AABC Commissioning Group

AIA Provider Number 50111116

Tales of Commissioning and Net Zero Building - Lombardo Welcome Center at Millersville University

Course Number: CXENERGY1918

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AKF

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Course Description

The Lombardo Welcome Center is designed to be Millersville's first Zero Energy Building. Now open, the building stands as a clear testament of the owner's commitment to sustainability and to the goal of pursuing carbon neutrality by 2040. This case study presentation examines the challenges and rewards associated with this ambitious project.

Learning Objectives

At the end of the this course, participants will be able to:

1. Examine system design strategies employed for high performance and energy savings.

2. Identify key commissioning challenges associated with net zero buildings.

3. Discuss the teamwork and shared focus required by all parties (designers, owners, contractors, and Cx) to achieve net zero energy.

4. Evaluate the building's ongoing performance and how the study of this data has led to lessons learned.


Lombardo Welcome Center Location
Millersville University

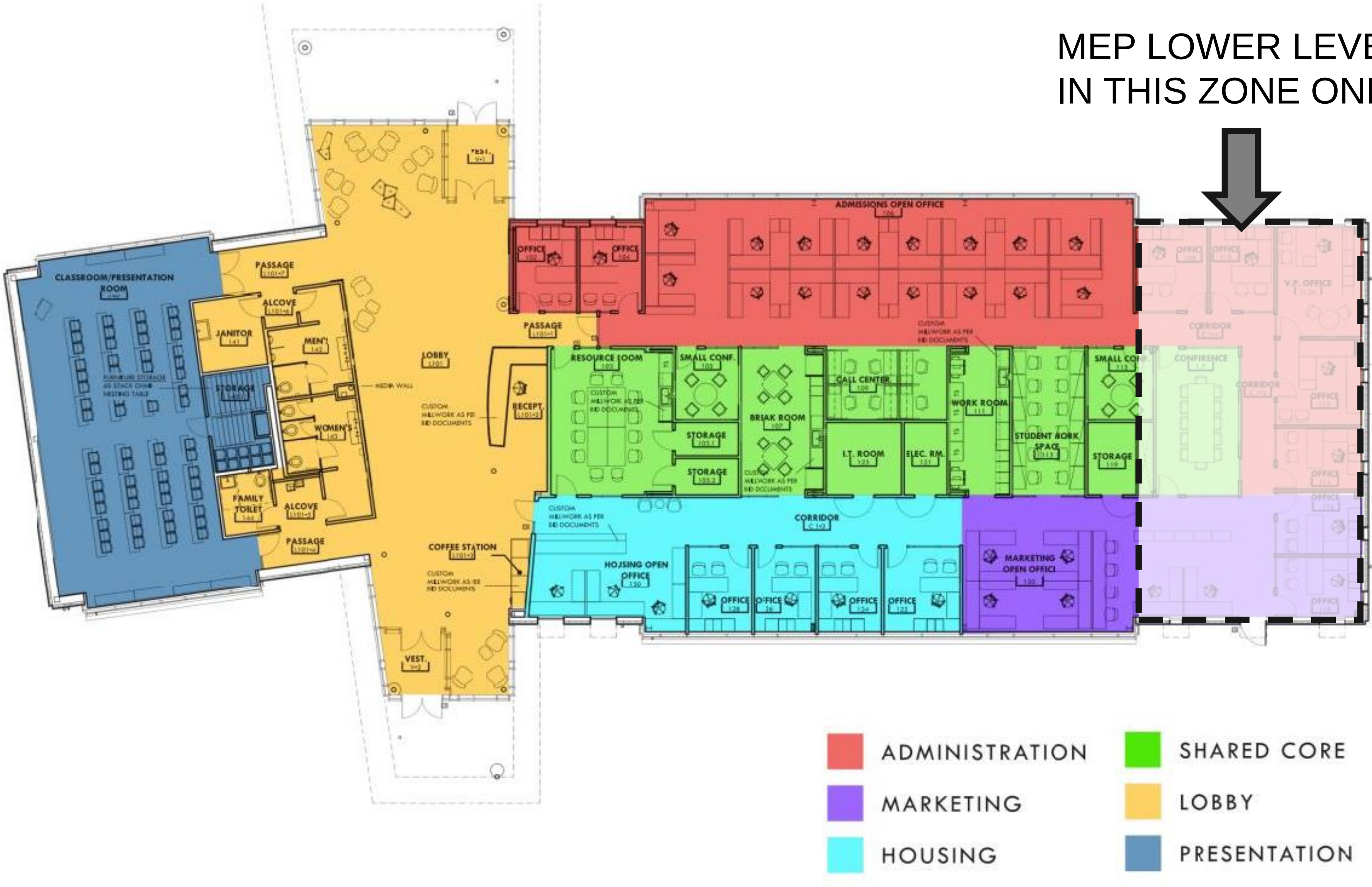
WELCOME CENTER STAFF PARKING (38 SPACES)
EXISTING PARKING (214 SPACES)
ADA ACCESSIBLE RAMPS
JAMES STREET
WELCOME CENTER VISITOR PARKING (17 SPACES)
ADA ACCESSIBLE RAMP
EXISTING PARKING LOT
EXISTING DROP-OFF
LOMBARDO WELCOME CENTER
RESIDENCE HALL
SOLAR TRACKER
GORDINIER HALL
GORDINIER ADDITION
FIRE LANE
SETBACK LINE
EASEMENT LINE
RIGHT-OF-WAY LINE
CENTER LINE
PROPOSED SIGN
LIGHT STANDARDS
EXISTING FENCE
PROPOSED FENCE
PROPOSED CONSTRUCTION FENCE
PROJECT LIMIT LINE
BOLLARD LIGHT
FIRE DEPARTMENT CONNECTION
ASPHALT PAVING
CONCRETE WALK

ZERO ENERGY
CERTIFICATION

INTERNATIONAL
LIVING FUTURE
INSTITUTE℠

Lombardo Floor Plan

MEP LOWER LEVEL
IN THIS ZONE ONLY

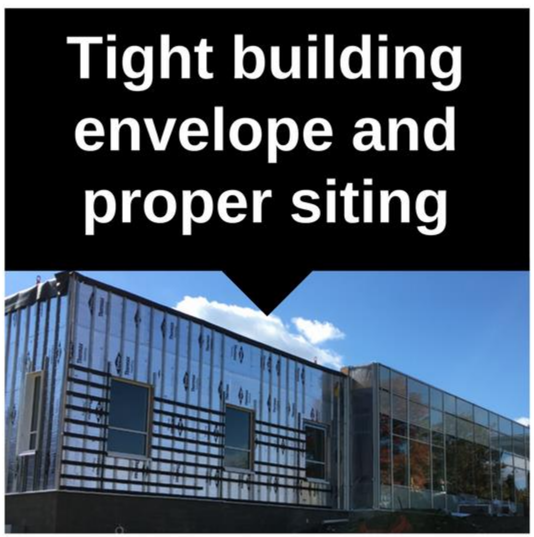


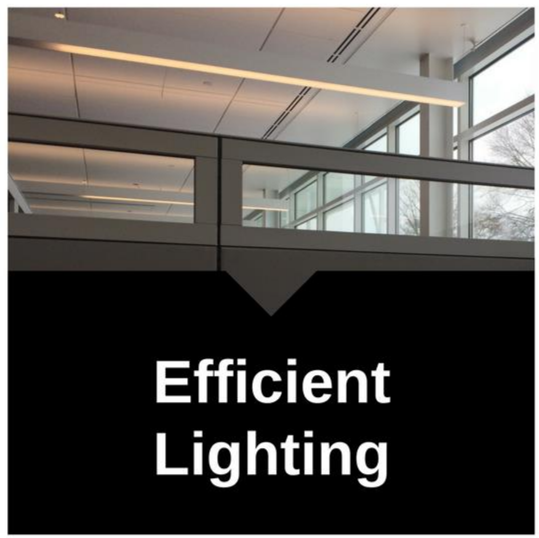
Lombardo Images

Design Stage: Energy Efficiency

Zero energy begins with energy efficiency.

A tight building envelope, proper siting, efficient lighting and passive heating and cooling all help make the Lombardo Welcome Center about 60% more efficient than other campus buildings.





Building Envelope Strategies

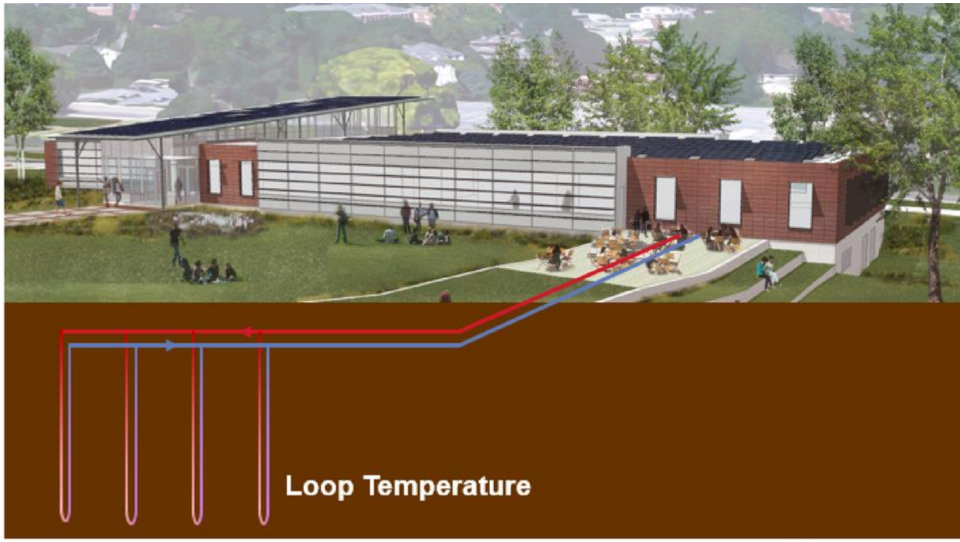
Highly Insulated Envelope, Limiting Thermal Bridging

