Custom Power Solar

Solar plus Storage
Focus on Storage Benefits

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Overview storage products

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

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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%
- May require maintenance
- Lifetime is typically 6-7 years
- Heavy
- Lead is a toxin

[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

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Lithium Ion 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
- Typically can last up to 10+ years

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Lithium Iron Phosphate Batteries

- Lithium Iron Phosphate (LiFePo)
- 96-98% efficiency
- 3000-5000 cycle life
- High DOD (80%+)
- 3.2-3.6V/cell
- -20 to 60C operating temperature
- Much lighter weight than lead-acid
- Typically can last up to 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

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

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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SGIP approved battery systems

- Energport
- LG
- SimpliPhi
- Tesla
- Contact your SGIP Program Administrator for specifics – no current online list

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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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Energport

Specifications by Model	L3060	L6060	L3020	L30120
Nominal Voltage (V) 3 Phase	480V/60Hz	480V/60Hz	480V/60Hz	480V/60Hz
Power Rated (kW AC)	29	60	29	29
Battery Capacity (kWh DC)	64.5	64.5	22.1	129.0
Duration of Discharge (Hours)	2.2	1.1	0.67	4.6
Nominal Voltage	358.4	358.4	204.8	716.8
DC Amp-Hours	180	180	108	180
Inverter CEC-AC Efficiency	97%	97%	97%	97%
Dimension (DxWxH) 42U Rack	800mm x 600mm x 2000mm (32" x 24" x 80")			800 x 1200 x 2000 32" x 48" x 80"
Weight	660kg (1500lbs)	700kg (1550lbs)	220kg (485lbs)	1360kg (3020lbs)
Real Time Power Monitor	Yes	Yes	Yes	Yes
Web / Smartphone App	Yes	Yes	Yes	Yes
Compliance	CE, UL	CE, UL	CE, UL	CE, UL
Warranty Length	10 years	10 years	10 years	10 years
California SGIP Eligibility (60% cost)	Yes	Yes	Yes	Yes
Financing Options	Lease, Finance, Buy			

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Storage Markets

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

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Some Residential Storage Systems

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

Residential Storage Systems Cont'd

- Custom Power Solar, Inc
- Outback Radian inverter
- Energport LiFePo batteries
  - 4kw/10kwh
  - 8kw/20kwh
- $478/kwh after rebates and Federal Incentive Tax Credit of 30%
- ITC applies only if installed with solar

Residential Storage Systems Cont'd

- Tesla Powerwall
- 5kw/14kwh
- -20 to 60C operating temperature
- $5900 not including install costs + install hardware

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Residential Storage Systems Cont'd

- LG Chem
  - 9.8kwh
  - $6150
- Solaredge inverter
  - 7.6kw
  - $4000
- Over $10,000 not including install costs + install hardware

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Residential Storage Systems cont'd

- SimpliPhi (LiFePo)
- 10.2kwh with 6.8kw Schneider inverter
- After SGIP rebate and ITC
- $500-$1000/kwh

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Commercial Storage Systems

- Usually in USA 480V 3 phase:
- Energport - $500/kwh
- Tesla Powerpack - $500/kwh
- LG Chem
- Sonnen
- Avalon (Flow batteries)
- Range of costs: $500-$1000/kwh
- After SGIP rebate and ITC - $250-$500/kwh

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Some Storage Systems Solutions Providers

- Advanced Microgrid Solutions
- Custom Power Solar with Energport
- LG Chem
- Sonnen
- STEM
- Tesla Powerpack
- Avalon (Flow batteries)
- Range of costs: $500-$1000/kwh
- After SGIP rebate and ITC costs: $250-$500/kwh

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
- Public model
  - Enernoc

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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

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 load of customer
- Note SGIP guidelines
- Make sure size fits available space
  - roof
  - ground
  - carport

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Cost Modeling Tool Tips

- 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 – rebate is not as large proportionally, but cost savings double that of 2X battery size(4X savings)

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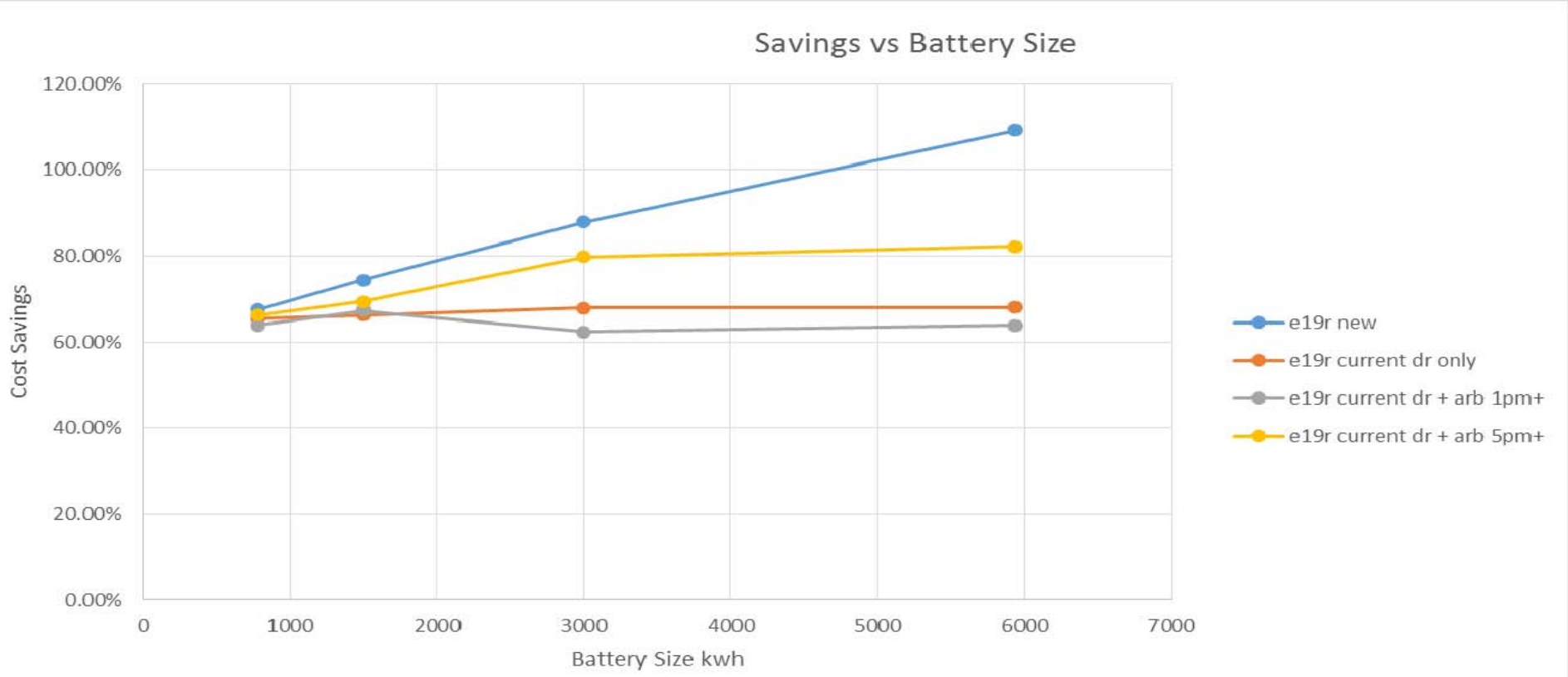
Battery Size vs Savings Solar+Storage



