Solar Potential at Treasure Valley Scout Reservation

Interdisciplinary Qualifying Project

Advisors: Fred Looft & Derren Rosbach
Authors: James Maxwell,
Lillian Neff, & Huyen Nguyen

GOAL STATEMENT

We Sought to Provide Sustainable Power Recommendations to TVSR West Camp

Columbus Lodge

West Lodge

PROBLEM STATEMENT

The Underwater Power Cable is of Concern & Two PCB-Filled Transformers Need Replacement

Cable
Inst. 1983

Transformer
Inst. 1973

$196,000

Cable Replacement — $92,000

Transformer Replacement — $52,000 (ea.)

We Believe the Power Cable Operates Below its Capacity

https://tinyurl.com/y3s9rjbw

Note: Yellow Dashed Line is the Power Cable

Cable capacity

- 600V (recc): 73.4 kW
- 1000V (max): 122.4 kW

Currently:

- Max non-surge: 50.1 kW
- Max surge: 62.5 kW

Completion of the Following Objectives Allowed for the Fulfillment of the Project Goal

Objective 1

Weeks 1-3

To Identify the Specific Power Needs of West Camp

Objective 2

Week 3

To Determine the Optimal Solar System to Meet the Needs of West Camp

Objective 3

Weeks 4-5

To Identify the Optimum Sites to Place the Solar Panels

Objective 4

Weeks 6-7

To Develop Recommendations Based On a Cost and Risk Assessment

The Following Measurements Were Collected

Obj 1 - Identify Power Needs

An Inventory and Load Assessment of West Camp were Conducted

	Lights	Appliances	Other	Total
Columbus Lodge	28	4	9	41
Venture Lodge	76	8	18	102
West Lodge	115	13	28	156

		CSAC
Columbus Lodge	**Average Power (W)**	1,023
	1-Day Energy (kWh)	25
	2-Day Energy (kWh)	50
Venture Lodge	**Average Power (W)**	3,329
	1-Day Energy (kWh)	80
	2-Day Energy (kWh)	160
West Lodge	**Average Power (W)**	2916
	1-Day Energy (kWh)	70
	2-Day Energy (kWh)	140

The Energy and Power Use of Each Building Were Determined

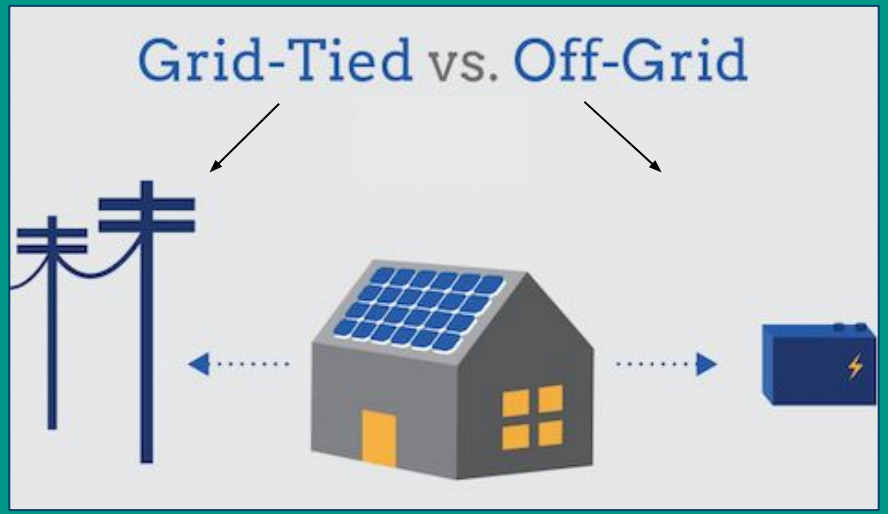
	Yearly Energy Use (kWh)	Max Power Non-Surge (W)	Max Power Surge (W)	% Total Energy Use
Columbus Lodge	1,166	3,890	4,390	6.3
Venture Lodge	7,687	20,175	28,004	41.7
West Lodge	9,594	15,979	21,499	52.0