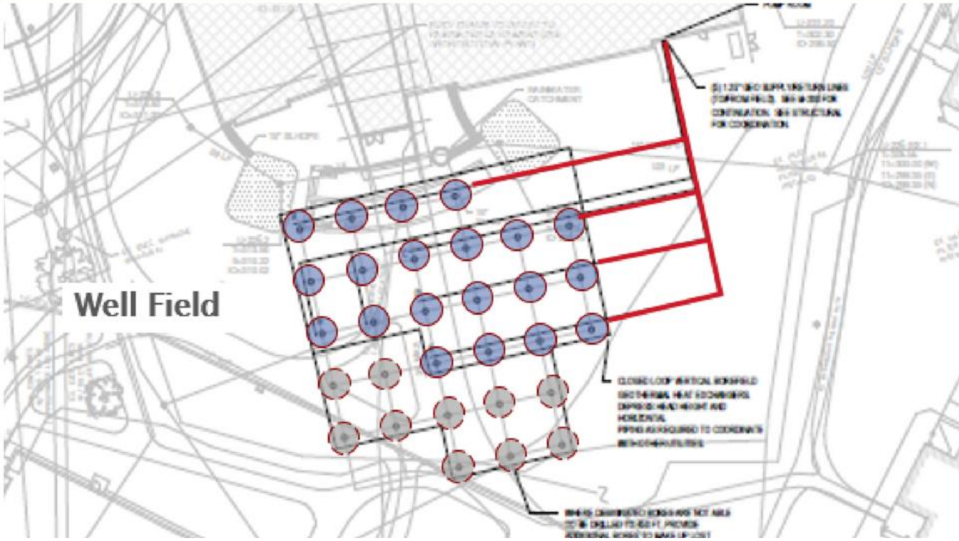
Shading and Glare Control

Lighting: LED Lights with Daylight Dimming Controls

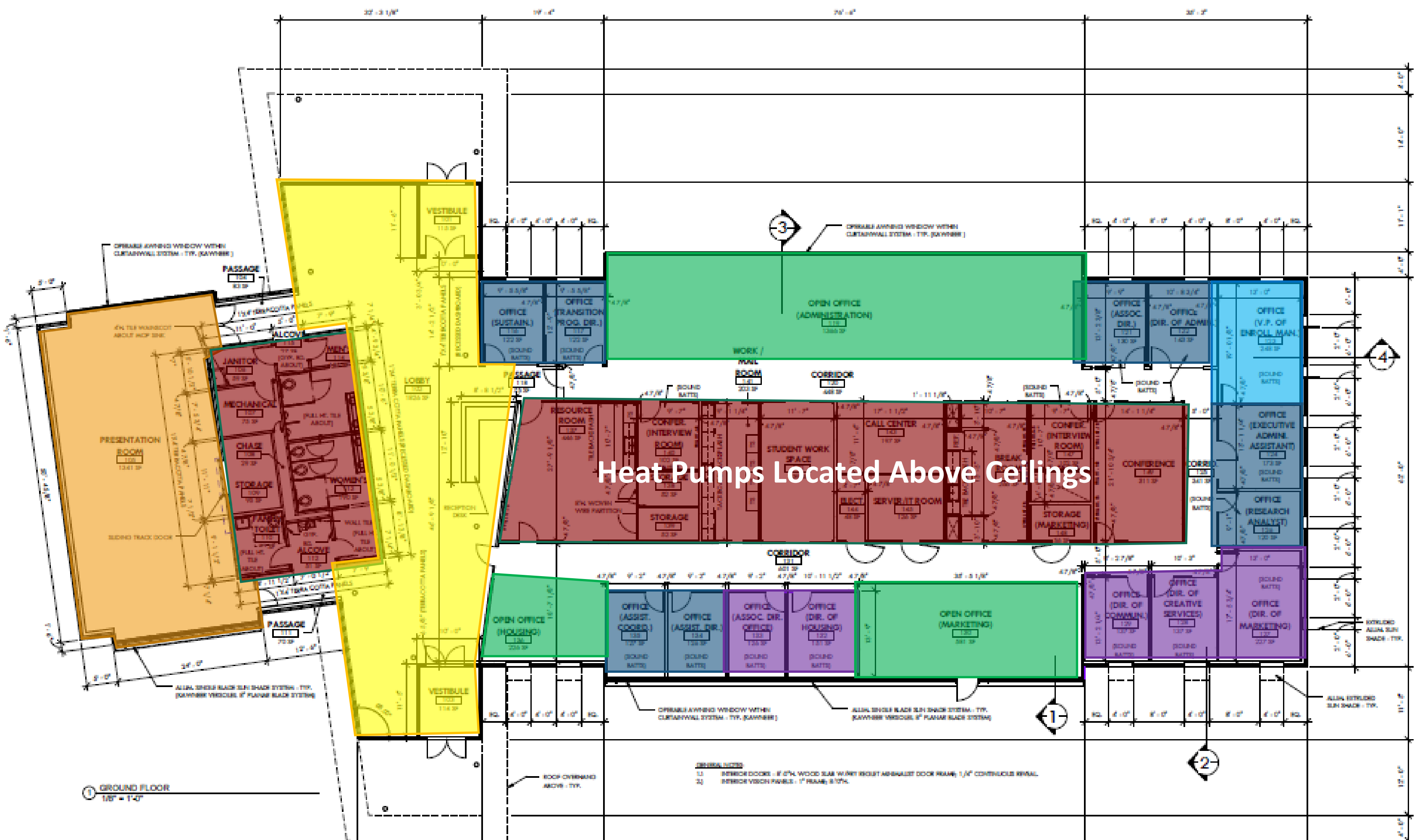
Interior Lighting: 0.63 w/sf (1.2 w/sf code allowance)

Geothermal Well System





Heating and Cooling
Geothermal and Multiple Heat Pumps
Flexibility – Saves Energy



Design Team Tried to Keep It Simple But…

Things happen during design that complicate the best of plans…

Original Concept (BOD):

- Distributed water source heat pumps serving individual spaces or zones.
- Approximately 40 individual Heat Pumps from ½ Ton to 3 Tons.
- Each heat pump will have an associated thermostat to control the unit
- Either horizontal concealed units above ceilings, vertical concealed units located in closets or console type units

Design Development Concept:

- Due to budget, design down to 20 Heat Pumps
- Up to 3 private offices on a single heat pump, 1 thermostat per heat pump
- All heat pumps are concealed above ceilings to save floor space. Many areas to not have ceilings so heat pumps are toward the central core.

Design Team Tried to Keep It Simple But…

Things happen during design that complicate the best of plans…

Construction Documents:

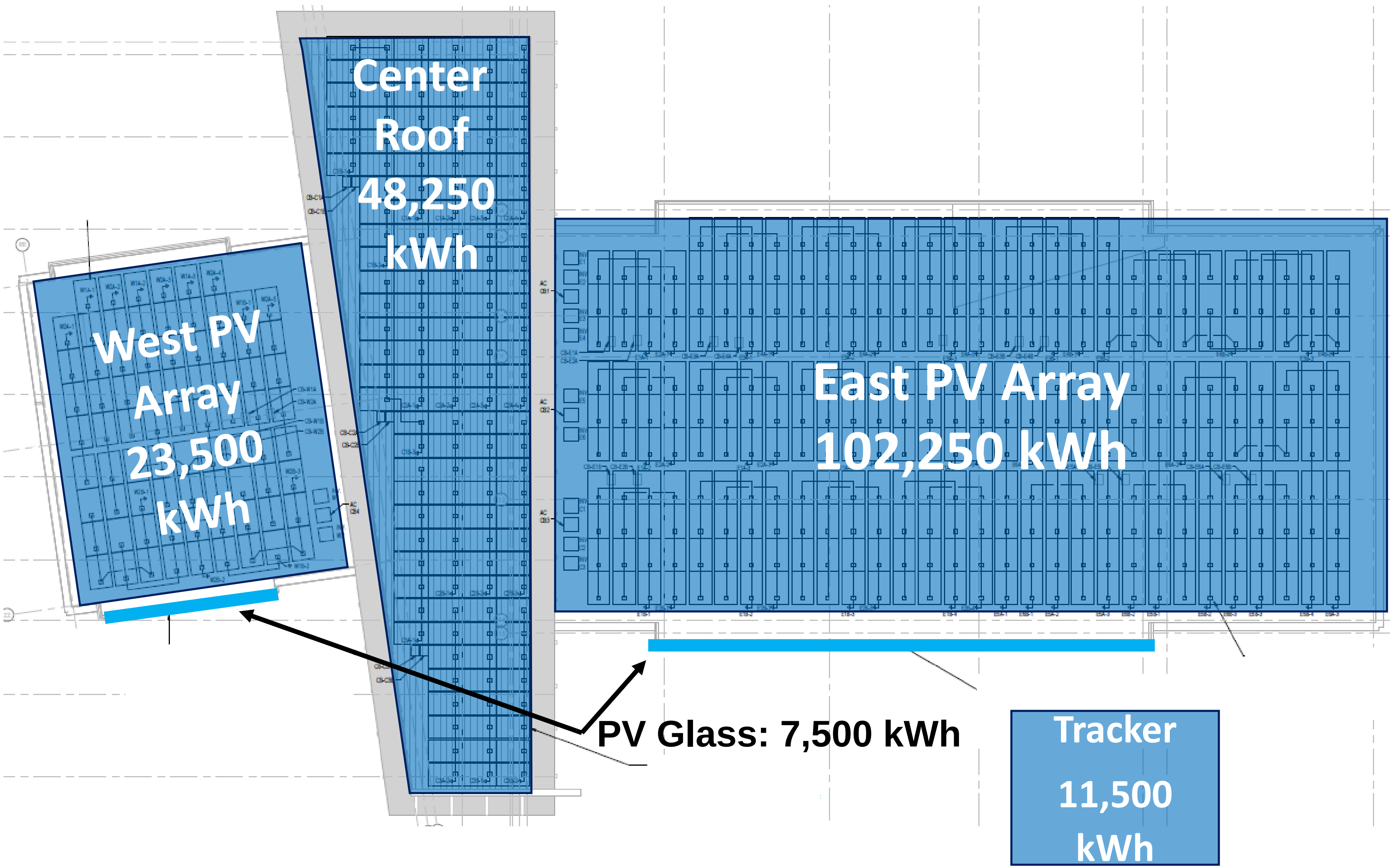
- Concerns raised by occupants about lack of control in each office.
- Limited space above ceilings and budget concerns only allow for a few units to be added. Design up to 23 heat pumps.
- Each office now has a thermostat
- Bypass VAV concept introduced to allow each office to set temperature

Construction:

- RFIs issued about bypass VAV design
- Confusion shows up on sheet metal shop drawings have to be reviewed multiple times
- Once again design changed.