New rates – value increases even with 4X batteries
Current rates – value same 2x-4X size
Plan for the future – go 4X
Note – 100% solar

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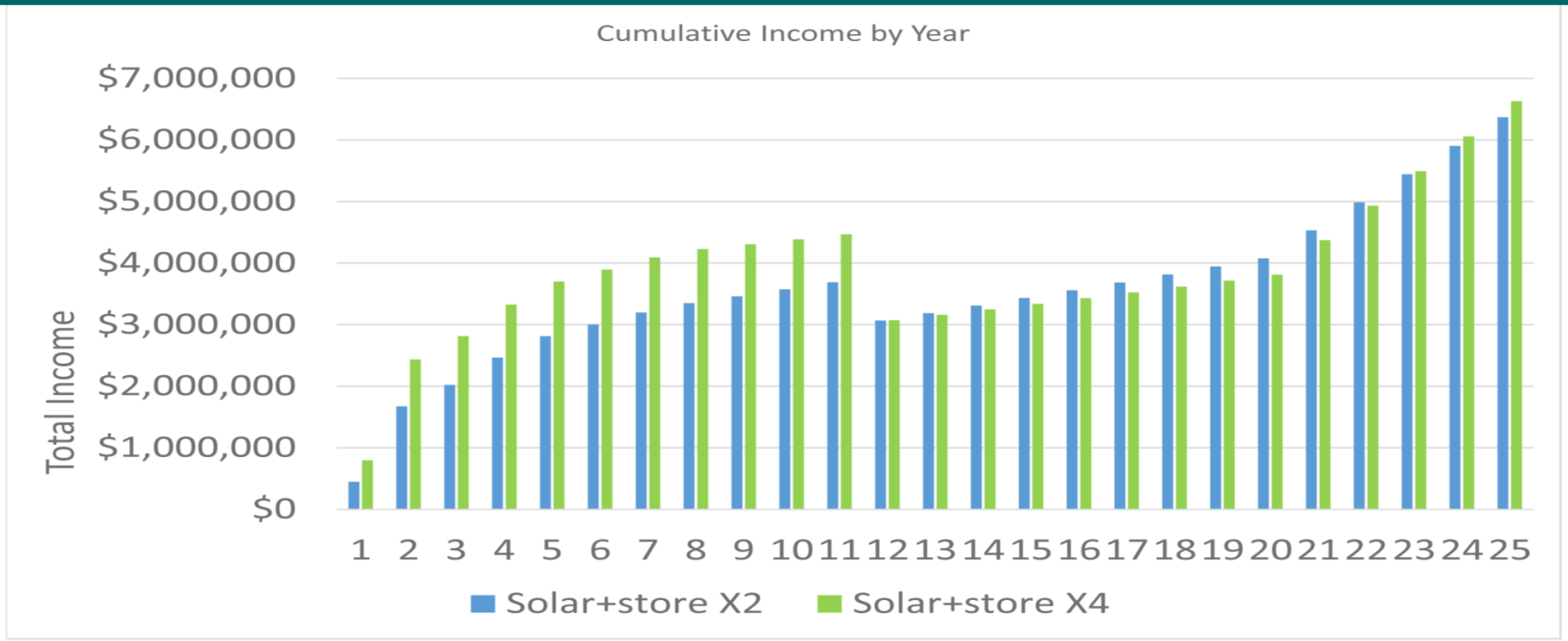
Financing



	Solar+store X2	Solar+store X4
Total Cost	$3,404,000	$4,884,000
Energy Annual Income 1st year	$397,128	$493,772
Battery rebate	$815,480	$1,223,220
Tax credits	$1,081,451	$1,551,647
Depreciation credits	$757,016	$1,086,153
Interest	$2,938,402	$4,215,969

	Solar+store X2	Solar+store X4	
Payments 1st yr	($322,520)	($462,746)	
Income 1st yr	$397,128	$493,772	
Payments 25 yr	$0	$0	
Income 25 yr	$501,856	$623,987	
Term	20	20	years
Rate	6.50%	6.50%	
Bank fees	5.90%	5.90%	

1480kw solar, X2 & X4 battery size $1.30/watt solar, $500/kwh storage, 50% replacement battery cost year 12

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Residential Solar+Storage+EV

Models by: **Custom Power Solar**

Load year 2017

Solar Data OAKLAND METROPOLITAN ARPT, CA

Annual

	sEVA	EVA
Cost	$2,358.15	$2,189.39
Cost Est. with Solar	-$331.85	-$1,460.64
Cost Est. with Solar+Storage	-$1,382.31	-$2,658.84
Improvement over solar only	44.55%	54.73%
Cost Advantage batteries	$1,050.46	$1,198.21
Difference vs optimized rate		54.13%
Total Value Solar+Storage	$3,740.45	$4,848.23
Optimized Rate		

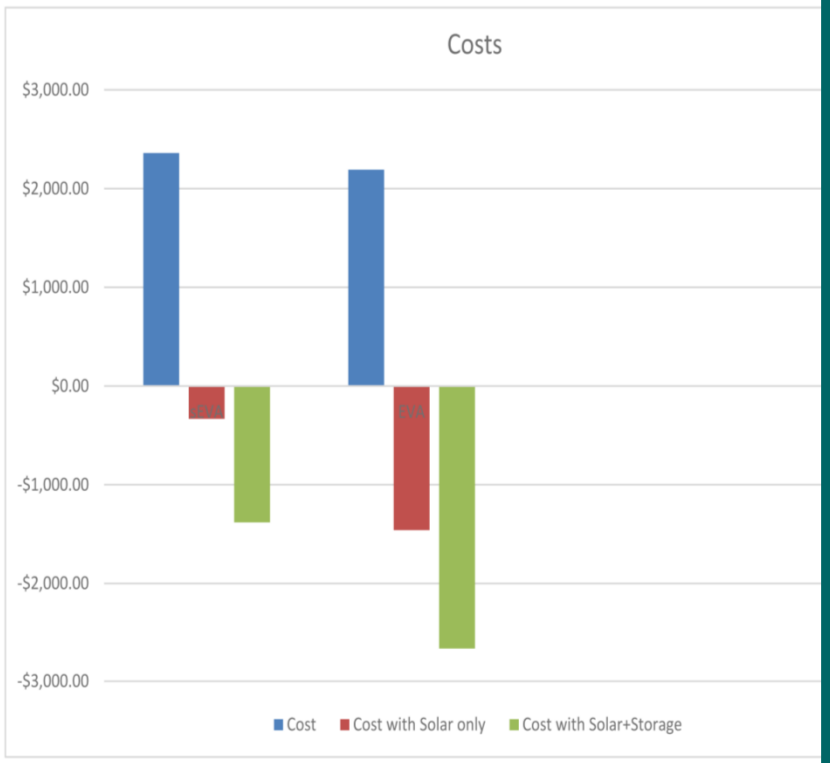
Total usage	10,657	kwh	5.00	kw Battery
Total solar	13,850	kwh	8.00	kw AC Solar
Surplus	3,193	kwh	20.00	kwh Battery
Percent solar vs usage	130.0%		84.9%	RTE
GHG savings	4,265	kgs/CO2	np15	GHG Data
GHG savings battery alone	490	kgs/CO2	6,418	kwh Battery use
Annual percent dispatchable	46.3%		8.79%	% of Life used

Annual Demand Charges

	sEVA	EVA	Max Demand
Cost	$0.00	$0.00	8.08
Cost Est. with Solar	$0.00	$0.00	8.08
Cost Est. with Solar+Storage	$0.00	$0.00	8.02

