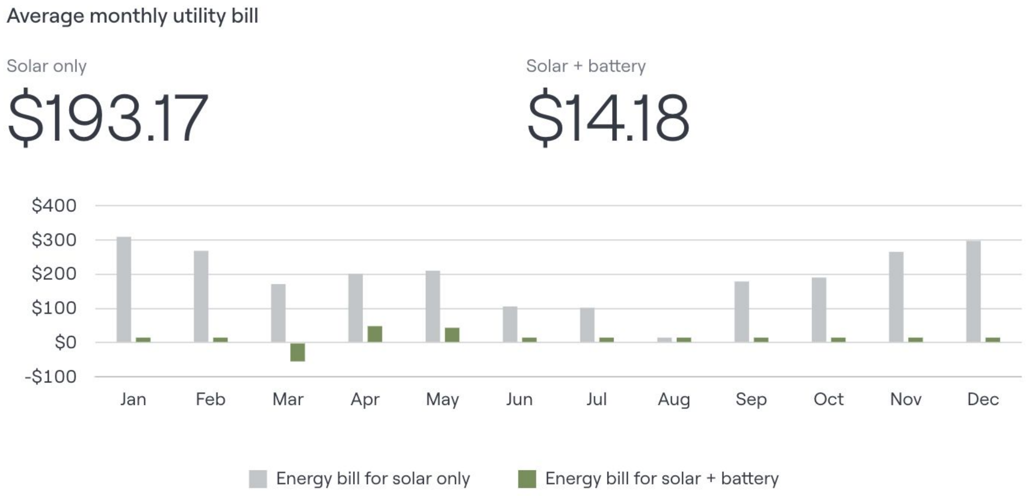


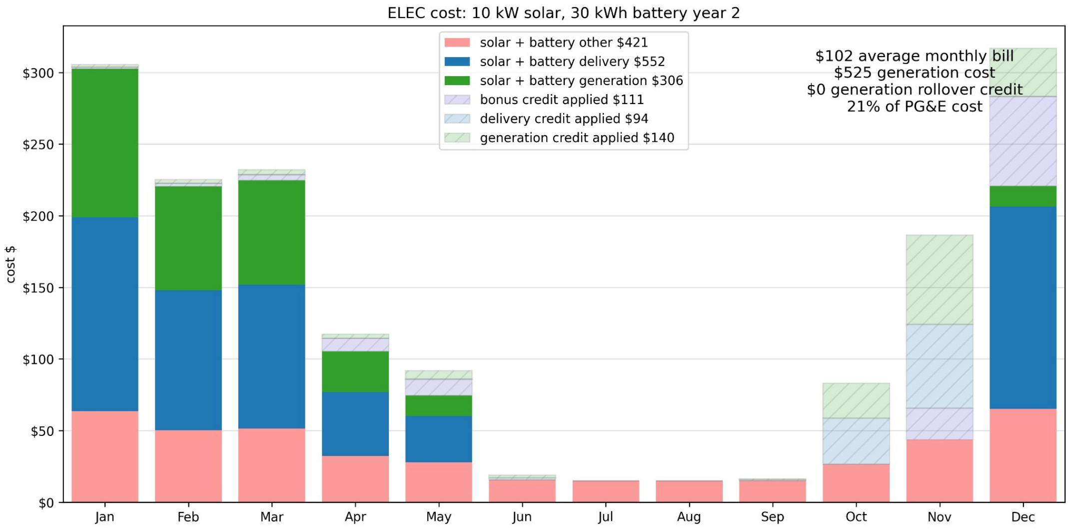
Cost estimates are very different

Solar company: $14, including winter months with low solar production

Flow model: $102, lower in summer.

- $15 monthly service charge
- Delivery is ⅔ of bill but generates fewer export credits
- Credits don't apply to other charges (5.7¢/kWh)



