Art Building and Moore Hall PV Battery Analysis

Model of the PV Power Plant Plan and Estimated Battery Needed

Executive Summary

Moore Hall

- Annual Generation: 332,000 kWh/yr
- Annual Building Consumption: 892,000 kWh/yr
- Annual PV Savings without Battery: 244,000 kWh

No battery necessary

PV System ROI is **15 years**

Art Building

- Annual Generation: 802,000 kWh/yr
- Annual Building Consumption: 1,266,000 kWh/yr
- Annual PV Savings without Battery: 537,000 kWh

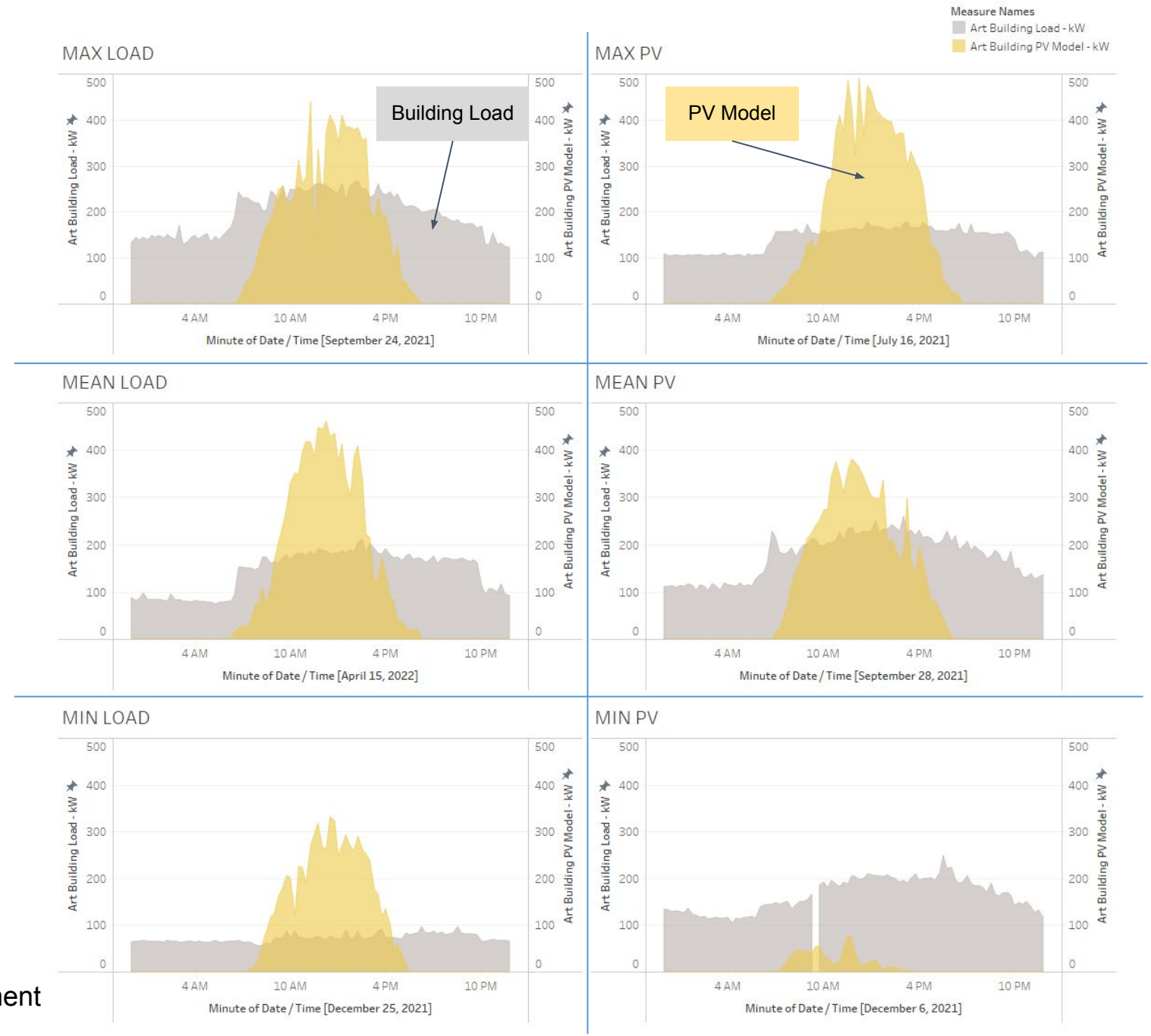
200 kW, 6 hour battery is ideal

247,000 kWh additional from battery

Battery cuts ROI from 19 to **15 years**

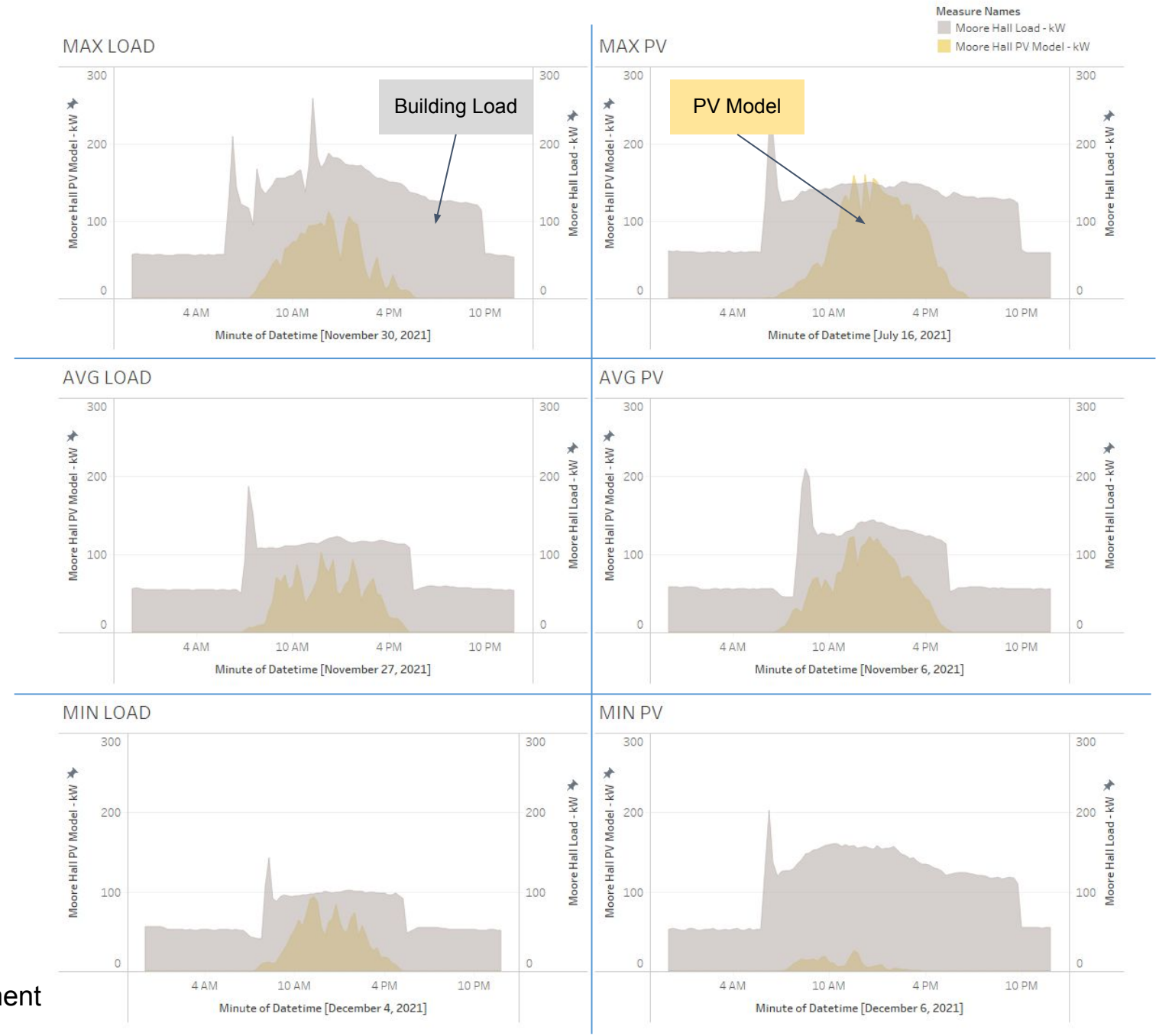
Art Building

- System Size: 537 kW DC
- Annual Generation: 802,000 kWh/yr
- Annual Building Consumption: 1,266,000 kWh/yr



Moore Hall

- System Size: 176 kW DC
- Annual Generation: 332,000 kWh/yr
- Annual Building Consumption: 892,000 kWh/yr



