Solar Plus Storage
Focus on Storage Benefits
NEM3 Edition

by Tom Rust

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Getting to 100% renewables

- We cannot get to 100% renewables without energy storage
- Solar+Storage
- Wind+Storage

Whole Home Solar+Battery Power

10kw - 22 450 watt bifacial PV modules

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Whole Home Solar+Battery Power

18kw inverters – 2 Sol-ark 12s plus 200A ATS – 45kwh LFP energy storage in 3 15kw blocks.
100A Grid service – 200A home service – all electric home

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Whole Home Solar+Battery Power

27kw inverters – 3 Sol-ark 12s plus 400A ATS – 90kwh LFP energy storage in 6 15kw blocks.
Add on to existing microinverter solar home

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Overview storage products

- Lead-acid
- Lithium ion
  - Nickel Cobalt Manganese (NCM)
  - Nickel Cobalt Aluminum (NCA)
- Lithium Iron Phosphate (LiFePo)
- Lithium Titanate (LTO)
- Flow Batteries

Lithium Iron Phosphate Batteries

- Lithium Iron Phosphate (LiFePo)
- 96-98% efficiency
- 3000-10,000 cycle life
- High DOD (80%+)
- 3.2-3.6V/cell
- -20 to 60C operating temperature
- Much lighter weight than lead-acid
- Safer, better fire resistance than Li-ion
- Tend to allow inverters to operate more efficiently
- Typically can last 10+ years
- Limiting to 80% DOD extends life

Value of Storage Batteries

- To evaluate batteries, calculate the actual lifetime dollars per kWh ($/kwh)
  - Typical lead-acid – $350/kwh / (1500 cycles * 50% DOD * 70% RTE1) = $0.67/kwh
  - Lithium - $500/kwh / (5000 cycles * 80% DOD * 85% RTE1) = $0.15/kwh
  - Lithium is 4X+ the value of lead-acid

1 RTE – Round Trip Efficiency = one way efficiency squared – includes inverter efficiency

Value of Storage Batteries

- Another way to evaluate batteries, calculate the actual lifetime dollars per kWh ($/kwh) per the mfg warranty
  - Example: Lithium - $500/kwh / (3500 cycles * 80% DOD * 85% RTE1) = $0.21/kwh

1 RTE – Round Trip Efficiency = one way efficiency squared – includes inverter efficiency

Value of Storage Batteries in Cost Savings

- Arbitrage – moving energy from low rate periods to high rate periods
  - Highest value when high delta off-peak rate vs peak rate
- Demand Reduction – reducing the peaks of energy usage spikes = reducing demand charges
- Backup – prevent loss of assets when grid fails

Storage Markets

- Residential – generally under 10kw
- Small commercial <30kw
- Commercial/Industrial >30kw
- Equity – Disadvantaged Communities & Resiliency
  - Residential
  - Non-residential

CCA Impacts

- East Bay Community Energy
  - New NEM customers can receive up to $2500/year cash back for excess power
- Marin Clean Energy
  - No limit on cash back for excess power
  - Net export annually at 2X PG&E rate (still only about $0.05/kwh)
- Peninsula Clean Energy
  - No limit on cash back for excess power
- Credits can roll over to succeeding years

Some Residential Storage Systems
LFP, NMC and other Lithium

- BMZ
- Custom Power Solar
- LG Chem
- SimpliPhi
- Sonnen
- Sunrun
- Tesla Powerwall
- Darfon

Lithium Iron Phosphate Battery Suppliers cycle life >3000

- Energport
- SimpliPhi
- BYD
- CATL
- Battle Born
- Kilovault
- Renogy
- Fortress
- Enphase
- Blue Ion
- Sonnen
- Discover
- Humless
- Iron Edison
- BigBattery
- EG4
- Dakota
- Orient Power
- Ark
- Homegrid

Shift to All Electric

- Over 50 cities have future bans on natural gas
- Some cities already have bans on installation of new gas hookups
- Shift away from gas furnaces and heaters – no gas heaters sold after 2030
- State shift to all electric vehicles
- Climate goals to net-zero by 2045

All Electric Homes/Businesses

- Heat pump heating, cooling, water heaters
- Induction stoves
- Electric dryers (some heat pump versions)
- All-electric vehicles
- Solar+storage generation

Heat Pump Examples

Mini split heat pump heating/cooling inside and outside units

Heat pump hybrid water heater

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All Electric Home Example Costs

- 1500 sqft home 4 occupants
- Heat pump heating, cooling - $15-25k installed
- Heat pump water heater - $3-5k installed
- Induction stoves – from <$100 for single to $2k for full stove
- Electric dryers (some heat pump versions) $1-1.5k
- Heat pumps 2-3X more efficient than gas
- All-electric vehicles – Bolt $30k Tesla M3 - $47k
- Solar+storage generation 10kw PV 30kwh storage $37k after tax credits – 16,000kwh/yr generation
- Rebates available

All Electric Home Example Costs

- 1500 sqft home 4 occupants
- All except EV - $21k-34k
- Solar+storage generation 10kw+30kwh savings $7.6k/yr – simple payback 4.8yr with EV 3.7yr
- Including all electric appliance cost simple payback 7.6-9.3yr with EV 5.7-7yr

Upgrading 100A service to 200A service

- Often older homes are only 100A service. Upgrading the service entrance wiring to 200A from the utility can run $6000+. But upgrading the service entrance wire from utility to 200A is NOT needed. Solar+storage provides a lower cost solution.
- Sol-ark solution provides a 200A transfer switch, up to 62A of ADDITIONAL power, plus the 100A existing service to power a NEW 200A main panel. The existing 100A panel connections can be left in place.
- Solar+storage with whole home backup + 200A service upgrade WITHOUT the extra cost of a utility service upgrade

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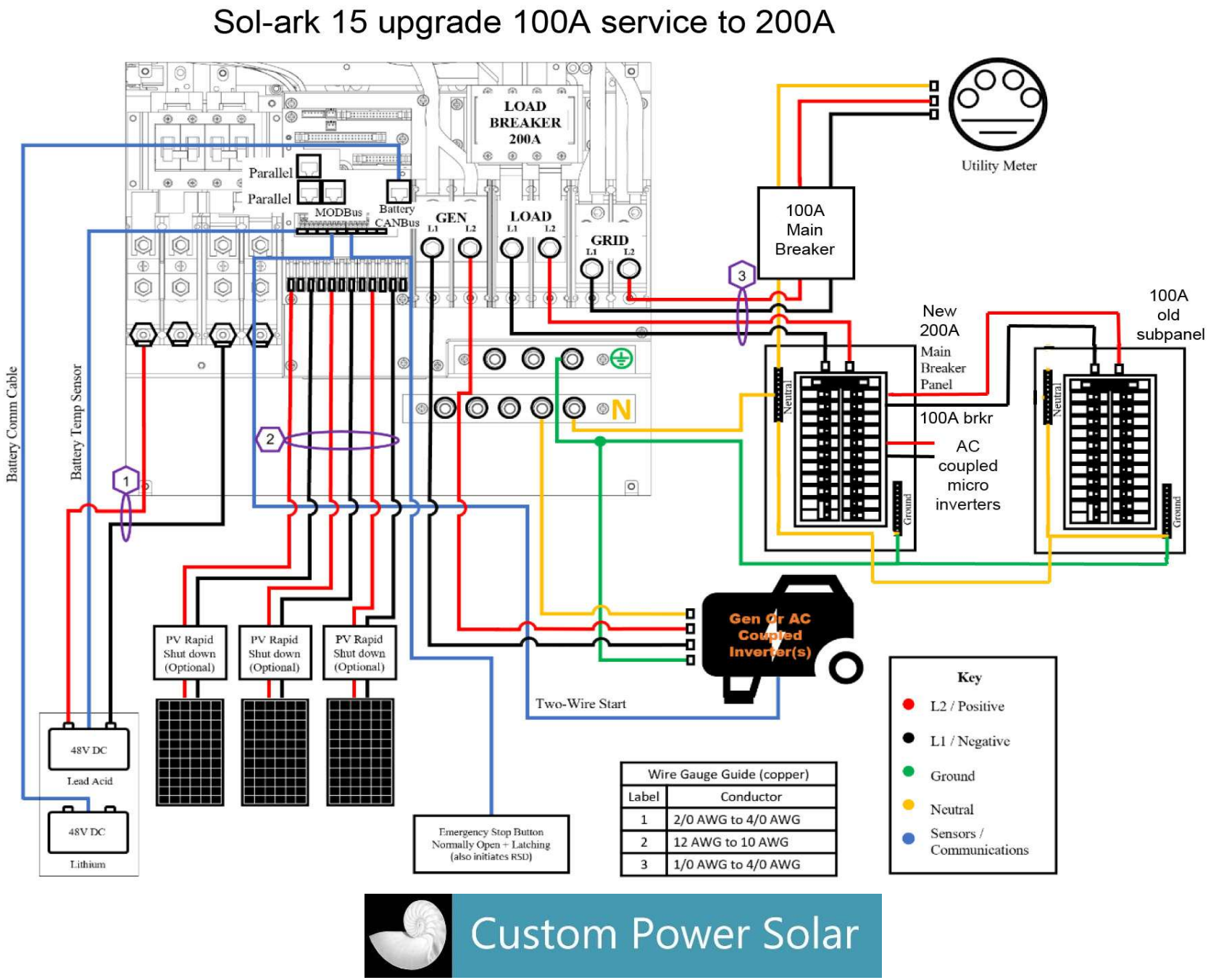
Upgrading 100A service to 200A service



