Solar Plus Storage
Focus on Storage Benefits

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Getting to 100% renewables

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

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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

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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

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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% RTE[1]) = $0.67/kwh
  - Lithium - $500/kwh / (5000 cycles * 80% DOD * 85% RTE[1]) = $0.15/kwh
  - Lithium is 4X+ the value of lead-acid

[1] RTE – Round Trip Efficiency = one way efficiency squared

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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

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Storage Markets

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

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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

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Some Residential Storage Systems

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

Lithium Iron Phosphate Battery Suppliers cyle life >3000

- Energport
- SimpliPhi
- BYD
- CATL
- Battle Born
- Kilovault
- Renogy

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

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

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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

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Residential Storage Only Systems

- Custom Power Solar
- Outback inverter includes automatic transfer switch (ATS)
- Energport LiFePo batteries
  - 4kw/10kwh - $14k
  - 8kw/20kwh - $21k
- $500/kwh after rebates and Federal Incentive Tax Credit of 26%

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

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EV2 SOLAR+STORAGE RATE 2020
EV is NOT required: Solar+storage is required

Summer	Peak	$0.47861
	Part-Peak	$0.36812
	Off-Peak	$0.16611
Winter	Peak	$0.35150
	Part-Peak	$0.33480
	Off-Peak	$0.16611

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

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Residential EV-A vs new storage EV2 rate - Savings 8kw/20kwh

	Solar only	Solar+Storage	Difference
EVA	$3,825	$4,944	129%
EV2	$2,863	$4,241	148%
Difference	75%	86%	

All EVA customers will be moved to EV2 rate after grandfathering period

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

	Solar+Storage Savings	Raw Cost	Final Cost	Simple Payback Years	Payback with EV	kwh generated per year
4kw PV/10kwh	$2,120	$32,700	$21,698	10.2	6.0	6400
6kw PV/10kwh	$2,863	$34,500	$23,030	8.0	5.3	9600
7kw PV/20kwh	$3,757	$41,925	$26,024	6.9	4.9	11200
8kw PV/20kwh	$4,241	$45,800	$28,892	6.8	5.0	12800
12kw PV/20kwh	$5,725	$49,200	$31,408	5.5	4.3	19200

[1]Typical Installation costs – systems using Outback Radian or Skybox with LFP batteries & 20%+ efficiency 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 $0.20/watt-hour

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Storage Benefit - Residential Solar+Storage EV2 rate

Savings	Solar Only	Solar+Storage	Storage Benefit
4kw PV/10kwh	$1,430	$2,120	48%
6kw PV/10kwh	$2,147	$2,863	33%
7kw PV/20kwh	$2,410	$3,758	56%
8kw PV/20kwh	$2,863	$4,241	48%
12kw PV/20kwh	$4,295	$5,725	33%

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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 Generator input supports use
  - Option on Custom Power Solar systems
  - Emergency use to backfill home & battery
- Coming
  - OSSIACO

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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						

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Commercial Storage Systems

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

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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

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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

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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

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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

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Cost Modeling Tool Tips Cont'd

- Storage size – best SGIP rebate value
- = 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 double that of 2X battery size (4X savings).