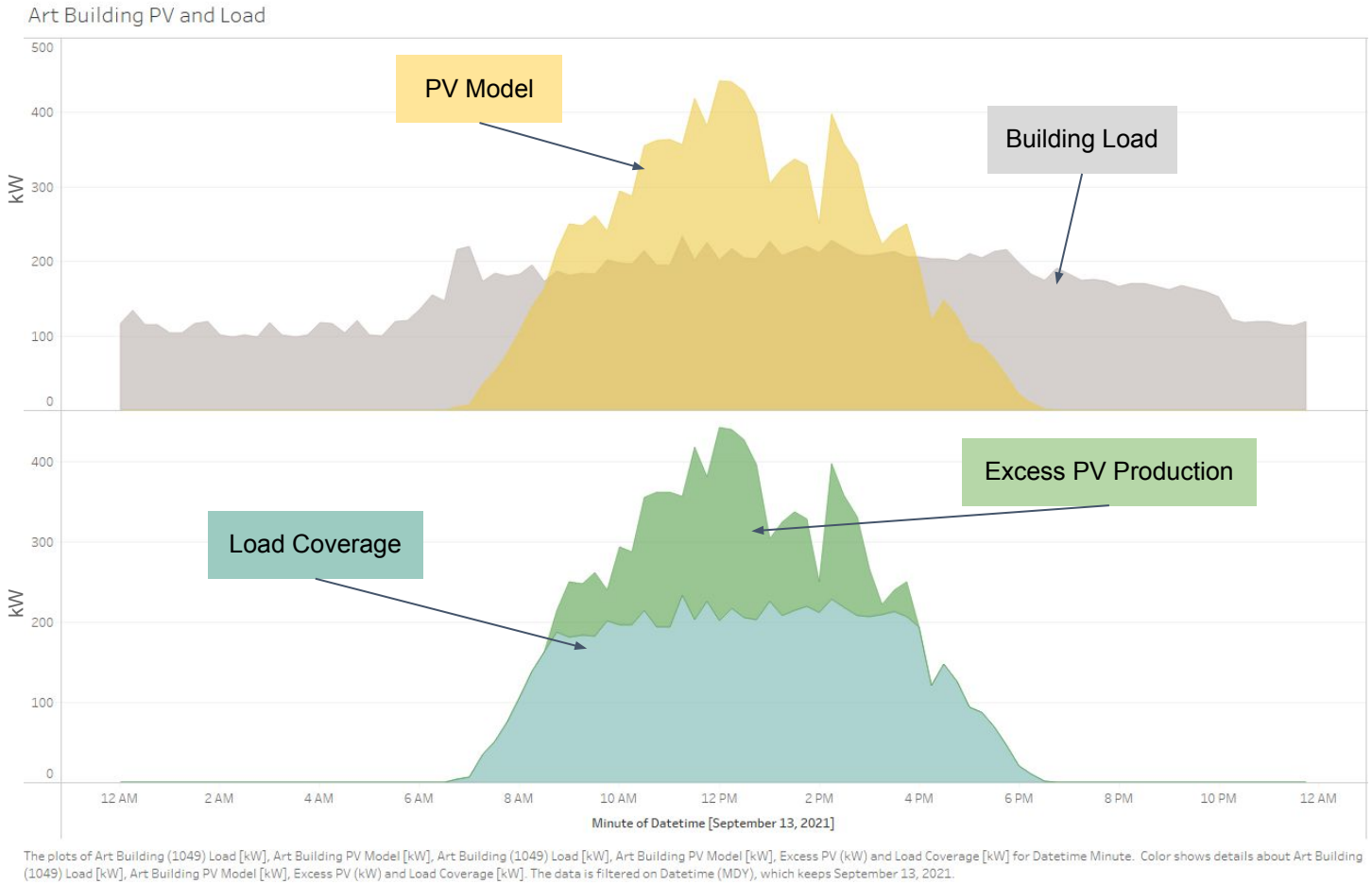
Solar Savings

Without a battery, a PV system can only supply electricity to the building during peak production hours.

Art Building Load Coverage: 537,000 kWh annual (19 year ROI)

Moore Hall Load Coverage: 244,000 kWh annual (15 year ROI)

Building savings could be increased by capturing the Excess PV Production in a battery storage system.



Battery Storage System Pricing by NREL

Lithium Ion Battery (LIB) price study by the National Renewable Energy Laboratory (NREL) offers cost estimates.

Estimates vary depending on the flowrate [kW] and the duration [hrs] of the battery, and can be calculated from the capacity [kWh] of the system.

To plan a battery storage system, flowrate and capacity needs of a PV model must be analyzed.

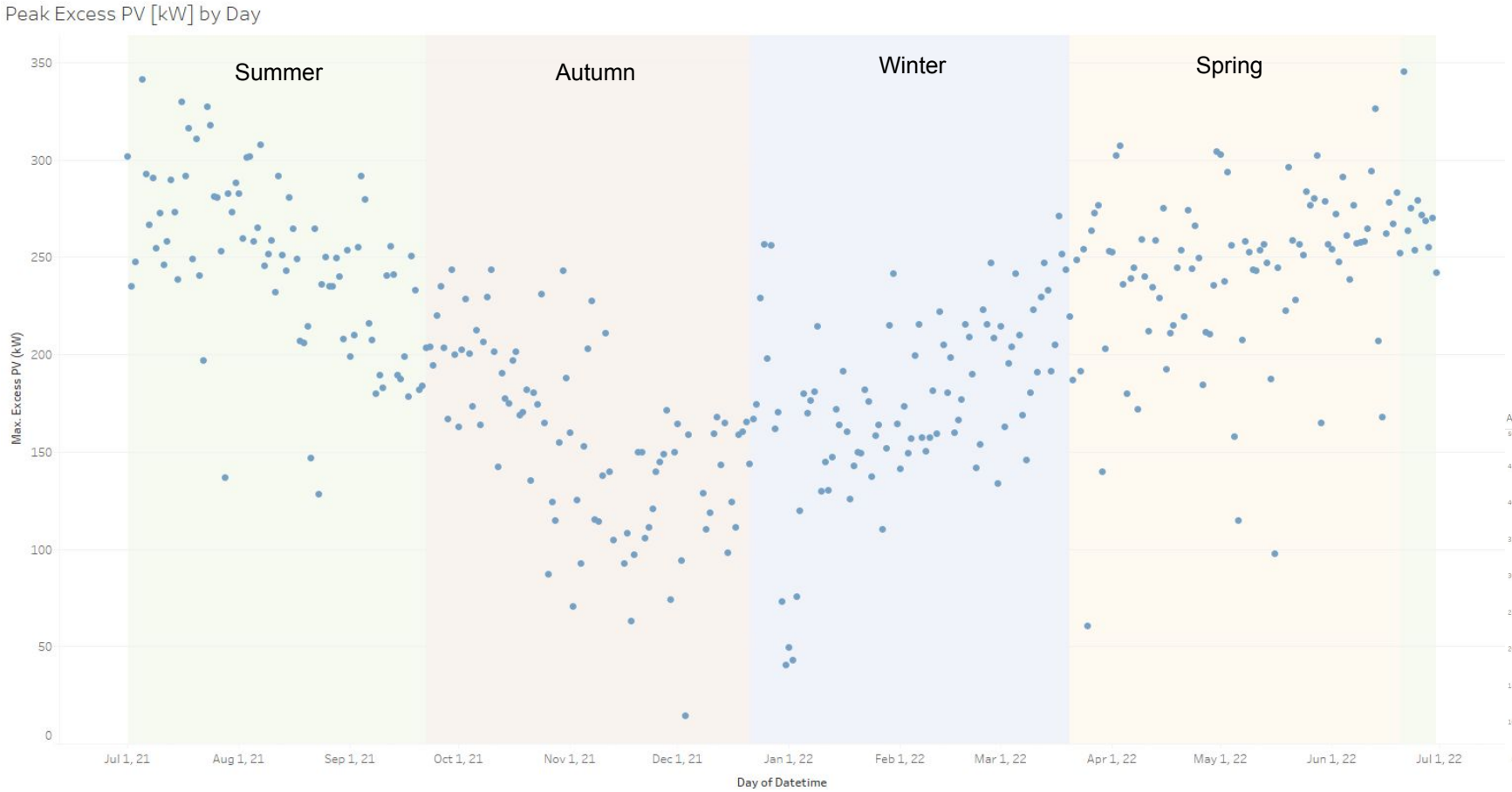
Table 1. Commercial and Industrial LIB Energy Storage Systems: 2021 Cost Benchmark Model Inputs and Assumptions (2020 USD)

Model Component	Modeled Value	Description
System size	60–1,200 kW_{DC} power capacity 1-8 E/P ratio	Battery capacity is in kW_{DC}. E/P is battery energy to power ratio and is synonymous with storage duration in hours.
LIB price	1-hr: $211/kWh 2-hr: $168/kWh 4-hr: $165/kWh 6-hr: $144/kWh 8-hr: $135/kWh	Ex-factory gate (first buyer) prices (Ramasamy et al., 2021)
Inverter/storage ratio	1.67	Ratio of inverter power capacity to storage battery capacity (Denholm et al., 2017)
Battery central inverter price	$75/kW	Ex-factory gate (first buyer) prices

*these prices do not reflect the Hawaii market inflation

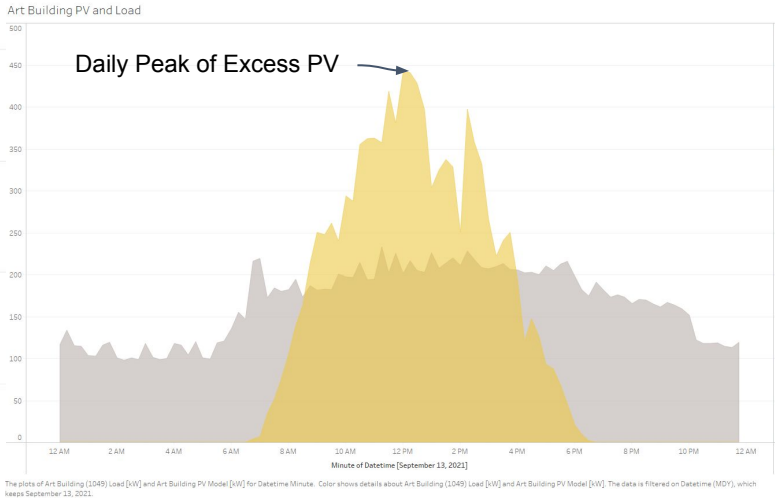
[1] https://atb.nrel.gov/electricity/2022/commercial_battery_storage