BOD: Simple – Final Installed System: Complicated.

Lombardo Roof Plan



Total Potential System Generation: 193,000 kWh

Lombardo PV Image

Aiming for Net Positive

The plan for the project was to carry up to 20% contingency in the PV production to allow for variables including weather, extra building usage and extra plug loads by occupants, etc.

Energy Model Predicted Annual Energy 152,500 kWh

Roof Only PV Generation Prediction 179,000 kWh

Roof only provides a 17% contingency

PV Tracker and Glass added as teaching tools

Final Design PV Generation Prediction* 193,000 kWh

Final Planned contingency 27%

*During construction a few PV panels were removed from the design resulting in slightly reduced PV generation predictions.

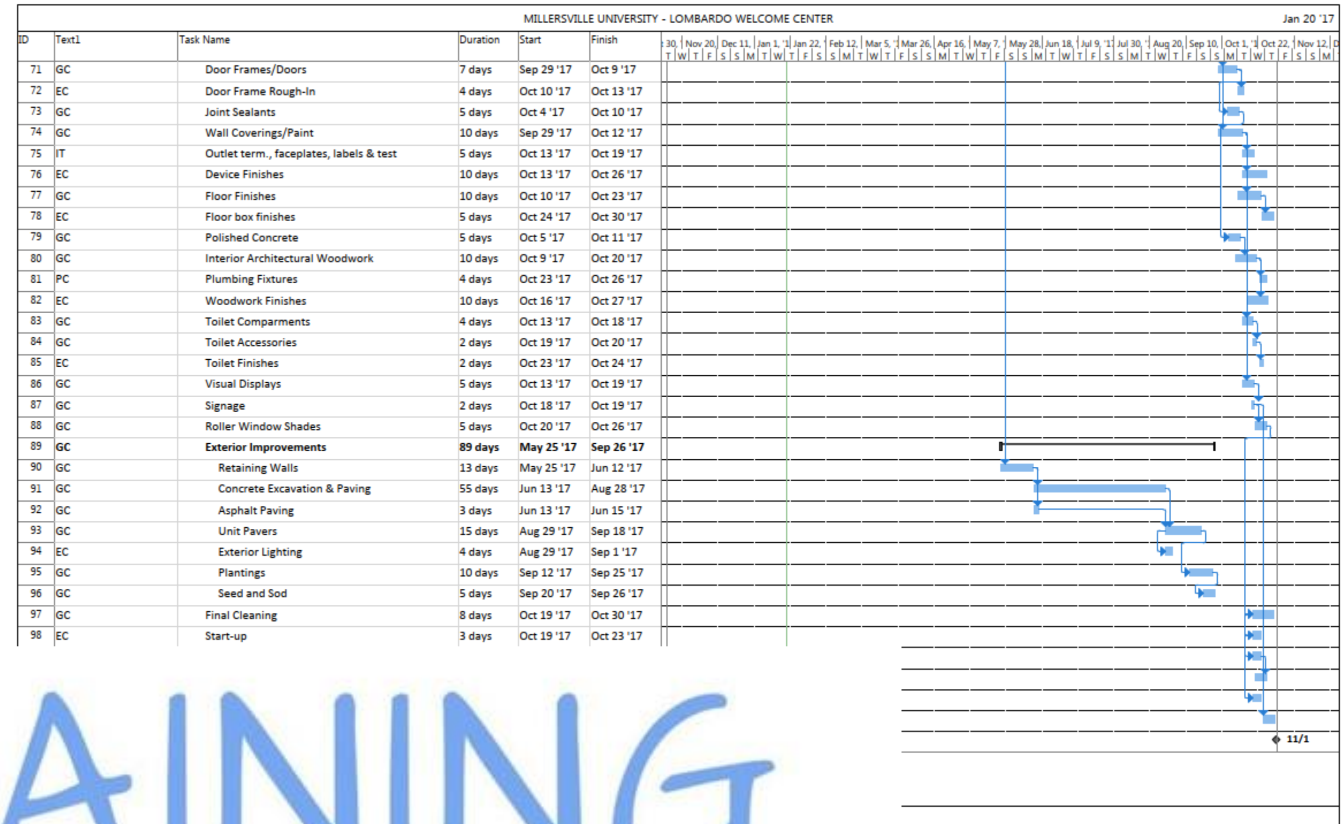
Getting to Net Zero is Not Just About Design

- Quality Construction
- Commissioning
- Occupancy/Operations

Key Commissioning Challenges for Net-Zero Buildings

- All the typical new building commissioning challenges PLUS
- Energy Model to ACTUAL
- Occupant Engagement/training
- Operator Engagement/training
- Efficient and Effective
- Persistence - First Year and beyond