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Finance Options

- Cash - is king for contractors
- Home owner
- Equity Line Of Credit (HELOC)– 3 - 5% typical rate
- PACE funding – payments go on property taxes, 0% down, terms up to 25 years

Residential Storage Only Systems

- Custom Power Solar
- Sol-ark inverter includes automatic transfer switch (ATS) – some with 200A ATS – whole home backup
- CATL LiFePo batteries 6000 cycle 20 year
  - 4kw/13.5kwh - $14k
  - 8kw/27kwh - $21k
- $370/kwh after rebates and Federal Incentive Tax Credit of 26%

[1]Typical Installation costs - costs may vary and does not include permitting costs

Custom Power Solar

NEM3

- New applications after April 23 will go under NEM3
- Any ***usage*** billed at TOU rate.
- ANY ***exports*** credited at value based on Avoided Cost Calculator, with different values for every hour, monthly basis, and weekends different than weekdays.
- Except for narrow window in summer 5-7pm, these values are MUCH lower than retail rates – average $0.10/kwh
- During solar peak, average is even lower - $0.06/kwh

Custom Power Solar

NEM3 – weekday export value

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ave
1	0.0744	0.0751	0.0709	0.0642	0.0707	0.0693	0.0720	0.0746	0.0720	0.0713	0.0703	0.0745	0.0716
2	0.0746	0.0754	0.0728	0.0623	0.0702	0.0693	0.0716	0.0735	0.0714	0.0712	0.0699	0.0742	0.0714
3	0.0739	0.0743	0.0720	0.0609	0.0685	0.0698	0.0713	0.0738	0.0711	0.0711	0.0691	0.0737	0.0708
4	0.0735	0.0741	0.0715	0.0619	0.0697	0.0703	0.0714	0.0736	0.0704	0.0708	0.0687	0.0733	0.0708
5	0.0738	0.0750	0.0719	0.0646	0.0739	0.0705	0.0720	0.0737	0.0705	0.0712	0.0689	0.0734	0.0716
6	0.0751	0.0769	0.0752	0.0667	0.0730	0.0712	0.0733	0.0734	0.0726	0.0722	0.0702	0.0744	0.0729
7	0.0784	0.0811	0.0750	0.0559	0.0517	0.0664	0.0702	0.0742	0.0724	0.0727	0.0727	0.0770	0.0706
8	0.0802	0.0837	0.0615	0.0300	0.0385	0.0630	0.0703	0.0751	0.0677	0.0697	0.0703	0.0790	0.0657
9	0.0790	0.0721	0.0502	0.0273	0.0357	0.0620	0.0733	0.0798	0.0675	0.0679	0.0668	0.0783	0.0633
10	0.0769	0.0658	0.0470	0.0270	0.0355	0.0618	0.0730	0.0792	0.0677	0.0681	0.0666	0.0775	0.0622
11	0.0759	0.0629	0.0463	0.0259	0.0351	0.0618	0.0728	0.0774	0.0670	0.0682	0.0650	0.0753	0.0611
12	0.0748	0.0622	0.0445	0.0253	0.0337	0.0616	0.0727	0.0770	0.0663	0.0682	0.0641	0.0740	0.0604
13	0.0735	0.0605	0.0428	0.0234	0.0324	0.0620	0.0739	0.0772	0.0662	0.0680	0.0639	0.0733	0.0598
14	0.0733	0.0605	0.0413	0.0219	0.0320	0.1102	0.0784	0.0792	0.0677	0.0675	0.0646	0.0732	0.0641
15	0.0743	0.0669	0.0423	0.0208	0.0320	0.1186	0.1293	0.0833	0.0728	0.0694	0.0665	0.0741	0.0709
16	0.0763	0.0676	0.0462	0.0248	0.0351	0.1783	0.1479	0.0912	0.1311	0.0784	0.0759	0.0788	0.0860
17	0.0827	0.0839	0.0666	0.0376	0.0484	0.2076	0.3612	0.3101	0.1650	0.1333	0.0819	0.0831	0.1385
18	0.0839	0.0863	0.0858	0.0803	0.0820	0.2789	0.3758	0.6327	1.9532	0.3759	0.0806	0.0845	0.3500
19	0.0838	0.0837	0.0906	0.0794	0.0828	0.2339	0.5036	1.2838	2.2423	0.4145	0.0803	0.0849	0.4386
20	0.0836	0.0837	0.0897	0.0820	0.0862	0.1724	0.2552	0.5109	0.1975	0.0902	0.0804	0.0856	0.1515
21	0.0836	0.0835	0.0862	0.0773	0.0829	0.1017	0.1127	0.5991	0.1265	0.0793	0.0809	0.0856	0.1333
22	0.0823	0.0846	0.0816	0.0750	0.0796	0.0886	0.0974	0.4625	0.1124	0.0768	0.0796	0.0830	0.1170
23	0.0779	0.0802	0.0754	0.0743	0.0793	0.0793	0.0787	0.0802	0.0761	0.0745	0.0748	0.0772	0.0773
24	0.0757	0.0781	0.0738	0.0760	0.0789	0.0734	0.0762	0.0784	0.0814	0.0780	0.0749	0.0775	0.0768
	1	2	3	4	5	6	7	8	9	10	11	12	0.1073

Custom Power Solar

NEM3 – weekend export value

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ave
1	0.0741	0.0735	0.0693	0.0647	0.0738	0.0694	0.0711	0.0756	0.0740	0.0718	0.0726	0.0758	0.0721
2	0.0731	0.0732	0.0703	0.0618	0.0716	0.0698	0.0716	0.0752	0.0732	0.0714	0.0721	0.0758	0.0716
3	0.0732	0.0726	0.0698	0.0613	0.0693	0.0706	0.0713	0.0746	0.0725	0.0709	0.0712	0.0751	0.0710
4	0.0722	0.0721	0.0700	0.0625	0.0706	0.0707	0.0710	0.0742	0.0718	0.0702	0.0706	0.0749	0.0709
5	0.0711	0.0713	0.0690	0.0651	0.0728	0.0704	0.0701	0.0741	0.0712	0.0697	0.0701	0.0745	0.0708
6	0.0693	0.0710	0.0682	0.0665	0.0695	0.0730	0.0706	0.0732	0.0711	0.0701	0.0701	0.0748	0.0706
7	0.0728	0.0727	0.0700	0.0529	0.0445	0.0675	0.0683	0.0726	0.0694	0.0706	0.0699	0.0758	0.0672
8	0.0731	0.0660	0.0533	0.0321	0.0367	0.0602	0.0627	0.0755	0.0674	0.0653	0.0660	0.0770	0.0613
9	0.0637	0.0468	0.0464	0.0283	0.0348	0.0585	0.0634	0.0811	0.0720	0.0640	0.0647	0.0761	0.0583
10	0.0599	0.0433	0.0428	0.0275	0.0347	0.0585	0.0641	0.0802	0.0691	0.0643	0.0645	0.0753	0.0570
11	0.0597	0.0434	0.0424	0.0279	0.0343	0.0588	0.0638	0.0807	0.0668	0.0658	0.0640	0.0749	0.0569
12	0.0597	0.0412	0.0417	0.0270	0.0333	0.0580	0.0630	0.0809	0.0658	0.0655	0.0636	0.0737	0.0561
13	0.0591	0.0411	0.0410	0.0276	0.0340	0.0565	0.0624	0.0830	0.0654	0.0644	0.0633	0.0723	0.0558
14	0.0594	0.0420	0.0389	0.0253	0.0326	0.0572	0.0630	0.0903	0.0679	0.0677	0.0642	0.0723	0.0567
15	0.0596	0.0423	0.0403	0.0229	0.0311	0.0588	0.0681	0.2057	0.0802	0.1880	0.0660	0.0726	0.0780
16	0.0654	0.0478	0.0423	0.0230	0.0325	0.0633	0.0837	0.2444	0.1047	0.2100	0.0734	0.0755	0.0888
17	0.0794	0.0787	0.0707	0.0276	0.0454	0.0779	0.1113	0.5921	0.1437	0.2404	0.0792	0.0796	0.1355
18	0.0834	0.0902	0.0876	0.0700	0.0798	0.0931	0.1369	0.8465	3.4013	0.3431	0.0803	0.0838	0.4497
19	0.0847	0.0908	0.0903	0.0674	0.0790	0.0980	0.5048	1.6737	3.8347	0.2166	0.0794	0.0843	0.5753
20	0.0844	0.0903	0.0896	0.0711	0.0825	0.0934	0.2150	0.7570	0.2518	0.0917	0.0796	0.0841	0.1659
21	0.0837	0.0909	0.0865	0.0654	0.0788	0.0857	0.0924	0.7257	0.1067	0.0821	0.0788	0.0825	0.1383
22	0.0820	0.0913	0.0828	0.0614	0.0747	0.0832	0.0842	0.4661	0.0891	0.0770	0.0783	0.0804	0.1125
23	0.0785	0.0836	0.0752	0.0625	0.0745	0.0813	0.0787	0.0786	0.0750	0.0742	0.0750	0.0773	0.0762
24	0.0769	0.0805	0.0712	0.0600	0.0740	0.0748	0.0754	0.0752	0.0743	0.0723	0.0725	0.0766	0.0736
	1	2	3	4	5	6	7	8	9	10	11	12	