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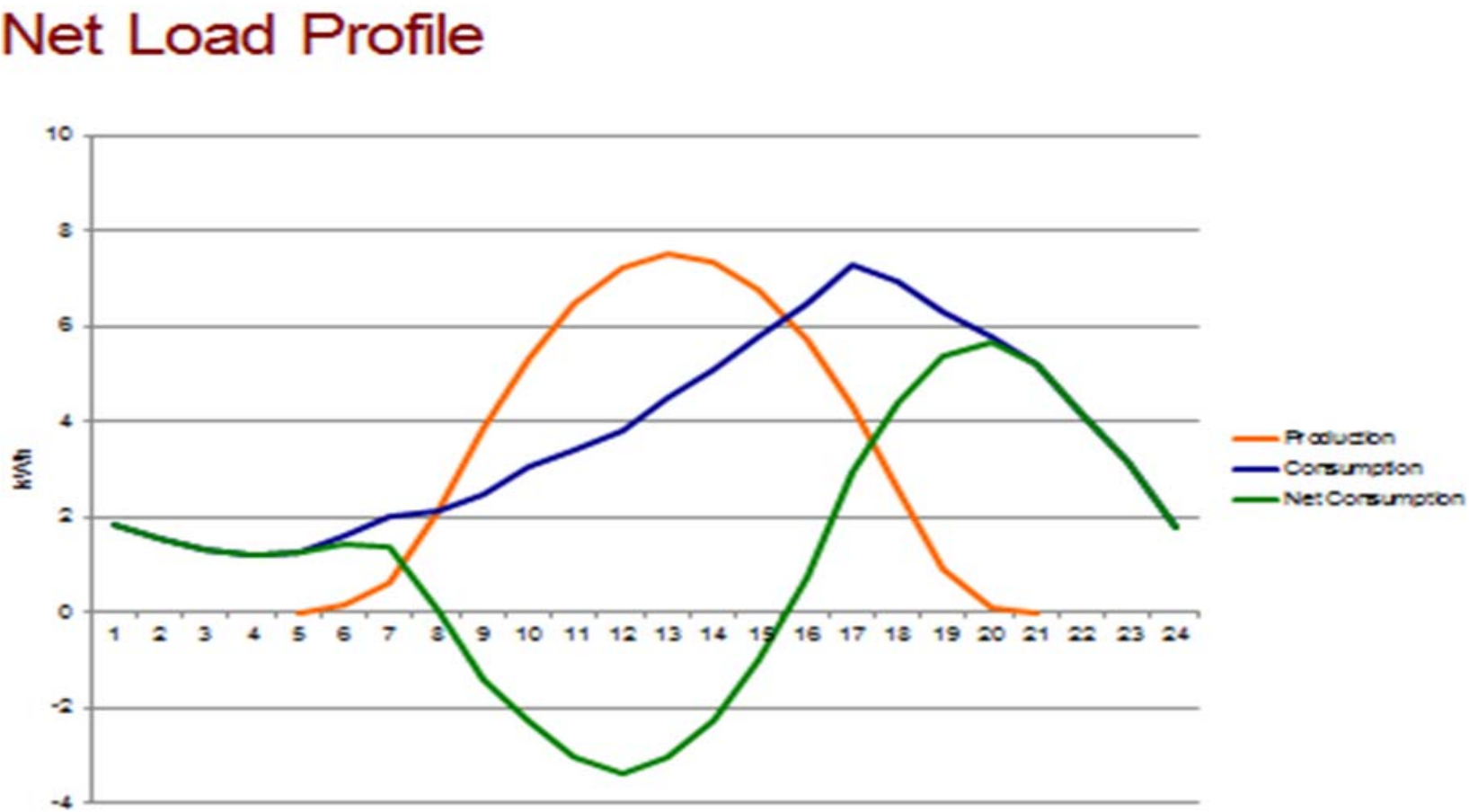
Typical Solar Production and Consumption