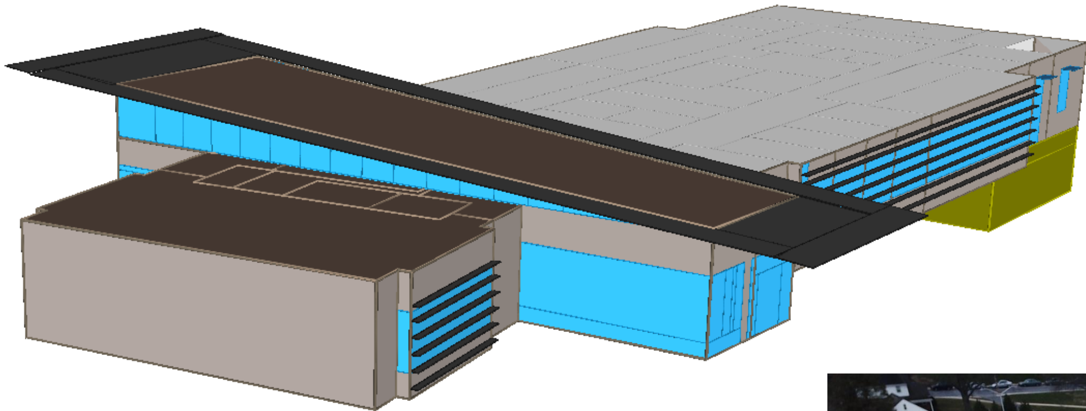
All the normal challenges of Cx +

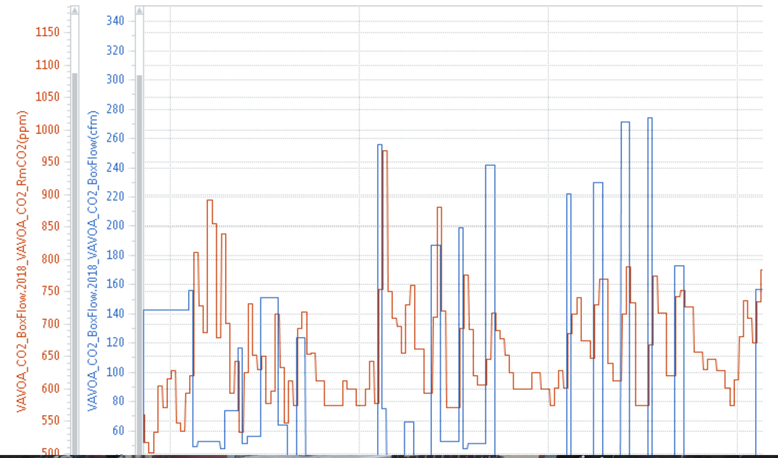


MILLERSVILLE UNIVERSITY - LOMBARDO WELCOME CENTER — Jan 20 '17

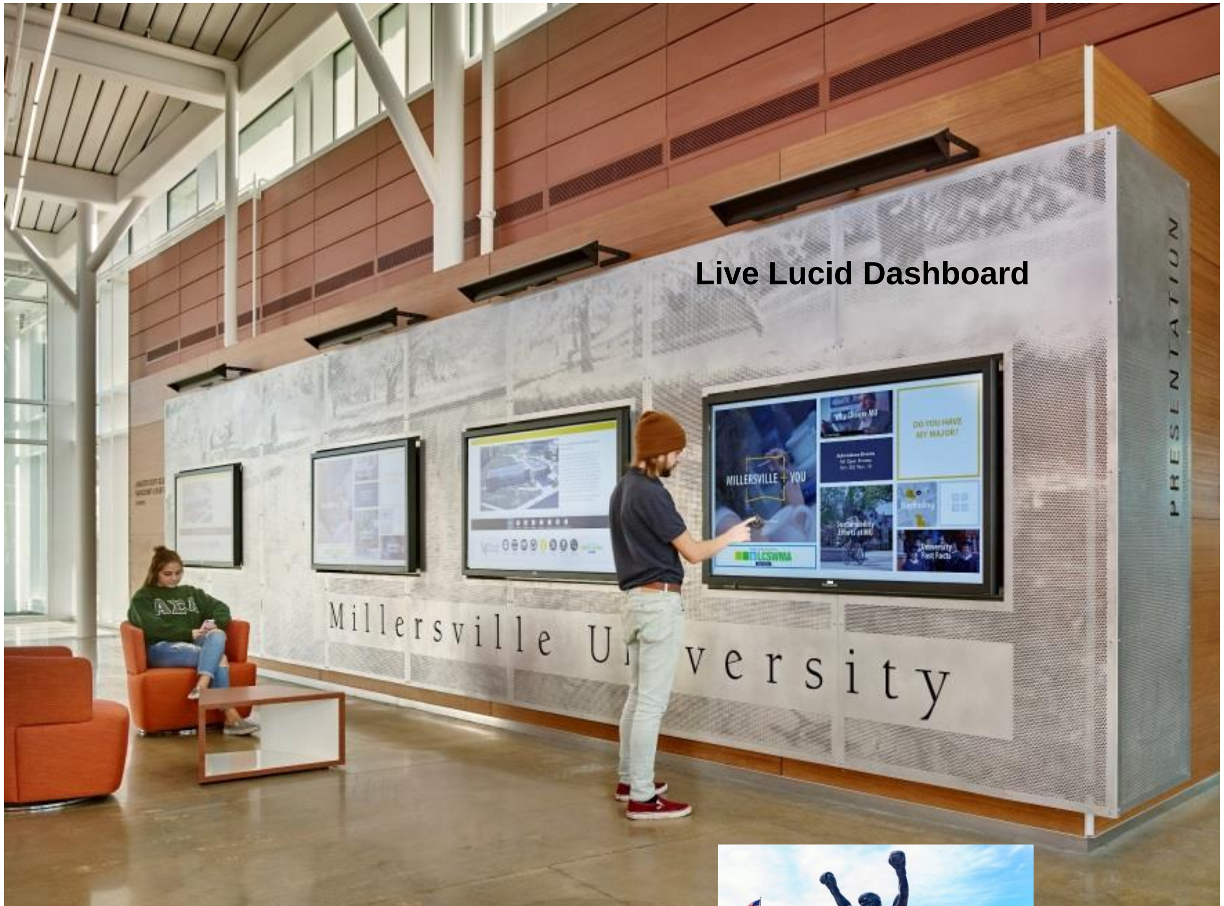
ID	Text1	Task Name	Duration	Start	Finish
71	GC	Door Frames/Doors	7 days	Sep 29 '17	Oct 9 '17
72	EC	Door Frame Rough-In	4 days	Oct 10 '17	Oct 13 '17
73	GC	Joint Sealants	5 days	Oct 4 '17	Oct 10 '17
74	GC	Wall Coverings/Paint	10 days	Sep 29 '17	Oct 12 '17
75	IT	Outlet term., faceplates, labels & test	5 days	Oct 13 '17	Oct 19 '17
76	EC	Device Finishes	10 days	Oct 13 '17	Oct 26 '17
77	GC	Floor Finishes	10 days	Oct 10 '17	Oct 23 '17
78	EC	Floor box finishes	5 days	Oct 24 '17	Oct 30 '17
79	GC	Polished Concrete	5 days	Oct 5 '17	Oct 11 '17
80	GC	Interior Architectural Woodwork	10 days	Oct 9 '17	Oct 20 '17
81	PC	Plumbing Fixtures	4 days	Oct 23 '17	Oct 26 '17
82	EC	Woodwork Finishes	10 days	Oct 16 '17	Oct 27 '17
83	GC	Toilet Comparments	4 days	Oct 13 '17	Oct 18 '17
84	GC	Toilet Accessories	2 days	Oct 19 '17	Oct 20 '17
85	EC	Toilet Finishes	2 days	Oct 23 '17	Oct 24 '17
86	GC	Visual Displays	5 days	Oct 13 '17	Oct 19 '17
87	GC	Signage	2 days	Oct 18 '17	Oct 19 '17
88	GC	Roller Window Shades	5 days	Oct 20 '17	Oct 26 '17
89	**GC**	**Exterior Improvements**	**89 days**	**May 25 '17**	**Sep 26 '17**
90	GC	Retaining Walls	13 days	May 25 '17	Jun 12 '17
91	GC	Concrete Excavation & Paving	55 days	Jun 13 '17	Aug 28 '17
92	GC	Asphalt Paving	3 days	Jun 13 '17	Jun 15 '17
93	GC	Unit Pavers	15 days	Aug 29 '17	Sep 18 '17
94	EC	Exterior Lighting	4 days	Aug 29 '17	Sep 1 '17
95	GC	Plantings	10 days	Sep 12 '17	Sep 25 '17
96	GC	Seed and Sod	5 days	Sep 20 '17	Sep 26 '17
97	GC	Final Cleaning	8 days	Oct 19 '17	Oct 30 '17
98	EC	Start-up	3 days	Oct 19 '17	Oct 23 '17