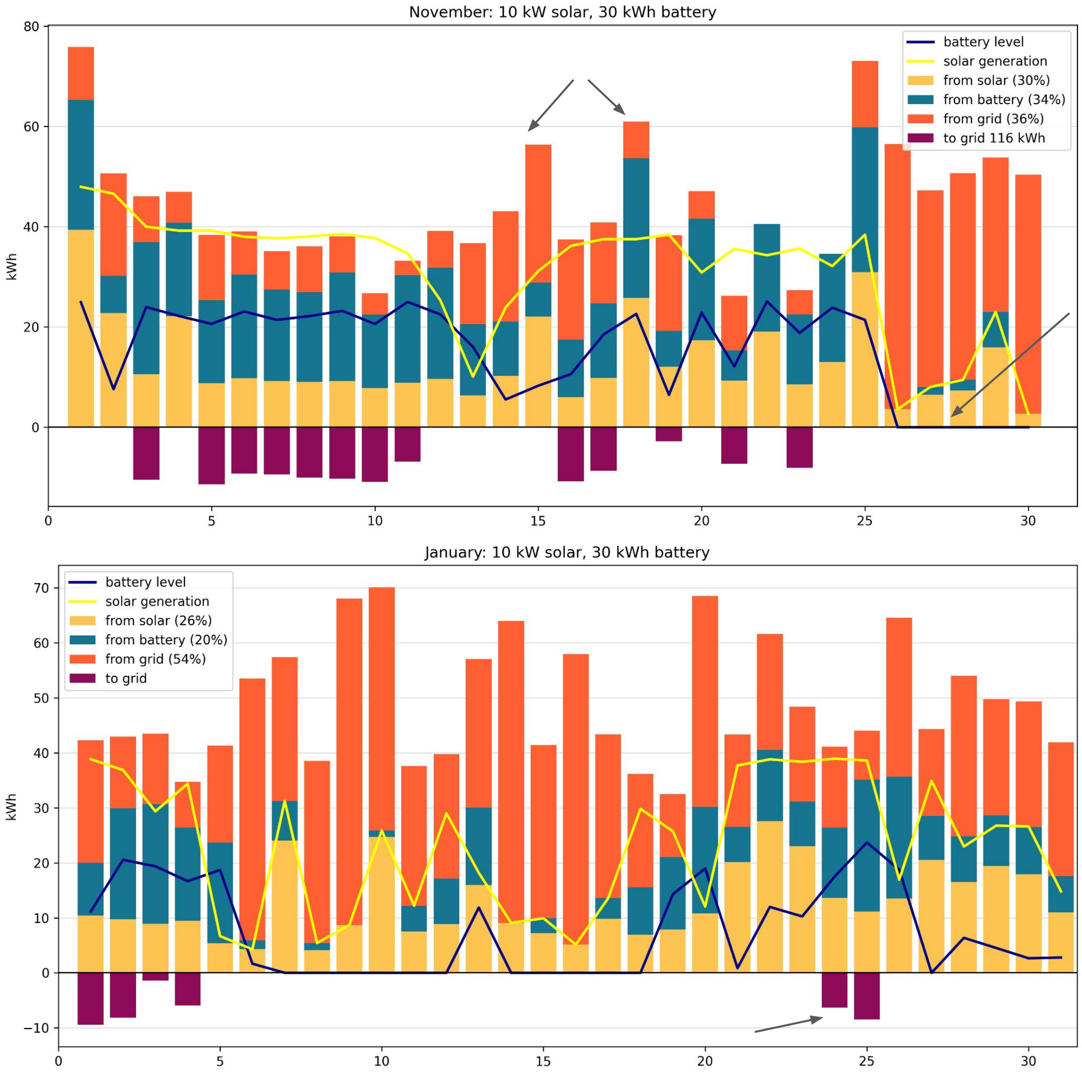


Variable patterns

EV charging can increase daily use by 50%, but is not every day.

Solar output may be low for days at a time, and the battery can drop to 0.

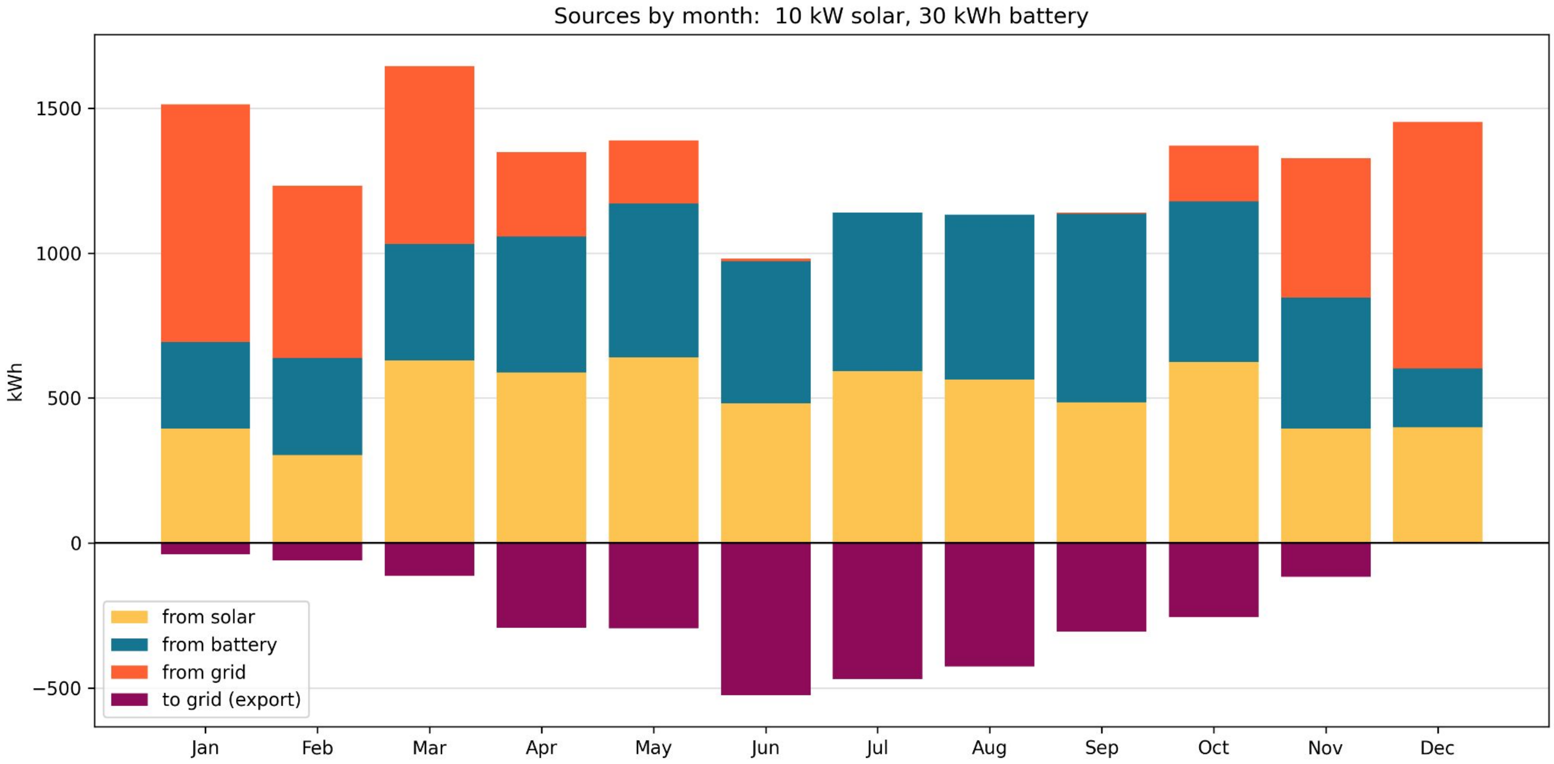
In Dec-Feb, there's usually not enough solar available to cover demand. But even in January, a 30 kWh battery sometimes fills, creating exports.



Base: 10 kW panels and 30 kWh battery capacity

July and August are solar+battery only; June and September almost are.

Some export in all but December: runs of sun overfill the battery but runs of cloud require grid.



