



Solar Plus Storage

Focus on Storage Benefits

by Tom Rust

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Getting to 100% renewables

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



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
- Better fire resistance than Li-ion – they cannot burn
- 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 – $\$350/\text{kwh} / (1500 \text{ cycles} * 50\% \text{ DOD} * 70\% \text{ RTE1}) = \$0.67/\text{kwh}$
 - Lithium - $\$500/\text{kwh} / (5000 \text{ cycles} * 80\% \text{ DOD} * 85\% \text{ RTE1}) = \$0.15/\text{kwh}$
 - 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
- Peninsula Clean Energy
 - No limit on cash back for excess power
- Credits can roll over to succeeding years



Some Residential Storage Systems

- 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



Lithium Iron Phosphate Battery Suppliers cycle life >3000 (continued)

- Enphase
- Blue Ion
- Sonnen
- Discover
- Fortress
- Humless
- Iron Edison
- CATL



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
- Outback inverter includes automatic transfer switch (ATS)
- 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%

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



EV2 SOLAR+STORAGE RATE 2021

EV is NOT required: Solar+ storage is required

Summer	Peak	\$0.49781
	Part-Peak	\$0.38732
	Off-Peak	\$0.18530
Winter	Peak	\$0.37070
	Part-Peak	\$0.35400
	Off-Peak	\$0.18531

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



Custom Power Solar

EVA SOLAR+STORAGE RATE 2021

EV is required

Summer	Peak	\$0.56483
	Part-Peak	\$0.30869
	Off-Peak	\$0.14427
Winter	Peak	\$0.41127
	Part-Peak	\$0.24932
	Off-Peak	\$0.14769

Peak: 2:00 p.m. to 9:00 p.m. Monday through Friday. 3:00 p.m. to 7:00 p.m. Saturday, Sunday and Holidays.

Partial-Peak: 7:00 a.m. to 2:00 p.m. and 9:00 p.m. to 11:00 p.m. Monday through Friday, except holidays.

Off-Peak: All other hours.

Summer: May through October. Winter: November through April

Note: EV-A is no longer open for enrollment



Custom Power Solar

Typical 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	\$4,110	\$35,000	\$25,900	6.3	4.6	\$20,956	(\$834)
10.00	0.5	5.00	\$85	\$4,535	\$36,750	\$26,445	5.8	4.4	\$25,256	(\$1,259)
10.00	1	10.00	\$83	\$4,940	\$38,500	\$26,990	5.5	4.2	\$29,328	(\$1,664)
10.00	2	20.00	\$83	\$5,770	\$42,000	\$28,080	4.9	3.9	\$37,700	(\$2,494)
10.00	4	40.00	\$80	\$7,310	\$49,000	\$30,260	4.1	3.4	\$53,077	(\$4,034)
PV Rate \$/watt	\$3.50		Rate	EV2						
Storage rate \$/kwh	\$350.00			Residential solar+storage						
Savings rate PV	\$411.00									
SGIP rebate rate \$/wh	\$0.15									
ITC	26%									
PV Size	10	kw								
Storage Only	0	1 if calc for storage only								
Ave Load Rate	\$0.213		\$3,276	Load Cost						
Gen rate	1538	kwh/kw								
Solar percent of load	100%									
Annual gen	15,380	kwh								
Annual Load	15,380	kwh								



Typical Residential Solar+Storage Savings - PG&E EVA 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	\$5,690	\$35,000	\$25,900	4.6	3.6	\$38,968	(\$2,414)
10.00	0.5	5.00	\$133	\$6,355	\$36,750	\$26,445	4.2	3.4	\$46,005	(\$3,079)
10.00	1	10.00	\$126	\$6,950	\$38,500	\$26,990	3.9	3.2	\$52,243	(\$3,674)
10.00	2	20.00	\$126	\$8,210	\$42,000	\$28,080	3.4	2.9	\$65,517	(\$4,934)
10.00	4	40.00	\$97	\$9,570	\$49,000	\$30,260	3.2	2.7	\$78,842	(\$6,294)
PV Rate \$/watt	\$3.50		Rate	EVA						
Storage rate \$/kwh	\$350.00			Residential solar+storage						
Savings rate PV	\$569.00									
SGIP rebate rate \$/wh	\$0.15									
ITC	26%									
PV Size	10	kw								
Storage Only	0	1 if calc for storage only								
Ave Load Rate	\$0.213		\$3,276	Load Cost						
Gen rate	1538	kwh/kw								
Solar percent of load	100%									
Annual gen	15,380	kwh								
Annual Load	15,380	kwh								