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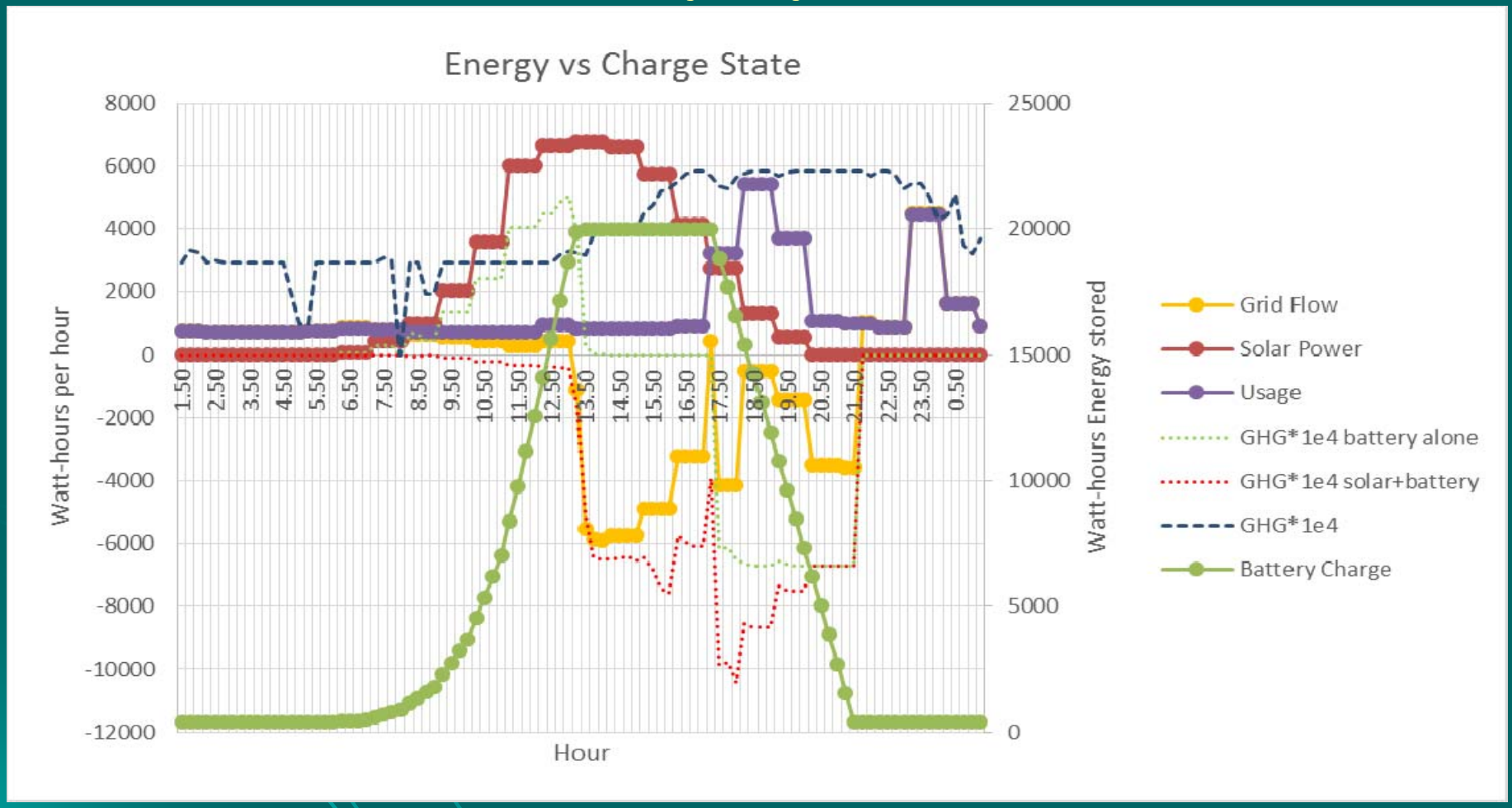
Residential Solar+Storage+EV – Arbitrage Daily Cycle