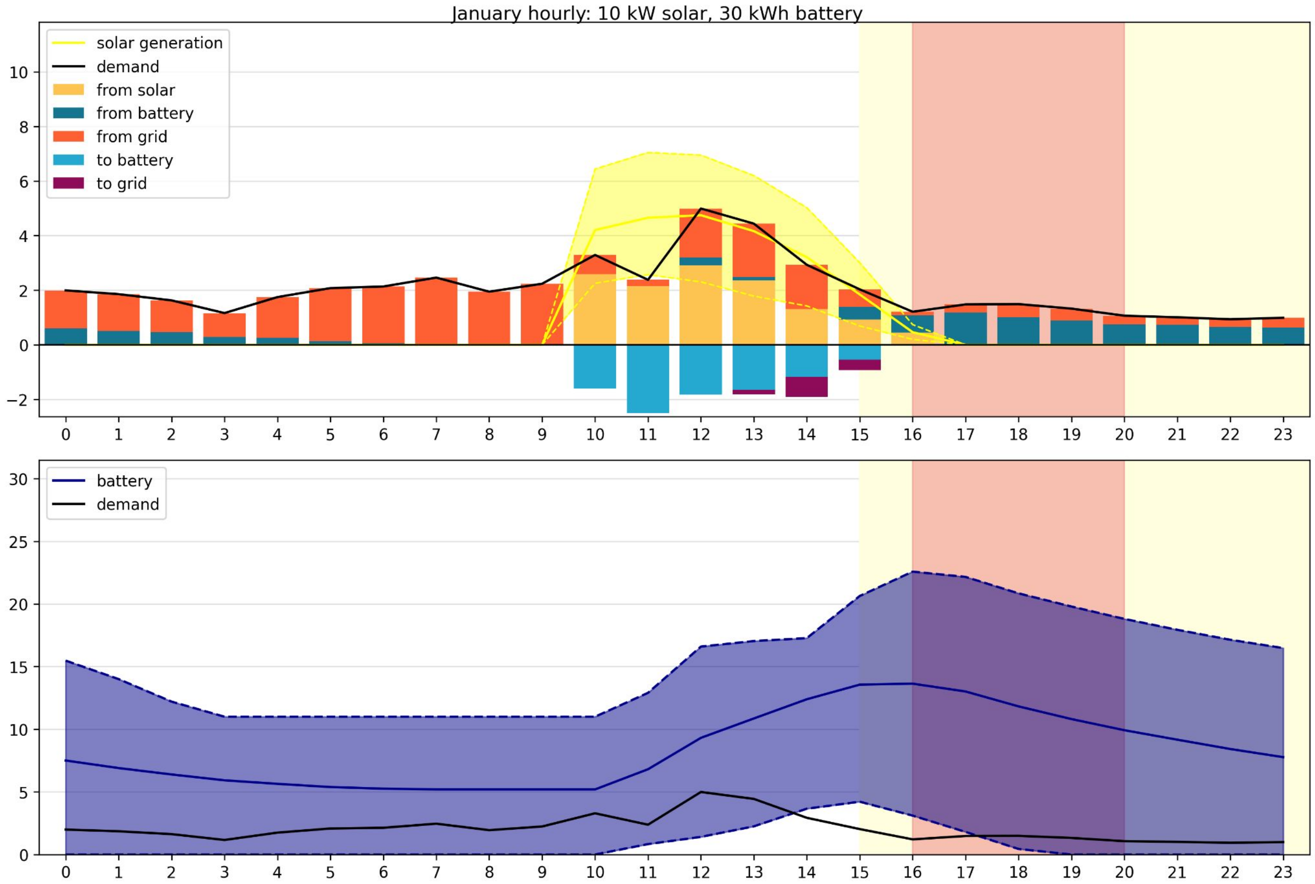
January

Solar is variable, usually not enough to cover demand.

A sunny week creates exports.

The battery is often near empty.

Shading is 25-75th percentiles.

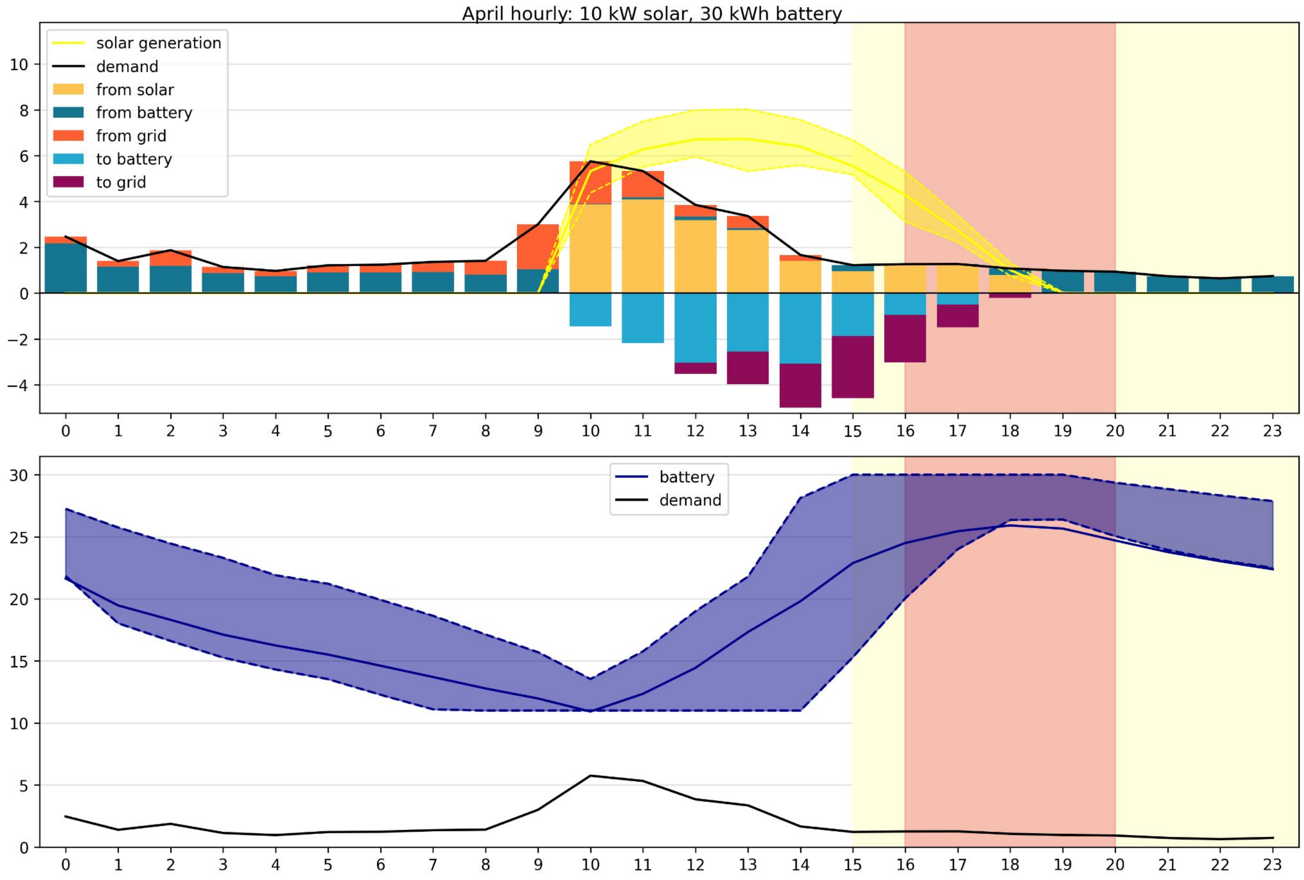


April

Solar is more reliable, mostly covering demand.