Annual Energy Charges

	sEVA	EVA
Cost	$2,358.15	$2,189.39
Cost Est. with Solar	-$331.85	-$1,460.64
Cost Est. with Solar+Storage	-$1,382.31	-$2,658.84
Grid Charge	0 kwh	
Grid Charge	0 days	



EV Use	35.0	mi/day	GHG Value Adder
EV Charge	3190.6	kwh	$65 $/mT
EV Gas Savings	$1,701.64		$31.82 GHG Savings Battery alone
EV GHG savings	3786.1	kg	$2,189.39 Baseline rate cost
Total GHG Savings	8,051	kg	($2,658.84) Optimized rate final cost
Net GHG savings	4,564	kg	$4,880.05 Total Savings
GHG Load Only	-3,487	kg	

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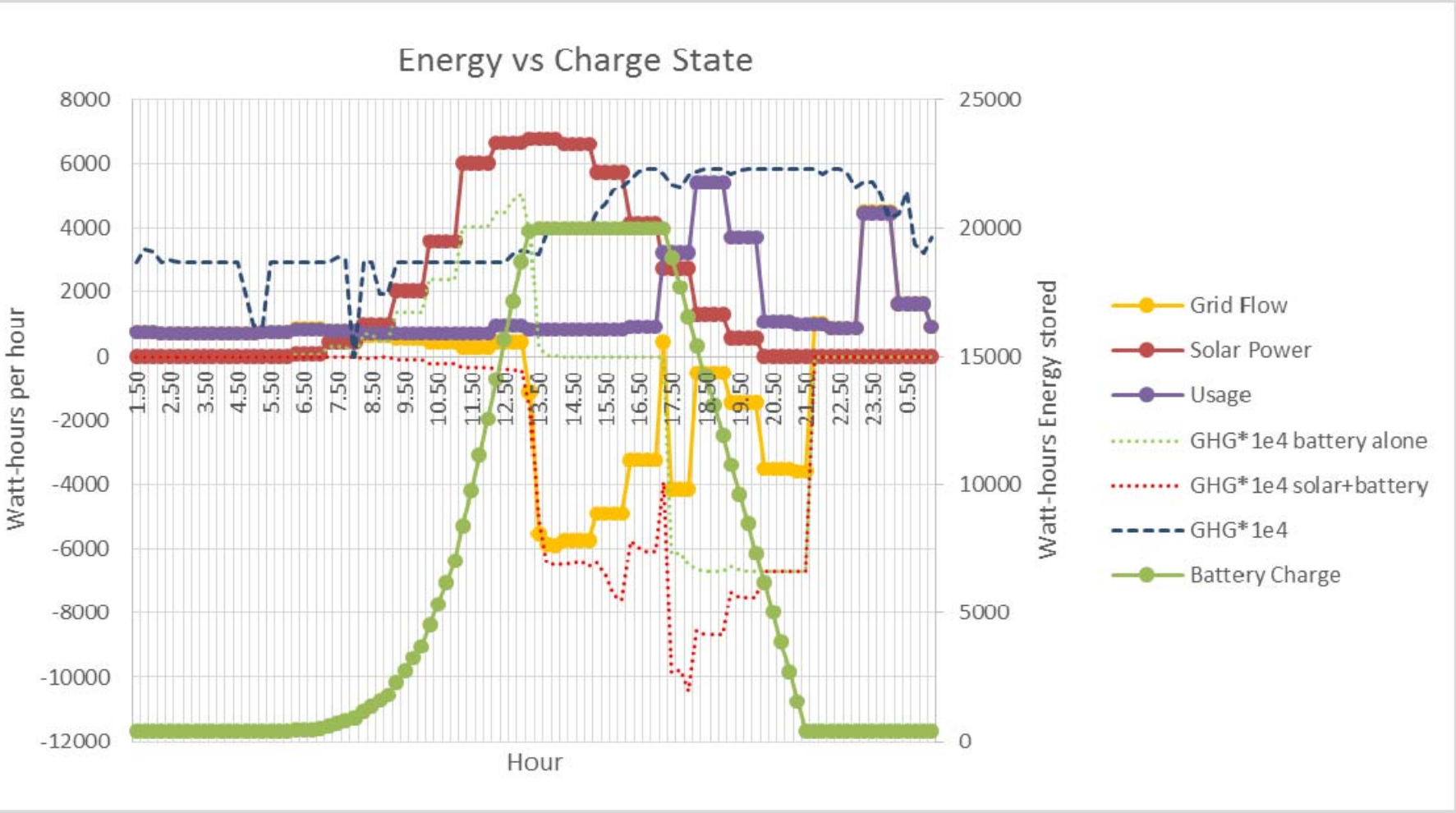
Residential Solar+Storage+EV – Daily Cycle



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

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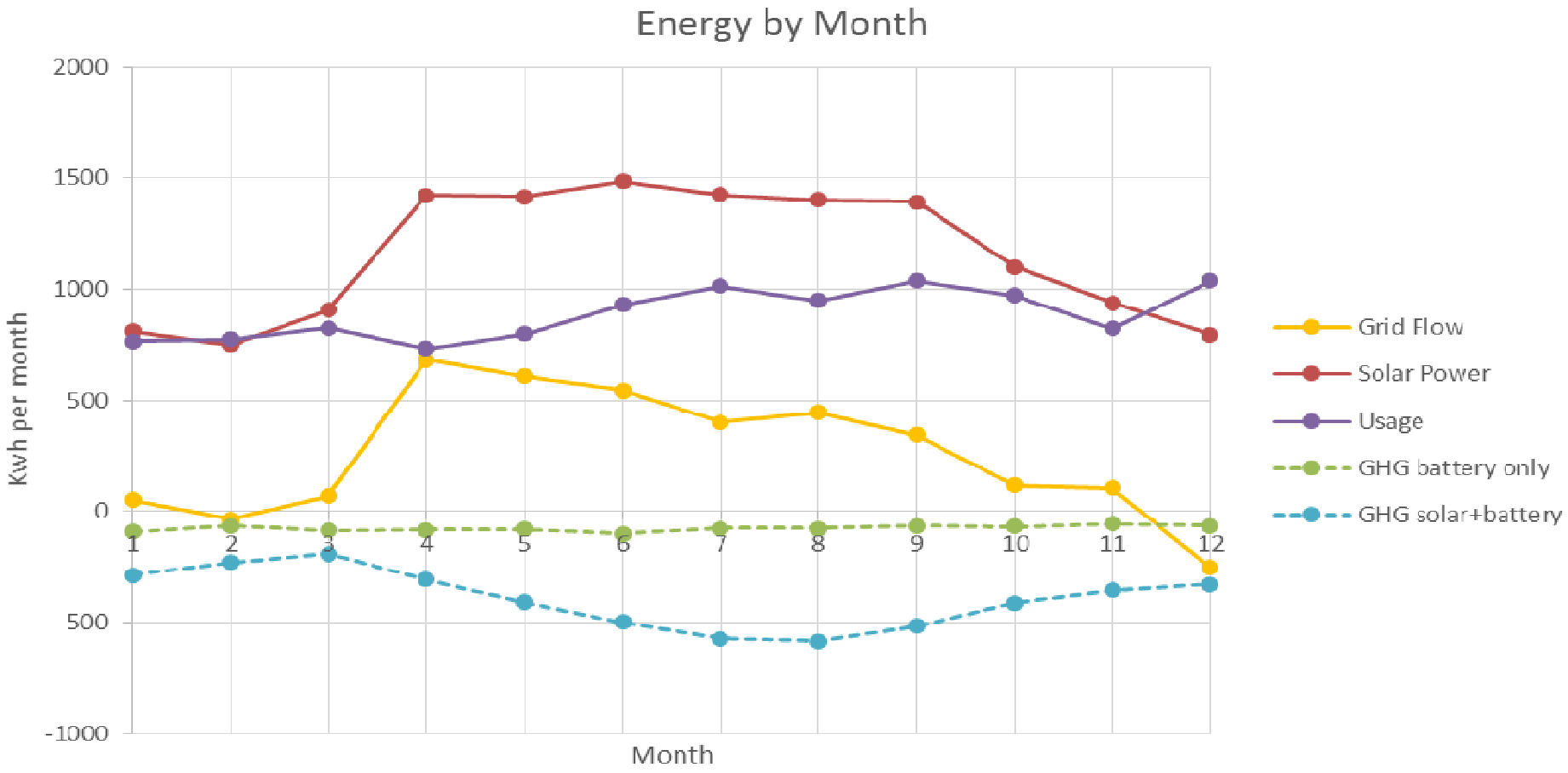
Residential Solar+Storage+EV – Annual Cycle