Off-Grid is the Optimal Solar Energy System

Obj 2 - Type of Solar System

Grid-Tied

- Cable
- Professional inst.
- No batteries
- Smart metering
- Likely no tax advantages (non-profit)



http://tinyurl.com/y4g9rpck

Off-Grid

- Cable load reduction
- Reliable power
- Self-inst.
- Batteries
- Buy used PV Panels
- Indep. of rate changes

The West Camp Parking Lot & the Roof of Venture Lodge are the Best Locations for Solar Panels

Obj 3 - Solar Panel Placement

	Average % Solar Radiation
West Lodge (Front)	41
West Camp Parking Lot	71
Columbus Clearing	53
Venture Lodge (Front)	58
Venture Lodge (Back)	35
Venture Lodge Roof (Average)	65

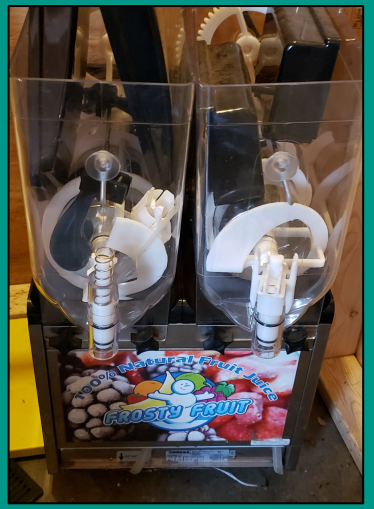
https://tinyurl.com/yync7c6k

Actions to Reduce the Energy Use of West Camp

Columbus Lodge Actions

- Remove ridge fan
- Replace ceiling fan
- Relocate fridge
- Relocate freezer
- Relocate slushy machines
- All lights to LEDs

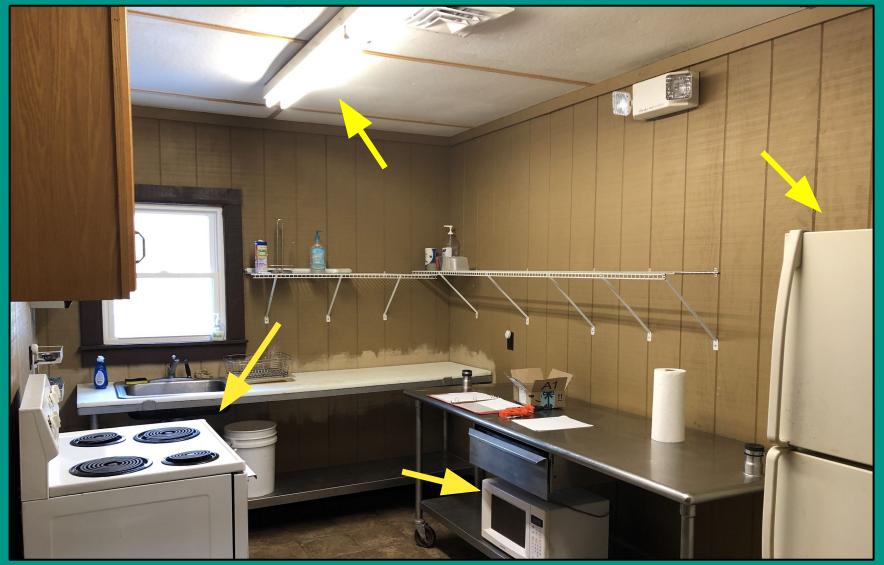
Fridge Freezer



Slushy Machine

Venture Lodge Actions

- Replace electric stove
- One AC for infirmary
- Water pumped from East Camp
- Upgrade refrigerator
- Use a half-power microwave
- All lights to LEDs