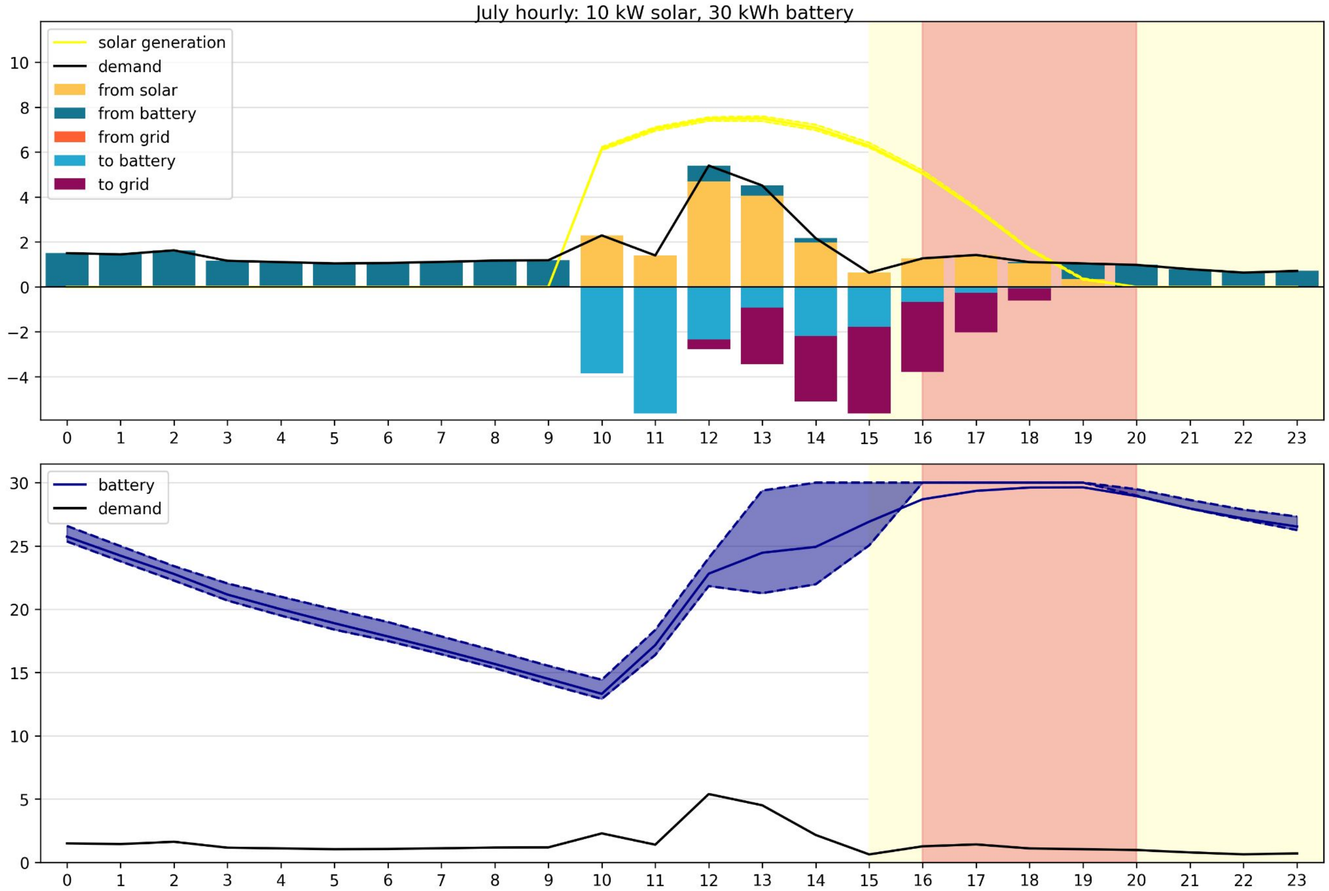
Battery level bottoms out at reserve level.

Used summer/winter battery levels, but might want to adjust monthly: Apr is different than Jan.