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

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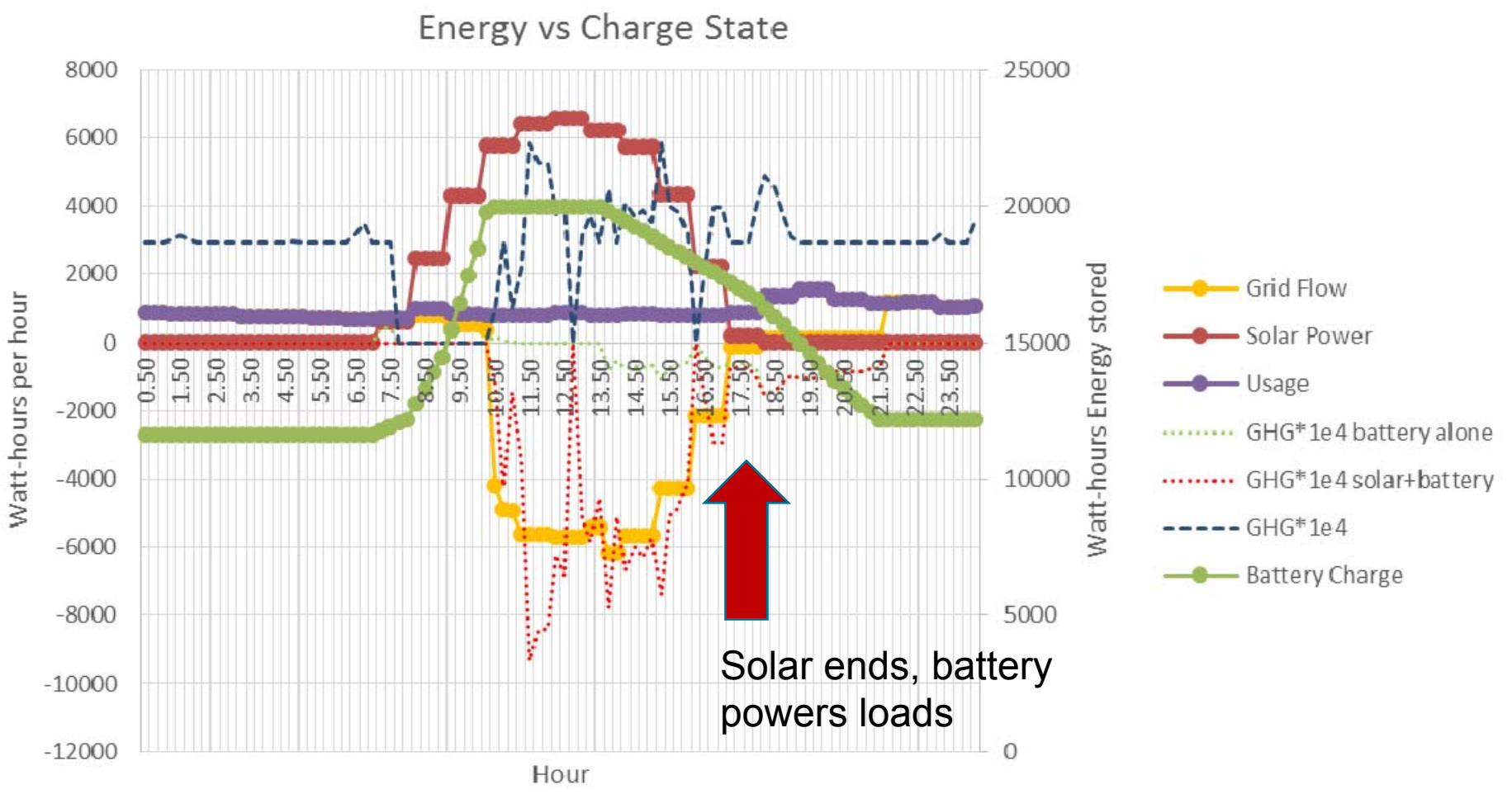
Resi Solar+Storage+EV Self Supply– Daily Cycle