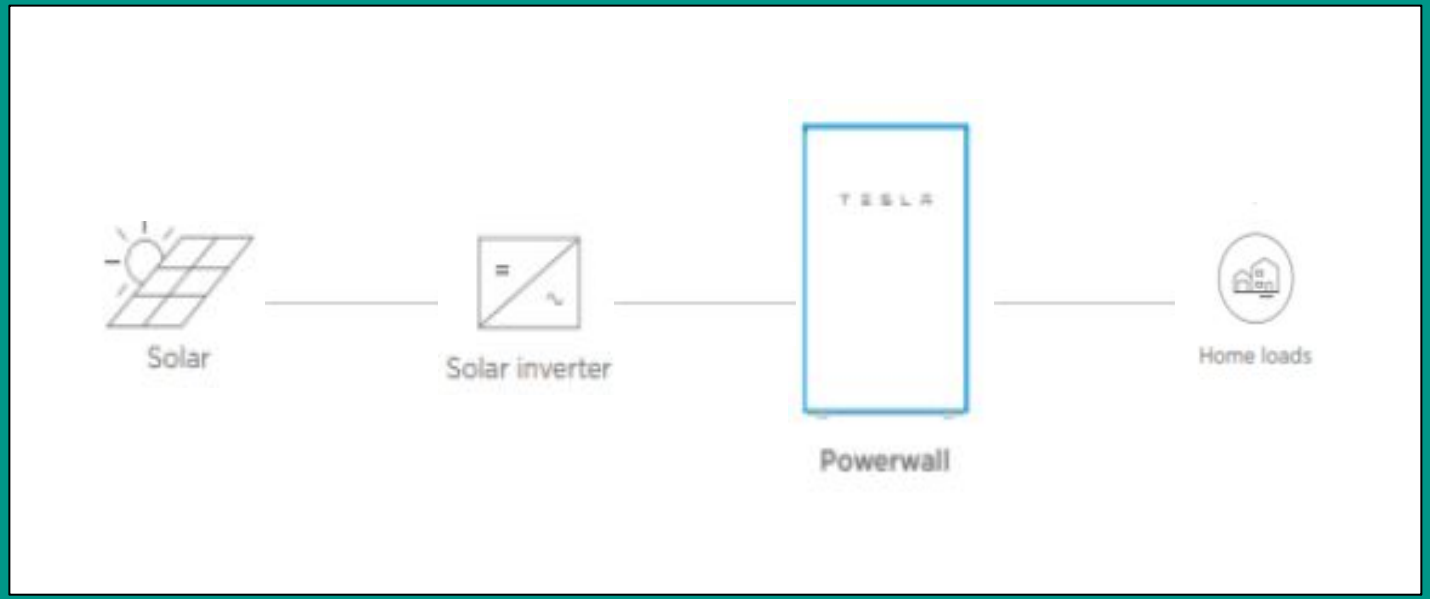


West Lodge Actions

- Remove AC units
- Remove dishwasher
- Remove Polar refrigerator
- Replace Hot Point fridge
- Replace Kenmore freezer
- Use one small coffee pot
- All lights to LEDs