Residential Solar+Storage (sEV-A)
New Storage Rate in PGE Territory

Models by: **Custom Power Solar**

Load year 2017

Solar Data OAKLAND METROPOLITAN AR

Annual

	sEVA	EVA
Cost	$2,358.15	$2,189.39
Cost Est. with Solar	-$331.85	-$1,460.64
Cost Est. with Solar+Storage	-$1,494.96	-$2,331.15
Improvement over solar only	49.32%	39.76%
Cost Advantage batteries	$1,163.11	$870.52
Difference vs optimized rate		35.46%
Total Value Solar+Storage	$3,853.10	$4,520.54
Optimized Rate		

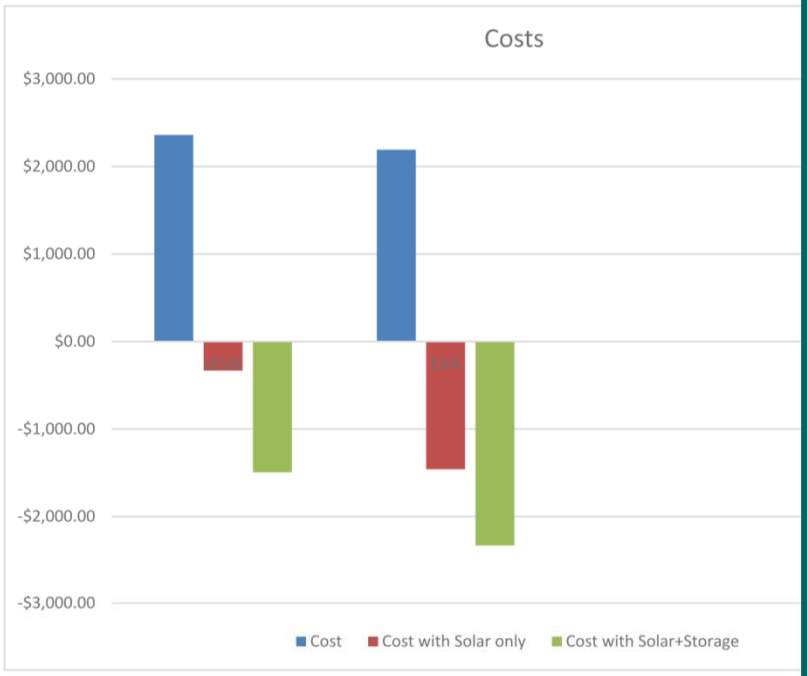
Total usage	10,657	kwh	5.00	kw Battery
Total solar	13,850	kwh	8.00	kw AC Solar
Surplus	3,193	kwh	20.00	kwh Battery
Percent solar vs usage	130.0%		84.9%	RTE
GHG savings	4,692	kgs/CO2	np15	GHG Data
GHG savings battery alone	917	kgs/CO2	6,602	kwh Battery use
Annual percent dispatchable	47.7%		9.04%	% of Life used

Annual Demand Charges

	sEVA	EVA	Max Demand
Cost	$0.00	$0.00	8.08
Cost Est. with Solar	$0.00	$0.00	8.08
Cost Est. with Solar+Storage	$0.00	$0.00	8.02

Annual Energy Charges

	sEVA	EVA
Cost	$2,358.15	$2,189.39
Cost Est. with Solar	-$331.85	-$1,460.64
Cost Est. with Solar+Storage	-$1,494.96	-$2,331.15
Grid Charge	0 kwh	
Grid Charge	0 days	



EV Use	35.0	mi/day	GHG Value Adder
EV Charge	3190.6	kwh	$65 $/mT
EV Gas Savings	$1,701.64		$59.58 GHG Savings Battery alone
EV GHG savings	3786.1	kg	$2,189.39 Baseline rate cost
Total GHG Savings	8,478	kg	($1,494.96) Optimized rate final cost
Net GHG savings	4,991	kg	$3,743.92 Total Savings
GHG Load Only	-3,487	kg	

New rate available to all solar+storage customers in PG&E territory*
Limited to 30,000 customers at present

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Resi Solar+Storage+EV – Self Supply

Models by: **Custom Power Solar**

Load year 2017

Solar Data OAKLAND METROPOLITAN ARPT, CA

Annual

	sEVA	EVA
Cost	$2,358.15	$2,189.39
Cost Est. with Solar	-$331.85	-$1,460.64
Cost Est. with Solar+Storage	-$678.68	-$1,858.84
Improvement over solar only	14.71%	18.19%
Cost Advantage batteries	$346.82	$398.20
Difference vs optimized rate		50.05%
Total Value Solar+Storage	$3,036.82	$4,048.23
Optimized Rate		

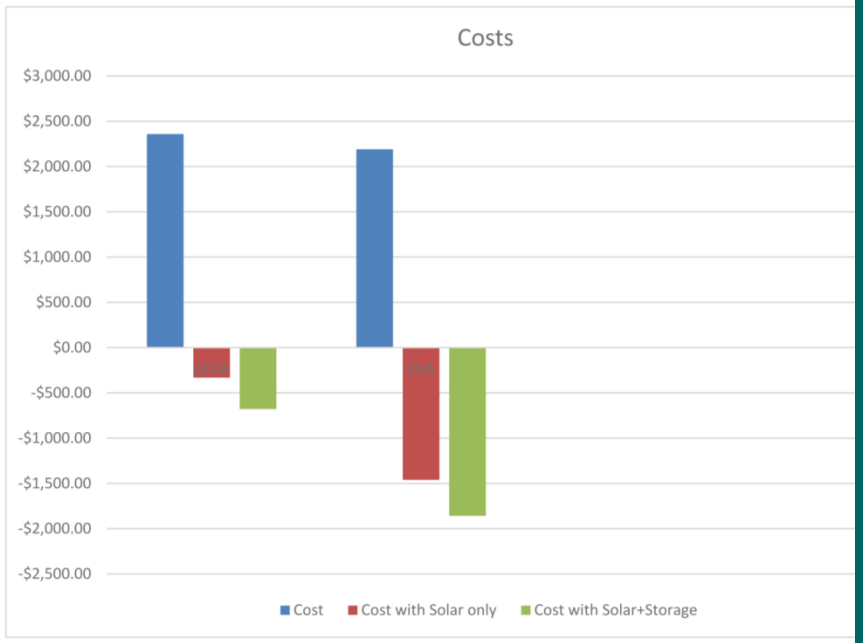
Total usage	10,657 kwh		5.00 kw Battery	
Total solar	13,850 kwh		8.00 kw AC Solar	
Surplus	3,193 kwh		20.00 kwh Battery	
Percent solar vs usage	130.0%		84.9% RTE	
GHG savings	4,077 kgs/CO2	np15	GHG Data	
GHG savings battery alone	302 kgs/CO2		2,875 kwh Battery use	
Annual percent dispatchable	20.8%		3.94% % of Life used	