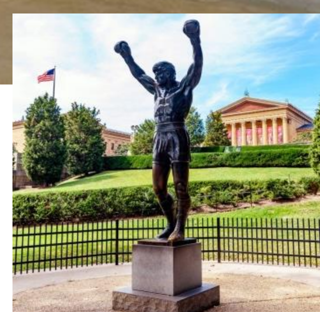
Energy Model to ACTUAL





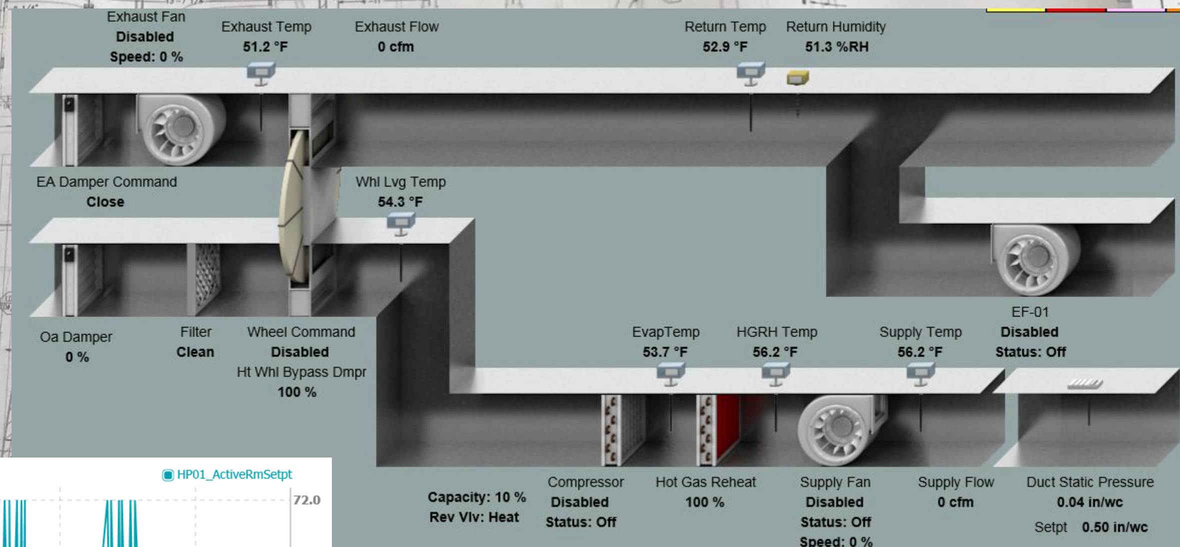
Occupant Engagement/Training

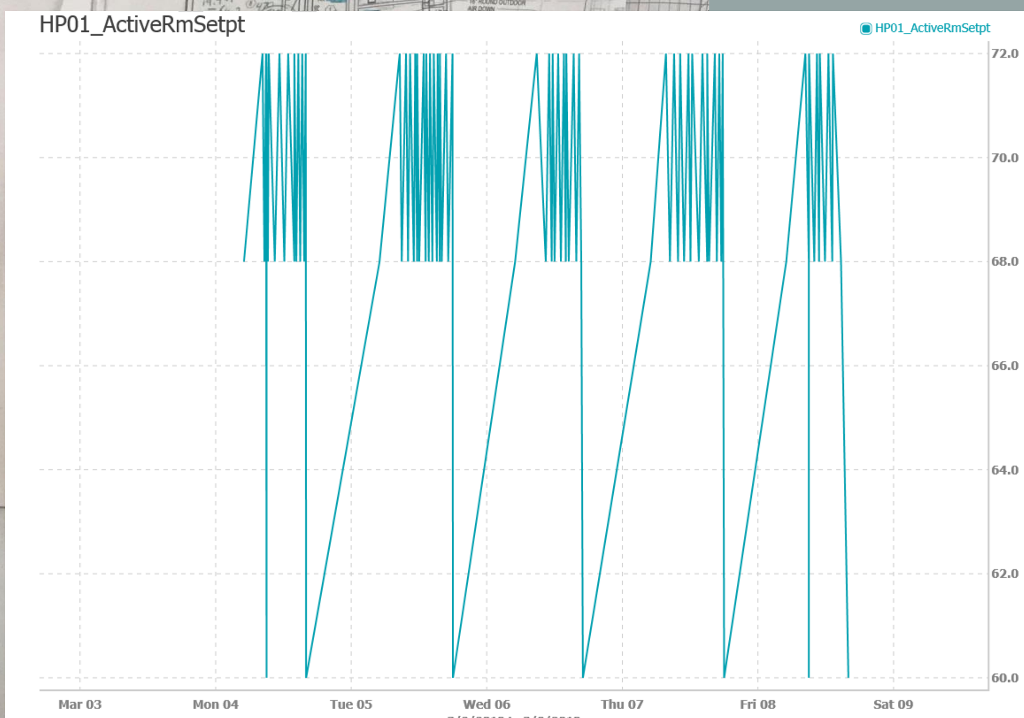




Chris Steuer, Sustainability Director

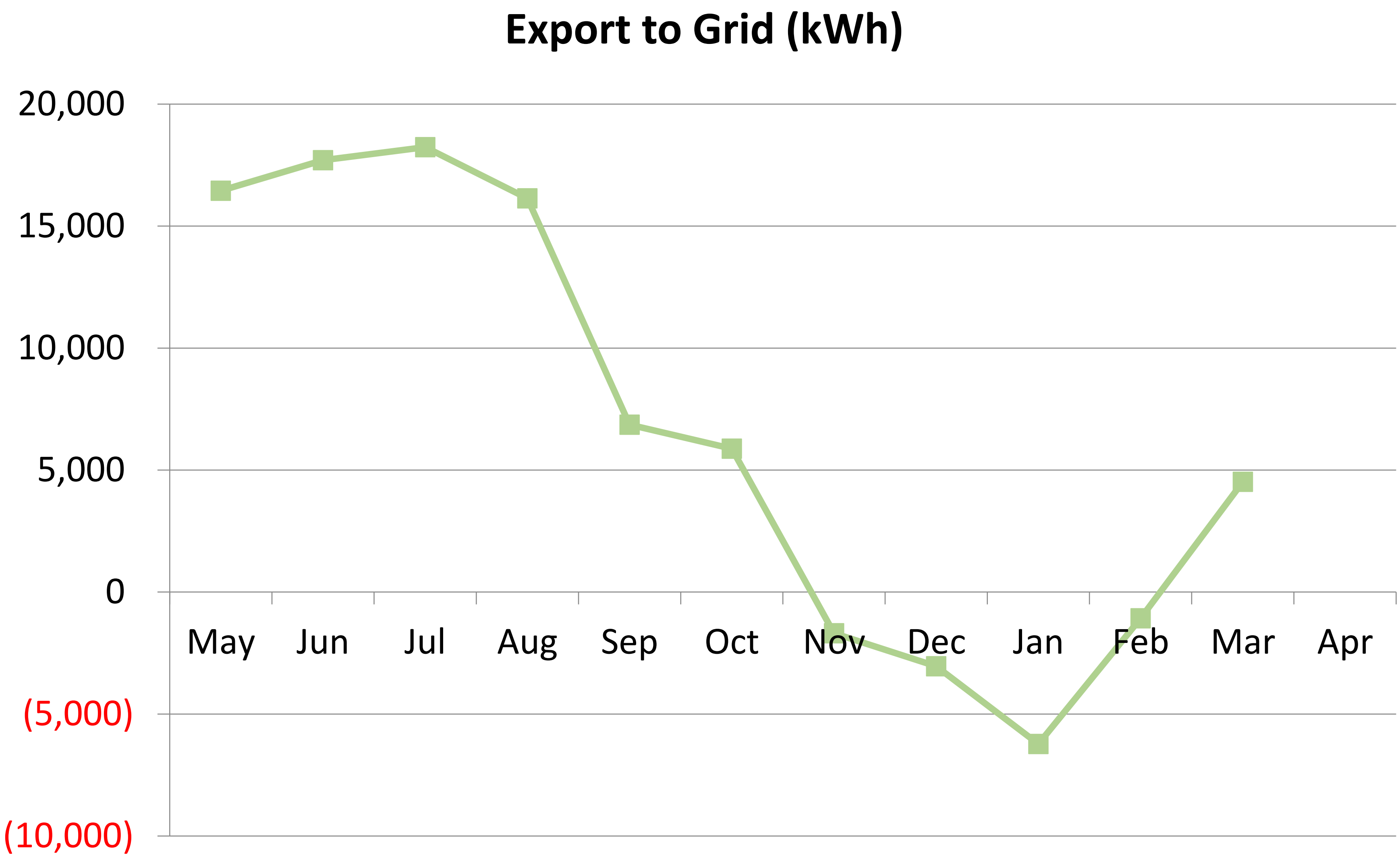
Operator Engagement/Training





Efficient <u>and</u> Effective

Persistence -
Monitoring and Ongoing Commissioning



Teamwork and shared focus required to achieve net zero energy - Design, Commissioning, and OPR

- Predesign: Architectural and Engineering Team spent extra time understanding client and occupant's needs, expectations, and behaviors
  - Used to help better estimate energy use
  - Helped with development of OPR
- Design: Focused on energy efficiency, occupant needs, and energy generation.
- Construction: State-funded, multi-prime. Contractors invited to participate in helping to achieve NZE.
- Commissioning: Focused on mechanical systems only (per owners request). Design engineer recommended all energy systems, but owner was wary about Cx.

Predesign Studies
Understanding The Occupants
Managing Plug In Equipment

Millersville University Lombardo Welcome Center

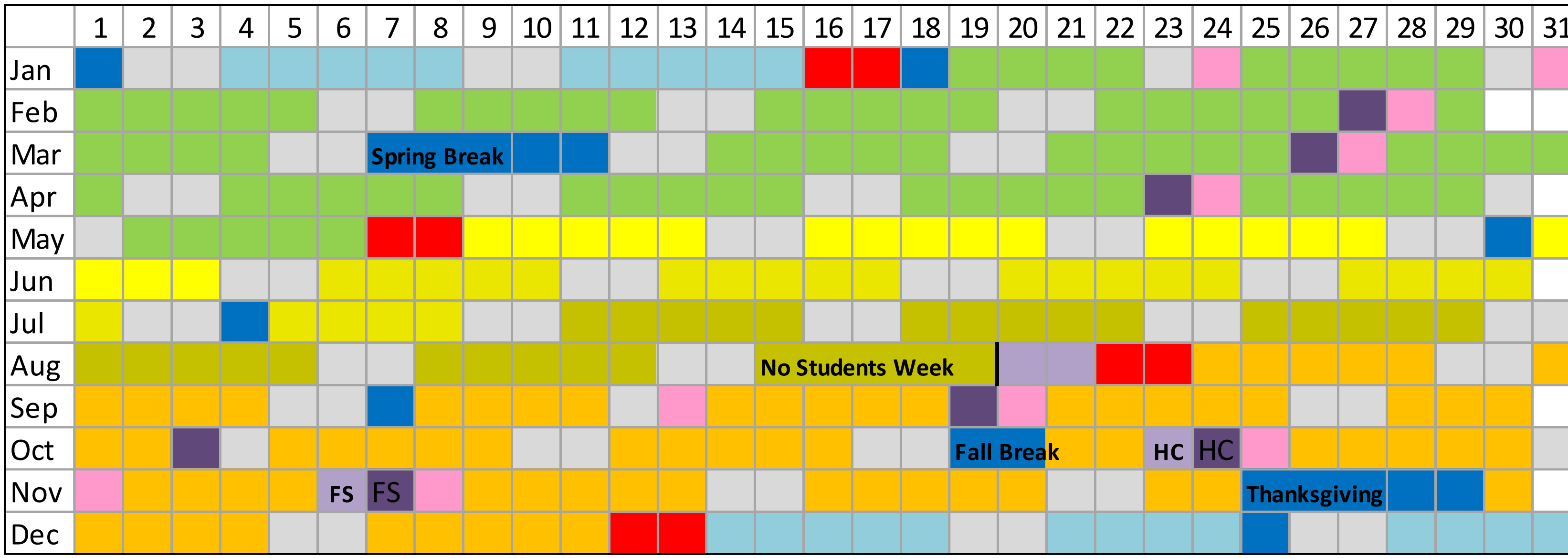
		Plug Loads						Schedule		
	SF	kW	Occupied Load Factor	Unoccup. Load Factor	Other Load Factors	Daily KWh with Load Factor	w/sf	Occ	Unocc	other
Lobby	2026	7.78	11.0%	5.8%	81.8%	16.89	3.84	15	9	8.0
Presentation Room	1424	2.18	25.1%	0.6%		8.33	1.53	15	9	
Resource Room	544	4.65	7.0%	0.8%		5.25	8.55	15	9	
Student Housing	733	0.49	30.9%	1.1%		2.33	0.67	12	12	
Admissions	1551	1.09	28.9%	1.2%		4.85	0.70	12	12	
Marketing	920	0.31	32.2%	0.8%		1.51	0.33	12	12	
Student Workers	443	0.72	28.0%	1.2%		3.10	1.63	12	12	
Support Spaces	995	12.61	12.8%	0.6%		28.99	12.67	15	9	
Circulation	1254	1.20	0.0%	20.0%		2.16	0.96	15	9	
Restrooms	470	4.32	1.7%	0.0%		1.08	9.19	15	9	
MEP spaces	1276	1.86	100.0%	100.0%		44.56	1.46	15	9	
Total	11636	37.20				119.04804	3.196686			