Art - Excess PV Power [kW] Analysis

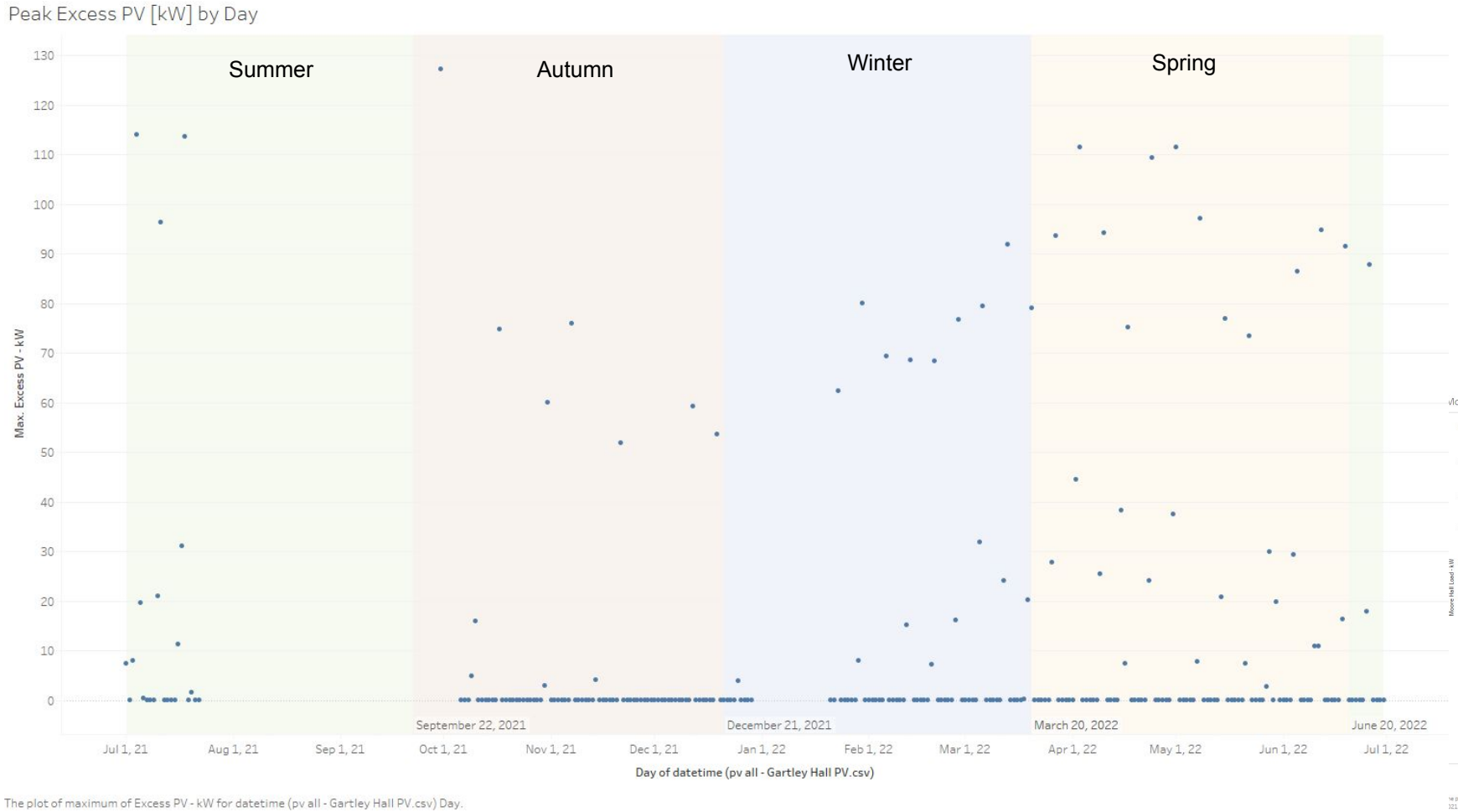


The battery will be charged only when PV production exceeds the power demand of the building (when there is excess PV).

“Peak Excess PV” refers to the maximum PV flowrate at the height of each day. This is how many kW could flow into the battery.



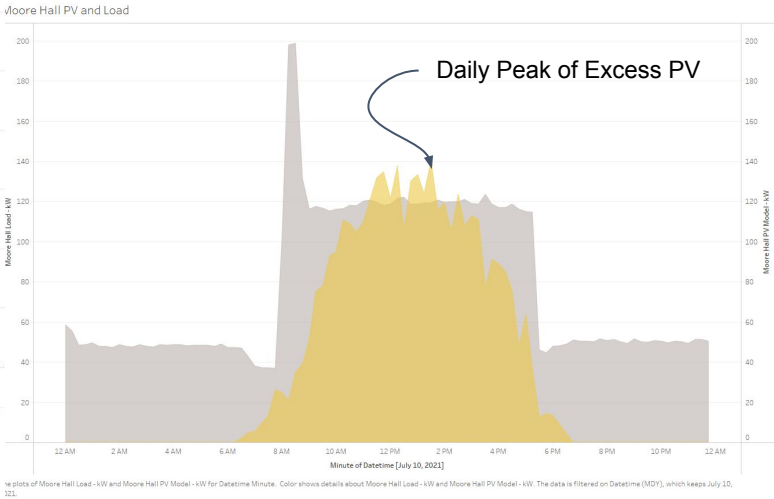
Moore - Excess PV Power [kW] Analysis



The plot of maximum of Excess PV - kW for datetime (pv all - Gartley Hall PV.csv) Day.

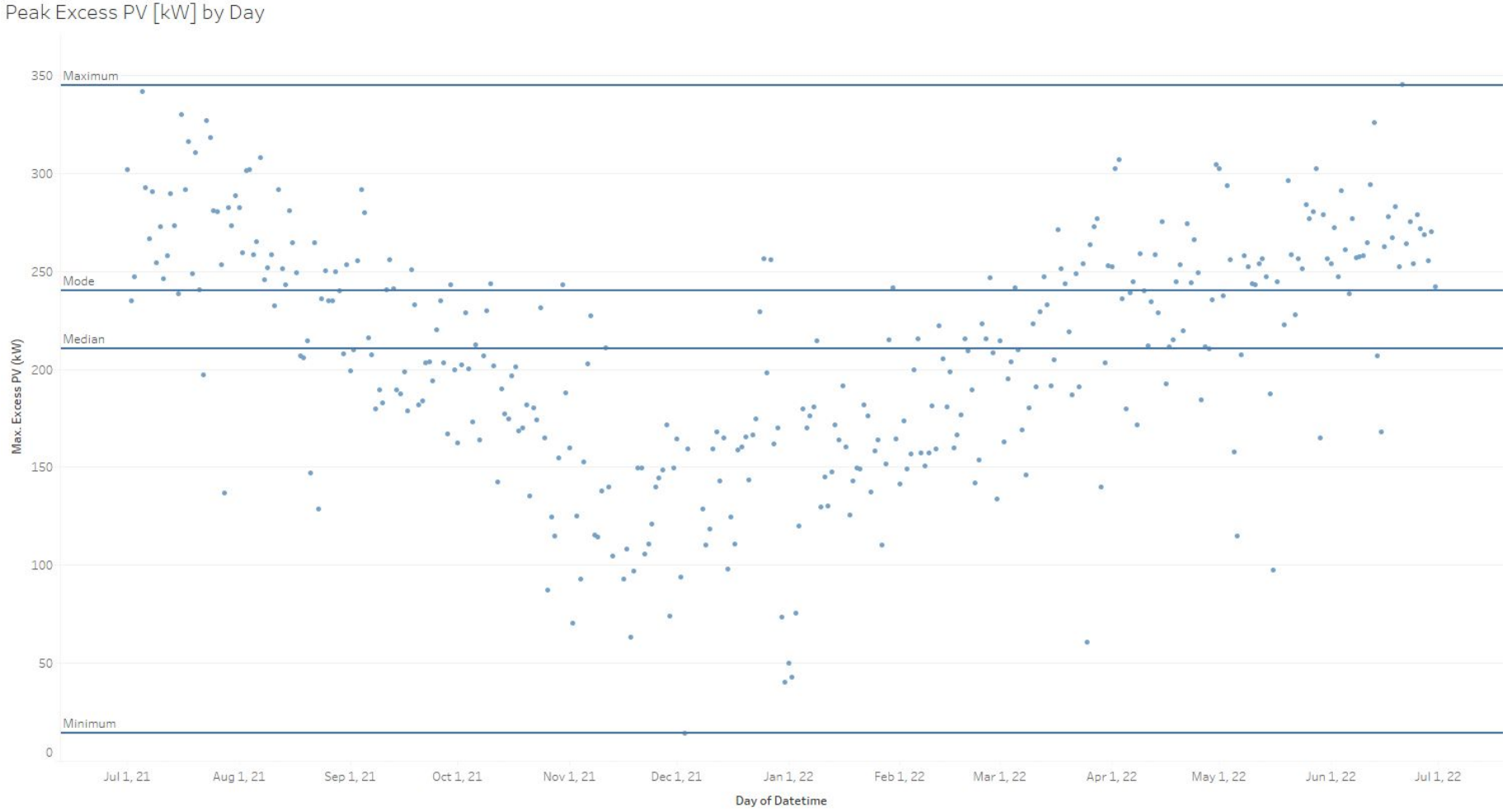
The battery will be charged only when PV production exceeds the power demand of the building (when there is excess PV).

“Peak Excess PV” refers to the maximum PV flowrate at the height of each day. This is how many kW could flow into the battery.



<u>Moore Hall does not produce significant or consistent excess PV power for statistical analysis.</u>