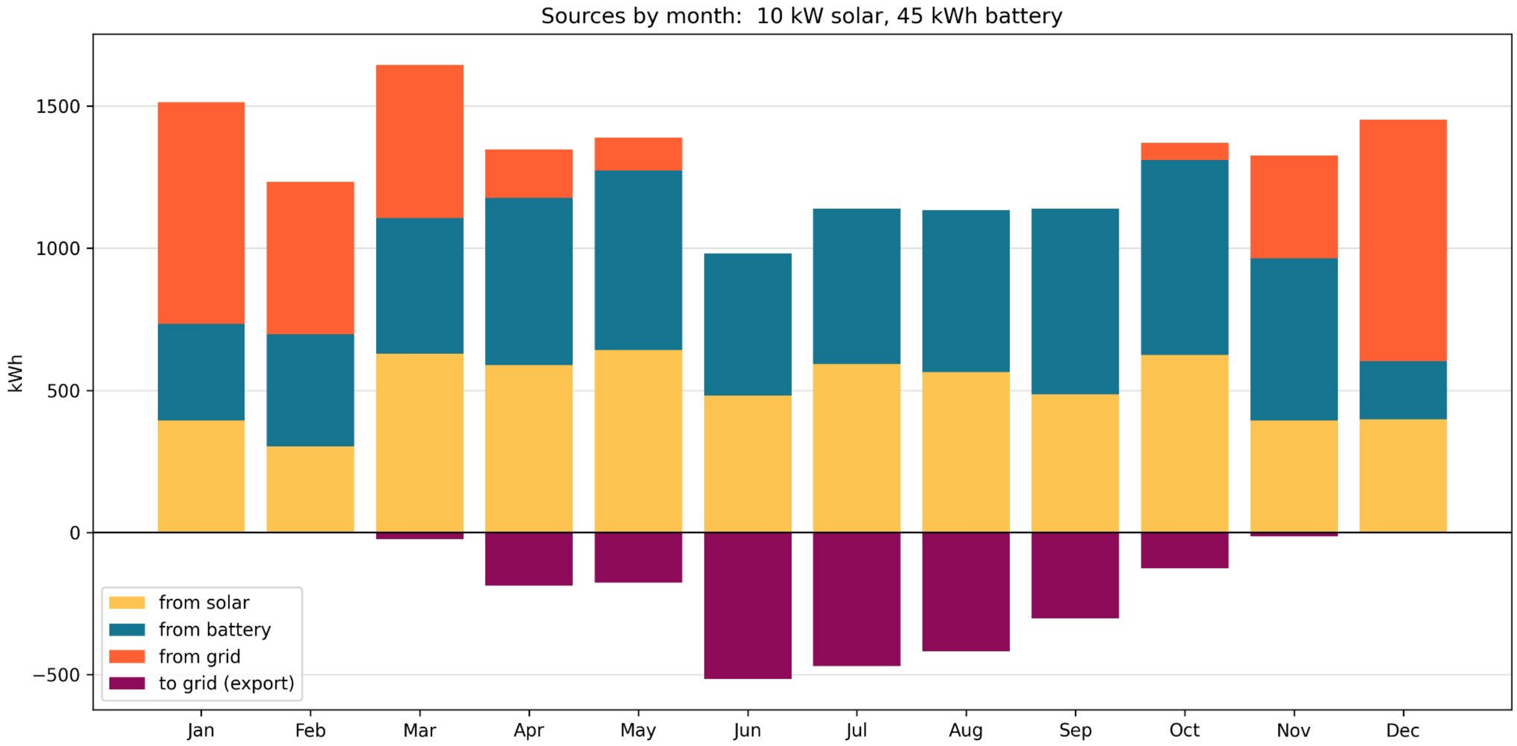
July

Consistently sunny conditions keep the battery overflowing.



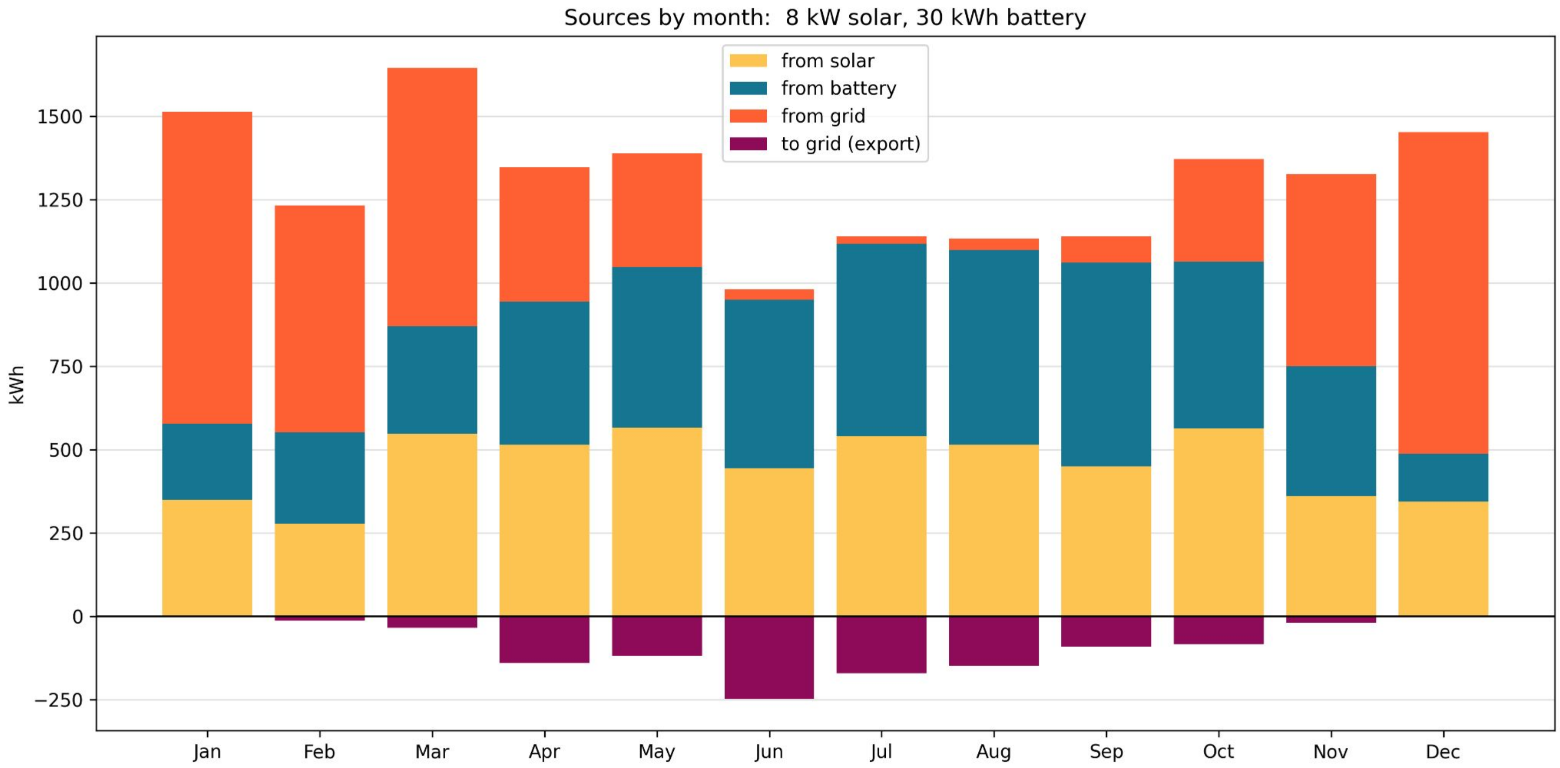
More battery: 10 kW panels and 45 kWh battery capacity

Solar generated when the battery is full is a waste: the 4¢/kWh credit is a fraction of grid rates. With more storage capacity, we could replace $0.35-0.61 grid use. But batteries are expensive: $14k for 15 kWh capacity unit ($910/kWh).



Fewer panels: 8 kW panels and 30 kWh battery capacity

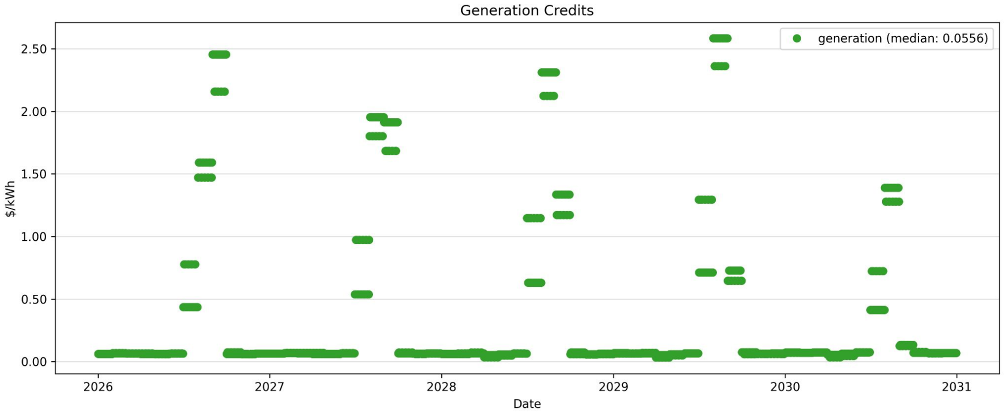
Reduce generation to reduce grid export waste. Fewer panels cost less. Summer months show low grid use, but also exports. How can these be better matched?