in:posse 2015

Understanding The Occupants

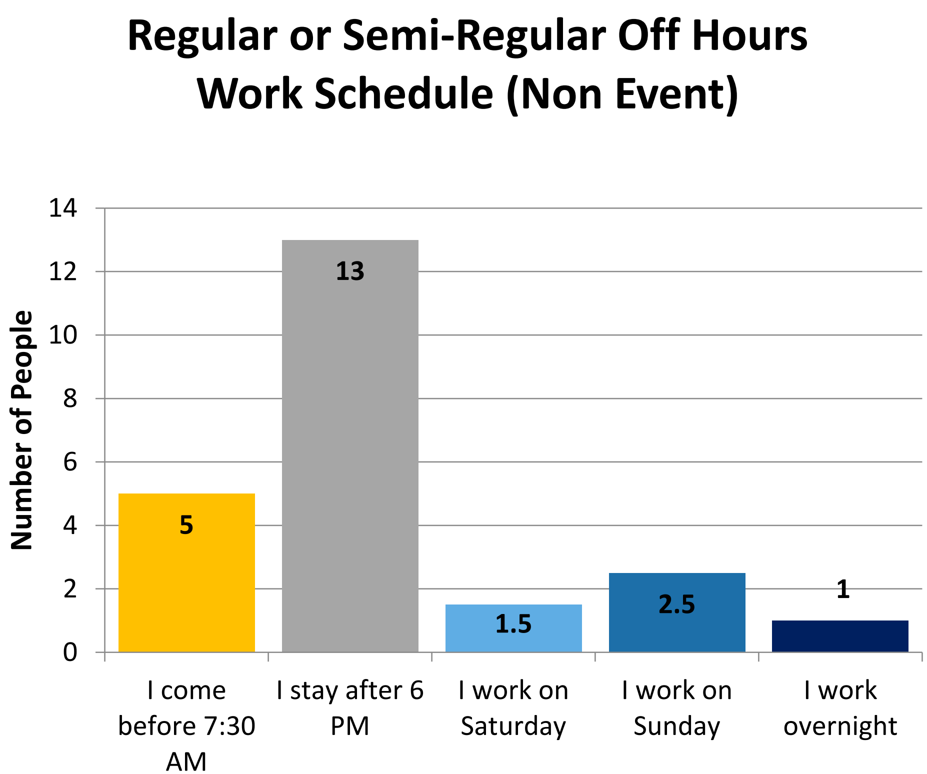
Building Schedules

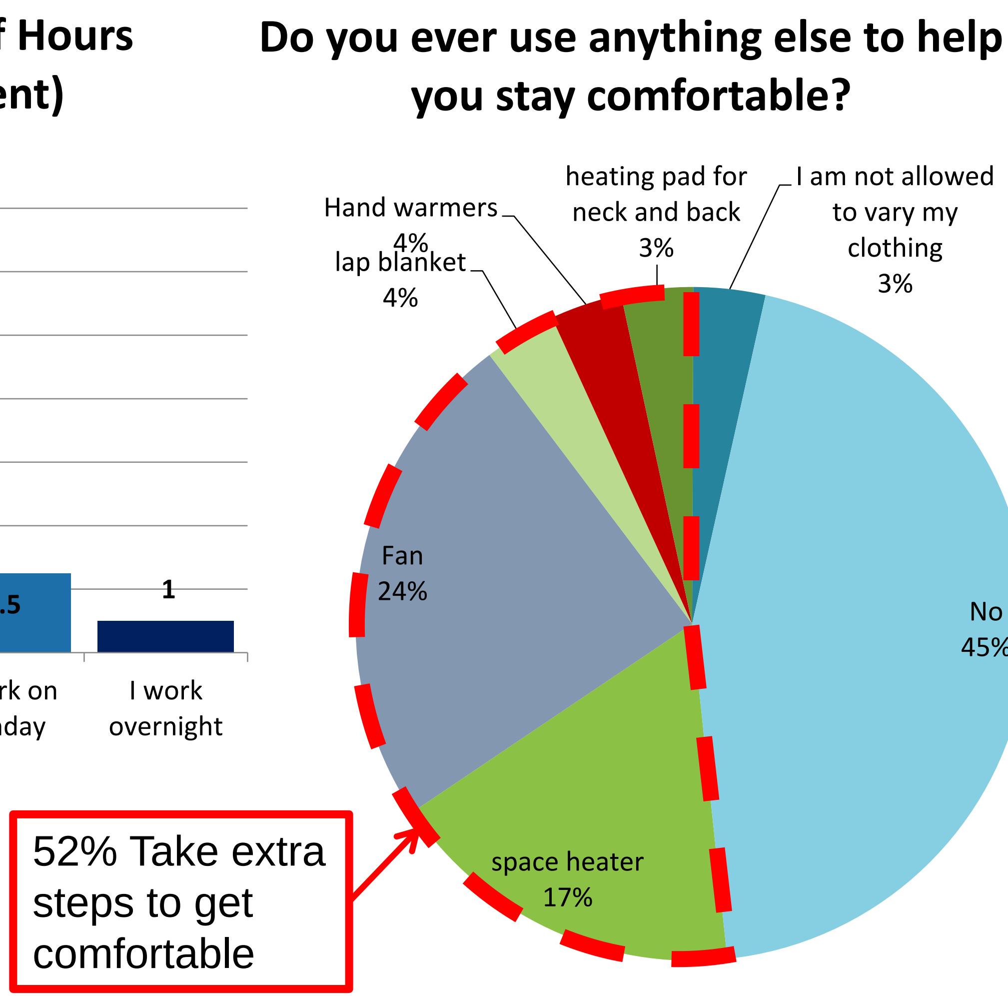
Lombardo Center Annual Schedule



Standard Weekday Hours Spring/Fall	**Fall Term**	**16 weeks**
	Spring Term	**15 weeks**
Standard Weekday Hours Summer/Winter	**Winter Term**	**5 weeks**
	Summer Terms	**Summer 1 - 4 weeks, Summer 2 and 3 - 5 weeks**
Events	**Weekday Admissions Event**	**4 days**
	Weekend Admissions Events	**7 days**
Working Weekend	**Weekend Admissions Work**	**10 days**
	Weekend Housing Work	**8 days**
Weekend	**Weekends**	**77 days**
Holiday/Closed	**Holiday (Housing Open)**	**18 days**

Verifying Occupant Impacts
Off Hours Work Trends and Temperature





Occupant Usage: Schedules

Energy Usage As a Percent of Building Total

- Select staff works extreme hours at critical periods in the year.
- The University wanted to understand the impact of providing full HVAC for these added hours.
- Study looked at an additional 229 hours of afterhours HVAC system usage.
- This change alone would **increase** the energy usage by **7.7%**

Plan For Lombardo Temperature Controls
Based On Survey Results

Thermostat Locations:

Each private office will have a thermostat. Open office areas will have a thermostat per open area grouping.

Temperature Range:

The temperature range will be set to the following:
Summer: 74 deg. Winter: 68 deg. Thermostats will allow +/- 2 deg.

Humidity:

The system will remove humidity in the summer to make sure the relative humidity is no higher than 60%. Lower humidity will help the building feel cooler.

Windows:

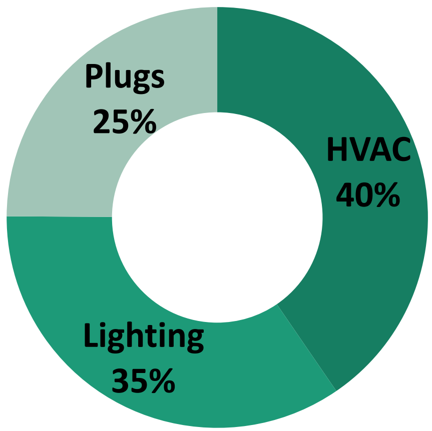
The windows will not open in the building. Open windows mess up the thermostats and humidity control. If the heating/cooling system is still running, they also result in wasted energy. Shading will be provided on the windows to prevent extra heat from the sun during the summer. This will help keep spaces cooler too.

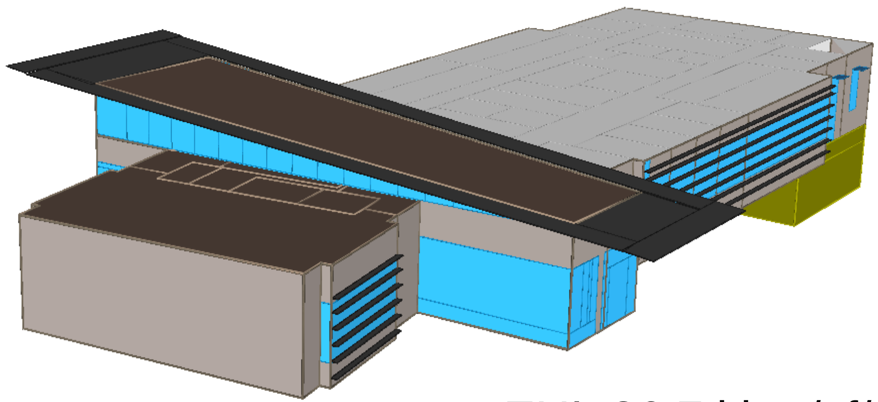
After Hours:

There will be override switches for each heating/cooling unit and they will need to be activated by zone. Overrides will provide heating and cooling for a period of 1 hour each time it is activated.

Building Performance – Baseline
(estimated, theoretical)