Art - Excess PV Power Statistics



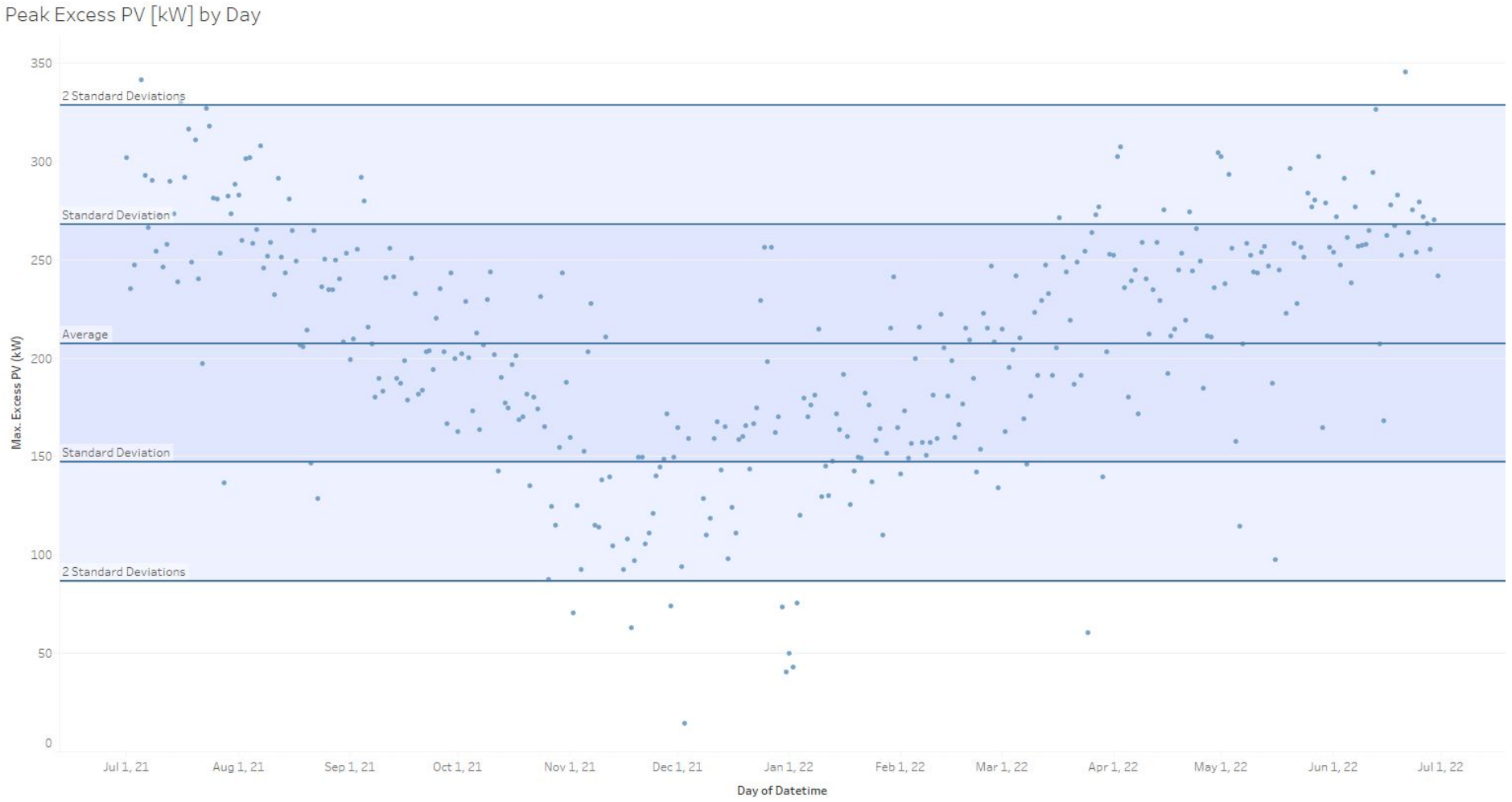
MAX: 345 kW

MODE: 240 kW

MEDIAN: 210 kW

MIN: 14 kW

Art - Excess PV Power Statistics



+2 STD: 329 kW

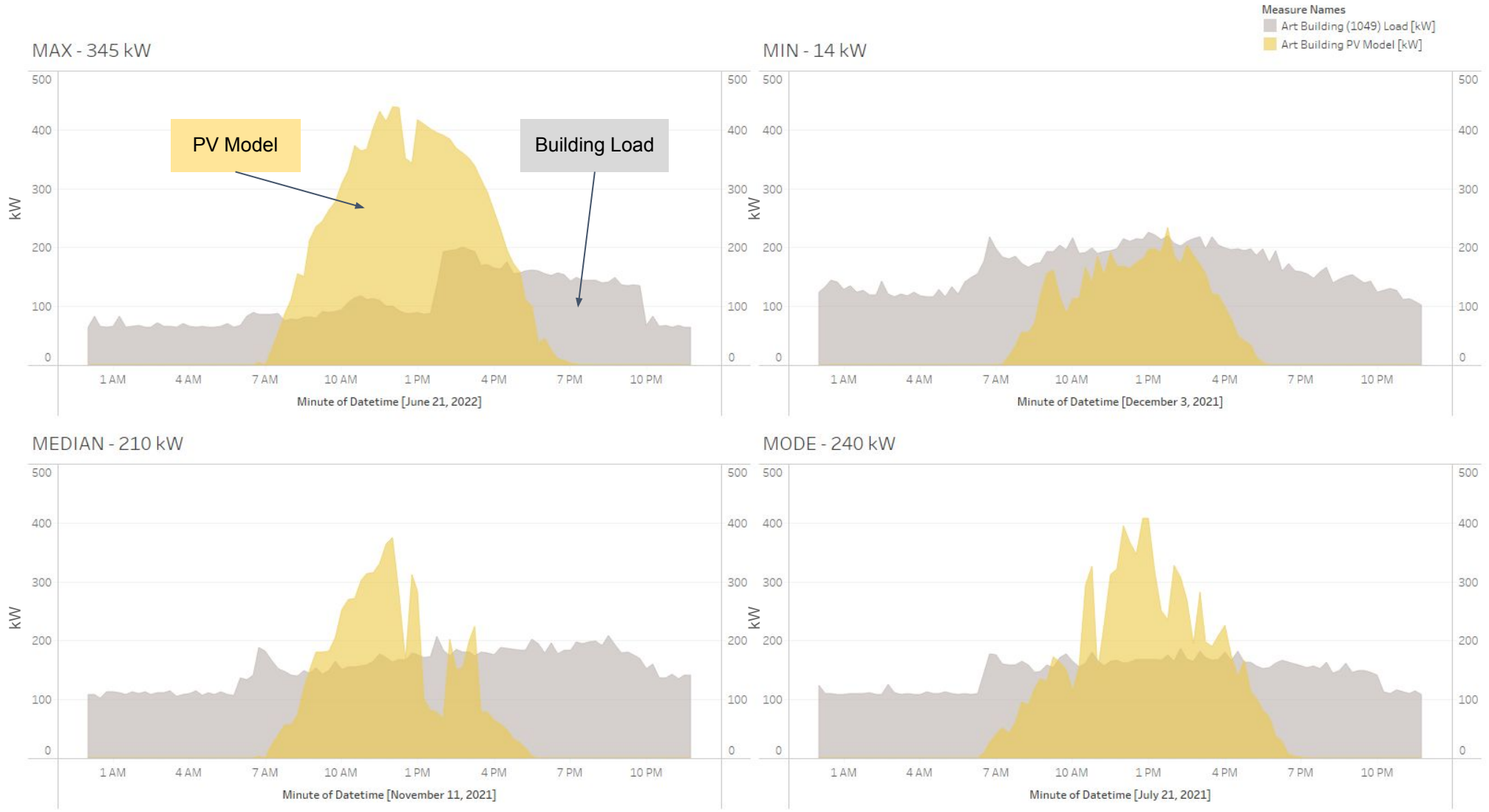
+1 STD: 268 kW

AVG: 208 kW, STD: 61 kW

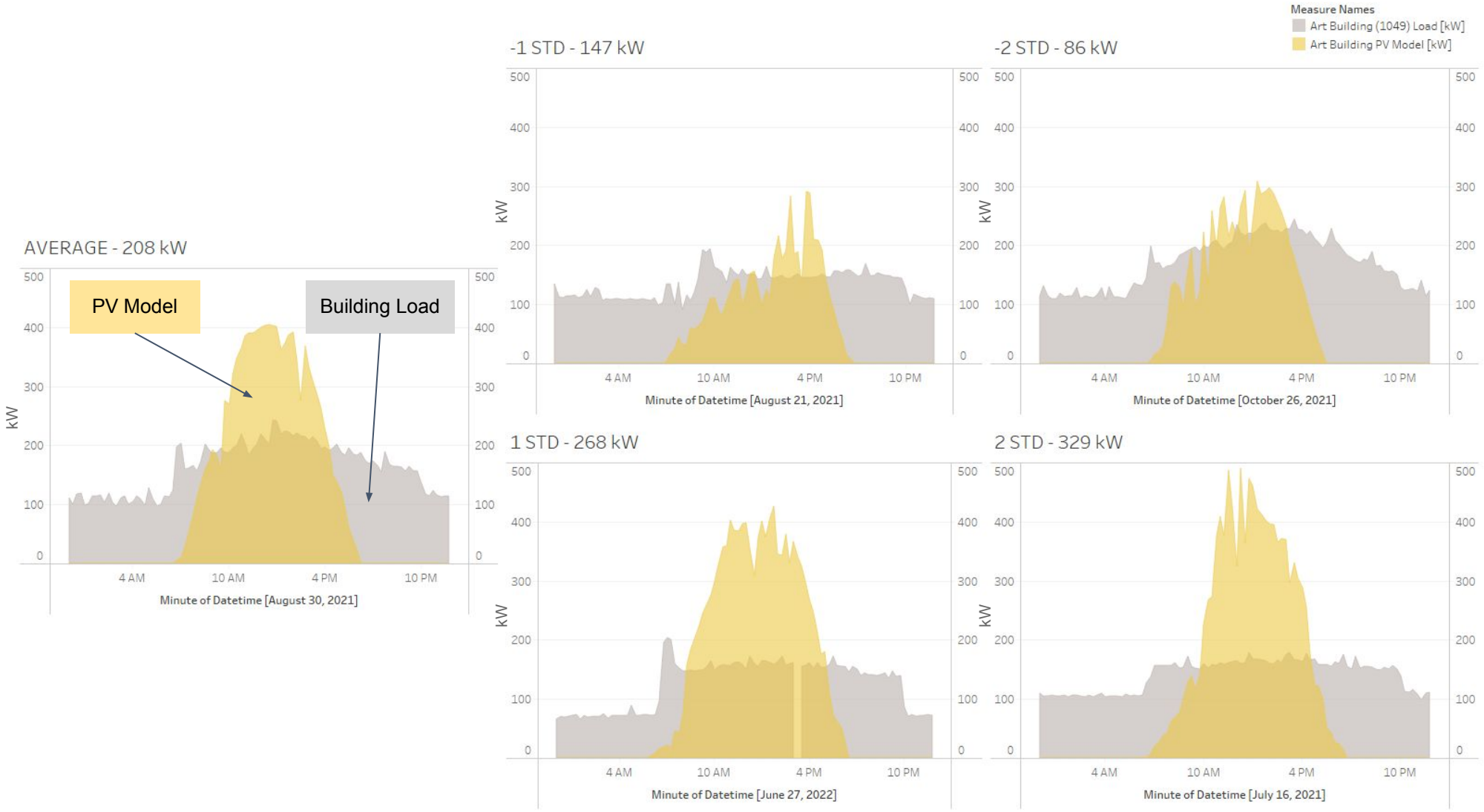
-1 STD: 147 kW

-2 STD: 86 kW

Art - Power Statistical Days



Art - Power Statistical Days



Excess PV Power [kW] Overview

Art Building:

- High end days: 250-350 kW, approximately 90 days
- Typical days: 150-250 kW, approximately 200 days
- Low end days: 0-150 kW, approximately 75 days

Art building's battery system should have a flowrate between 200 and 300 kW.