Annual Demand Charges

	sEVA	EVA	Max Demand
Cost	$0.00	$0.00	8.08
Cost Est. with Solar	$0.00	$0.00	8.08
Cost Est. with Solar+Storage	$0.00	$0.00	8.02

Annual Energy Charges

	sEVA	EVA
Cost	$2,358.15	$2,189.39
Cost Est. with Solar	-$331.85	-$1,460.64
Cost Est. with Solar+Storage	-$678.68	-$1,858.84
Grid Charge	0 kwh	
Grid Charge	0 days	



EV Use	35.0 mi/day	GHG Value Adder	
EV Charge	3190.6 kwh	$65	$/mT
EV Gas Savings	$1,701.64	$19.65	GHG Savings Battery alone
EV GHG savings	3786.1 kg	$2,189.39	Baseline rate cost
Total GHG Savings	7,863 kg	($678.68)	Optimized rate final cost
Net GHG savings	4,377 kg	$2,887.71	Total Savings
GHG Load Only	-3,487 kg		

Cost savings – 18% vs 54% - $800 less

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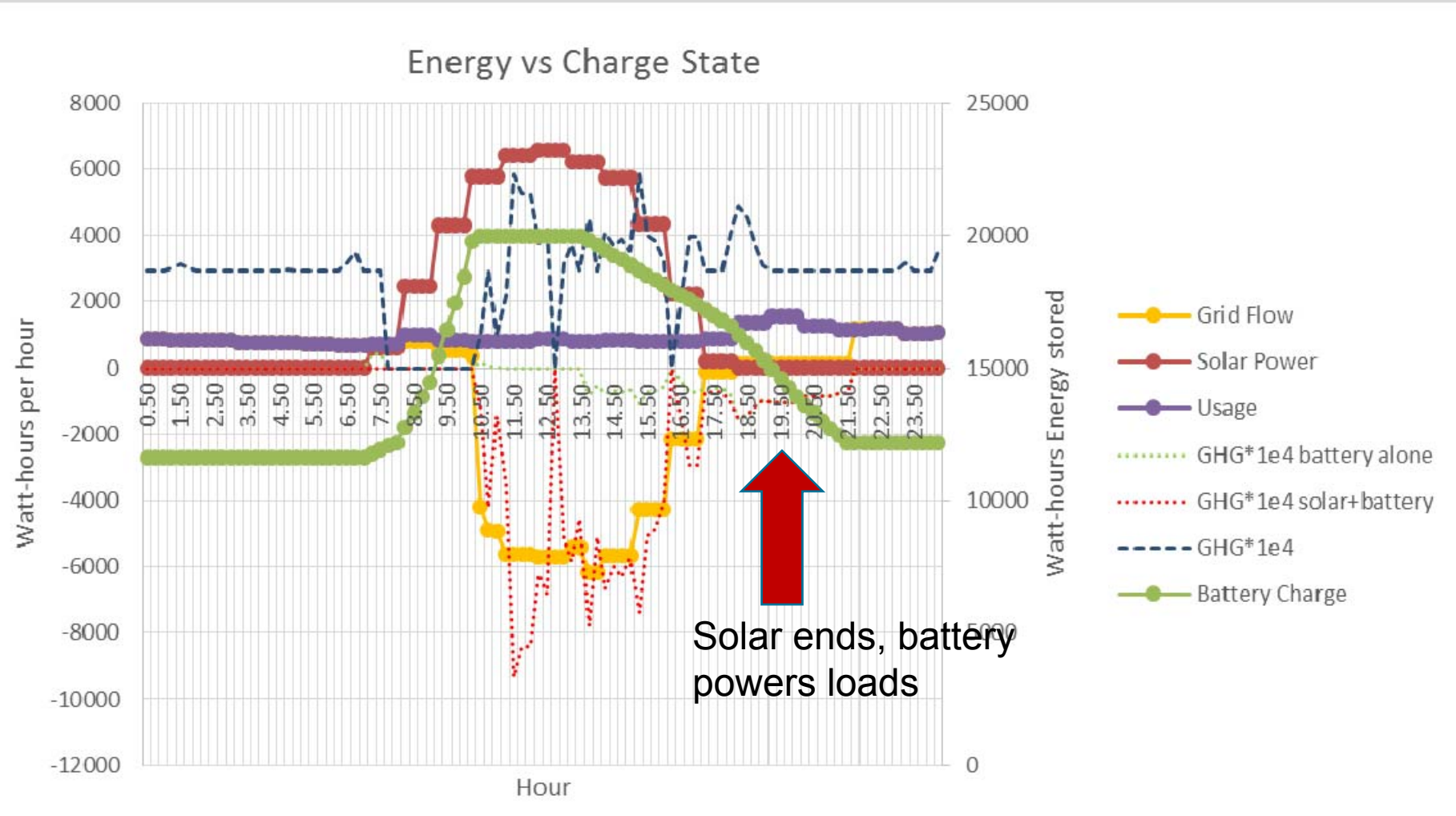
Resi Solar+Storage+EV Self Supply– Daily Cycle



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 Assessment

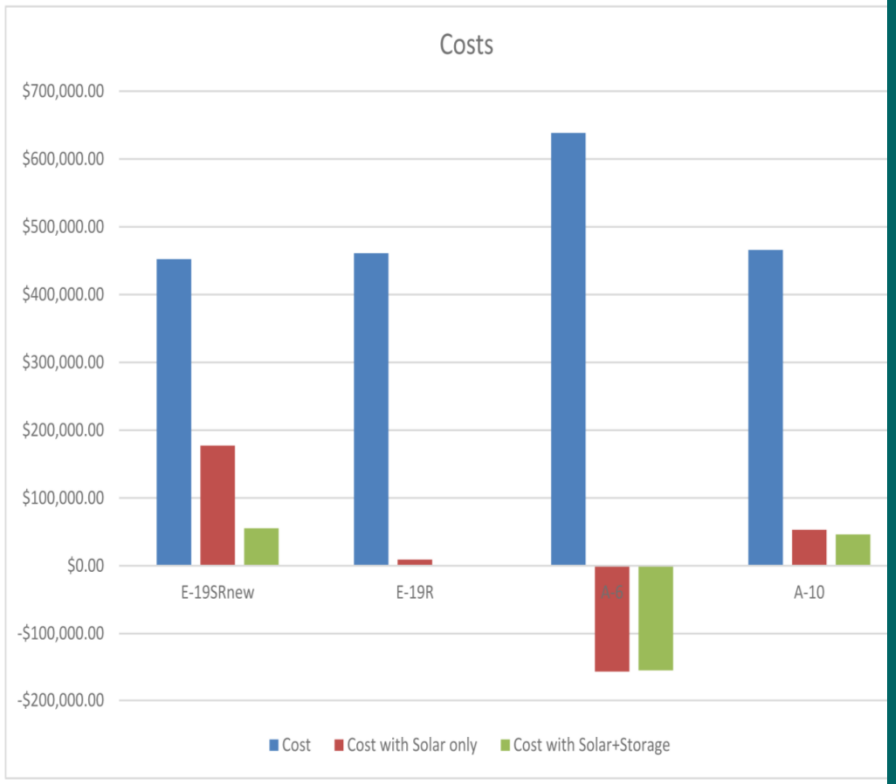
Models by: **Custom Power Solar** C3_e19rnew_v63_5_10_18.xlsx