Typical Residential Solar+Storage Savings EVA vs EV2

- EVA 30% to 40% greater value than EV2, but must have had an EV to qualify. No new enrollment in EVA. But good value for existing EVA customers.
- Typical Installation costs – systems using Outback Radian or Sol-Ark with LFP batteries & modules at \$0.60/watt. Savings assumes full arbitrage storage mode. Payback with EV assumes gas savings average 31 miles/day \$4/gal compared to 30mpg. Final cost includes ITC (Investment Tax credit of 26%) and SGIP rebate (Self-Generation Incentive Program) at current rate



Custom Power Solar

Solar+Storage Revenue Generator

9kw PV + 45 kwh LFP storage

- \$7500/year in revenue on EVA rate in Marin Clean Energy territory (2 12kw EV chargers)
- Store solar energy during off-peak, export to grid during peak
- 22 395 watt Canadian Solar bifacial modules
- 2 Sol-Ark 12 inverters total 18kw
- 1 200A Asco model 300 Automatic Transfer Switch
- 125A home service from PG&E
- 200A service panel in home (added)



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
 - OSSIACO



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	\$32,745	\$42,299.25	\$0.28	\$6,428.57	3.5		7.63	0.575449
Toyota Camry	\$30,000	\$55,836.36	\$0.37	\$17,142.86		35	36.77	2.773985
Tesla 3 standard	\$35,615	\$45,169.25	\$0.30	\$6,428.57	3.5		7.63	0.575449
Hyundai Kona	\$27,995	\$37,549.25	\$0.25	\$6,428.57	3.5		7.63	0.575449
Toyota Prius Prime	\$27,050	\$47,064.26	\$0.31	\$11,320.75		53	24.28	1.831877
Best		\$37,549.25					7.63	
Worst		\$55,836.36					36.77	
Difference		\$18,287.12					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	\$4	\$/gal						
GHG gas	0.0085806	mT/gal						
GHG electric off-peak	0.000178	mT/kwh						



Commercial Storage Systems

- Typical in USA 240V/480V 3 phase:
- Range of costs: \$250-\$1000/kwh
- After SGIP rebate and ITC - \$0- \$500/kwh



Some Commercial Storage Systems Providers

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



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
143.04	0	0.00	\$0	\$28,172	\$214,564	\$158,778	5.6	\$162,399	\$32,328
143.04	0.5	71.52	\$74	\$33,441	\$239,597	\$156,560	4.7	\$224,684	\$27,059
143.04	1	143.04	\$60	\$36,696	\$264,629	\$154,343	4.2	\$264,009	\$23,804
143.04	2	286.09	\$52	\$43,083	\$314,694	\$149,909	3.5	\$341,257	\$17,417
143.04	4	572.17	\$38	\$50,001	\$414,824	\$141,040	2.8	\$428,988	\$10,499
PV Rate \$/watt	\$1.50		Rate	B-19R					
Storage rate \$/kwh	\$350			Up to 1MW demand					
Savings rate PV	\$197								
SGIP rebate rate \$/wh	\$0.29								
ITC	26%								
PV Size	143.0429 kw								
Storage Only	0	1 if calc for storage only							
Ave Load Rate	\$0.275		\$60,500	Load Cost					
Gen rate	1538 kwh/kw								
Solar percent of load	100%		Enter percentage of load desired to be generated by solar						
Annual gen	220,000 kwh								
Annual Load	220,000 kwh		Enter annual energy usage here						

PG&E B-19R rate. 10 year income includes 3%/yr utility increases, -0.5% solar degradation. Does not include depreciation

http://www.custompowersolar.com/savings_simple_models.xlsx



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



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



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 – $\text{Annual Usage(kwh)} / 1500 = \text{PV size in kw}$
- Make sure size fits available space
 - roof
 - ground
 - carport