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

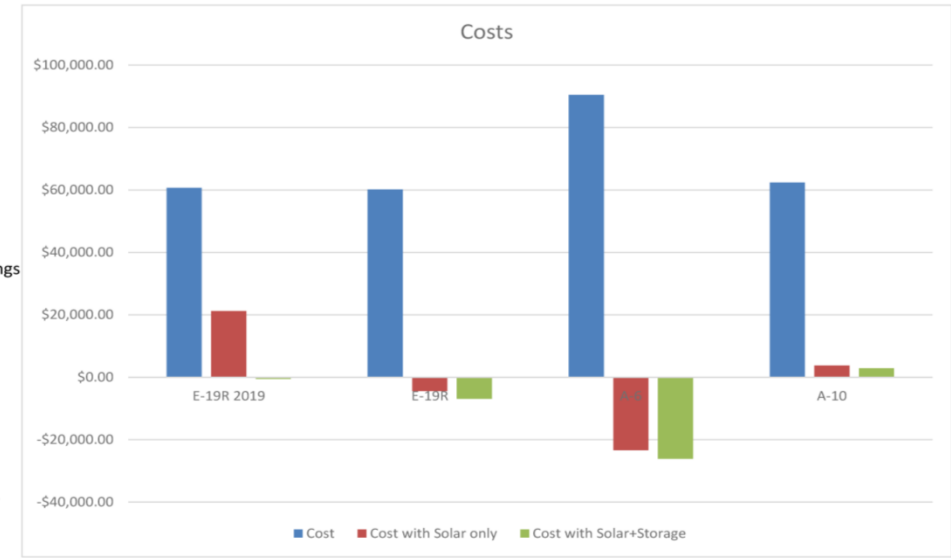
Total usage	**361,803**	**kwh**	**120.00**	**kw Battery**
Total solar	**361,803**	**kwh**	**235.19**	**kw AC Solar**
Surplus	**0**	**kwh**	**480.00**	**kwh Battery**
Percent solar vs usage	**100.0%**		**84.9%**	**RTE**
GHG savings	**117,208**	**kgs/CO2**	np15	**GHG Data**
GHG savings battery alone	**19,709**	**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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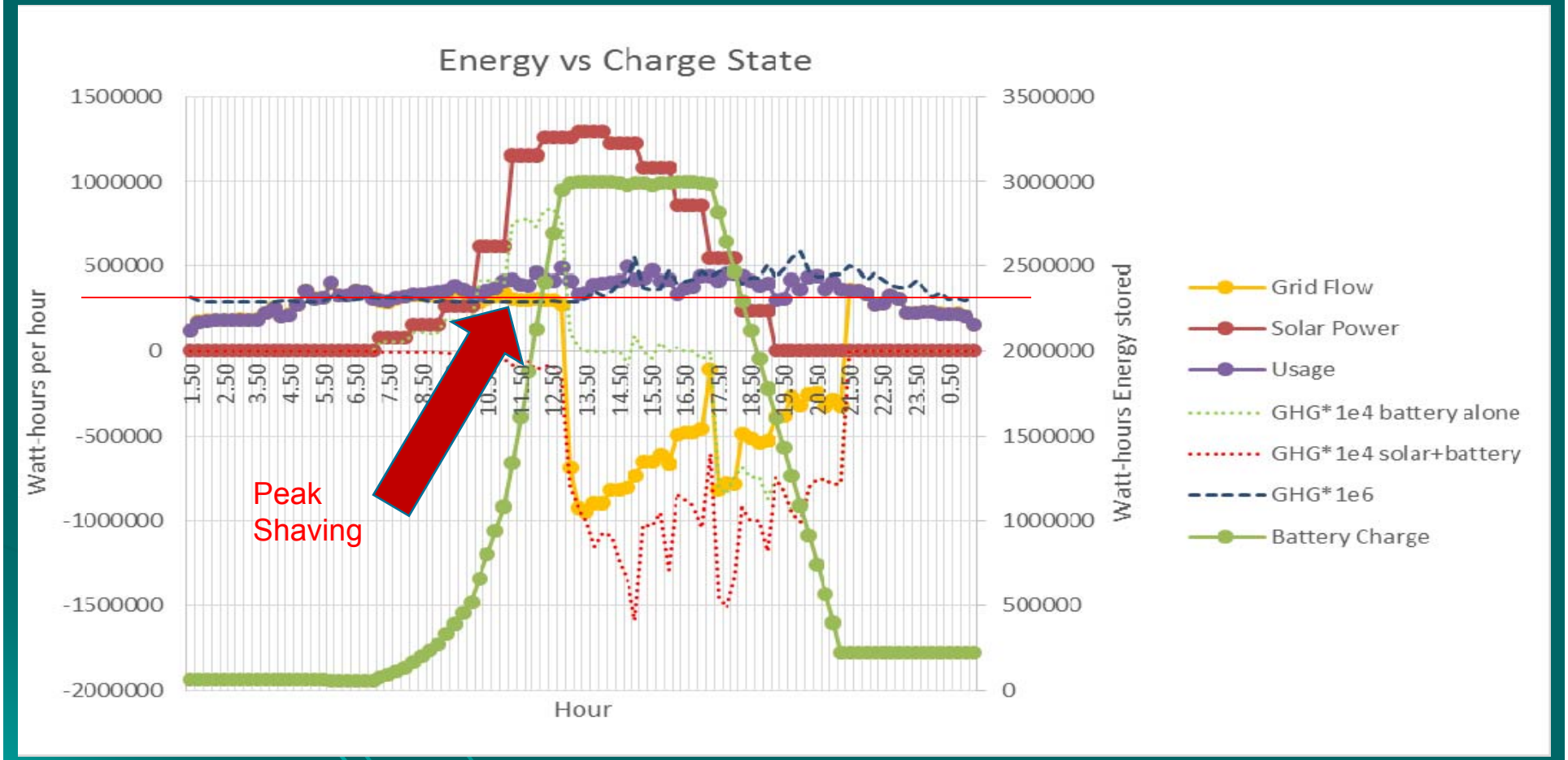
Commercial Solar+Storage – Arbitrage & Demand Reduction Daily Cycle