Moore Hall:

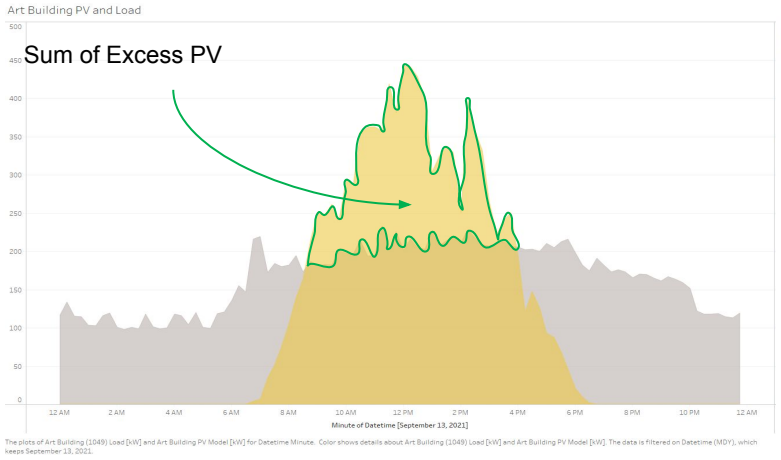
- High end days: 100-130 kW, approximately 10 days
- Mid-range days: 50-100 kW, approximately 35 days
- Low end days: 0-50kW, approximately 320 days

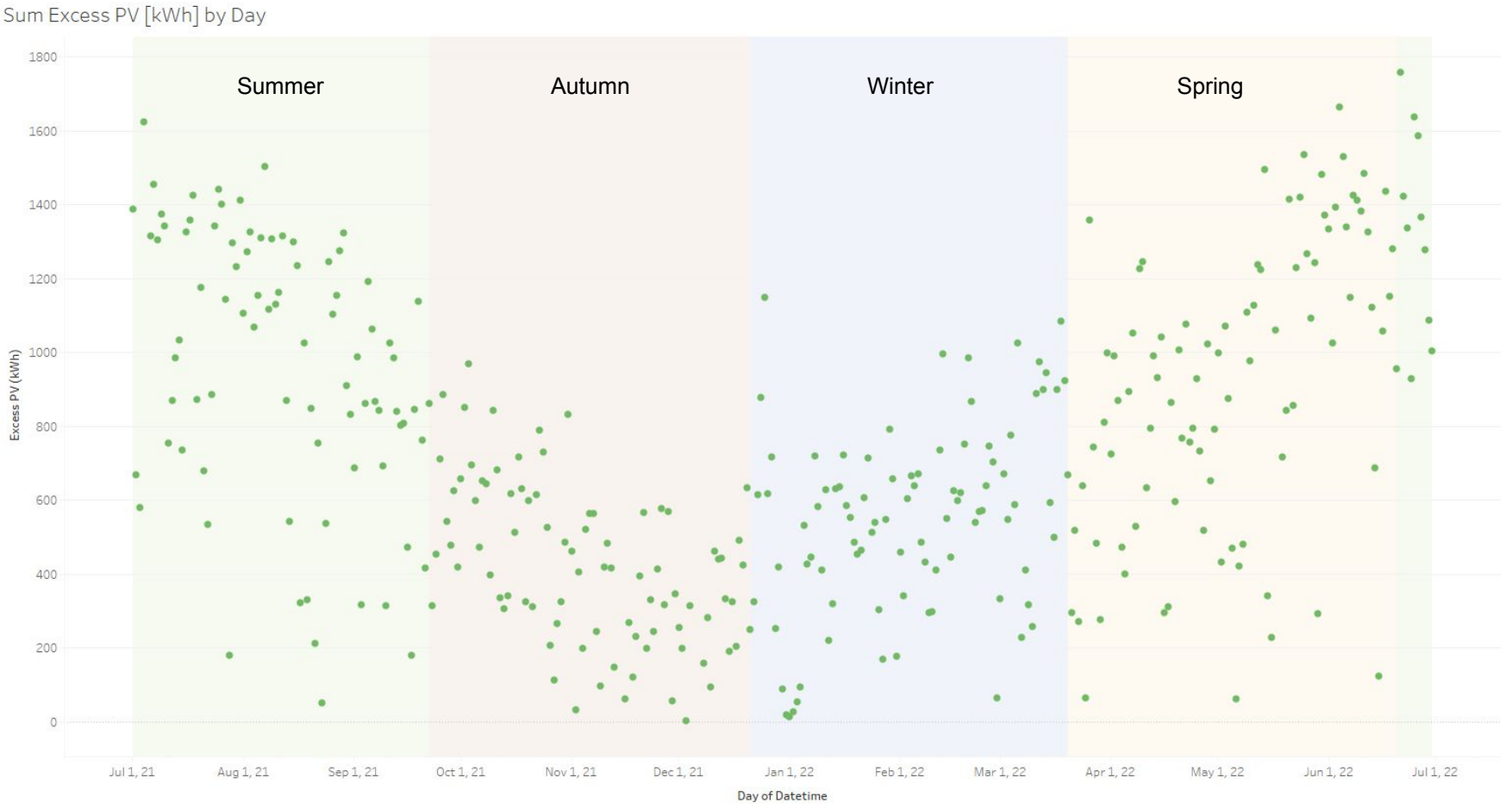
Moore Hall may not require a battery system.

Art - Excess PV Energy Storage [kWh] Analysis

The battery will be charged only when PV production exceeds the power demand of the building (when there is excess PV).

“Sum Excess PV” refers to the total PV capacity throughout each day. This is how many kWh a battery could charge each day.



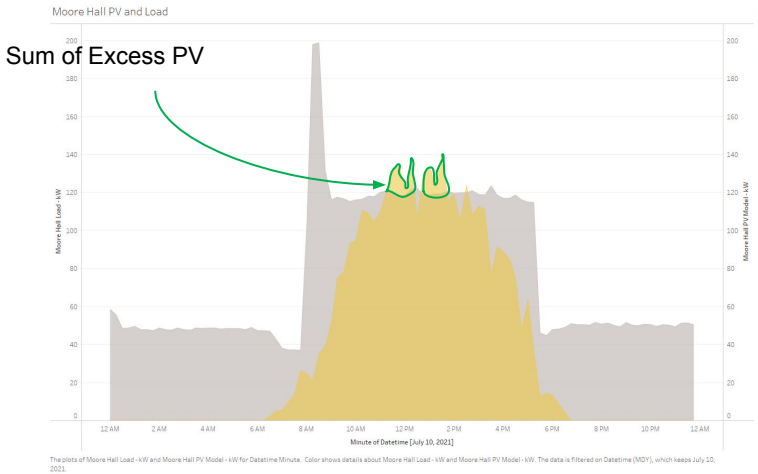


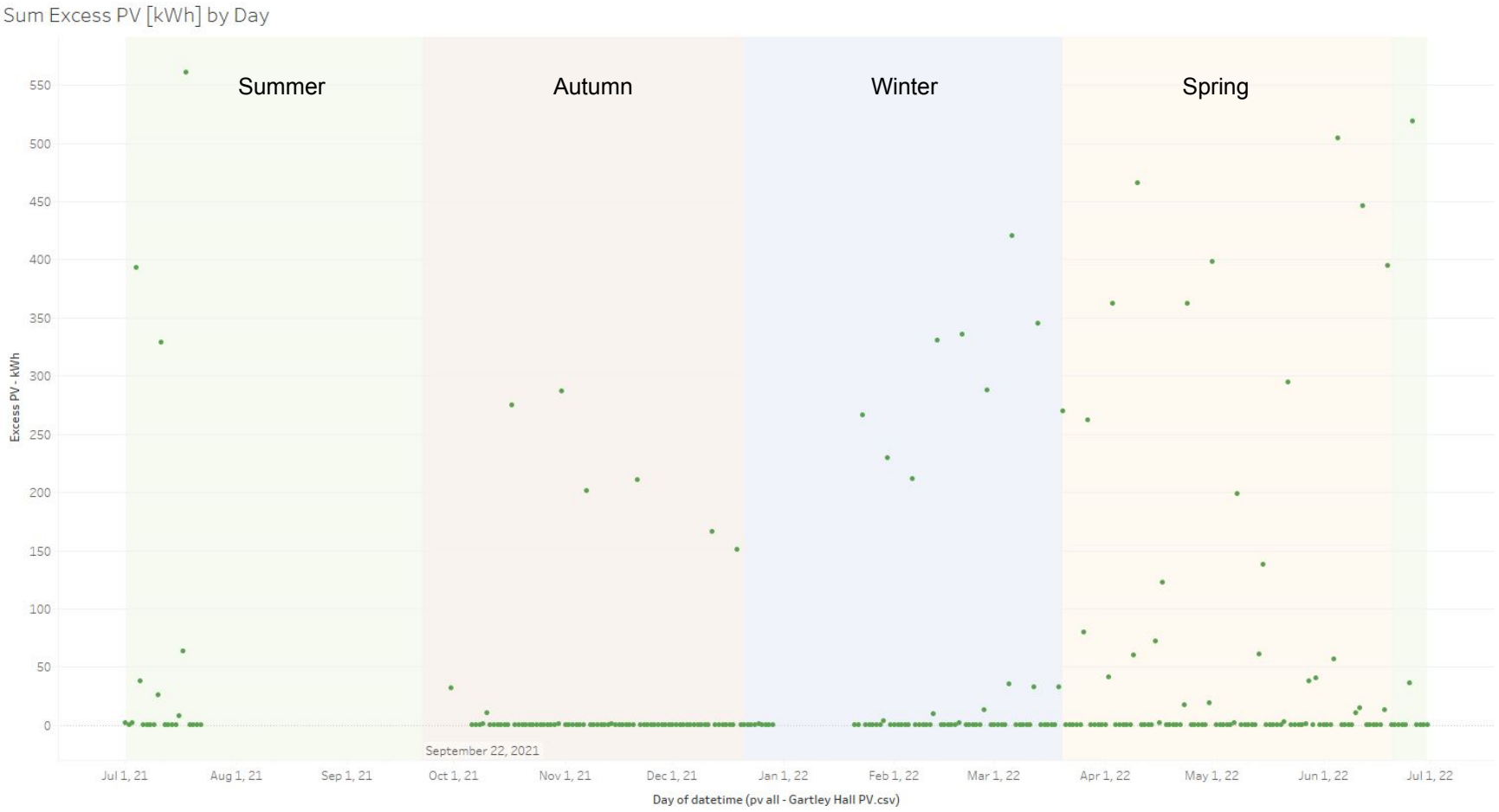
The plot of sum of Excess PV (kWh) for Datetime Day. The data is filtered on Datetime Day, which excludes July 5, 2021.

Moore - Excess PV Energy Storage [kWh] Analysis

The battery will be charged only when PV production exceeds the power demand of the building (when there is excess PV).

“Sum Excess PV” refers to the total PV capacity throughout each day. This is how many kWh a battery could charge each day.