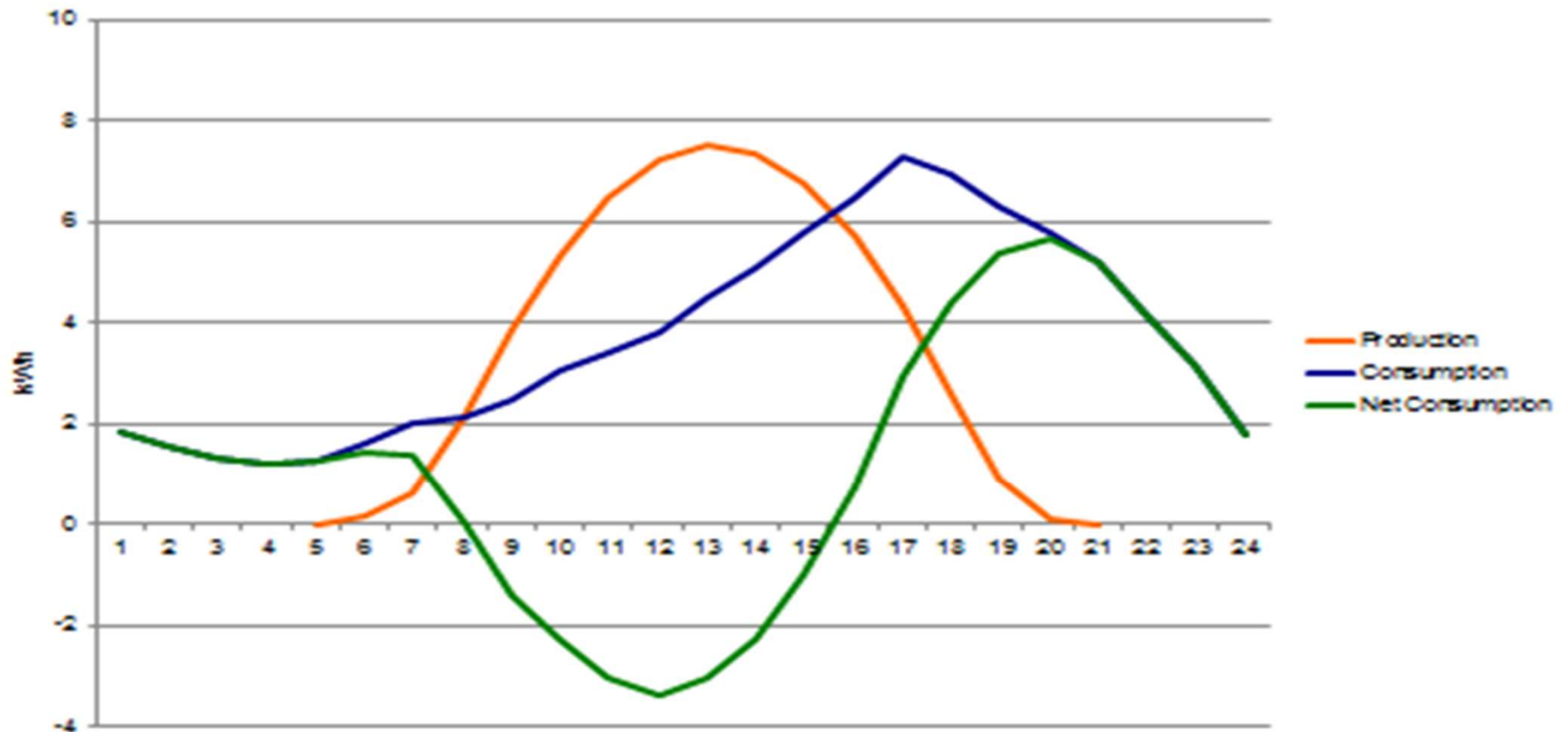
Cost Modeling Tool Tips Cont'd

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

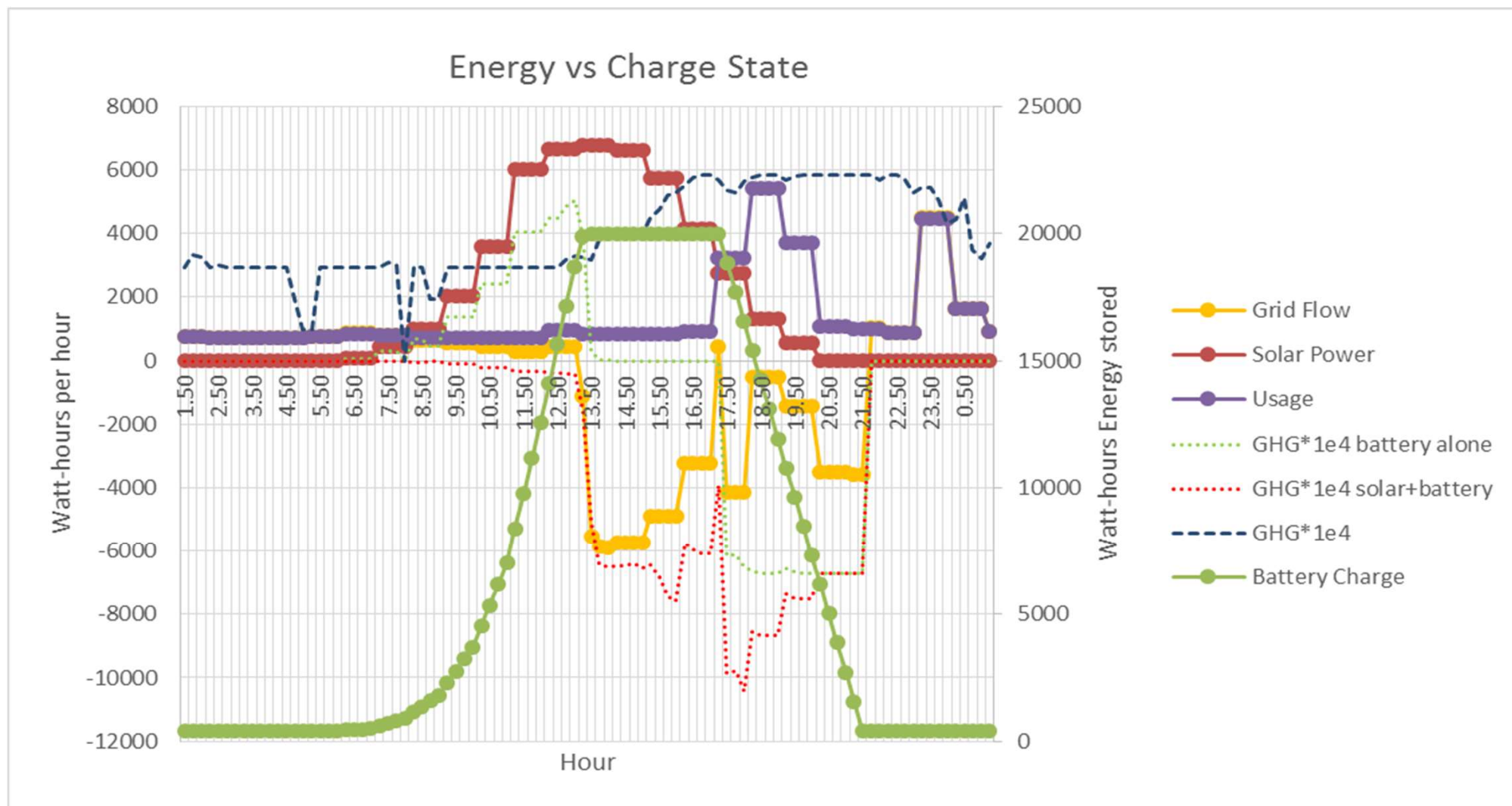


Typical Solar Production and Consumption

Net Load Profile