NEM3

- ***<u>Value of solar only generation gets cut by 40% vs NEM2</u>***
- Example system 10kw PV, solar value under NEM2 $5100/yr, under NEM3 only $3100/yr
- However, with large enough storage, used properly, most of that value can be recovered

E-ELECT new rate for NEM3
Similar to EV2

		EV2	E-ELECT
	Peak	$0.5595	$0.52900
Summer	Part Peak	$0.44901	$0.36800
	Off Peak	$0.24699	$0.31100
	Peak	$0.43239	$0.29400
Winter	Part Peak	$0.41569	$0.27200
	Off Peak	$0.24699	$0.25800

Peak: 4PM – 9PM, All Days
Part-Peak: 3PM – 4PM & 9PM – 12AM, All Days
Off-Peak: 12AM – 3PM, All Days

Summer: June through September. Winter: October through May
Bills refer to this rate as EV2A. EV not required for EV2, only solar+storage

Optimal savings strategy under NEM3

- Winter rate months – November through May

- Solar energy stores power in batteries during the day, battery runs loads ALL other times. Minimal grid use.

- Summer rate months – June through October

- Solar energy storage power in batteries during the day. Energy from batteries dumped to load/grids during 2 hour window 5-7pm in evenings. This has a value of average $0.95/kwh

- Optimal battery size 3X the PV size, ex 10kw PV, 30kwh battery.

- Also needs inverter/battery capable of high power output – ex 20kwh dumped in 2 hr = 10kw inverter

These can all be set for automatic operation, plus allow reserves, with some inverters (Sol-ark ex)

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Example Residential Solar+Storage Savings - PG&E New E-ELECT NEM3 rate

PV size kw	Storage Multiplier	Storage size kwh	Storage savings per kwh	Solar+Storage Savings	Raw Cost	Final Cost	Simple Payback Years	Payback with EV	10 year Total Income	Annual Cost-Savings
10.00	0	0.00	$0	$3,080	$35,000	$24,500	8.0	4.6	$10,613	$1,380
10.00	0.5	5.00	$85	$3,505	$38,000	$26,600	7.6	4.7	$13,358	$955
10.00	1	10.00	$112	$4,200	$41,000	$28,700	6.8	4.5	$19,182	$260
10.00	2	20.00	$123	$5,540	$47,000	$32,900	5.9	4.2	$30,258	($1,080)
10.00	3	30.00	$122	$6,740	$53,000	$37,100	5.5	4.1	$39,739	($2,280)
10.00	4	40.00	$93	$6,800	$59,000	$41,300	6.1	4.6	$36,223	($2,340)
PV Rate $/watt	$3.50			E-ELECT	Residential					
Storage rate $/kwh	$600.00		LCOE	$0.130						
Savings rate PV $/kw	$308.00		Lifetime	25	years					
SGIP rebate rate $/wh	$0.00		PV Degrade rate	0.50%	Percent/yr					
ITC	30%		Battery Degrade Rate	1%	Percent/yr					
PV Size	10.00	kw	Storage Block Size		10	kwh	100%	percentage bat capacity used		
Storage Only	0	1 if calc for storage only								
Ave Load Rate	$0.290		$4,460	Load Cost						
Gen rate	1538	kwh/kw								
Solar percent of load	100%									
Annual gen	15,380	kwh								
Annual Load	15,380	kwh								
Average Daily Use	42.14	kwh								

Lifetime is used only for Levelized Cost of Energy (LCOE) calculation. PV lifetime is essentially infinite, 90% of power available after 25 years

Custom Power Solar

Example Residential Solar+Storage Savings - PG&E EV2 Rate

PV size kw	Storage Multiplier	Storage size kwh	Storage savings per kwh	Solar+Storage Savings	Raw Cost	Final Cost	Simple Payback Years	Payback with EV	10 year Total Income	Annual Cost-Savings
10.00	0	0.00	$0	$5,190	$35,000	$24,500	4.7	3.3	$34,668	($730)
10.00	0.5	5.00	$85	$5,615	$38,000	$26,600	4.7	3.4	$37,413	($1,155)
10.00	1	10.00	$83	$6,020	$41,000	$28,700	4.8	3.5	$39,931	($1,560)
10.00	2	20.00	$83	$6,850	$47,000	$32,900	4.8	3.6	$45,193	($2,390)
10.00	3	30.00	$82	$7,650	$53,000	$37,100	4.8	3.8	$50,113	($3,190)
10.00	4	40.00	$80	$8,390	$59,000	$41,300	4.9	3.9	$54,350	($3,930)
PV Rate $/watt	$3.50		Rate	EV2	Residential solar+storage					
Storage rate $/kwh	$600.00		LCOE	$0.130						
Savings rate PV $/kw	$519.00		Lifetime	25	years					
SGIP rebate rate $/wh	$0.00		PV Degrade rate	0.50%	Percent/yr					
ITC	30%		Battery Degrade Rate	1%	Percent/yr					
PV Size	10.00	kw	Storage Block Size		10	kwh	100%	percentage bat capacity used		
Storage Only	0	1 if calc for storage only								
Ave Load Rate	$0.290		$4,460	Load Cost						
Gen rate	1538	kwh/kw								
Solar percent of load	100%									
Annual gen	15,380	kwh								
Annual Load	15,380	kwh								
Average Daily Use	42.14	kwh								

Lifetime is used only for Levelized Cost of Energy (LCOE) calculation. PV lifetime is essentially infinite, 90% of power available after 25 years

Custom Power Solar

Vehicle to Home (V2H)

- Current offerings
  - 2kw from 12V auxiliary system fed by traction battery in EV/hybrids
  - All EVs/hybrids have this capability
  - EV must remain on to maintain power
  - Outback Power & Sol-Ark Generator input supports use
  - Option on Custom Power Solar systems
  - Emergency use to backfill home & battery
- Coming
  - Dcbel bidirectional charger
  - F-150
- Many EV mfg now making with EVs bidirectional charging option or AC power output options

Vehicle to Home (V2H) example

- Potential example use case:
  - Energy stored from solar during the day during off-peak (12am-3pm) into charging EV
  - Energy discharged to home and grid during part-peak or peak (4-9pm)
  - EV2 cost differential peak minus off-peak summer - $0.31/kwh, winter $0.19/kwh
  - Daily charge/discharge of 25% of battery capacity (60kwh *25%= 15kwh)
  - 15kwh * $0.31/kwh * 4mo * 30days = $558 for summer
  - 15kwh * $0.19/kwh * 8mo * 30days = $684 for winter
  - Total value - $1242/yr
  - Discharge rate – 15kwh/5hr=3kw
  - GHG savings – 48kg/kwh or 48 * 15 = 720kg/year
  - EV GHG savings – 8.5kg/gal of gas – average driving of 11,315 mi/yr 30mpg comparison car = 377gal gas saved, 3206kg of GHG saved/yr

EV value

- https://ev.pge.com/compare_vehicles
- http://custompowersolar.com/ev_vs_ICE_GHG.xlsx

EV value vs ICE

Car	Cost after incentives	Lifetime cost	Lifetime cost/mi	Fuel cost	mi/kwh	mi/gal	GHG mTons	GHG Mt/yr
Chevy Bolt	$27,200	$36,754.25	$0.25	$6,428.57	3.5		7.63	0.575449
Toyota Camry	$26,000	$59,464.93	$0.40	$24,771.43		35	36.77	2.773985
Tesla 3 standard	$47,000	$56,554.25	$0.38	$6,428.57	3.5		7.63	0.575449
Hyundai Kona	$33,550	$43,104.25	$0.29	$6,428.57	3.5		7.63	0.575449
Toyota Prius Prime	$25,075	$50,126.99	$0.33	$16,358.49		53	24.28	1.831877
Best		$36,754.25					7.63	
Worst		$59,464.93					36.77	
Difference		$22,710.69					29.15	
% improvement							79%	
Lifetime	150,000	miles						
Average use	31	mi/day						
	11,315	mi/yr						
Years lifetime	13							
Cost of electricity	$0.15	$/kwh						
Cost of gas	$6	$/gal						
GHG gas	0.0085806	mT/gal						
GHG electric off-peak	0.000178	mT/kwh						

GHG assumes using California grid off-peak – if solar powered GHG emissions may be 0. Does not include license fees. Includes average maintenance costs including tires.