Based on These Actions, Energy Reductions and Hardware Costs Were Determined

Off-Grid Tesla Powerwall System Diagram



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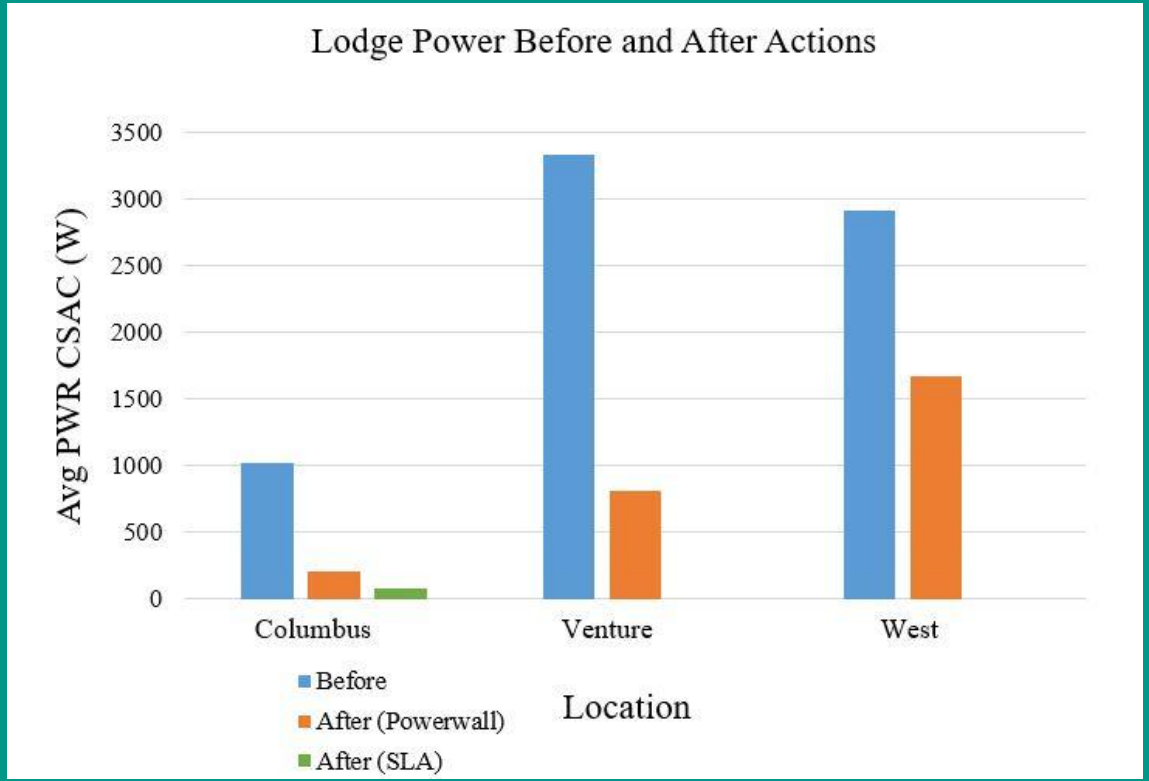
The Actions Significantly Cut Average Power



Hardware Costs (Powerwall)

	Total PV Panel Cost	Inverter Cost	Tesla Wall Cost	All Hardware
Columbus Lodge	$400 (4 panels)	$229 (1.5kW)	$6,700 (1)	$7,329
Venture Lodge	$1,600 (16 panels)	$339 (5kW)	$26,800 (4)	$28,739
West Lodge	$3,300 (33 panels)	$678 (2x 5kW)	$46,900 (7)	$50,878
West Camp Total	$5,300 (53 panels)	$1,246	$80,400 (12)	**$86,946**

https://tinyurl.com/y5jupyyw

A Cost and Risk Assessment was Conducted to Provide Final Recommendations

Obj 4 - Develop Recommendations

Cost and Risk Assessment

	Low-Risk	Moderate-Risk	High-Risk
Low-Cost	Appliance Upgrades and Removal $5,500-$6,000 *(without rebates)*	(1) Columbus Lodge Off-Grid Solar (SLA Batteries) $2,970 (2) Columbus Lodge Off-Grid Solar (Tesla Powerwall) $9,629	
High-Cost	Cable and Transformer Replacement $196,000		West Camp Completely Off-Grid $86,946

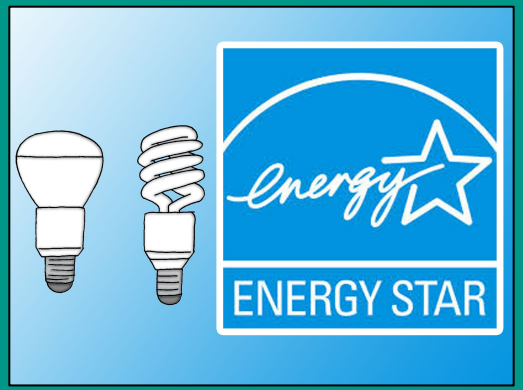
Low-Cost Low-Risk

Replacement or Upgrade of Existing Appliances in West Camp

Cost: $5,500-$6,000 (*without rebates*)