Residential Solar+Storage+EV – Arbitrage Daily Cycle

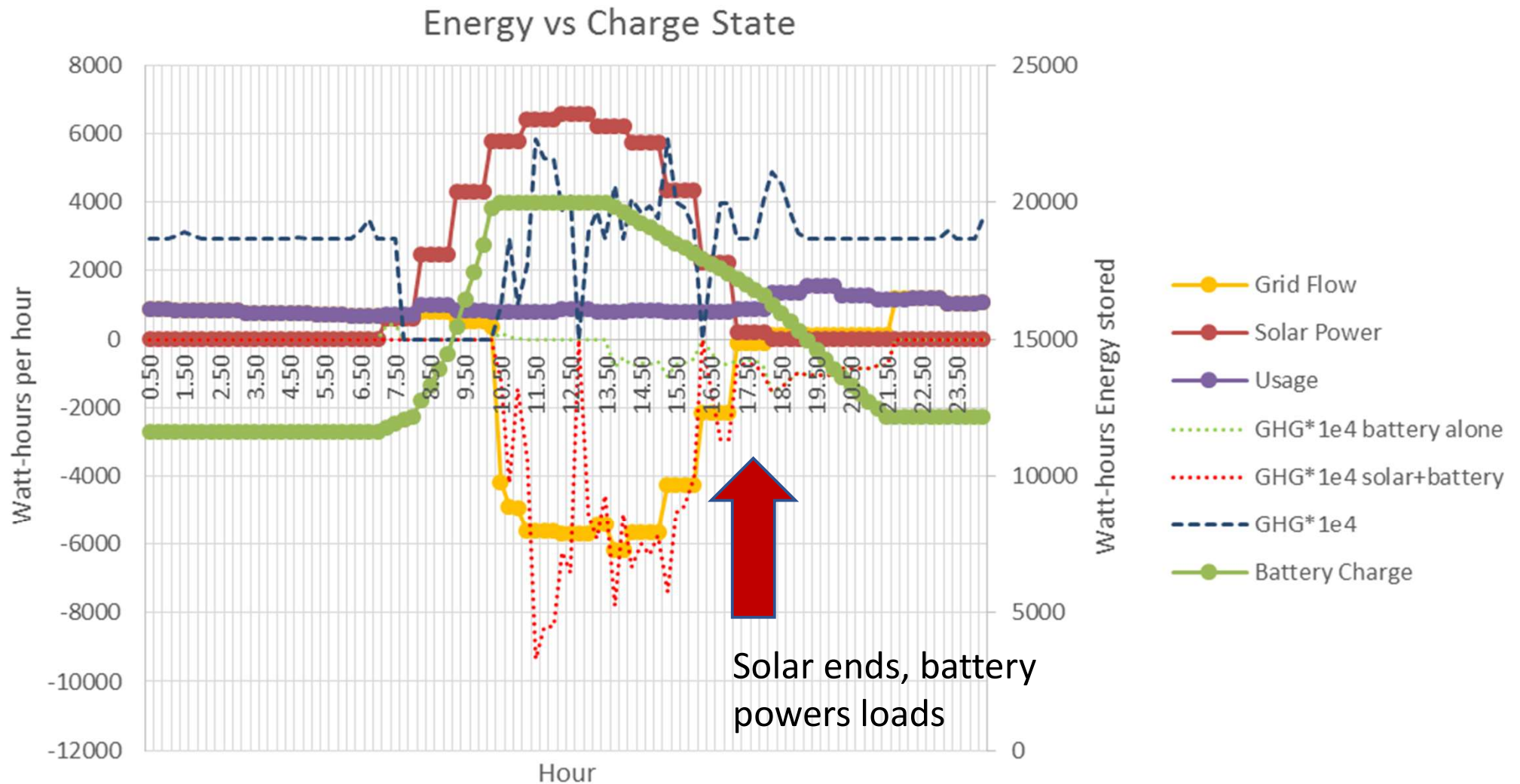


6/21 – cost savings through arbitrage – store solar power in am, discharge during peak



Custom Power Solar

Resi Solar+Storage+EV Self Supply– Daily Cycle