Commercial Storage Systems

- Typical in USA 240V/480V 3 phase:
- Range of costs: $250-$1000/kwh – larger systems lower $/kwh $250/kwh for Mwh scale
- After ITC - $200- $500/kwh

Some Commercial Storage Systems Providers

- Advanced Microgrid Solutions
- BYD
- Custom Power Solar
- LG Chem
- Sonnen
- STEM
- Tesla Powerpack
- Avalon (Flow batteries)

B-1ST STORAGE RATE 2022

B-1ST		10/22/2022	% increase	2021
	Peak	$0.44884	12.2%	$0.39816
Summer	Part Peak	$0.30754	18.9%	$0.25686
	Off Peak	$0.26021	23.2%	$0.20953
	Peak	$0.35089	16.2%	$0.30021
Winter	Part Peak	$0.32139	18.0%	$0.27071
	Off Peak	$0.23234	26.8%	$0.18166
	Super Off Peak	$0.21592	29.5%	$0.16524

Summer: Peak 4-9pm
Part Peak 2-4pm and 9-11pm
Off Peak All other hours

Winter: Peak 4-9pm
Part Peak 2-4pm and 9-11pm
Super Off Peak 9am-2pm March, April, May only
Off Peak All other hours

Summer: June through September. Winter: October through May

Custom Power Solar

Battery Size vs Savings Solar+Storage

PV size kw	Storage Multiplier	Storage size kwh	Storage savings per kwh	Solar+Storage Savings	Raw Cost	Final Cost	Simple Payback Years	10 year Total Income	Annual Cost-Savings
100.00	0	0.00	$0	$41,600	$250,000	$175,000	4.2	$299,258	$4,540
100.00	0.5	7.50	$174	$42,905	$252,625	$176,838	4.1	$312,298	$3,235
100.00	1	15.00	$109	$43,235	$255,250	$178,675	4.1	$314,222	$2,905
100.00	2	30.00	$78	$43,940	$260,500	$182,350	4.1	$318,585	$2,200
100.00	4	60.00	$59	$45,140	$271,000	$189,700	4.2	$324,915	$1,000
PV Rate $/watt	$2.50		Rate	B-1ST	Up to 75kw demand				
Storage rate $/kwh	$350.00		LCOE	$0.060					
Savings rate PV $/kw	$416.00		Lifetime	25	years				
SGIP rebate rate $/wh	$0.00		PV Degrade rate	0.50%	Percent/yr				
ITC	30%		Battery Degrade Rate	1%	Percent/yr				
PV Size	100.00	kw	Storage Block Size		15	kwh			
Storage Only	0	1 if calc for storage only							
Ave Load Rate	$0.300		$46,140	Load Cost					
Gen rate	1538	kwh/kw							
Solar percent of load	100%								
Annual gen	153,800	kwh							
Annual Load	153,800	kwh							
Average Daily Use	421.37	kwh							

Lifetime is used only for Levelized Cost of Energy (LCOE) calculation. PV lifetime is essentially infinite, 90% of power available after 25 years

Custom Power Solar

Cost Modeling Tools

- Why do cost modeling?
- Determine cost savings using customer load profile and projected solar size
- Compare rates
  - Energy Toolbase
  - Geli
- Developer runs analysis for you
  - Custom Power Solar

Simple approximation model – good for PG&E residential and commercial:
http://www.custompowersolar.com/savings_simple_models.xlsx

Cost Modeling Tools and Financial Modeling

- Model financial returns over time
- Property Assessed Clean Energy
  - HERO
  - Ygrene
  - Renew Financial PACE funding –
- CleanFund
- For Non-Profits – Collective Sun
- Green Bridge Energy

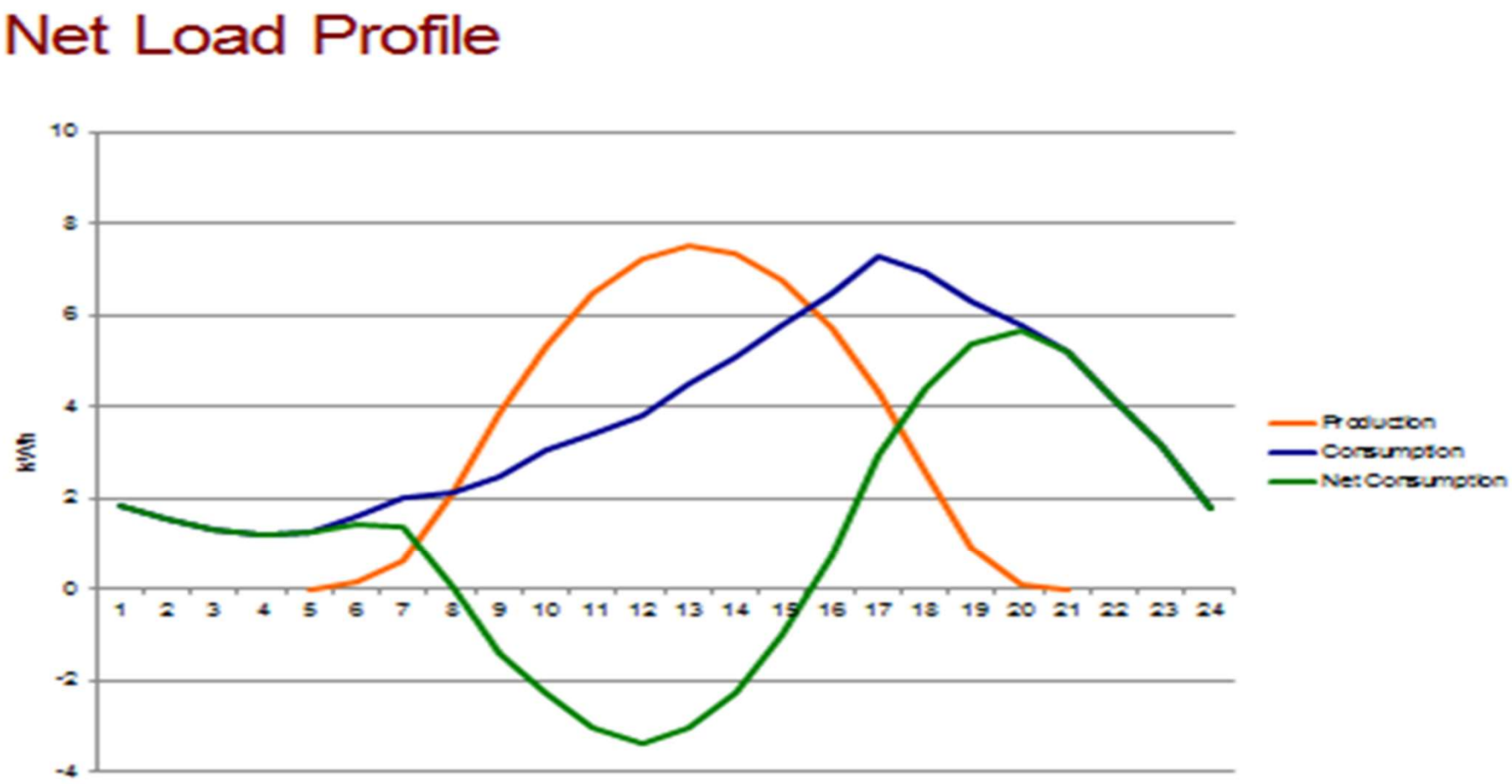
Cost Modeling Tool Tips

- Get the load profile
  - UtilityAPI – helps with format you need
  - PG&E Green Button
- Calculate solar size
- Best size - at least 100% of the annual energy usage in kwh of customer
- Quick estimate – Annual Usage(kwh)/1500 = PV size in kw
- Make sure size fits available space
  - roof
  - ground
  - carport

Cost Modeling Tool Tips Cont'd

- Storage size
- = 2X the solar size
- Example:
  - 5kw solar needed,
  - 5*2=10kwh battery best value
- Best customer long term value –
  - >2X, 4X the solar size
- 4X –cost savings almost double that of 2X battery size (4X savings).