Develop & Implement a Set of Rules

- Turning off lights / appliances when not used
- Limit unnecessary appliance use



http://tinyurl.com/y25a8cft

http://tinyurl.com/y3mdf8qq

Low-Cost Moderate-Risk

Columbus Lodge Off-Grid Solar

SLA Batteries

Approximate Cost: $2,970

- Solar Panel Cost: $200
- SLA Batteries Cost: $2,600
- Inverter & Charge Controller Cost: $170

2 Solar Panels Required

13 SLA Batteries Required

https://tinyurl.com/y5szu4n5

Tesla Powerwall

Approximate Cost: $9,629

- Solar Panel Cost: $400
- Tesla Powerwall Cost: $6,700
- Tesla Powerwall Installation & Hardware Cost: $2,300
- Inverter Cost: $229

4 Solar Panels Required

1 Tesla Powerwall Required

https://www.tesla.com/powerwall

Low-Cost Moderate-Risk

Columbus Lodge Off-Grid Solar

SLA Batteries

- Replacement every 3-5 yrs
- Maintenance required
- Limited extra energy
- Only lighting

https://tinyurl.com/y5szu4n5

Tesla Powerwall

- Extra energy storage
- More modernized
- Experience with Powerwall
- 10 yr warranty
- More appliance use

https://www.tesla.com/powerwall

High-Cost Low-Risk

Replacing Power Cable & 2 Transformers

Approximate Cost: $196,000

- Power Cable Replacement $92,000
- Transformer Replacement (x2): $52,000 each

Sizing of Power Cable:

- Future appliances/technology
- West Camp expansion

Cable

Transformer

High-Cost High-Risk

West Camp Off-Grid Solar

Approximate Cost: $112,246

- Solar Panel Cost: $5,300
- Tesla Powerwall Cost: $80,400 (x12)
- Tesla Powerwall Installation Cost: $25,300
- Inverter Cost: $1,246

53 Solar Panels Required

- Venture Lodge Panels Placed on Venture Lodge Roof
- Columbus and West Lodge Panels Placed in West Camp Parking Lot

https://www.tesla.com/powerwall

West Camp Parking Lot

Total West Camp Parking Lot Area:

20,000 ft^2

Area Required (36 PV Panels):

650 ft^2

Percentage of Parking Lot Used:

3.3%

https://tinyurl.com/y44dffwu

Summary

West Camp uses approximately 18,447 kWh of energy yearly

The cable is operating at 68% of capacity

Recommendations:

(1) Appliance upgrades/removals $5,500-$6,000 (*without rebates)*
(2) Columbus Lodge off-grid solar $2,970 (SLA) $9,629 (Powerwall)
(3) Cable and transformer replacement $196,000
(4) West Camp off-grid solar $87,734 (Powerwall)

Questions?

Tesla Powerwall Safety

Reasons for failure:

(1) Defects within the manufacturing of the battery
(2) Stress event such as vibration or an electrical short

Powerwall battery has a B fire classification; standard ABC or BC dry chemical fire extinguisher is used