Arbitrage opportunities

PG&E 20 year schedule has a few hours with much higher than usual export rates.

A	B	C	E
DateTime	**generation credit**	**delivery credit**	**total credit**
8/29 19:00	0.98	0.22	1.20
8/30 18:00	0.33	0.32	0.65
8/30 19:00	0.98	0.22	1.20
8/31 19:00	0.91	0.14	1.05
9/1 18:00	2.99	0.02	3.01
9/1 19:00	3.37	0.02	3.38
9/2 18:00	2.99	0.02	3.01
9/2 19:00	3.37	0.02	3.38
9/3 18:00	3.41	0.07	3.47
9/3 19:00	3.84	0.06	3.90
9/4 18:00	3.41	0.07	3.47



Arbitrage model: days with export value > peak

Before max daily export hour
Use all available solar generation to charge battery (to_battery)
If battery at capacity, use remaining solar for demand (from_solar)
Draw from grid to meet remaining demand (from_grid)
Max daily export hour(s)* max battery discharge is 10 kW; may need 2 hours
Export from battery (from_battery, to_grid)
Draw from grid for demand (from_grid)
After daily export hour
Draw from grid: no solar output, empty battery (from_grid)

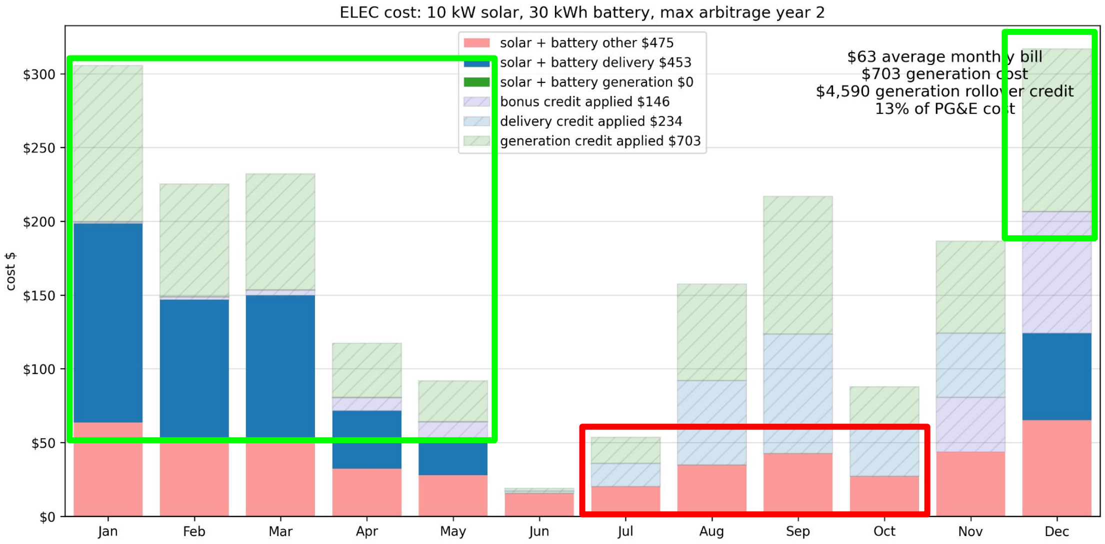
Arbitrage results

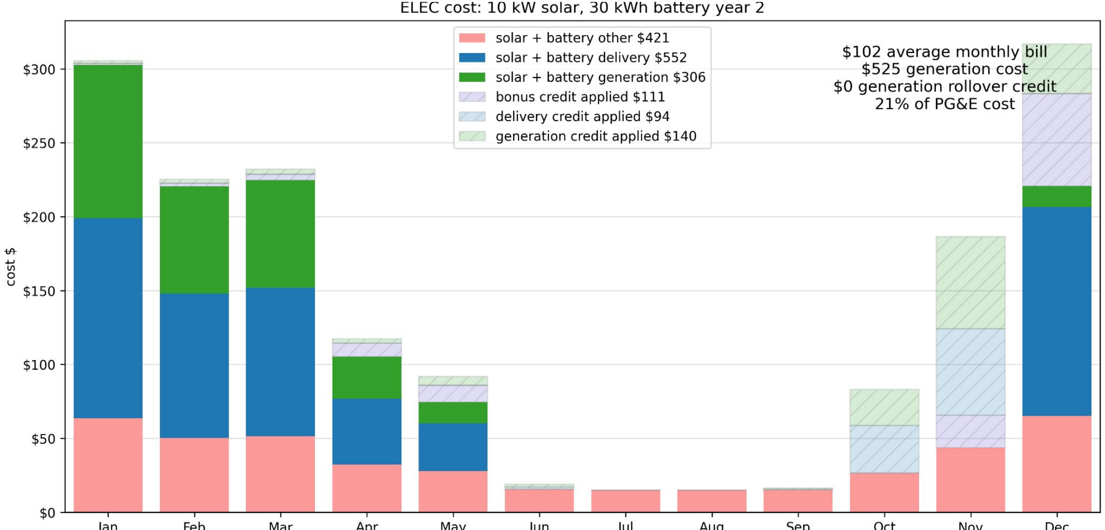
Generate massive generation credits!

- only apply to generation (⅓ of bill)
- grid use instead of battery 7pm-morning; peak/part peak until midnight
- delivery credits mostly used up replacing what could've been battery
- non-bypassable costs (5.7¢/kWh) on additional grid use add up

Generation costs go to 0, but delivery + other costs for winter months still significant.

Cost is lower: it works. But not as much value as high export values might indicate.