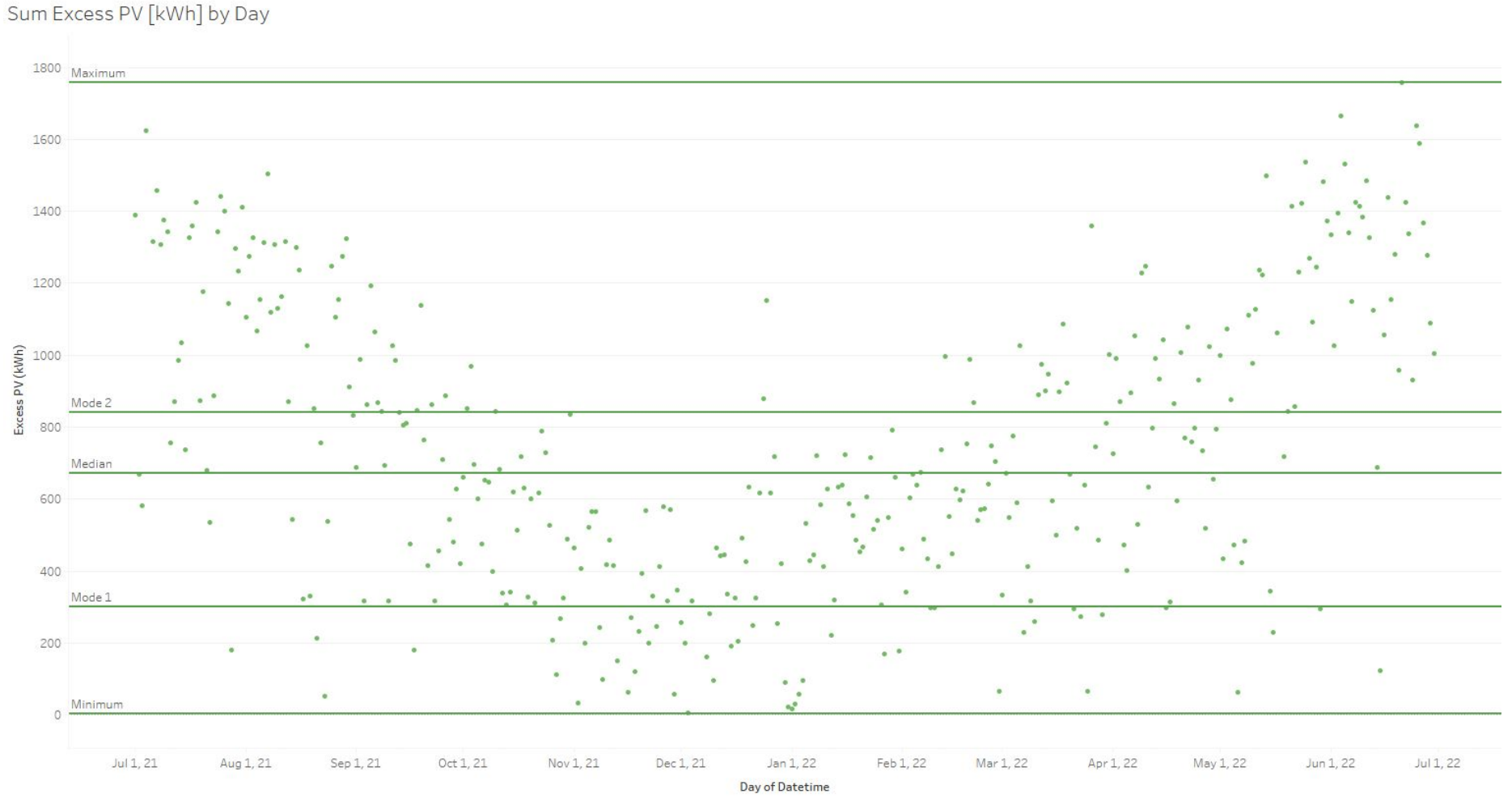




The plot of sum of Excess PV - kWh for datetime (pv all - Gartley Hall PV.csv) Day.

<u>Moore Hall does not produce consistent or significant excess PV energy for statistical analysis.</u>

Art - Excess PV Energy Storage Statistics



The plot of sum of Excess PV (kWh) for Datetime Day. The data is filtered on Datetime Day, which excludes July 5, 2021.