Few to no documented cases of failure

Individual cell fires (very rare) are isolated

Well Pump

1 HP motor, 220V

~2.5kW surge startup

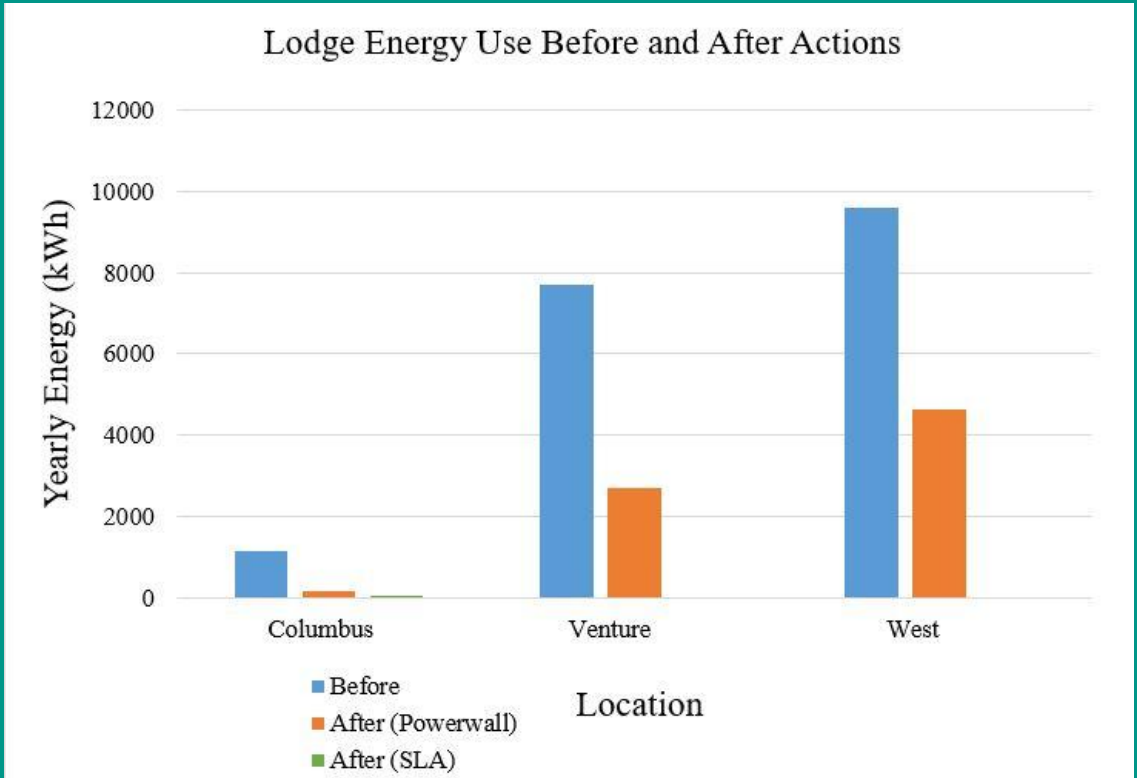
781 GPD (2015) (1,400 GPD max)

Submerged, single phase

At 30% runtime, 12kWh/day

https://tinyurl.com/y5smulsb

West Camp Energy Use Before and After



Current West Camp Inventory

	Lights	Appliances	Other	Total
Venture Lodge	76	8	18	102
West Lodge	115	13	28	156
Columbus Lodge	28	4	9	41

Current West Camp Load Assessment

		CSAC	Weekends
Columbus Lodge	Average Power (W)	1023.0	8.0
	1-Day Energy (kWh)	24.6	0.2
	2-Day Energy (kWh)	49.1	0.4
	Total Energy (kWh)	745.6	18.0
Venture Lodge	Average Power (W)	3328.6	1912.4
	1-Day Energy (kWh)	79.9	45.9
	2-Day Energy (kWh)	159.8	91.8
	Total Energy (kWh)	2796.0	4186.8
West Lodge	Average Power (W)	2916.2	1864.5
	1-Day Energy (kWh)	70.0	44.7
	2-Day Energy (kWh)	140.0	89.5
	Total Energy (kWh)	2449.6	3951.4

Current Appliance Power Values

	Appliance	Steady State Power (W)	Surge Power (W)	Wh/day	Wh/day (Energy Star)
Columbus Lodge	Ridge Fan	250.0	750.0	6000.0	
	Polar Fridge	167.3	1440.0	2254.0	1200.0
	Ice Cream Freezer	110.2	500.0	818.0	650.0
Venture Lodge	Refrigerator	189.5	2130.0	614.0	1411.0
	Well Pump	Unknown	2250.0	Unknown	
	Blower System	375.0	1125.0	3750.0	
	Air Conditioner	361.0	1560.0	6883.0	2075.0
West Lodge	Polar Refrigerator[4]	163.5	1620.0	2007.0	1200.0
	Hot Point Refrigerator	500.0 (compressor)	1500.0	4861.0	1200.0
	Freezer	120.2	1350.0	2776.0	1240.0
	Blower System	375.0	1125.0	3750.0	
	Air Conditioner	361.0	1560.0	3441.5 (12 hrs)	2075.0