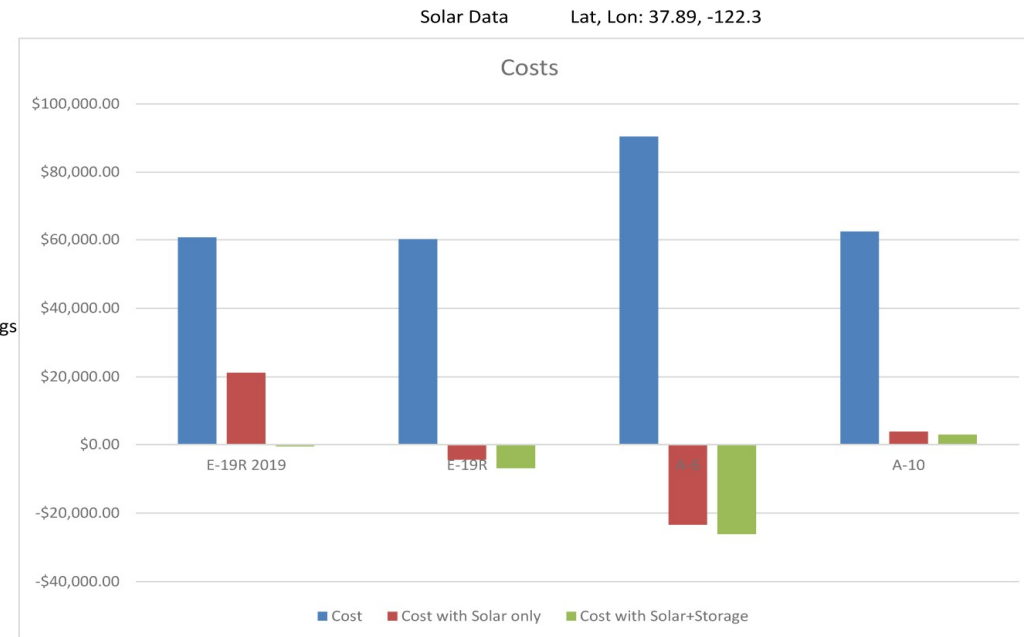
2/4 – cost savings through self supply – store solar power in am, discharge during peak but only power loads



Commercial Rate Analysis

Models by: Custom Power Solar Grocery_e19r_2019rates_10_18_19.xlsx
Load year 2017