MAX: 1,757 kWh

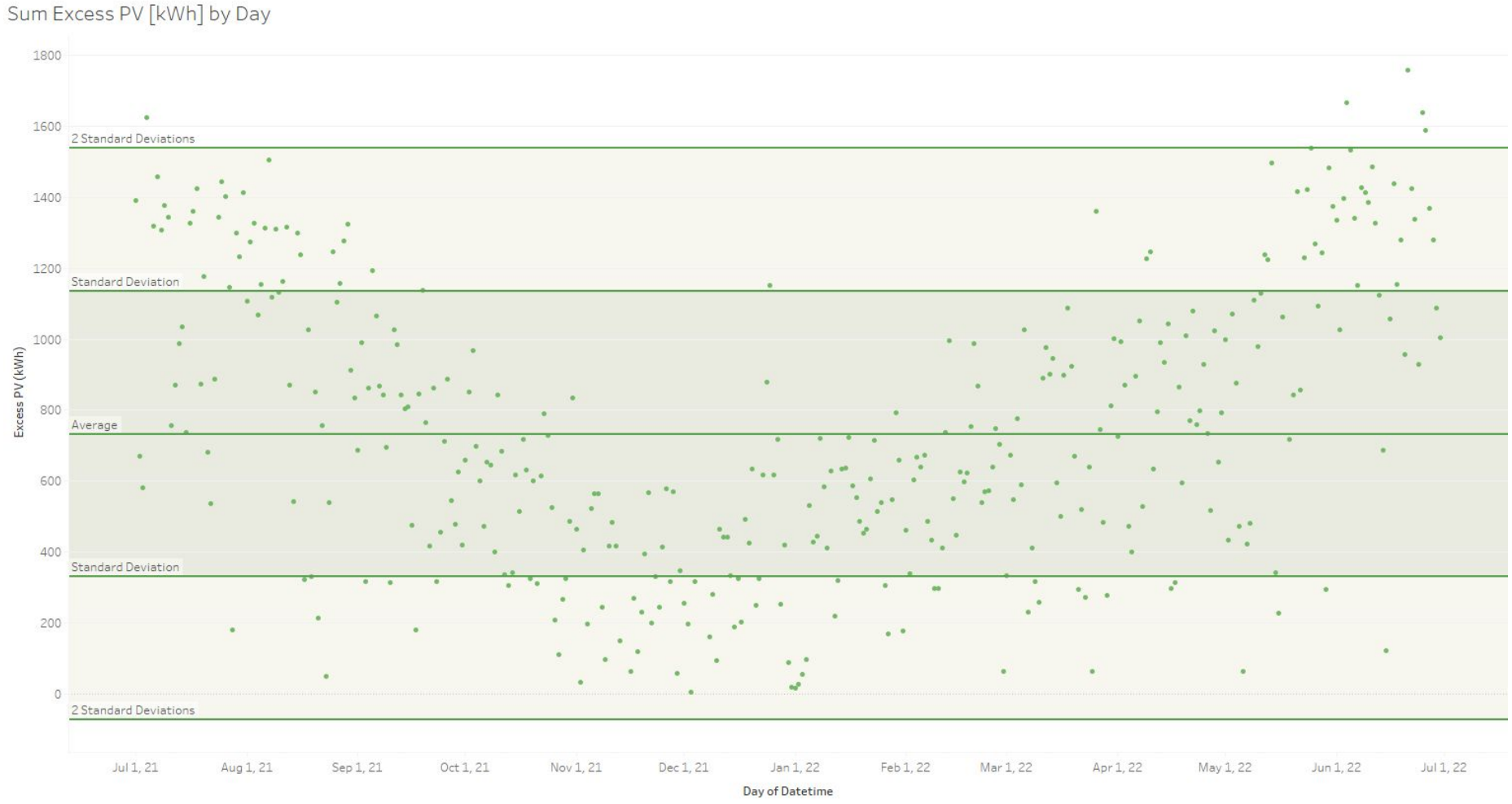
MODE 2: 840 kWh

MEDIAN: 672 kW

MODE 1: 300 kWh

MIN: 4 kW

Art - Excess PV Energy Storage Statistics



+2 STD: 1,537 kWh

+1 STD: 1,135 kWh

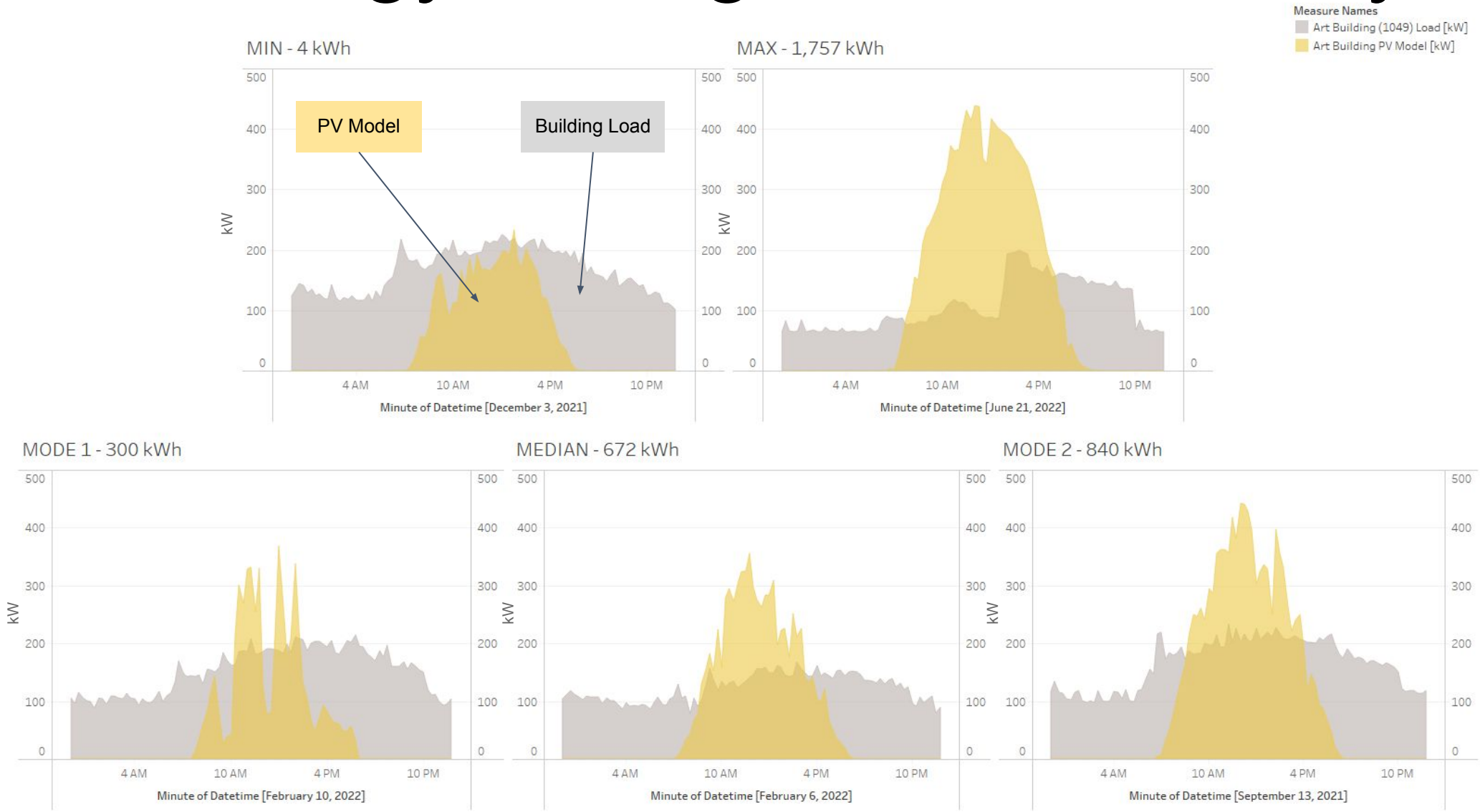
AVG: 733 kWh, STD: 402 kWh

-1 STD: 330 kWh

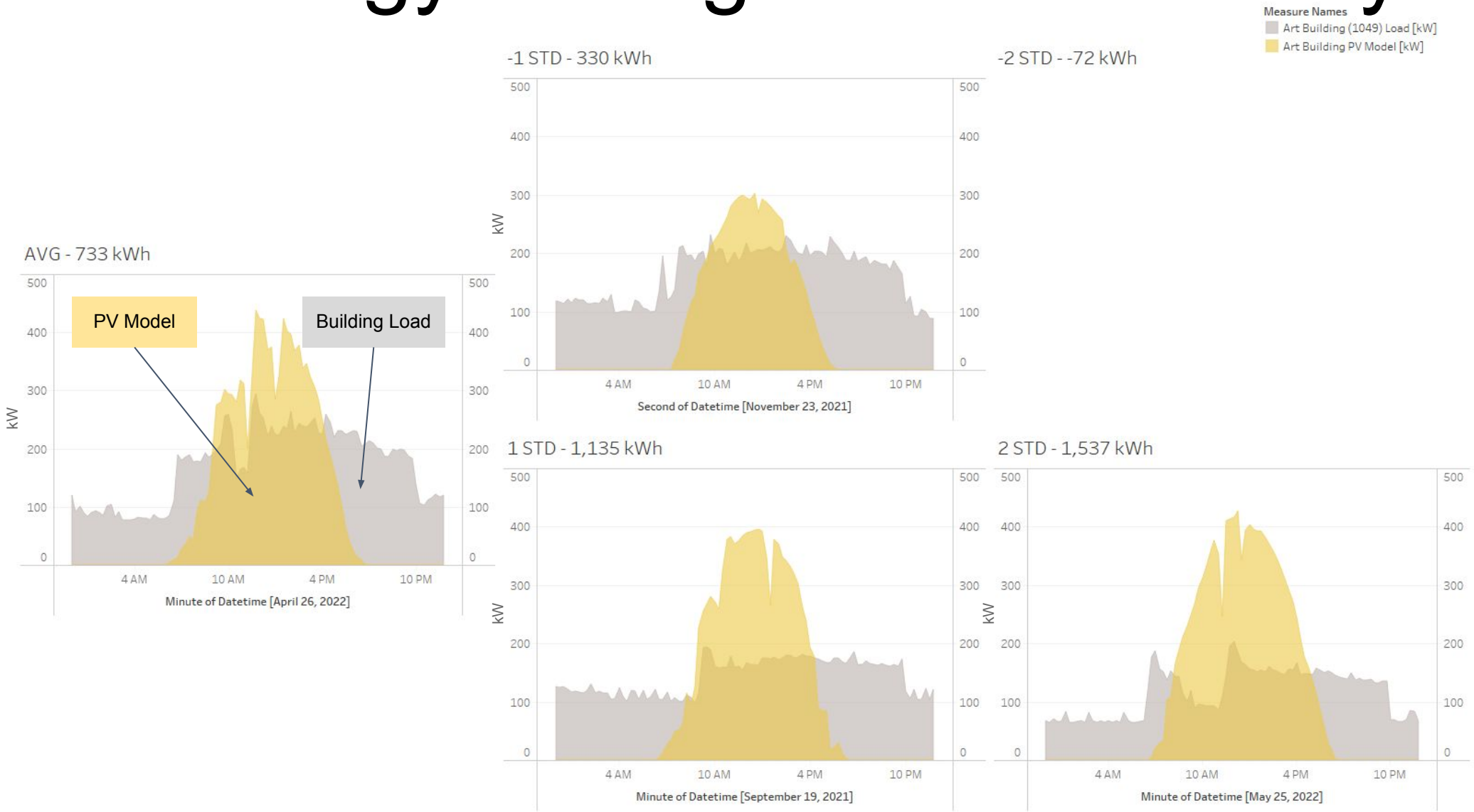
-2 STD: -72 kWh

The plot of sum of Excess PV (kWh) for Datetime Day. The data is filtered on Datetime Day, which excludes July 5, 2021.

Art - Energy Storage Statistical Days



Art - Energy Storage Statistical Days



Excess PV Energy Storage [kWh] Overview

Art Building:

- High end days: 1,000-1,800 kWh, approximately 100 days
- Typical days: 300-1,000 kWh, approximately 215 days
- Low end days: 0-300kWh, approximately 50 days

<u>Art Building's battery system should have a capacity between 400 and 1,600 kWh.</u>

Moore Hall:

- High end days: 450-550 kWh, approximately 10 days
- Mid-range days: 200-450 kWh, approximately 40 days
- Low end days: 0-200 kWh, approximately 315 days

<u>Moore Hall may not need a battery system.</u>

Art Building's Battery Options

Potential batteries could have 200-300 kW flowrates, with 2-6 hour durations, for 400-1,800 kWh capacities

Flowrate (kW)	Duration (h)	Capacity (kWh)	Battery Price (USD) *
200	2	400	$67,200.00
300	2	600	$100,800.00
200	4	800	$132,000.00
300	4	1200	$198,000.00
200	6	1200	$172,800.00
300	6	1800	$259,200.00

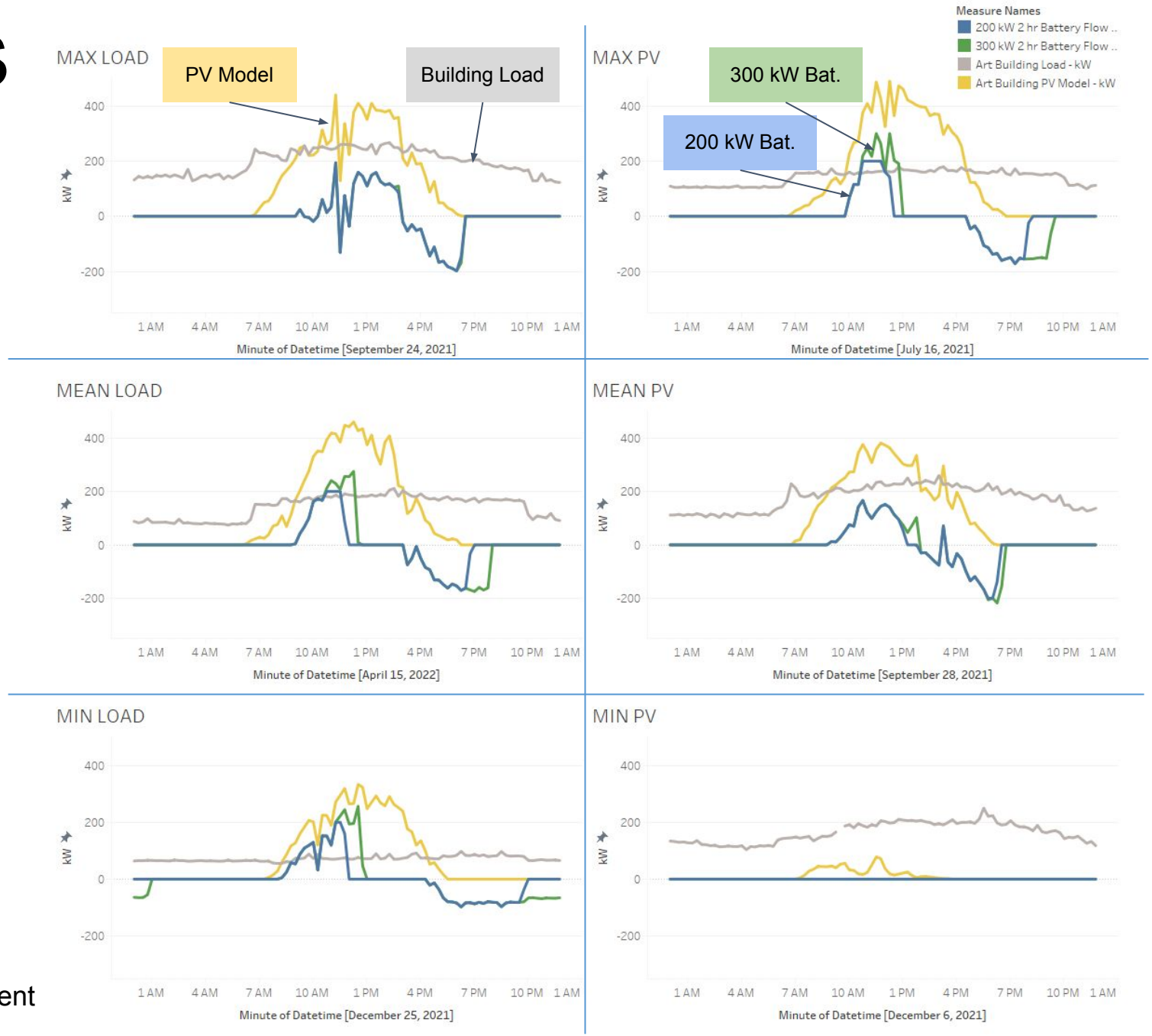
*these prices do not reflect the Hawaii market inflation