Current Max Power and Energy

	Yearly Energy Use (kWh)	% Total Energy Use	Max Power Non-Surge (W)	Max Power Surge (W)
Columbus Lodge	1166.0	6.3	3889.6	4389.6
Venture Lodge	7686.9	41.7	20174.7	28004.4
West Lodge	9593.7	52.0	15979.0	21499.0

Solar Pathfinder Data Summary

	Average % Solar Radiation
West Lodge (Front)	41
West Camp Parking Lot	71
Columbus Clearing	53
Venture Lodge (Front)	58
Venture Lodge (Back)	35
Venture Lodge Roof (Average)	65

Current Max Power and Energy (Adjusted)

	Adjusted Maximum Daily Energy Use (kWh)	Adjusted Maximum Power Surge (W)
Columbus Lodge	28.3	5048.0
Venture Lodge	91.9	32205.0
West Lodge	80.5	25298.9

Proposed Inventory

	Lights	Appliances	Other	Total
Venture Lodge	76	3	5	84
West Lodge	94	8	9	111
Columbus Lodge	23	0	0	23

Proposed Load Assessment

		CSAC	Weekends
Columbus Lodge	Average Power (W)	78.5	0
	1-Day Energy (kWh)	1.9	0
	2-Day Energy (kWh)	3.8	0.4
	Total Energy (kWh)	66.0	0
Venture Lodge	Average Power (W)	809.6	675.8
	1-Day Energy (kWh)	19.4	16.2
	2-Day Energy (kWh)	38.9	32.5
	Total Energy (kWh)	680.0	1397.0
West Lodge	Average Power (W)	1676.4	1009.2
	1-Day Energy (kWh)	40.2	24.2
	2-Day Energy (kWh)	80.5	48.5
	Total Energy (kWh)	1408.2	2021.7

Proposed Appliance Power Values

	Appliance	Steady State Power (W)	Surge Power (W)	Wh/day	Wh/day (Energy Star)
Venture Lodge	Refrigerator	189.5	2130.0	4548.0	1411.0
	Blower System	375.0	1125.0	3750.0	
	Air Conditioner	361.0	1560.0	6883.0	2075.0
West Lodge	Hot Point Refrigerator	155.0	1500.0	4861.0	1200.0
	Mini Freezer	Unknown			216.0
	Blower System	375.0	1125.0	3750.0	

Proposed Max Power and Energy

	Yearly Energy (kWh)	% Total Energy Use	Max Power Non-Surge (W)	Max Power Surge (W)
Columbus Lodge	66.0	0.9	157.0	157.0
Venture Lodge	2713.3	36.6	3904.7	8614.7
West Lodge	4634.4	62.5	6966.0	10366.0

Proposed Max Power and Energy (Adjusted)

	Adjusted Maximum Daily Energy Use (kWh)	Adjusted Maximum Power Surge (W)
Columbus Lodge	2.2	180.6
Venture Lodge	22.3	9906.9
West Lodge	46.2	11920.9

Proposed Off-Grid Hardware Requirements

	kWh / Day (Upper Estimate)	PV Panel/(kWh/day) (250W)	Battery/(kWh/day) (12V 100Ah)	No. Panels (250W)	No. of 100 Ah Batteries (2-Day)	Charge Controller (A)	Minimum Inverter Required (W)
Columbus Lodge	2.2	0.7	5.6	2	13	30	200
Venture Lodge	22.3			16	125	200	9,000
West Lodge	46.2			33	259	240	11,000

Proposed Off-Grid Costs (SLA Batteries)

	Cost per PV Panel (250W)	Cost per Battery (12V,100Ah)	Total PV Panel Cost	Total Battery Cost	Inverter Cost	MPPT Charge Controller Cost	All Hardware
Columbus Lodge	$100	$200	$200	$2,600	$90	$80	$2,970
Venture Lodge			$1,600	$25,000	$678	$788	$28,066
West Lodge			$3,300	$51,800	$1,017	$960	$57,077
West Camp Total			$5,100	$86,400	$1,785	$1,828	$88,113