Load year 2017

Solar Data OAKLAND METROPOLITAN ARPT, CA

Annual

	E-19SRnew	E-19R	A-6	A-10	EBCE FIT
Cost	$452,206.60	$460,742.60	$638,292.64	$465,773.36	
Cost Est. with Solar	$177,053.44	$8,864.19	-$156,145.93	$52,844.30	$277,625.31
Cost Est. with Solar+Storage	$55,078.88	$473.43	-$154,274.78	$45,892.74	**$453,227.08**
Improvement over solar only	**26.97%**	**1.82%**	**-0.29%**	**1.49%**	
Cost Advantage batteries	**$121,974.57**	**$8,390.76**	**-$1,871.15**	**$6,951.56**	
Difference vs optimized rate		**12.08%**	**46.30%**	**2.03%**	
Total Value Solar+Storage	**$397,127.73**	**$460,269.16**	**$792,567.42**	**$419,880.62**	
Optimized Rate					



Total usage	2,570,605 kwh		750.00 kw Battery		
Total solar	2,570,605 kwh		1,484.80 kw AC Solar		
Surplus	0 kwh		3,000.00 kwh Battery		
Percent solar vs usage	100.0%		84.9% RTE		
GHG savings	834,945 kgs/CO2	np15	GHG Data		
GHG savings battery alone	134,292 kgs/CO2		975,565 kwh Battery use		
Annual percent dispatchable	38.0%		8.91% % of Life used		

Annual Demand Charges

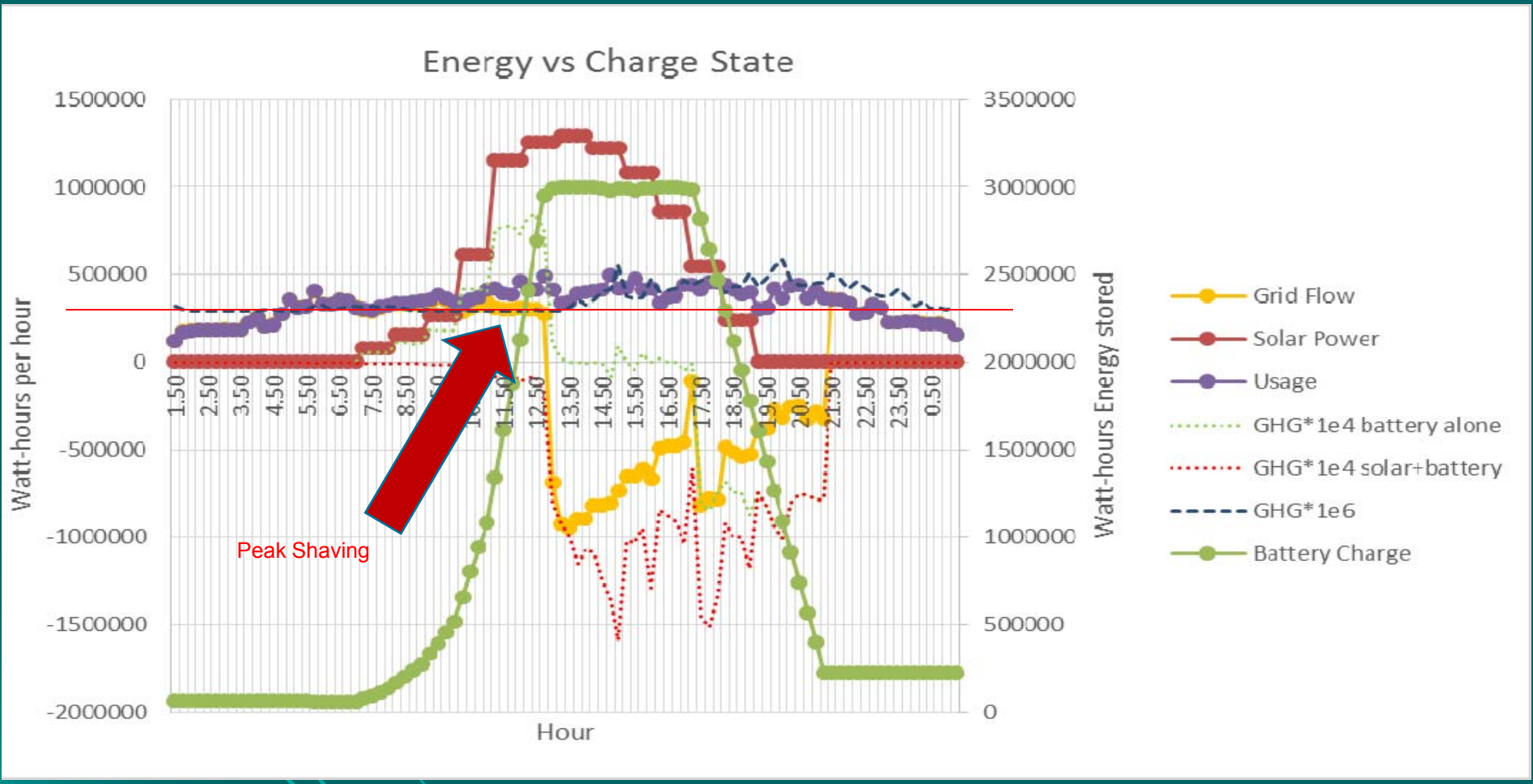
	E-19SRnew	E-19R	A-6	A-10	Max Demand
Cost	$136,554.92	$126,492.96	$0.00	$98,934.20	686.32
Cost Est. with Solar	$132,227.50	$118,934.62	$0.00	$95,268.96	651.69
Cost Est. with Solar+Storage	$123,175.88	$111,354.08	$0.00	$87,255.69	653.94

Annual Energy Charges

	E-19SRnew	E-19R	A-6	A-10
Cost	$315,651.68	$334,249.64	$638,292.64	$366,839.16
Cost Est. with Solar	$44,825.95	-$110,070.43	-$156,145.93	-$42,424.65
Cost Est. with Solar+Storage	-$68,097.00	-$110,880.65	-$154,274.78	-$41,362.95
Grid Charge	0 kwh			
Grid Charge	0 days			

		GHG Value Adder	
EV Use	0.0 mi/day	$65	$/mT
EV Charge	0.0 kwh	$8,728.96	GHG Savings Battery alone
EV Gas Savings	$0.00	$460,742.60	Baseline rate cost
EV GHG savings	0.0 kg	$55,078.88	Optimized rate final cost
Total GHG Savings	834,945 kg	$414,392.68	Total Savings
Net GHG savings	18,980 kg		
GHG Load Only	-815,965 kg		