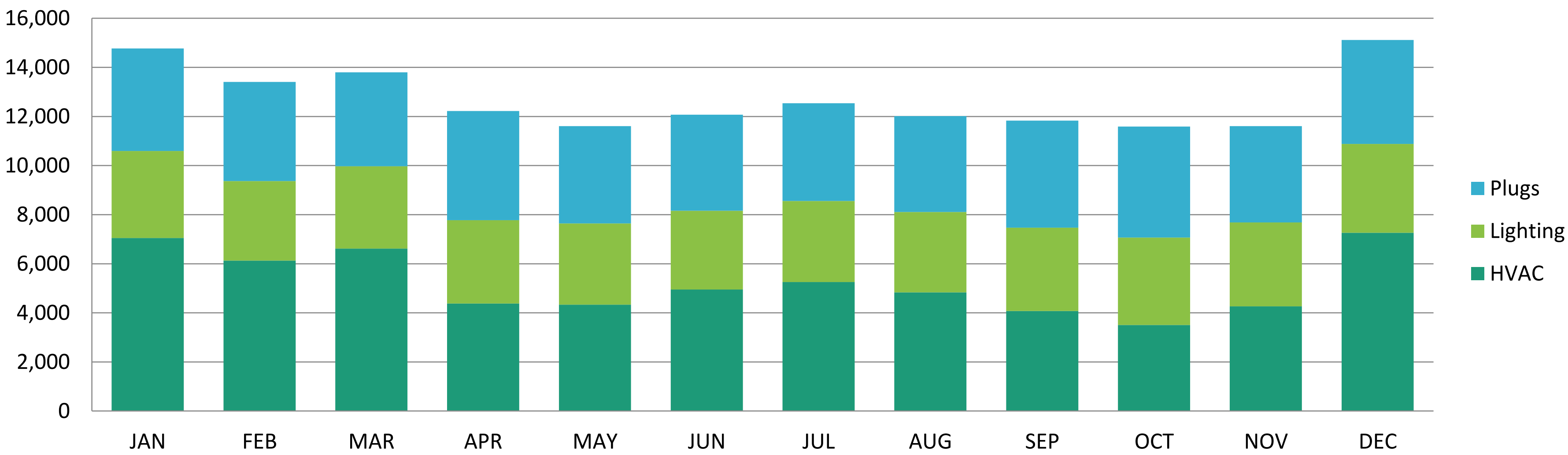
Energy Model - Enduse Breakdown





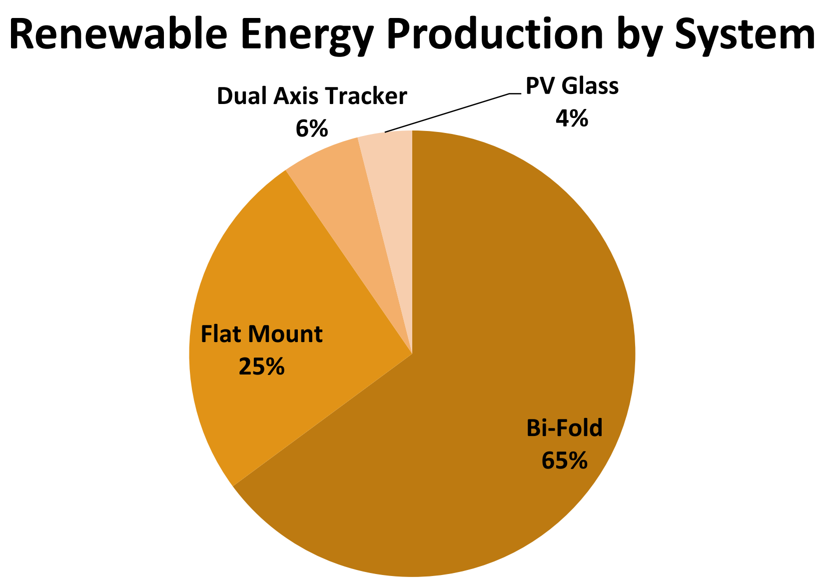
EUI: 36.7 kbtu/sf/yr

Enduse by Month

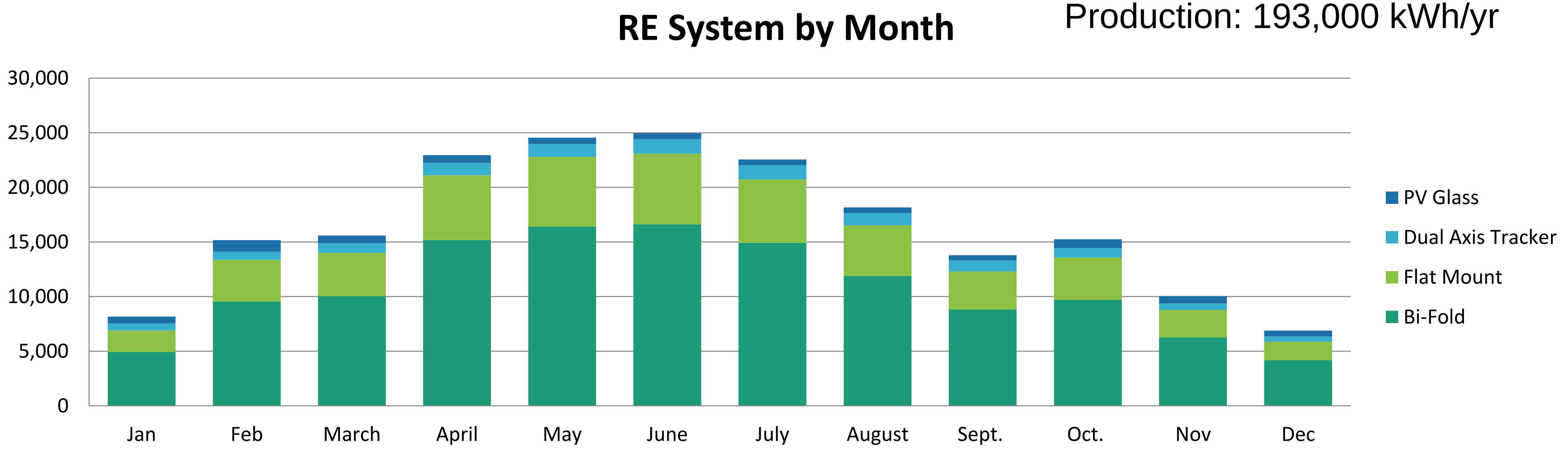


Renewable Energy Production – Baseline

(estimated, theoretical)



Production: 193,000 kWh/yr



Measuring Success: Metering & Tracking

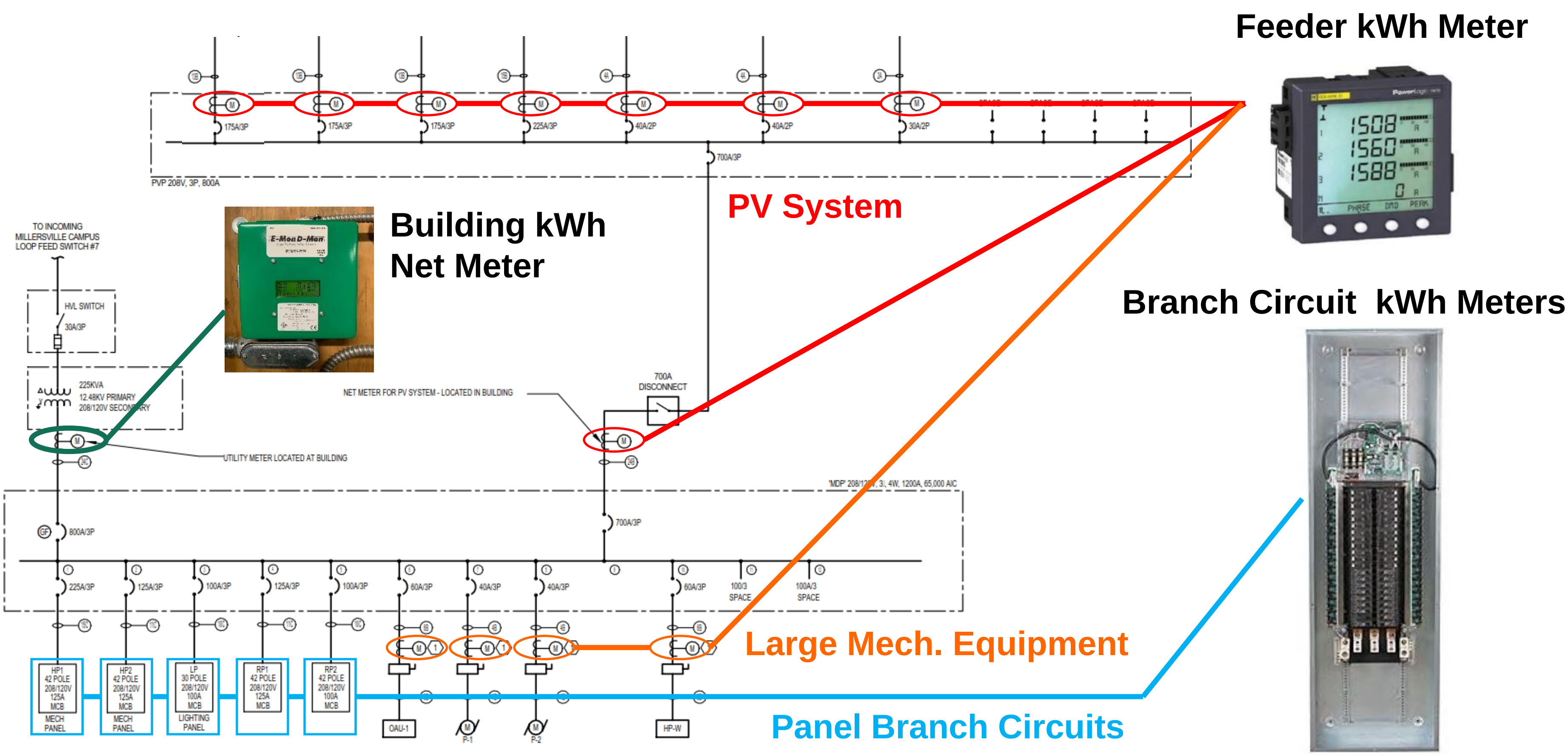
- Overall Metering: Whole Building net meter tracks energy pulled into the building and pushed out from the building to the campus grid.

- PV Metering: Each sub-array is metered so that performance of each can be tracked

- Loads Metering: Every building load is metered with branch circuit metering. Virtual meters were created to track energy by end use or zone

- Dashboard Display: Building performance towards Net Positive Energy is tracked daily and available to building occupants

Metering Connected to BMS



Metering and Monitoring: Electrical

BRANCH PANEL: LP

LOCATION: ELEC. RM
FED FROM::
FEEDER SIZE:
ENCLOSURE: Type 1

CKT	CIRCUIT DESCRIPTION
1	LIGHTING
3	LIGHTING
5	LIGHTING
7	LIGHTING
9	INVERTER
11	LIGHTING
13	LIGHTING
15	LIGHTING
17	LIGHTING
19	LIGHTING
21	SPARE
23	SPARE
25	SPARE
27	SPACE
29	SPACE

LOAD CLASSIFICATION
Lighting
Other

NOTES:PROVIDE BRANCH CIRCUITI

BRANCH PANEL: RP1

LOCATION: ELEC. RM
FED FROM::
FEEDER SIZE:
ENCLOSURE: Type 1

CKT	CIRCUIT DESCRIPTION
1	RECEPTACLE OFFICE 104
3	IT RACK REC.
5	RECEPTACLE ROOM 103, 102
7	RECEPTACLE ADMISSIONS OPEN...
9	RECEPTACLE ADMISSIONS OPEN...
11	RECEPTACLE ROOM 127, 126
13	RECEPTACLE ADMISSIONS OPEN...
15	RECEPTACLE ROOM 107, 106
17	RECEPTACLE ROOM 110, 109
19	RECEPTACLE MARKETING OPEN...
21	RECEPTACLE MARKETING OPEN...
23	RECEPTACLE ROOM 116, 117
25	RECEPTACLE HOUSING OPEN OFFIC
27	RECEPTACLE ROOM 121, 122, 123
29	RECEPTACLE WORK ROOM 129
31	RECEPTACLE STUDENT WORK SPAC
33	RECEPTACLE OFFICE 112
35	RECEPTACLE RESOURCE ROOM 120
37	RECEPTACLE STUDENT WORK SPAC
39	RECEPTACLE OFFICE 124
41	SPARE