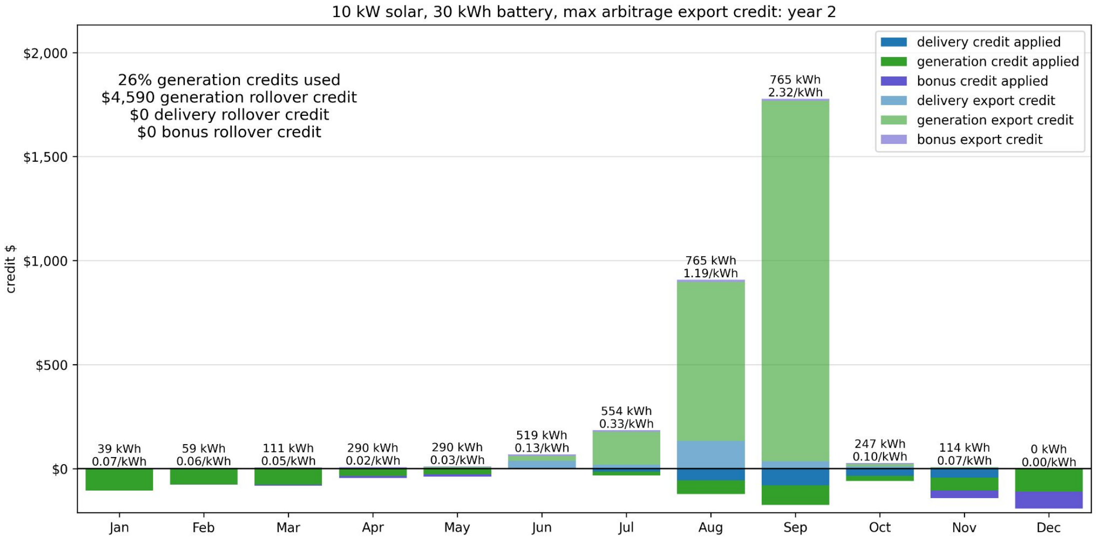
Arbitrage results

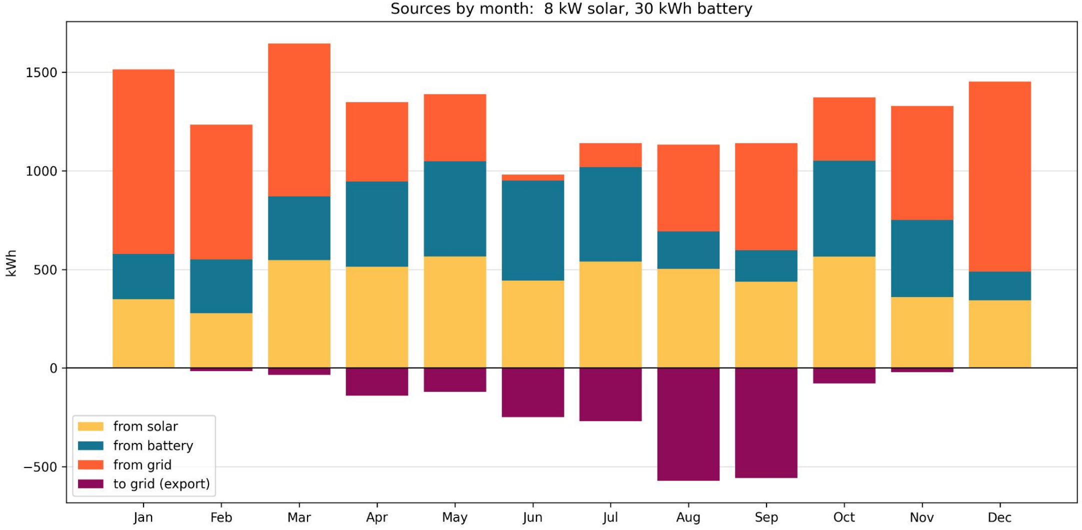
Sep '26	Credit	Future peak use
Generation	\$2.52, \$2.31	7.7 hr
Delivery	\$0.067, \$0.069	0.3 hr

Not 100% solar in summer months.

Delivery credits don't fully offset future use.

Credits roll over, but decrease in value as rates increase.