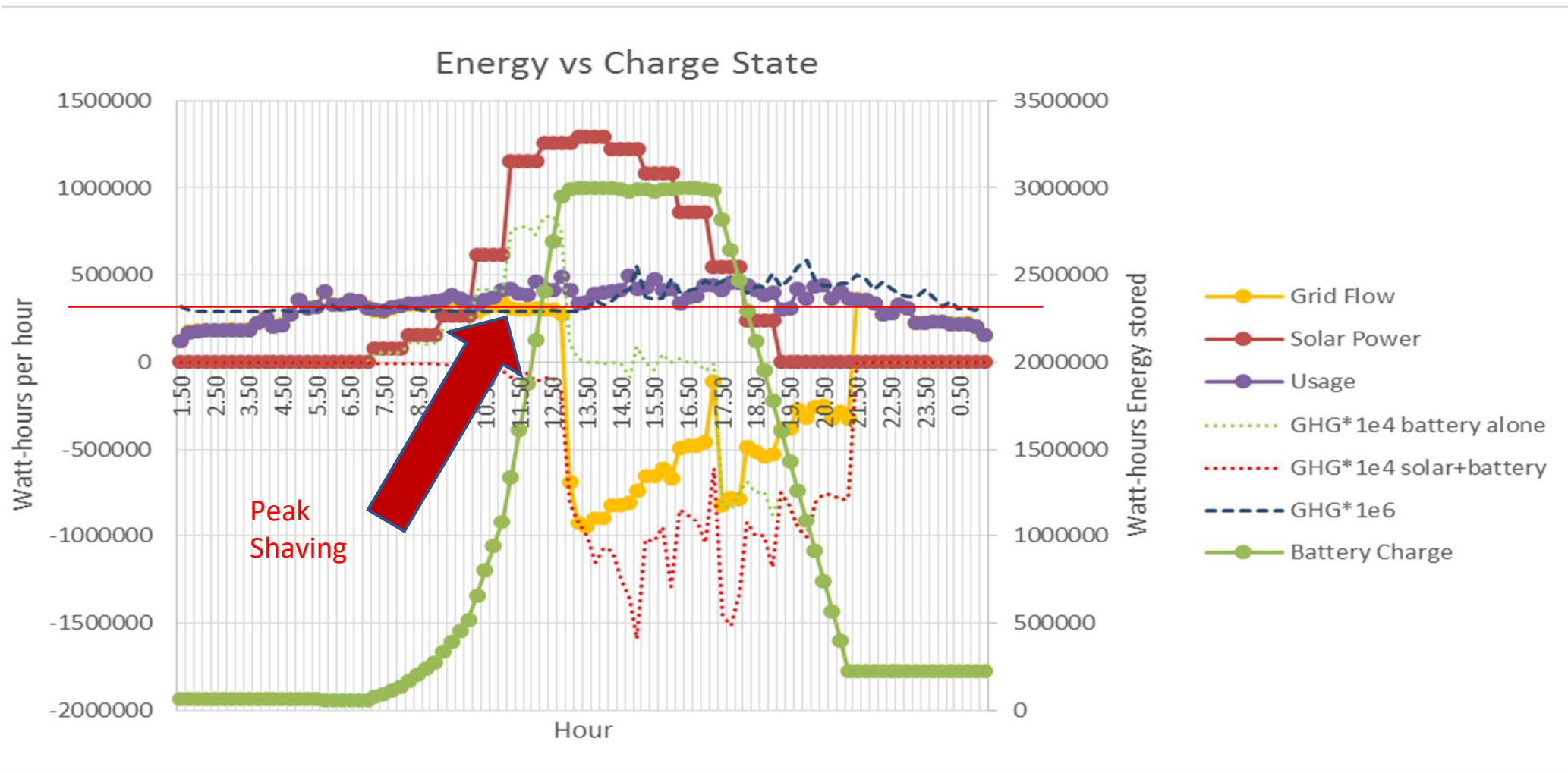
	Annual				EBCE FIT
	E-19R 2019	E-19R	A-6	A-10	
Cost	\$60,641.85	\$60,148.60	\$90,395.58	\$62,384.84	
Cost Est. with Solar	\$21,195.30	-\$4,417.59	-\$23,409.90	\$3,752.30	\$39,074.74
Cost Est. with Solar+Storage	-\$527.03	-\$6,881.43	-\$26,189.82	\$2,871.97	\$67,534.67
Improvement over solar only	55.07%	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				