[1] https://atb.nrel.gov/electricity/2022/commercial_battery_storage

2 Hour Batteries

200 kW, 2 hr battery
- 400 kWh capacity
- $67,200.00 estimate
- 132,506.23 kWh captured annually

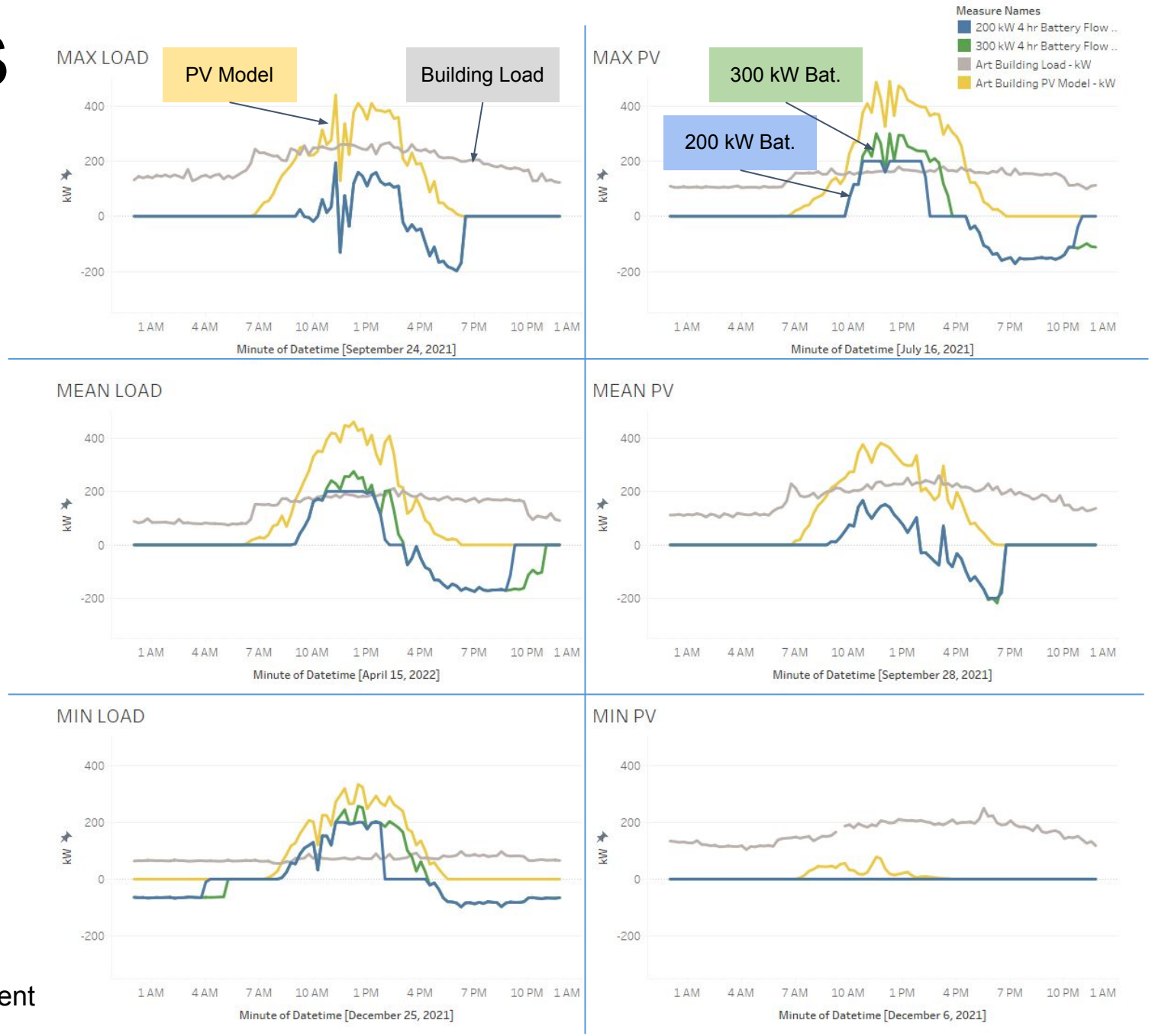
300 kw, 2 hr battery
- 600 kWh
- $100,800.00 estimate
- 180,064.05 kWh captured annually



4 Hour Batteries

200 kW, 4 hr battery
- 800 kWh capacity
- $132,000.00 estimate
- 213,011.13 kWh captured annually

300 kw, 4 hr battery
- 1,200 kWh
- $198,000.00 estimate
- 253,029.87 kWh captured annually



6 Hour Batteries

200 kW, 6 hr battery
- 1,200 kWh capacity
- $172,800.00 estimate
- 247,106.60 kWh captured annually

300 kw, 6 hr battery
- 1,800 kWh
- $259,200.00 estimate
- 262,549.21 kWh captured annually

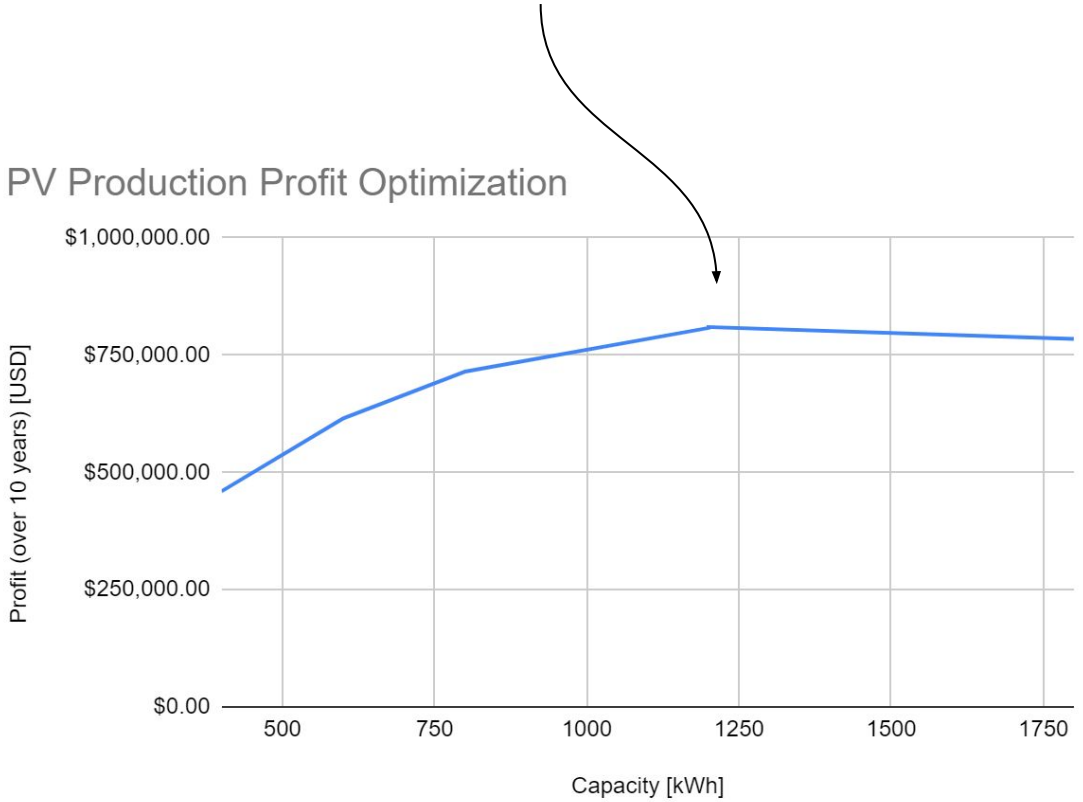
Art - Battery Cost Analysis

10 year profit based on the battery system's 10 year electricity savings, future value, and the battery's price

Flowrate (kW)	Duration (h)	Capacity (kWh)	Battery Price (USD)	10 yr profit (USD)
200	2	400	$67,200.00	$459,591.37
300	2	600	$100,800.00	$615,062.09
200	4	800	$132,000.00	$714,846.42
300	4	1200	$198,000.00	$807,944.78
200	6	1200	$172,800.00	$809,596.26
300	6	1800	$259,200.00	$784,589.83

The NREL pricing study and a 2.8% escalation rate were used to model system profits.

The 200 kW, 6 hour battery which yields a 1,200 kWh capacity returned the greatest profit over a 10 year period in this model.



Art Building - Conclusion

The Art Building rooftop PV system, priced at $4,564,500, could yield an annual 537,000 kWh.

A 200 kW, 6 hour battery storage system, estimated at $172,800, could add 247,000 kWh of annual energy savings.

The energy savings from this battery could pay itself off in 2 years with the energy storage it would offer, and help to pay the whole PV system off in 15 years (19 years without battery).

200 kW, 6 hour Battery			*Cost:* *$172,800.00*
Number of Years	Energy Storage [kWh]	Energy Savings [USD]	Profit [USD]
1	247,107	$86,487.31	-$86,312.69
2	494,213	$175,396.27	$2,596.27
3	741,320	$266,794.67	$93,994.67
4	988,426	$360,752.24	$187,952.24
5	1,235,533	$457,340.61	$284,540.61
6	1,482,640	$556,633.46	$383,833.46
7	1,729,746	$658,706.51	$485,906.51
8	1,976,853	$763,637.60	$590,837.60
9	2,223,959	$871,506.76	$698,706.76
10	2,471,066	$982,396.26	$809,596.26
11	2,718,173	$1,096,390.67	$923,590.67
12	2,965,279	$1,213,576.92	$1,040,776.92
13	3,212,386	$1,334,044.39	$1,161,244.39
14	3,459,492	$1,457,884.94	$1,285,084.94
15	3,706,599	$1,585,193.03	$1,412,393.03

Moore Hall - Conclusion

Moore Hall rooftop PV system, priced at $1,496,000, could yield an annual 244,000 kWh.

Excess PV energy that could be captured by a battery totals 14,643 kWh annually. This would not require a commercial-scale battery.

The energy savings from the PV system alone would offer an ROI of 15 years.