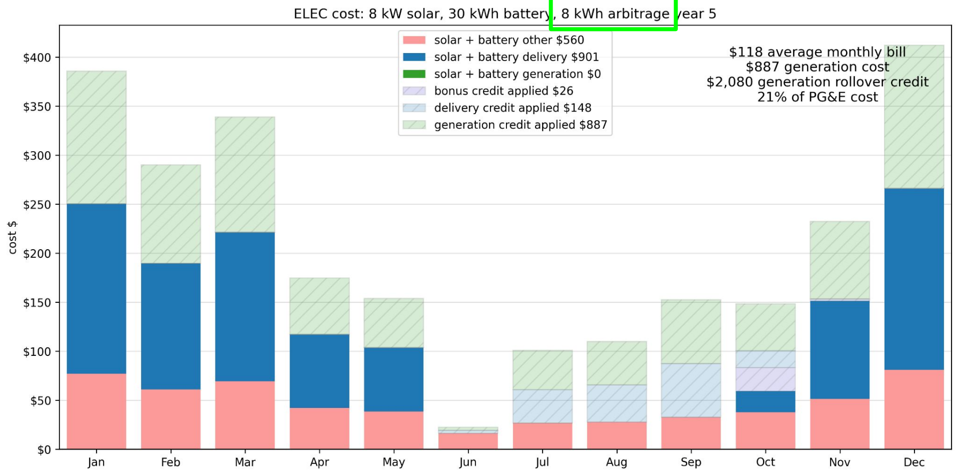


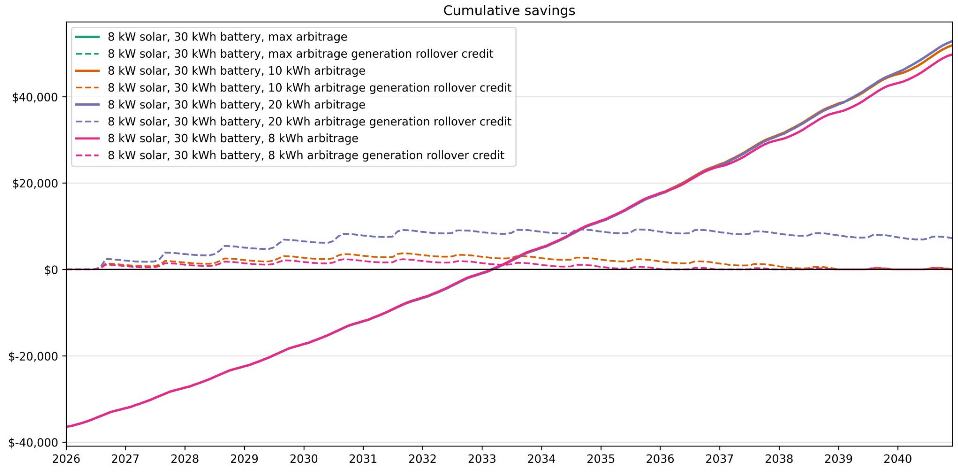
Arbitrage results

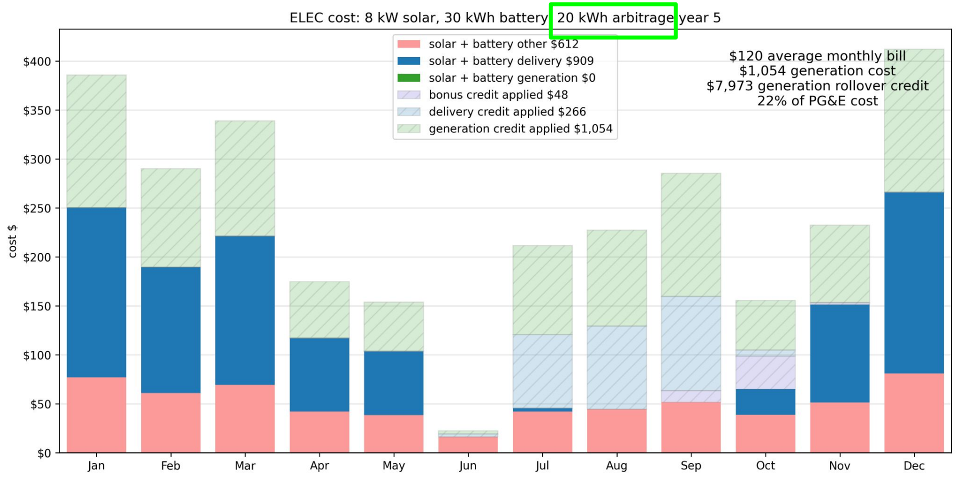
Tested 30, 20, 10, 8, 6 kWh exports.

8 kWh is the sweet spot: balances high credits vs additional grid use.

PG&E: “There is no financial benefit to installing a system larger than your home needs.”







Cost review

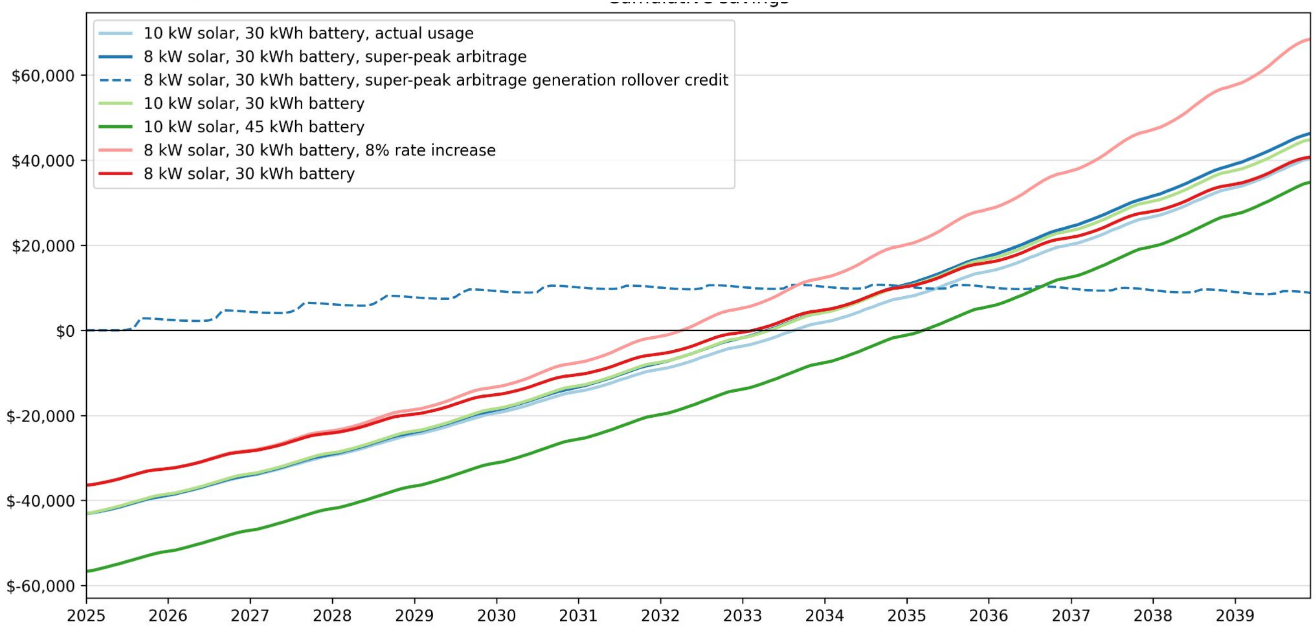
Battery is too expensive.

10 kW catches up eventually but it takes a long time.

Arbitrage generates massive credits. But generation credits can't be fully used & more grid use.

With: high electricity costs, high solar output, 30% install cost credit: **not a good investment on $ terms**.

Scenario	Payback years	ROI	Solar usage
8 kW solar, 30 kWh battery, 8 kWh arbitrage	8.6	1.03%	65%
8 kW solar, 30 kWh battery, 8% rate increase	8.8	1.15%	67%
8 kW solar, 30 kWh battery	9.6	0.86%	67%
10 kW solar, 30 kWh battery	9.8	0.81%	74%
10 kW solar, 45 kWh battery	11.7	0.52%	78%



Other considerations

Solar company quote shows ROI but that’s not the right metric; more like a kitchen remodel

Reduced grid dependence

Really is solar power (see How clean is your clean power?)

Battery backup for power outages (but maintaining reserve requires grid use)

Variables & assumptions

- Solar model quality & future weather patterns
- Change in use patterns
  - - school commute (EV usage)
  - + induction stove, heat pump (replaces gas heat, but during winter), A/C, 2nd EV
- Rate change forecast
  - used 4% to match quote
  - 10 year median = 5%
  - average = 8% (> 10% 2022-2024)
- Maintenance
  - Linear warranties
- 15 year ROI period: from battery warranty
  - Solar panel warranty is 25 years product, 30 years performance with 87% output
  - Used -0.04% annual degradation
- Export credit value: based on value to grid (+ solar company lobbying)
  - After 9 years, credit values updated every two years with current energy prices
- Solar panel prices
  - -91% last 15 years; -42% last 5 years