GHG Value Adder		
EV Use	0.0 mi/day	\$65 \$/mT
EV Charge	0.0 kwh	\$1,281.07 GHG Savings Battery alone
EV Gas Savings	\$0.00	\$60,148.60 Baseline rate cost
EV GHG savings	0.0 kg	(\$527.03) Optimized rate final cost
Total GHG Savings	117,208 kg	\$61,956.70 Total Savings
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	

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

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

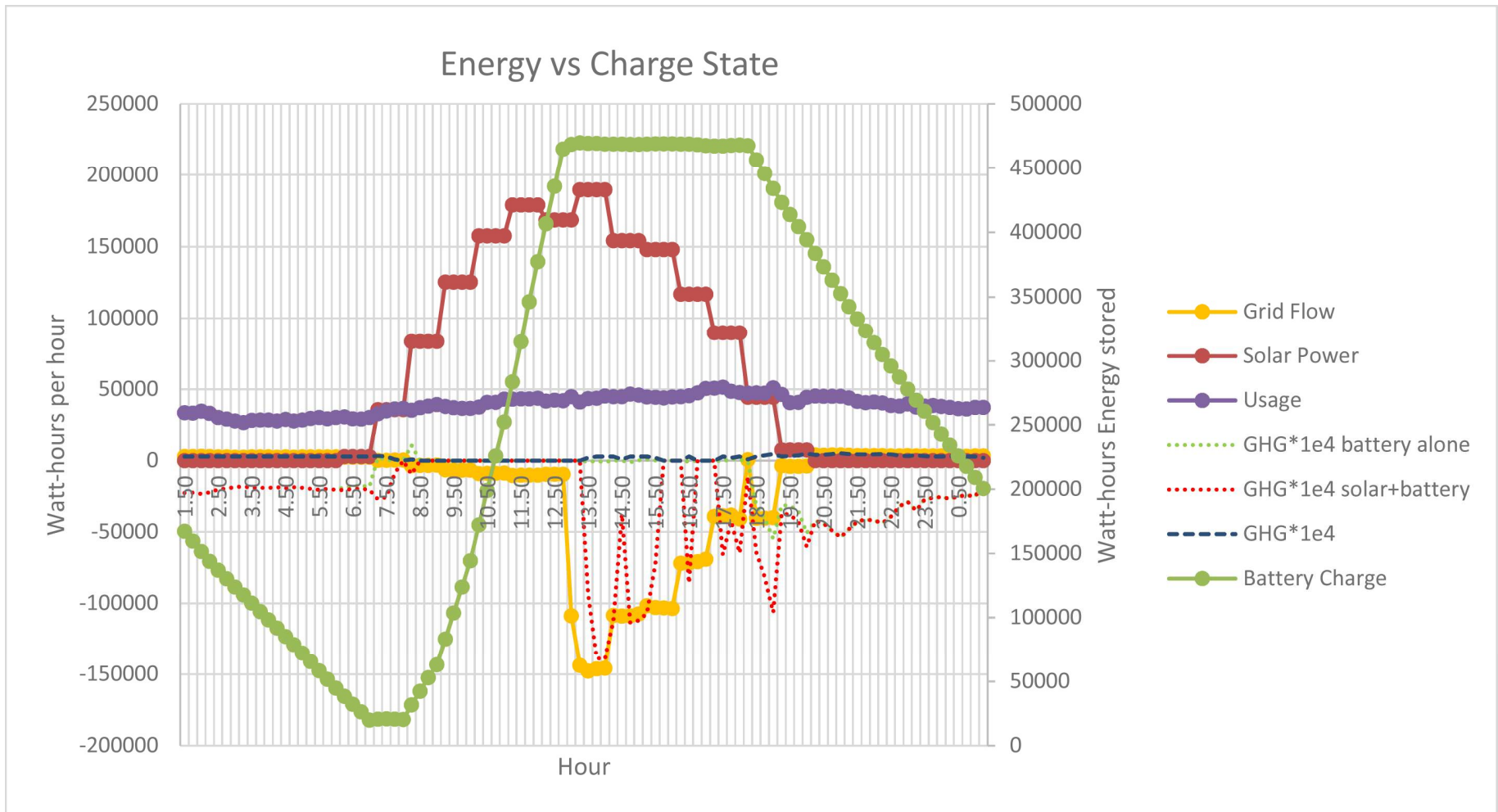


Best Rates for Solar+Storage- Commercial

- PG&E
 - A1STORE
 - B-19R
 - Option S if high demand charges
 - B-20R – very large systems over 1MW demand



Backup



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



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!