Typical Solar Production and Consumption



Typical CAISO net grid daily profile – solar decreases daily demand, but demand peaks in evening – driving high peak rates

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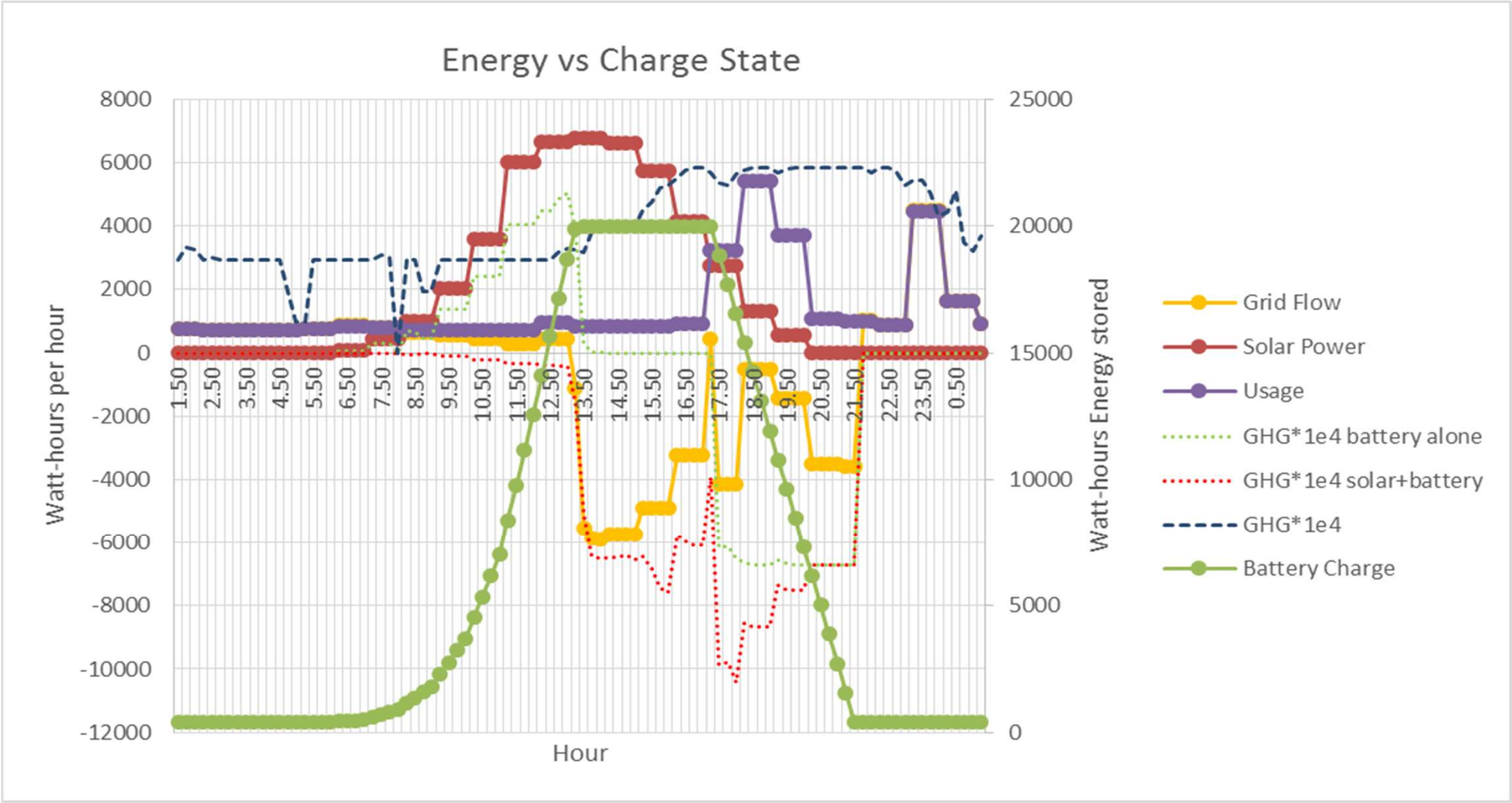
Residential Solar+Storage+EV – Arbitrage Daily Cycle



6/21 – cost savings through arbitrage – store solar power in am, discharge during peak

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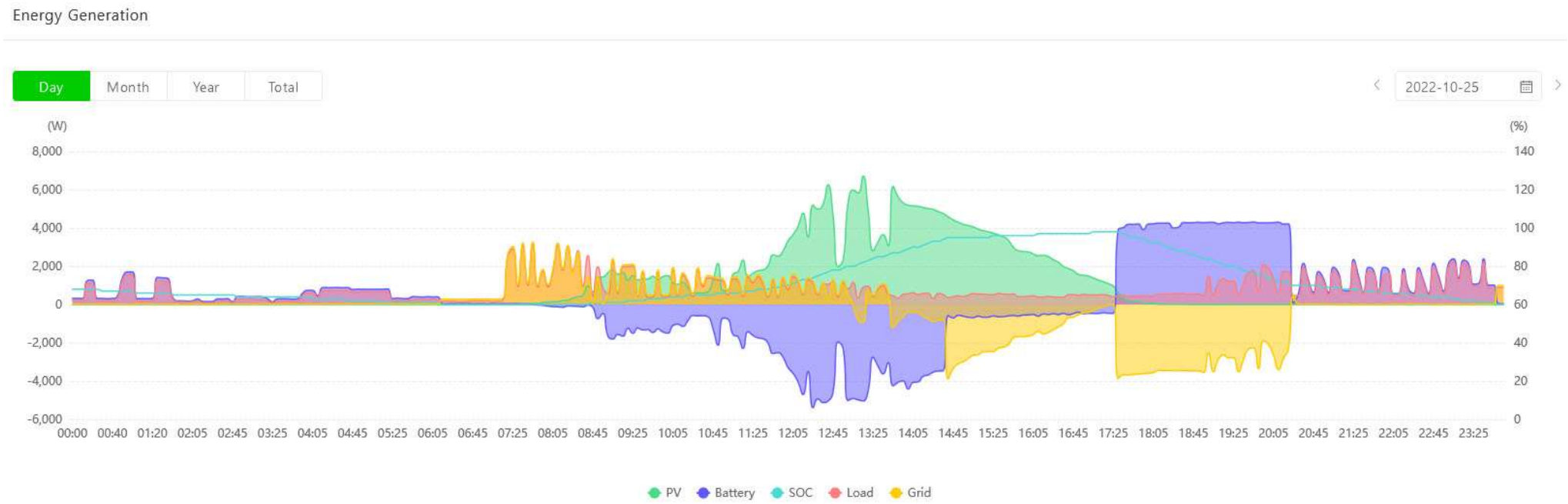
Residential Solar+Storage+EV – Arbitrage Daily Cycle



Cost savings through arbitrage – store solar power from beginning of solar at 7:20 to 2:45pm, discharge during peak rate period 5:30pm-8:30pm, and additionally power loads part-peak 9pm-midnight. 60% capacity held in reserve, max charge to 95% capacity to maximize cell lifetime. Note excess solar exported after 14:45. 40 kwh storage system