Proposed Off-Grid Costs (Powerwall)

	Total PV Panel Cost	Inverter Cost	No. of Tesla Wall	Cost per Tesla Wall	Total Battery/Tesla Wall Cost	Battery and Charge Controller Cost	All Hardware
Columbus Lodge	$200	$90				$2,860	$2,970
Venture Lodge	$1,600	$678	4	$6,700	$26,800		$28,400
West Lodge	$3,300	$1,017	7		$46,900		$50,300
West Camp Total	$5,100	$1,785			$73,700	$2,860	$83,365

Detailed Solar Pathfinder Data

	January	February	March	April	May	June	July	August	September	October	November	December	Average
West Lodge (Front)	0	0	45	75	86	76	81	81	46	0	0	0	41
West Camp Parking	56	69	71	75	83	85	87	80	75	67	55	49	71
Columbus Clearing	41	43	54	54	67	66	67	68	55	46	41	39	53
Venture (Front)	57	62	54	60	59	57	59	65	60	56	57	53	58
Venture (Back)	0	22	40	44	60	61	60	47	42	31	7	0	35
Venture Roof (Right)	47	45	62	83	78	78	77	80	63	46	47	39	62
Venture Roof (Middle)	37	41	78	82	84	85	87	81	77	45	34	33	64
Venture Roof (Left)	39	71	76	78	88	87	88	82	76	70	39	40	70

Current Off-Grid Hardware Requirements

	kWh / Day (Upper Estimate)	PV Panel/(kWh/day) (250W)	Battery/(kWh/day) (12V 100Ah)	No. Panels (250W)	No. of 100 Ah Batteries (2-Day)	Charge Controller (A)	Minimum Inverter Required (W)
Columbus Lodge	28.3	0.7	5.6	20	159	100	5,000
Venture Lodge	91.9			65	513	600	29,000
West Lodge	80.5			57	451	500	22,000

Current Off-Grid Costs (SLA Batteries)

	Cost per PV Panel (250W)	Cost per Battery (12V,100Ah)	Total PV Panel Cost	Total Battery Cost	Inverter Cost	MPPT Charge Controller Cost	All Hardware
Columbus Lodge	$100	$200	$2,000	$31,800	$339	$395	$34,534
Venture Lodge			$6,500	$102,600	$2,034	$2,370	$111,134
West Lodge			$5,700	$90,200	$1,695	$1,975	$99,570
West Camp Total			$14,200	$224,600	$4,068	$4,740	$247,608

Current Off-Grid Costs (Powerwall)

	Total PV Panel Cost	Inverter Cost	No. of Tesla Wall	Cost per Tesla Wall	Total Tesla Wall Cost	All Hardware
Columbus Lodge	$2,100	$339	5	$6,700	$33,500	$35,939
Venture Lodge	$6,300	$2,034	14		$93,800	$102,134
West Lodge	$5,600	$1,695	12		$80,400	$87,695
West Camp Total	$14,000	$4,068	31		$207,700	$225,768

Example Calc PV Panel per kWh/day

$$\frac{167\left(\frac{W}{\frac{kWh}{day}}\right)}{250\frac{W}{panel}} = 0.668 \text{ [250W PV Panel / (kWh/day)]}$$

Example Calc Battery per kWh/day

$$\frac{1000Wh}{12V} \times \frac{10}{3} \times \frac{1battery}{100Ah} \times 2\ days = 5.56\ [12V\ 100Ah\ SLA\ battery\ /\ (kWh/day)]$$

Example Calc West Lodge Charge Controller Sizing

$$\frac{Max\ PWR\ Surge\ (W)}{Battery\ Voltage\ (V)} + 8A\ (PV\ Panel) = \frac{10366.0W}{48V} + 8A = 224A \sim 240A$$