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Custom Power Solar



Custom Power Solar

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 ₂ H ₄	3.06
Ethane	C ₂ H ₆	1.19
Propene	C ₃ H ₆	1.01
Propane	C ₃ H 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



Custom Power Solar

Lead Acid Batteries

- 80-85% efficiency¹
- 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



Custom Power Solar

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



Custom Power Solar

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



Custom Power Solar

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



Custom Power Solar

BYD Energy Storage System



240 Kwh in outdoor container
Includes all operational and climate controls



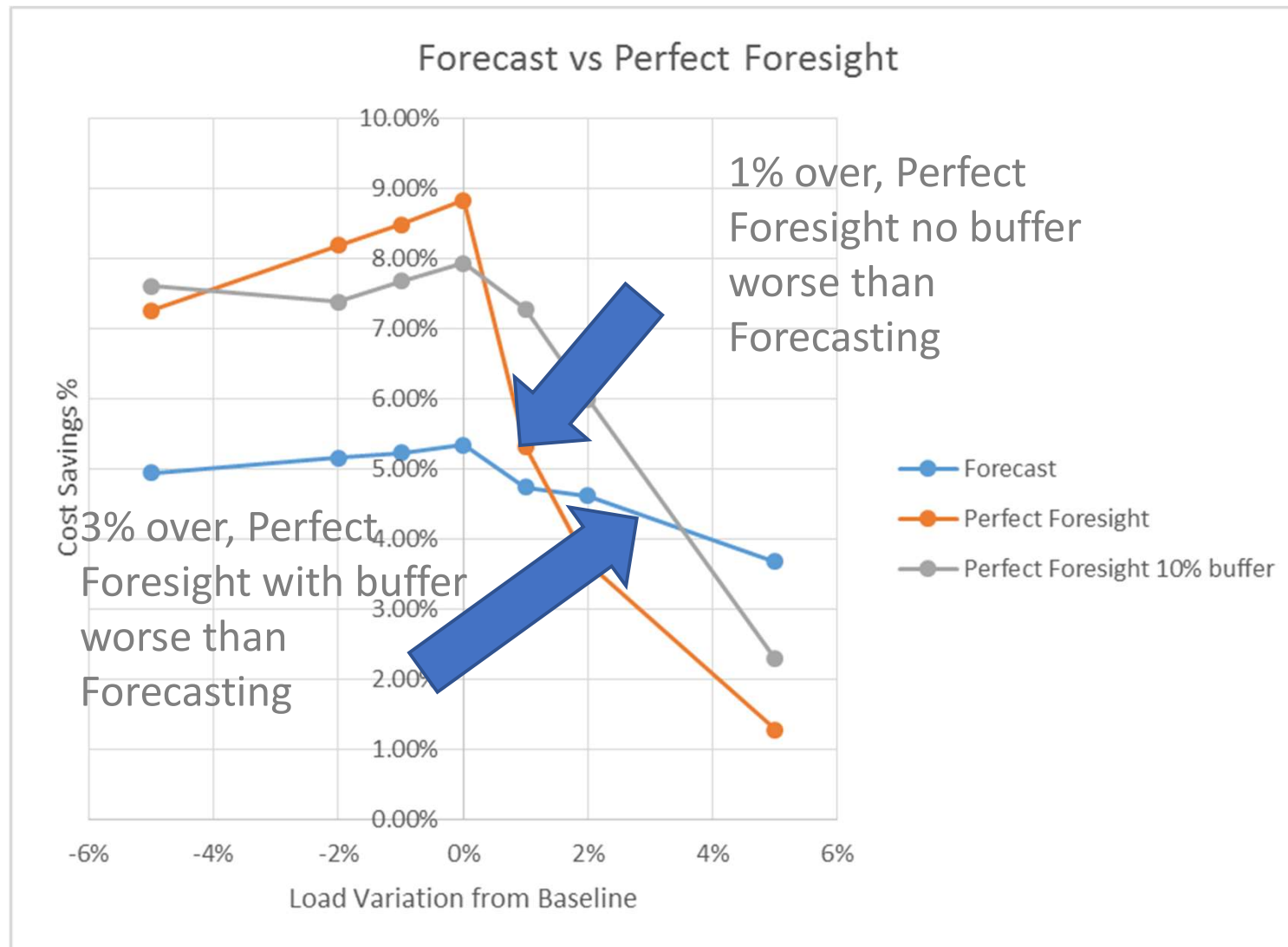
Custom Power Solar

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



Custom Power Solar

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

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