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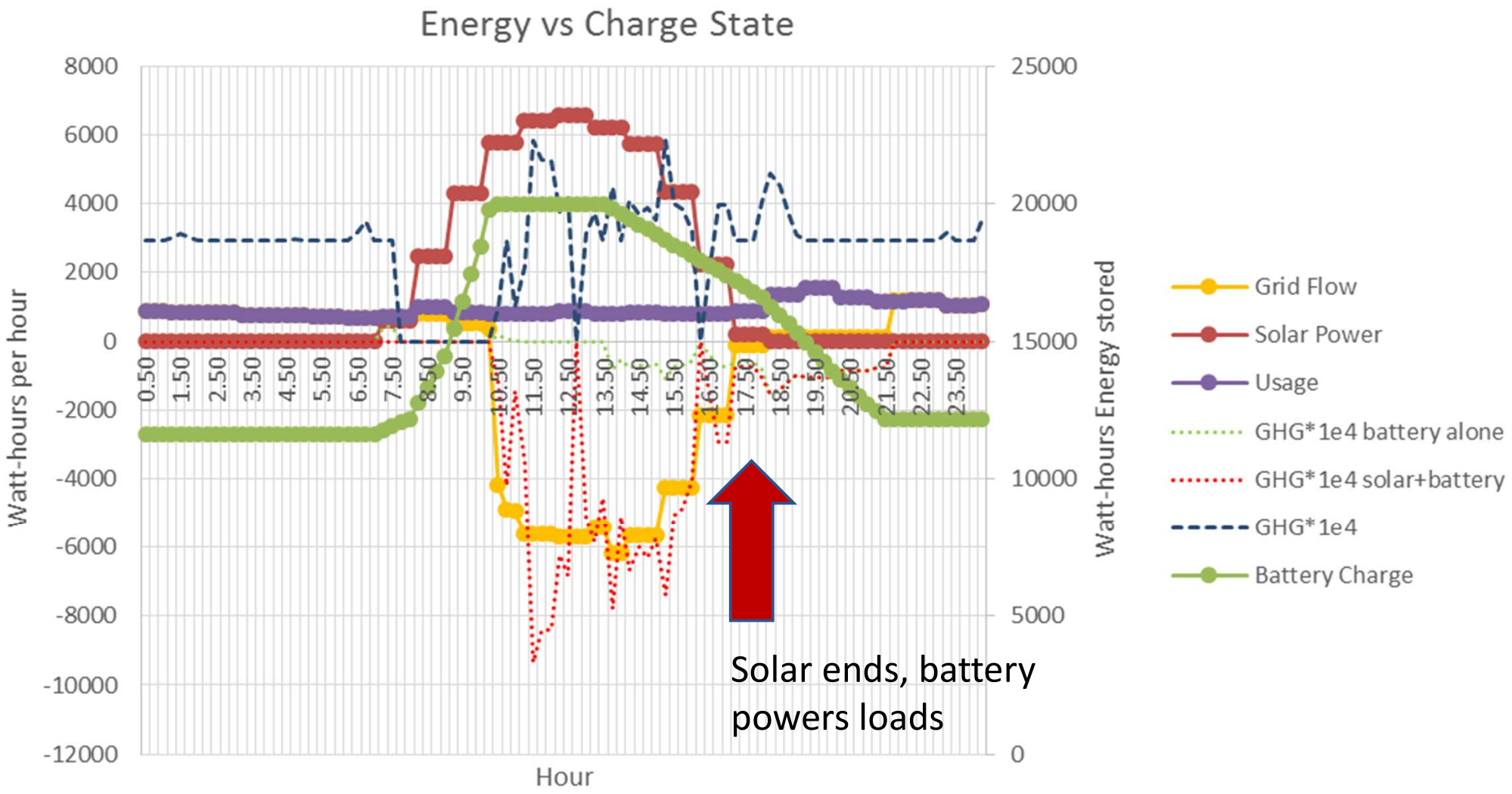
Resi Solar+Storage+EV Self Supply– Daily Cycle



2/4 – cost savings through self supply – store solar power in am, discharge during peak but only power loads

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Commercial Rate Analysis

Models by: **Custom Power Solar** Grocery_e19r_2019rates_10_18_19.xlsx

Load year 2017

Solar Data Lat, Lon: 37.89, -122.3

Annual

	E-19R 2019	E-19R	A-6	A-10	EBCE FIT	
Cost	$60,641.85	$60,148.60	$90,395.58	$62,384.84		
Cost Est. with Solar	$21,195.30	-$4,417.59	-$23,409.90	$3,752.30	$39,074.74	
Cost Est. with Solar+Storage	-$527.03	-$6,881.43	-$26,189.82	$2,871.97	**$67,534.67**	
Improvement over solar only	**55.07%**	**3.82%**	**2.44%**	**1.50%**		
Cost Advantage batteries	**$21,722.33**	**$2,463.84**	**$2,779.92**	**$880.32**		
Cost savings solar only	$39,446.55	$64,566.19	$113,805.48	$58,632.55		
Total Value Solar+Storage	**$61,168.88**	**$67,030.03**	**$116,585.40**	**$59,512.87**		
Optimized Rate	$167.72	$274.53	$483.89	$249.30	solar only savings	
	$45.25	$5.13	$5.79	$1.83	storage only savings	

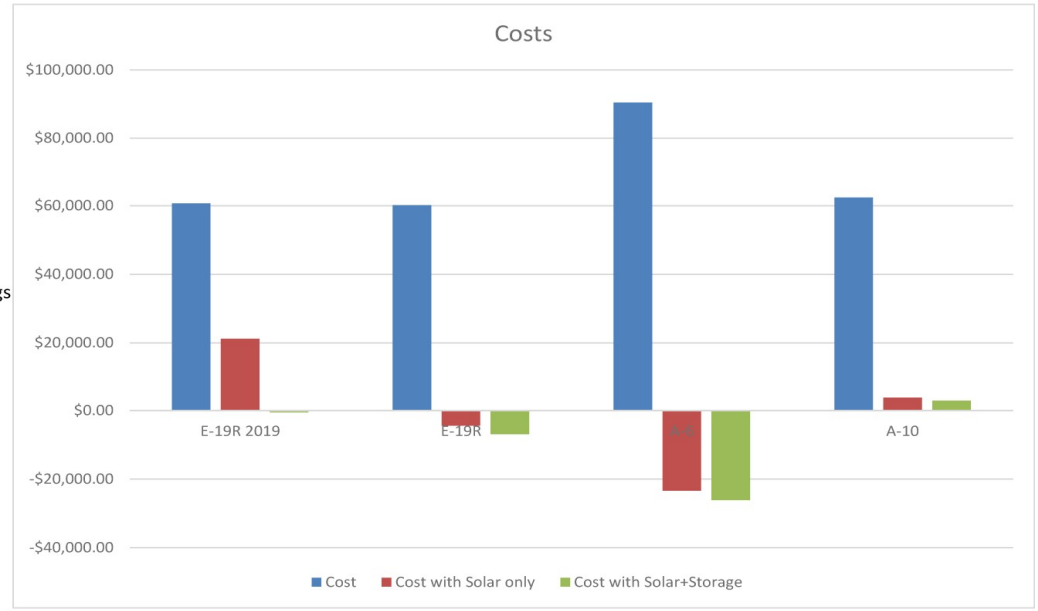
Total usage	**361,803**	**kwh**	**120.00**	**kw Battery**
Total solar	**361,803**	**kwh**	**235.19**	**kw AC Solar**
Surplus	**0**	**kwh**	**480.00**	**kwh Battery**
Percent solar vs usage	**100.0%**		**84.9%**	**RTE**
GHG savings	**117,208**	**kgs/CO2**	**np15**	**GHG Data**
GHG savings battery alone	**19,709**	**kgs/CO2**	**158,111**	**kwh Battery use**
Annual percent dispatchable	**43.7%**		**9.02%**	**% of Life used**

Annual Demand Charges **Max Demand**

	E-19R 2019	E-19R	A-6	A-10	
Cost	$14,304.38	$13,283.25	$0.00	$10,593.14	67.47
Cost Est. with Solar	$13,768.40	$12,531.79	$0.00	$10,200.49	64.69
Cost Est. with Solar+Storage	$13,038.70	$12,201.04	$0.00	$9,773.44	63.75

Annual Energy Charges

	E-19R 2019	E-19R	A-6	A-10
Cost	$46,337.47	$46,865.35	$90,395.58	$51,791.70
Cost Est. with Solar	$7,426.90	-$16,949.38	-$23,409.90	-$6,448.20
Cost Est. with Solar+Storage	-$13,565.73	-$19,082.47	-$26,189.82	-$6,901.46
Grid Charge	0	kwh		
Grid Charge	0	days		



EV Use	**0.0**	**mi/day**	
EV Charge	**0.0**	**kwh**	
EV Gas Savings	**$0.00**		
EV GHG savings	**0.0**	**kg**	
Total GHG Savings	**117,208**	**kg**	
Net GHG	**838**	**kg**	
GHG Load Only	**-116,370**	**kg**	

Solar rate	$1.50	**$/watt**
Storage rate	$350	**$/kwh**
Solar cost	$352,784.55	
Storage cost	$168,000.00	
Rebate rate	$0.29	$/wh
ITC	30%	
Final cost	$225,349.18	
Simple payback yrs	3.7	

GHG Value Adder

$65	**$/mT**	
$1,281.07	**GHG Savings Battery alone**	
$60,148.60	**Baseline rate cost**	
($527.03)	**Optimized rate final cost**	
$61,956.70	**Total Savings**	