Commercial Solar+Storage – 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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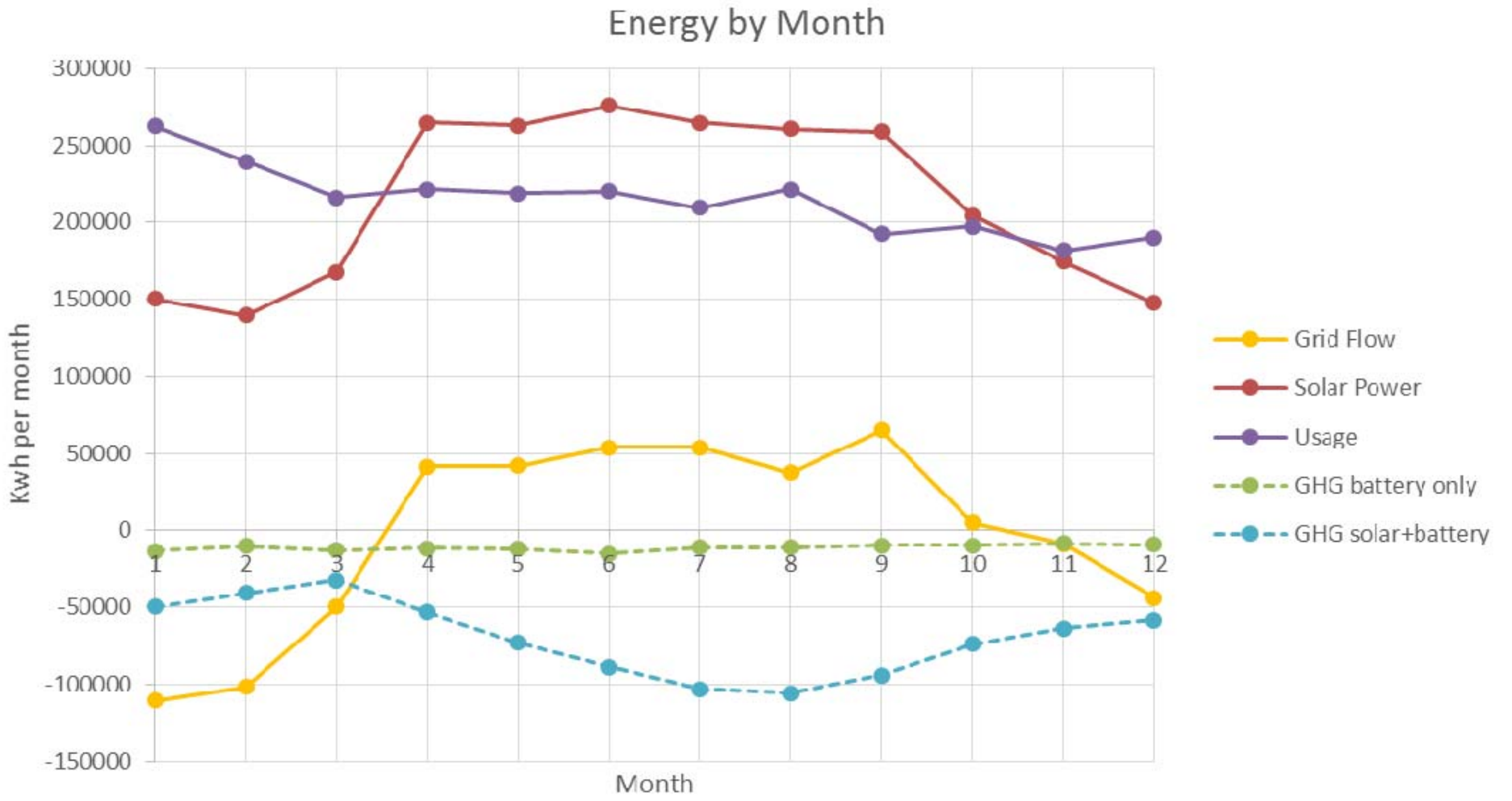
Commercial Solar+Storage – Annual Cycle



Best rates for solar+storage Residential

- PG&E
- EVA – EV customers only
- sEVA – coming in early 2019

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Rates with Highest Demand Charges

Utility	Rate	Applicable kW Range	Demand Charges
Southern California Edison	TOU-GS-2-B	20 – 200 kW	Demand Charge: $15.89 Summer OP: $19.89 Summer MP: $3.88
	TOU-GS-3-B	201 – 500 kW	Demand Charge: $18.29 Summer OP: $20.01 Summer MP: $3.94
	TOU-8-B	>500 kW	Demand Charge: $19.02 Summer OP: $21.73 Summer MP: $4.17
SDGE	AL-TOU	>=20 kW	Demand Charge: $22.55 Summer OP: $9.36 Summer MP: $6.86
PG&E	A-10 Secondary Voltage	200 – 499 kW	Summer: $19.52 Winter: $11.76
	E-19 Secondary Voltage	500 – 999 kW	Demand Summer: $17.74 Peak Demand Summer: $19.65 Part-Peak Demand Summer: $5.40 Demand Winter: $17.74
	E-20 Secondary Voltage	>=1000 kW	Demand Summer: $17.87 Peak Demand Summer: $19.02 Part-Peak Demand Summer: $5.23 Demand Winter: $17.87

Best rates for solar+storage Commercial

- PG&E
  - A-6 for arbitrage, but value going away over next few years
  - A1STORE – Nov 2019
  - E-19R
  - E-20R – very large systems over 1MW demand
- New TOU rates by Nov 2019

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Best rates for solar+storage Commercial

- SCE
  - TOU8BR

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Best rates for solar+storage Commercial

- SDG&E
  - DG-R
  - New – DR-SES

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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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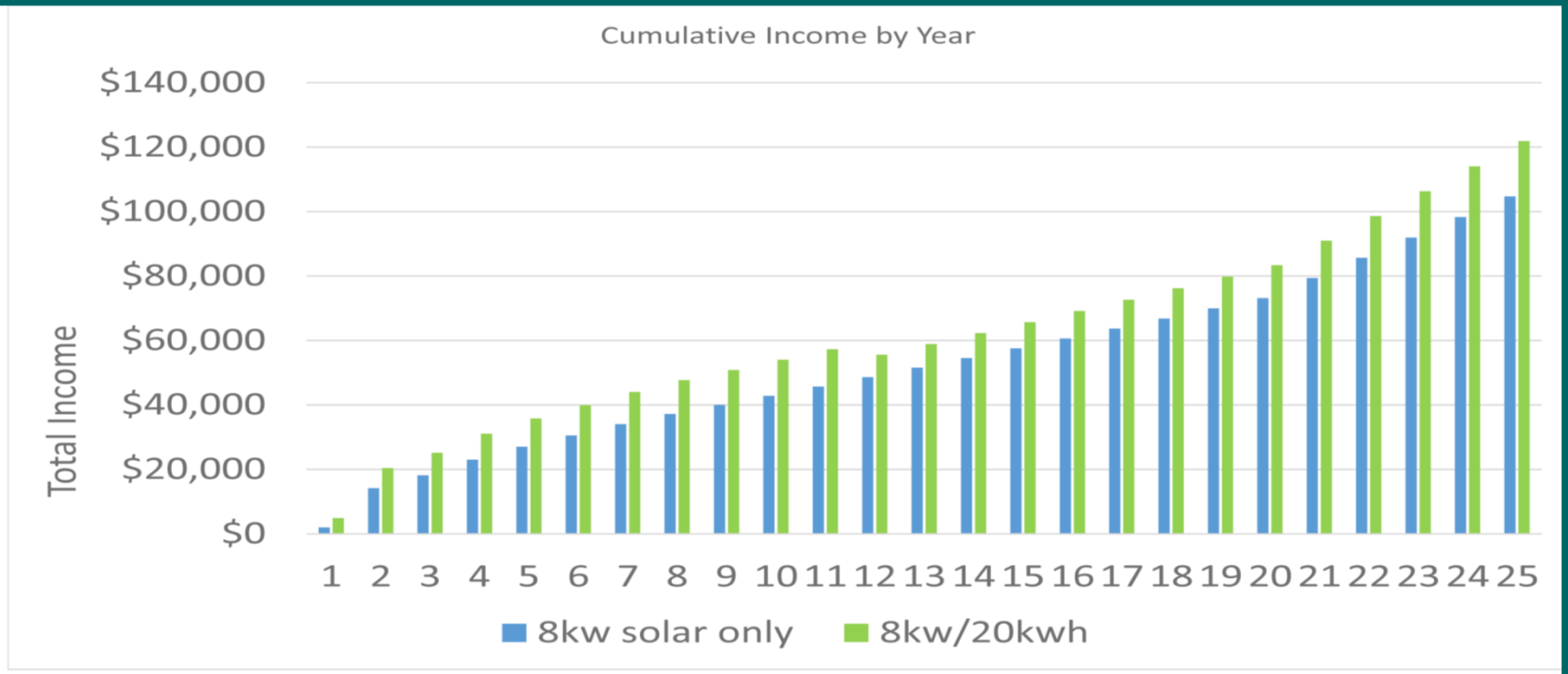
Finance Example: Residential