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

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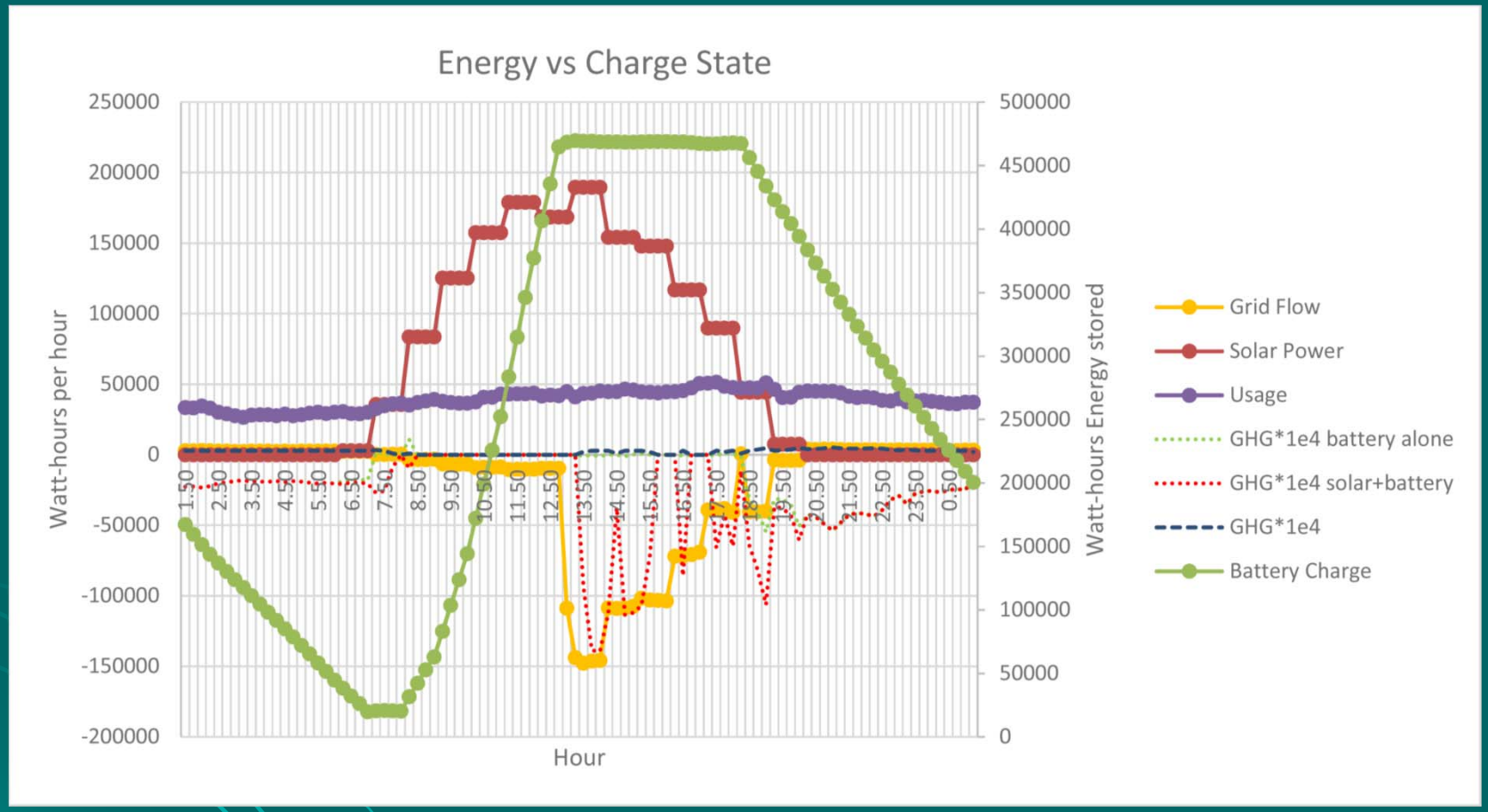
Backup



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

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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**

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Thank You!