All rates run with same conditions, optimized to first column rate

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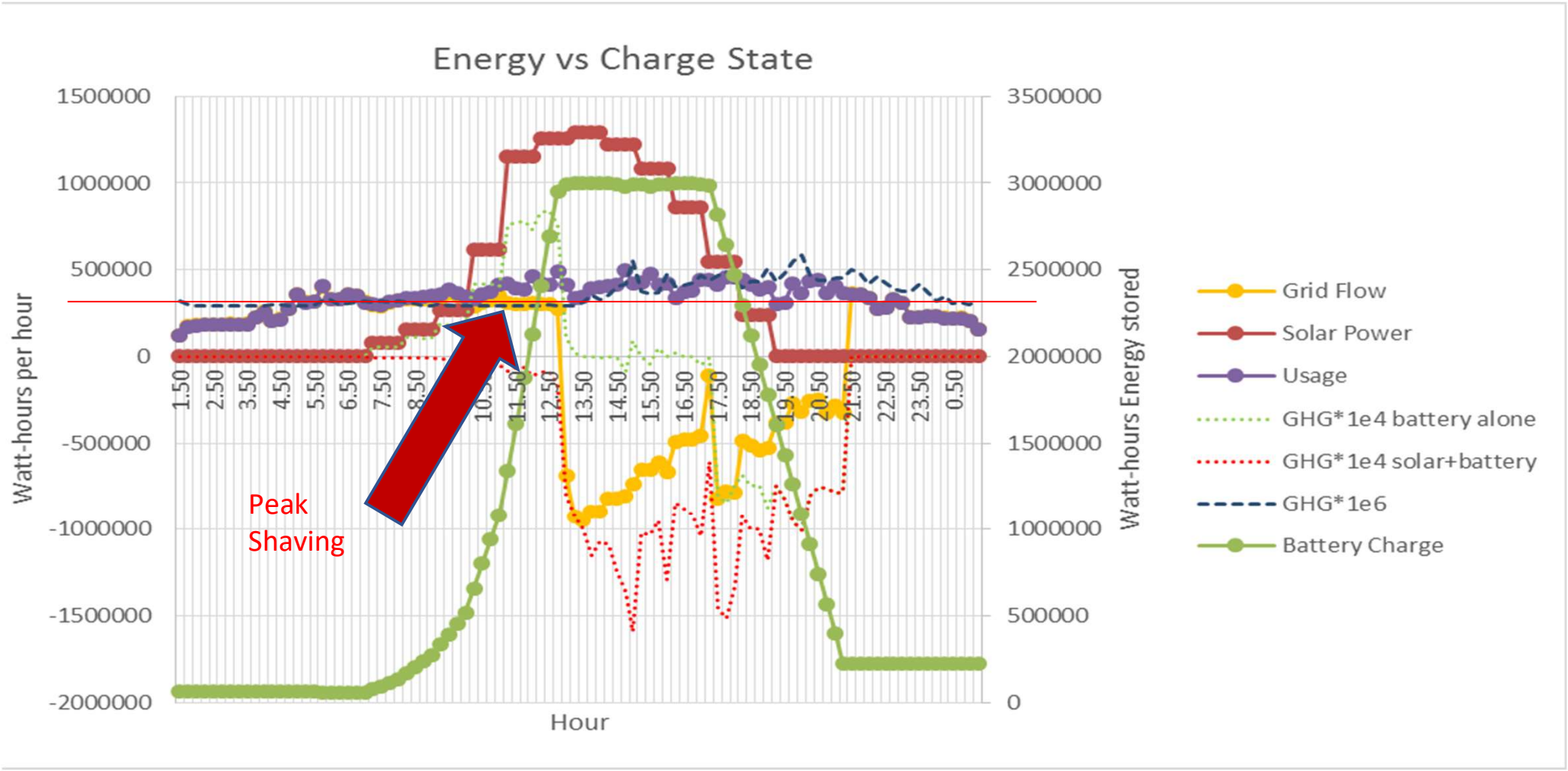
Commercial Solar+Storage – Arbitrage & Demand Reduction Daily Cycle



6/21 – cost savings through demand response – peak shaving (red line) and arbitrage – store solar power in am, discharge during peak

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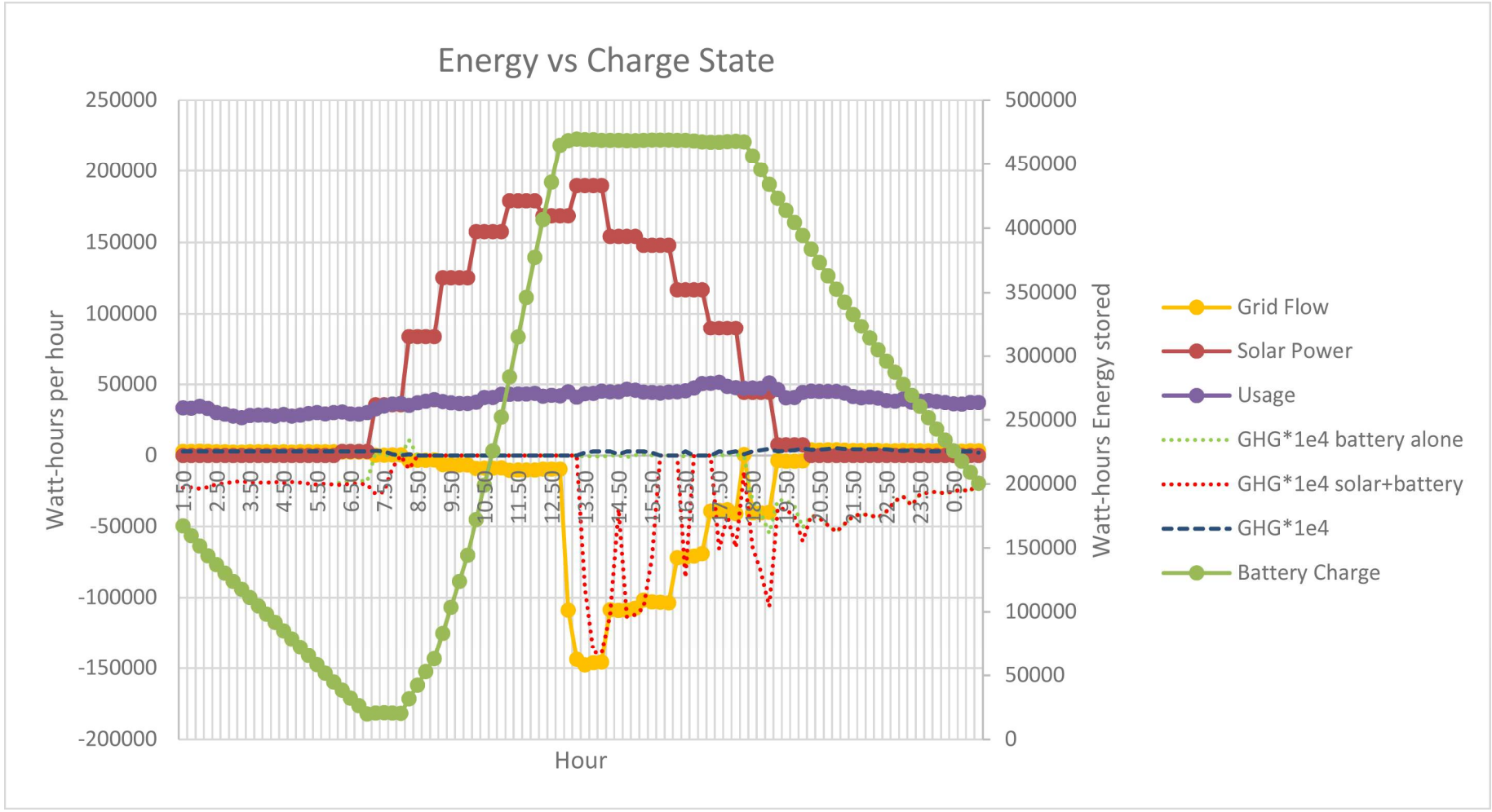
Best Rates for Solar+Storage- Commercial

- PG&E
  - B-1ST
  - B-19R if solar only
  - B-19S if solar+storage or storage addon
  - B-20R(or S) – very large systems over 1MW demand

Backup or Self-Supply



Date: 4/30 Grid flow all negative – only exporting to grid. No export during power outage. Solar sized = 100% of load, 2X battery size

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Conclusions

- Be conservative with storage cost savings projections – nothing worse than customers getting less than they planned on
- Design at least a 20% buffer in the size of the battery system
  - Improves lifetime
  - Reduces impact of day-to-day variations in use

Thank You!