	8kw solar only	8kw/20kwh
Total Cost	$32,000	$42,000
Energy Annual Income 1st year	$5,350	$6,549
Battery rebate	$0	$2,755
Tax credits	$10,166	$13,343
Depreciation credits	$7,116	$9,340
Interest	$27,623	$36,255

	8kw solar only	8kw/20kwh	
Payments 1st yr	($3,032)	($3,979)	
Income 1st yr	$5,350	$6,549	
Payments 25 yr	$0	$0	
Income 25 yr	$6,761	$8,276	
Term	20	20	years
Rate	6.50%	6.50%	
Bank fees	5.90%	5.90%	

Notes: $4/watt solar cost, $500/kwh storage cost, includes $1701/year value in gas savings with EV (35 miles per day average)

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Various projects sorted by value: $/kwh

Profile & battery scaler	battery size kwh	value/kwh battery alone
C6_X0.5	244.3197405	$165.14
C6_0P_90KW_180WH_DGR_opt	180.00	$126.34
C6_80P_90KW_180KWH_GDR	180.00	$101.89
C6_X1	488.639481	$96.54
C6_40P_90KW_180KWH_DGR	180.00	$95.72
C16_X0.5	8100	$87.87
C16_X0.5	8100	$87.87
C16_X0.5	8100	$87.87
C1_0P_90KW_180KWH	180.00	$85.84
C1_0P_90KW_180KWH_E19Snew	180.00	$83.39
C1_80P_90kw_180KWH	180.00	$74.90
C16_X0.5_good	8,748.12	$64.16
R8_EV_X1	6.16	$62.84
C16X_0P_30KW_60KWH	60.00	$62.84
C16_X1	16200	$62.79
C16_X1	16200	$62.60
C16X_0P_30KW_60KWH_noc	60.00	$62.51
R3_X1	2.71	$62.40
R7_EV_X1	5.12	$62.34
C1_40P_90KW_180KWH	180.00	$62.33
R2_X1_PGE	1.20	$61.66
R10_CARE_CV_X1	9.15	$61.55
C16_X0.5_flow	8,748.12	$61.16
R9_nonCARE_CV_X1	12.20	$61.05

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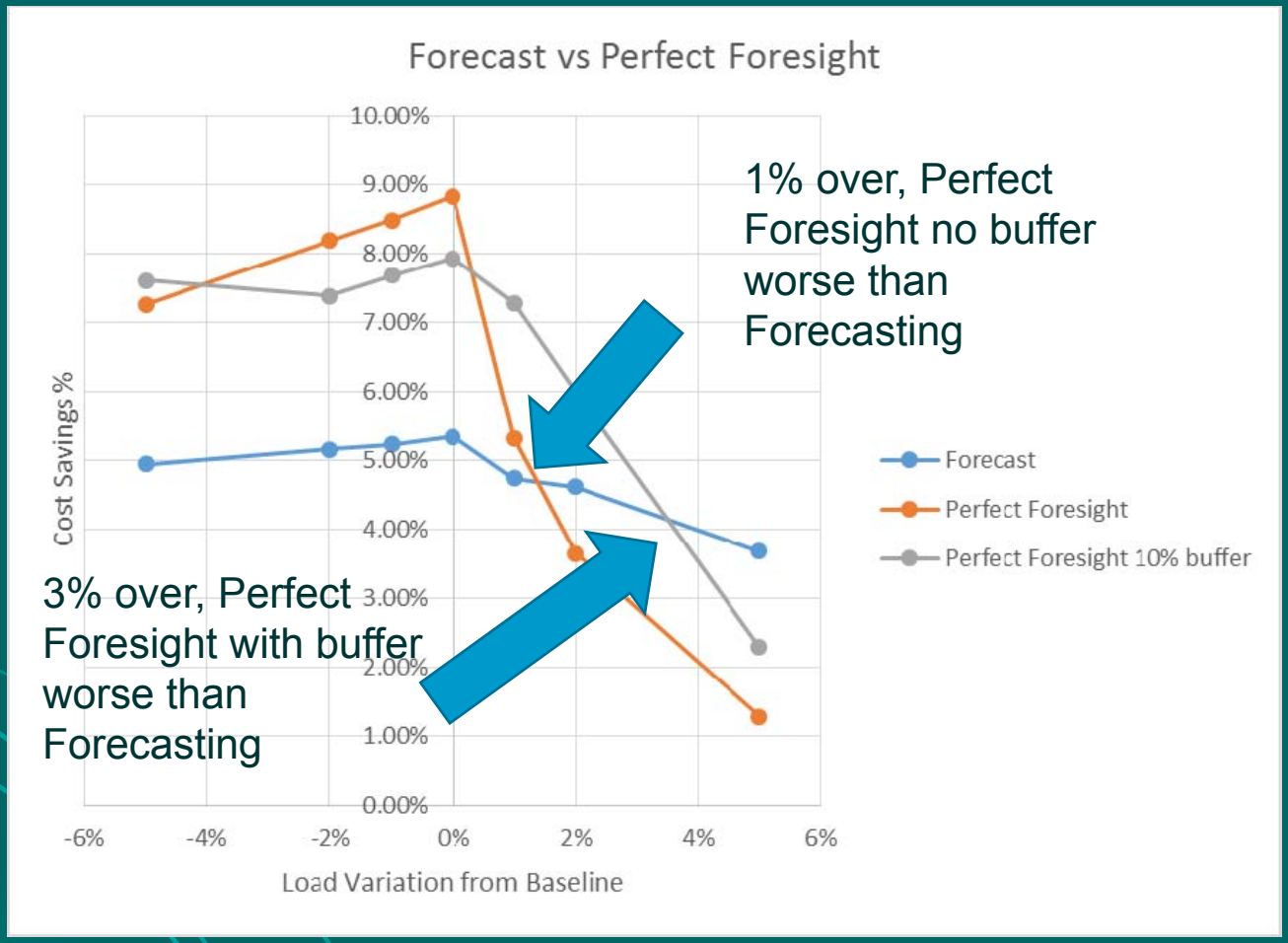
How Realistic is Perfect Foresight in Real world Storage Operations?

- 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

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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Thank You!

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