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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

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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

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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

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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

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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

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Flow Batteries

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

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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

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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

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Examples - SGIP approved battery systems

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

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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

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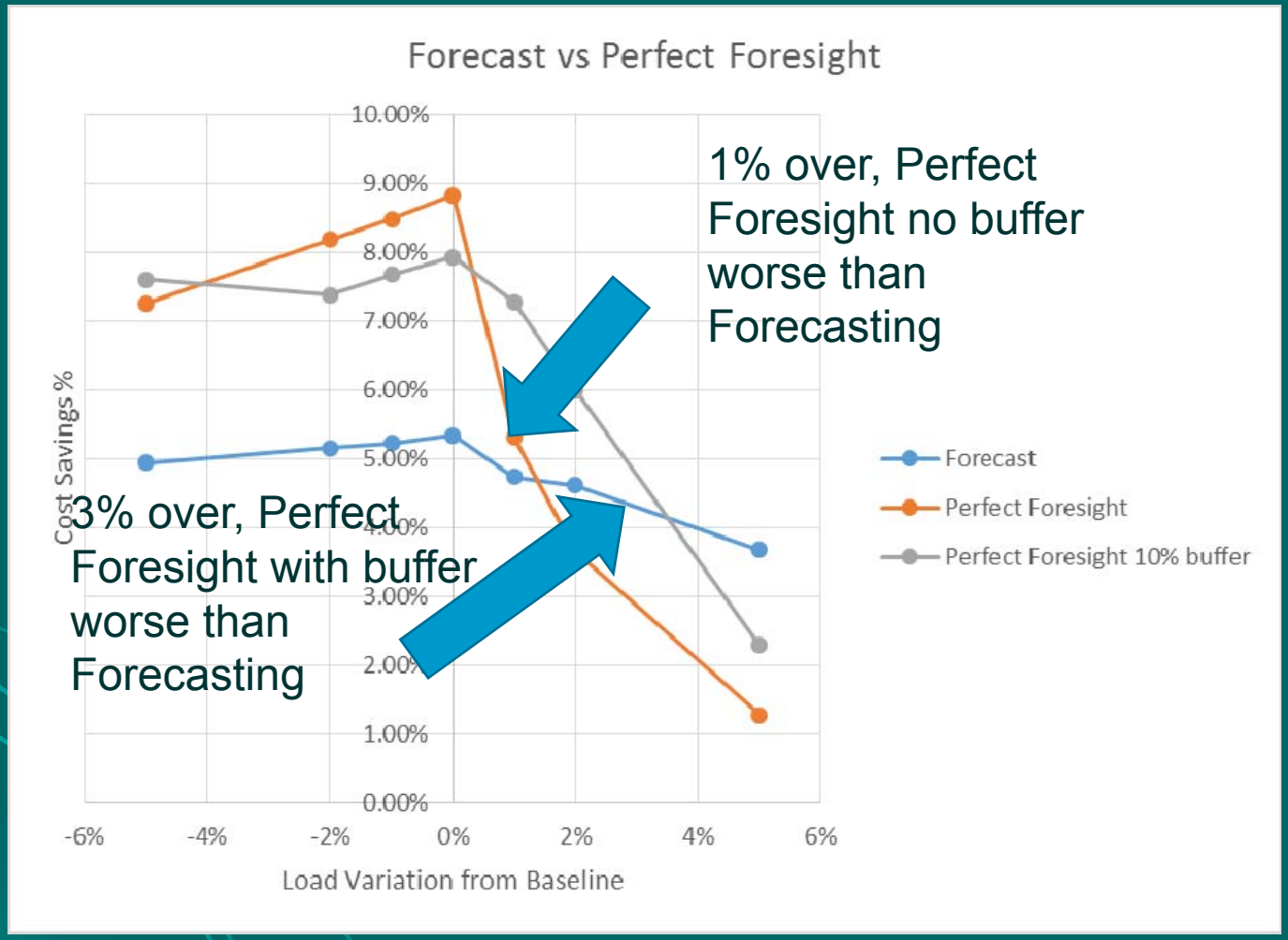
Forecasting Sensitivity Analysis – Cost Savings



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**

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