Tom Rust

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Custom Power Solar


CUSTOM
POWER
SOLAR
SOLAR + ENERGY STORAGE

Lithium Iron Phosphate Batteries

- Lithium Iron Phosphate (LiFePo)
- 96-98% efficiency
- 3000-6000 cycle life
- High DOD (80%+)
- 3.2-3.6V/cell
- -20 to 60C operating temperature
- Much lighter weight than lead-acid

- Better fire resistance than Li-ion
- Tend to allow inverters to operate more efficiently
- Typically can last 10+ years
- Raw cost for cells now only $110-130/kwh

LFP Safety

- Safest of all battery chemistries
- No Cobalt
- No Flourine in vented gas components if burns

Table 11 – Components measured in vented cell gas

Gas		Measured %
Hydrogen	H_2	50.73
Carbon Monoxide	CO	11.17
Carbon Dioxide	CO_2	24.86
Methane	CH_4	6.60
Ethylene	C_2H_4	3.06
Ethane	C_2H_6	1.19
Propene	C_3H_6	1.01
Propane	C_3H_8	0.40
-	C_4 (Total)	0.88
-	C_5 (Total)	0.10
Total	-	100

CATL LFP 272Ah cell UL9540A test data from cell heated to destruction

Lead Acid Batteries

- 80-85% efficiency[1]
- 1000-1500 cycle life at best
- Limited Depth of Discharge (DOD) for best lifetime
- Typical DOD only 50%
- Some require maintenance
- Lifetime is typically 6-7 years
- Heavy – 4X as heavy as Lithium batteries
- Lead is a toxin
- Recycling an issue

[1] One way efficiency

Lithium Ion Batteries

- Nickel Cobalt Manganese (NCM)
- Nickel Cobalt Aluminum (NCA)
- 96-98% efficiency
- 3000-5000 cycle life
- High DOD (80%+)
- 3.6-4.2V/cell
- 0-45C operating temperature
- Much lighter weight than lead-acid
- Typically can last 10+ years

Lithium Titanate Batteries

- Titanate (LTO)
- 96-98% efficiency
- 3000-30,000 cycle life
- High DOD (80%+)
- 2-2.6V/cell
- -30C to 45C operating temperature
- Lower energy density than other lithium
- Generally very high charge/discharge rate
- Higher cost but longer cycle life
- Typically can last 10+ years

Flow Batteries

- 80-85% efficiency
- 30,000+ cycle life
- Higher Capex
- Heavy
- Long cycles are typical

Storage System Components

- Batteries
  - Cells in parallel
  - Cell groups in series
- Battery Management System (BMS)
  - Required for lithium batteries
  - Maintains cells within 0.02V of each other
- Inverter
  - Moves energy to/from battery
- Automatic Transfer Switch (option)
  - Disconnects solar+storage system from grid
  - Allows on grid or off-grid operation

Storage System Components, cont'd

- Monitoring system - all system functions
  - Voltages
  - Temperatures
  - Current flows
- Typically data stored in cloud and locally
- Control –
  - Network interfaced system operations
- NGOM –
  - Separate Metering for monitoring solar vs battery
  - Not needed in residential systems

Examples - SGIP approved battery systems

- Energport
- BYD
- LG
- SimpliPhi
- Tesla
- Contact your SGIP Program Administrator for specifics

Custom Power Solar

Energport

Features:

- Saves electricity cost by reducing demand charges and shifting load to off-peak period
- System payback in less than 4 years
- Simple modular design, scalable for any size and use
- LFP - Safest Lithium ion battery on the market
- Cloud-based optimization and reporting
- Small footprint
- Connects to existing circuits
- Emergency backup as bonus function
- $0 down lease available
- Low APR financing available
- California SGIP rebate available
- 30% federal tax credit with Solar PV
- 15-year design life; 10-year warranty
- Fully installed for less than $0.40/Wh
- CE, UL compliance

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BYD Energy Storage System

240 Kwh in outdoor container
Includes all operational and climate controls

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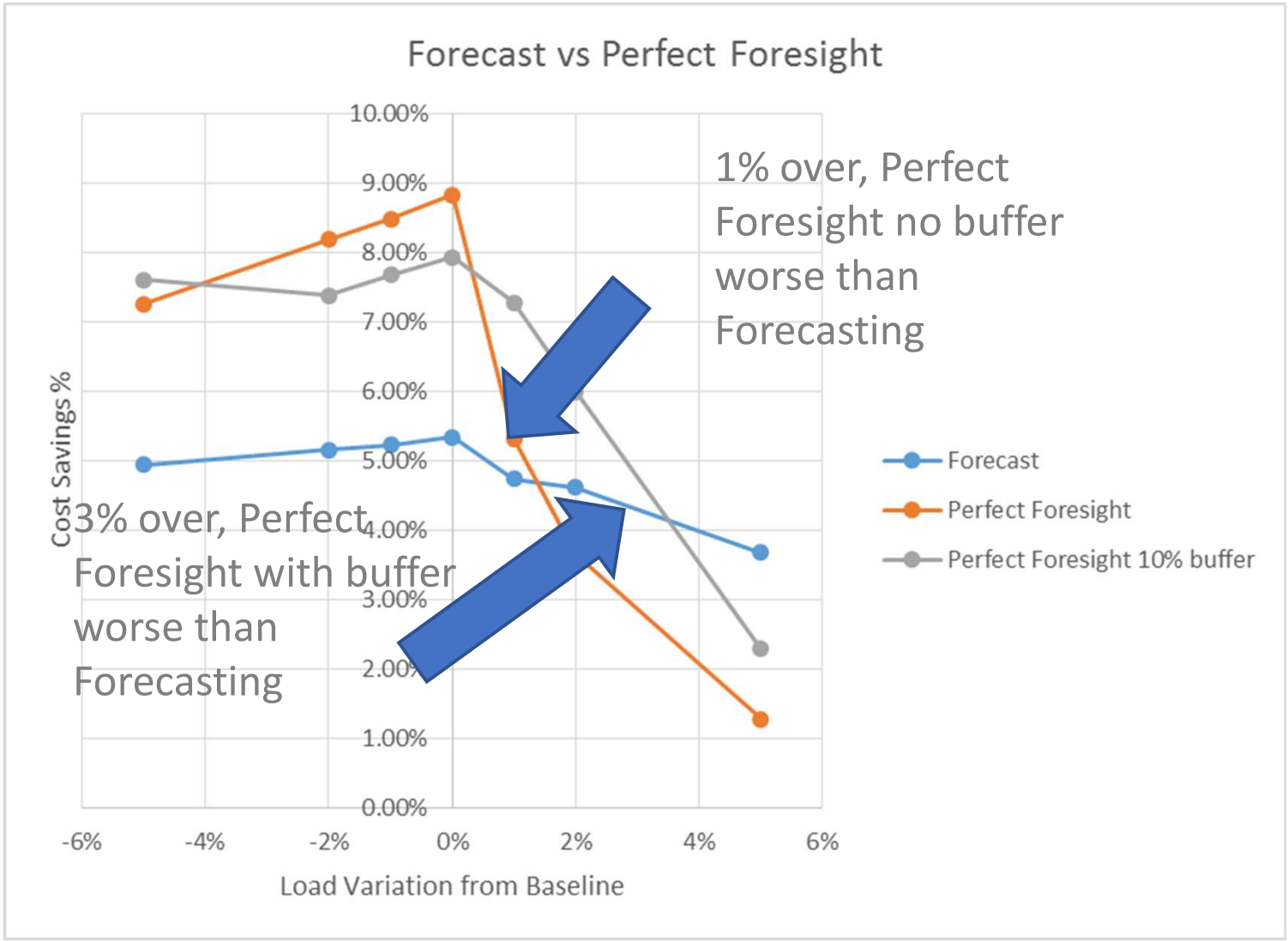
How Realistic is Perfect Foresight in Real World Storage Operations?

- Many tools (Energy Toolbase, Geli) use a Perfect Foresight model to analyze load profiles+solar with given rate and determine "best case" cost savings –
- Not realistic in real life use
- More realistic – Forecasting – used by Custom Power Solar

Forecasting Sensitivity Analysis – Cost Savings



Conditions – C9 load (500kw demand peak), storage only 370kw,870kwh

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Conclusions

- Perfect Foresight is extremely sensitive to real life load conditions – if load exceeds baseline – even slightly, savings are lost
  - 1% over load conditions eliminate all savings from Perfect Foresight vs Forecasting with no buffer
  - 1% over condition virtually certain in real life conditions
- Forecasting method likely produces more consistent, reliable cost savings than perfect foresight

THANK YOU

Together, Building
a Better California