LOAD CLASSIFICATION
Receptacle

NOTES:PROVIDE BRANCH CIRCUITING METI

BRANCH PANEL: RP2

LOCATION: ELEC. RI
FED FROM::
FEEDER SIZE:
ENCLOSURE: Type 1

CKT	CIRCUIT DESCRIPTION
1	RECEPTACLE
3	RECEPTACLE
5	FACP
7	RECEPTACLE LOBBY 135
9	COPIER
11	DOOR OPERATOR
13	RECEPTACLE ROOM 145, 146, 144
15	RECEPTACLE PRESENTATION ROOI
17	LAV FAUCETS
19	RECEPTACLE
21	RECEPTACLE
23	RECEPTACLE
25	LAV FAUCETS
27	OTHER CLASSROOM/PRESENTATIO
29	OTHER RESOURCE ROOM 103
31	RECEPTACLE BREAK ROOM 124
33	SPARE
35	SPARE
37	SPARE
39	SPARE
41	SPARE

LOAD CLASSIFICATION
Other
Power
Receptacle

NOTES:PROVIDE BRANCH CIRCUITING MET

BRANCH PANEL: HP1

LOCATION: ELEC. F
FED FROM::
FEEDER SIZE:
ENCLOSURE: Type 1

CKT	CIRCUIT DESCRIPTION
1	HP-6
3	
5	HP-8
7	
9	HP-10
11	
13	HP-12
15	
17	HP-14
19	
21	HP-16
23	
25	HP-18
27	
29	VAVB
31	TF-1
33	HP-2
35	
37	HP-5
39	
41	SPARE

LOAD CLASSIFICATION
Heating
Power

NOTES:PROVIDE BRANCH CIRCUITING ME

BRANCH PANEL: HP2

LOCATION: MECHANICAL 002
FED FROM::
FEEDER SIZE:
ENCLOSURE: Type 1

VOLTS (V): 120/208 Wye
PHASES: 3
WIRES: 4
MOUNTING: SURFACE

A.I.C. RATING: 22,000
MAINS TYPE: MAIN CIRCUIT BREAKER
MAINS RATING: 225 A
MCB RATING / POLES: 125A / 3P

NEUTRAL: 100%
BUSSING (CU/AL): CU
GROUND BUS: Yes
FEED (TOP/ BOTTOM):

CKT	CIRCUIT DESCRIPTION	TRIP	POLES	A		B		C		POLES	TRIP	CIRCUIT DESCRIPTION	CKT
1	HP-22	20	2	385	447					2	20	HP-19	2
3						385	447						4
5	GYLOCL SKID	20	1					500	730	2	20	HP-21	6
7	EF-1	20	1	0	730								8
9	P-4	20	1			0	730			2	20	HP-20	10
11	AC-1	20	2					104	730				12
13				104	0					1	20	VAVB	14
15	BR-1	30	1			2640	0			1	20	P-3	16
17	EF-2	20	1					35	2640	1	30	BR-1	18
19	MOTORIZED SHADES	20	1	500	385					2	20	HP-23	20
21	FLOOD CONTROL VALVE	20	1			250	385						22
23	BAS CONTROL PANEL	20	1					0	120	1	20	P-3	24
25	POWER ELEC. RM. 121	20	2	104	500					1	20	POWER	26
27						104	0			1	20	BAS CONTROL PANEL	28
29	POWER	20	1					2500	2080	2	30	ACCU-1	30
31	POWER	20	1	2000	2080								32
33	SPARE	20	1			0	0			1	20	SPARE	34
35	SPARE	20	1					0	0	--	--	SPACE	36
37	SPACE	--	--	0	0					--	--	SPACE	38
39	SPACE	--	--			0	0			--	--	SPACE	40
41	SPACE	--	--					0	0	--	--	SPACE	42
			TOTAL LOAD:	7234 VA		4940 VA		9439 VA					
			TOTAL AMPS:	63 A		41 A		82 A					

LOAD CLASSIFICATION	CONNECTED LOAD	DEMAND FACTOR	ESTIMATED DEMAND	PANEL TOTALS	
HVAC	35 VA	100.00%	35 VA		
Heating	5780 VA	100.00%	5780 VA	TOTAL CONN. LOAD:	21613 VA
Motor	120 VA	125.00%	150 VA	TOTAL EST. DEMAND:	21643 VA
Other	4000 VA	100.00%	4000 VA	TOTAL CONN.:	60
Power	11678 VA	100.00%	11678 VA	TOTAL EST. DEMAND:	60

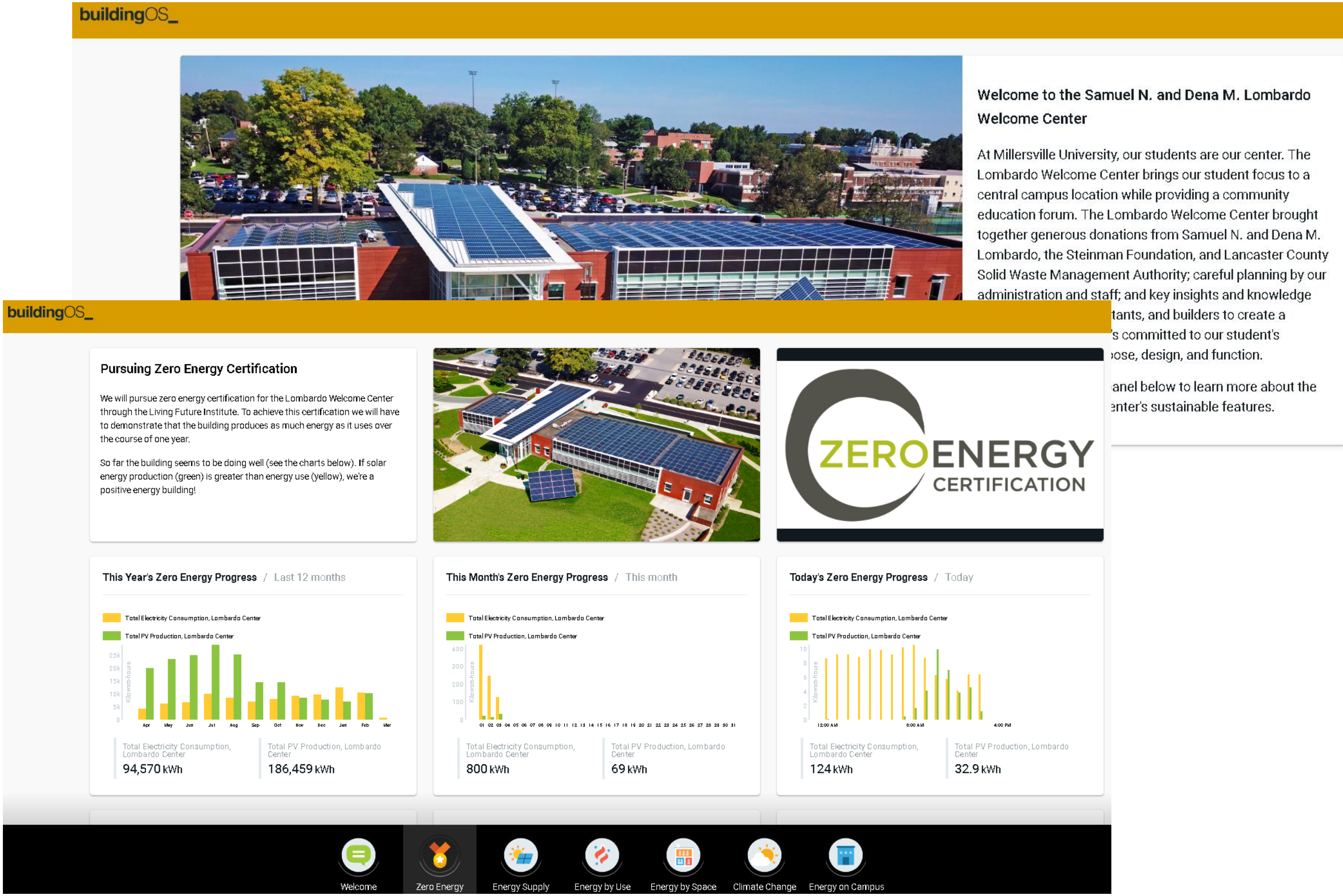
NOTES:PROVIDE BRANCH CIRCUITING METERING FOR PANEL HP2

Lighting Loads Only **Plug Loads Only** **Automated Building Systems Loads Only**

Monitoring Action Plan - Overview

- Lucid Dashboard
- Tracking by Area
- Tracking by End-use
- Critical Systems Tracking
  - Heating, Ventilating, and Air-Conditioning
  - Renewable Energy - Photovoltaic
- Identify Deficiencies and Opportunities for Improvement
- Root Cause Analysis and Investigation
- Net Positive

Lucid Dashboard

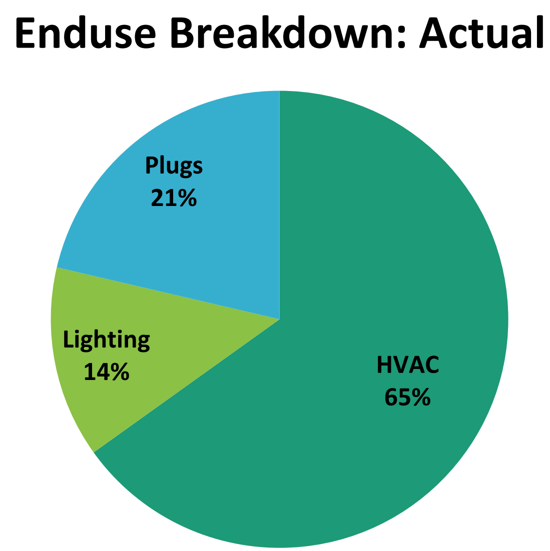


Tracking Usage by Team

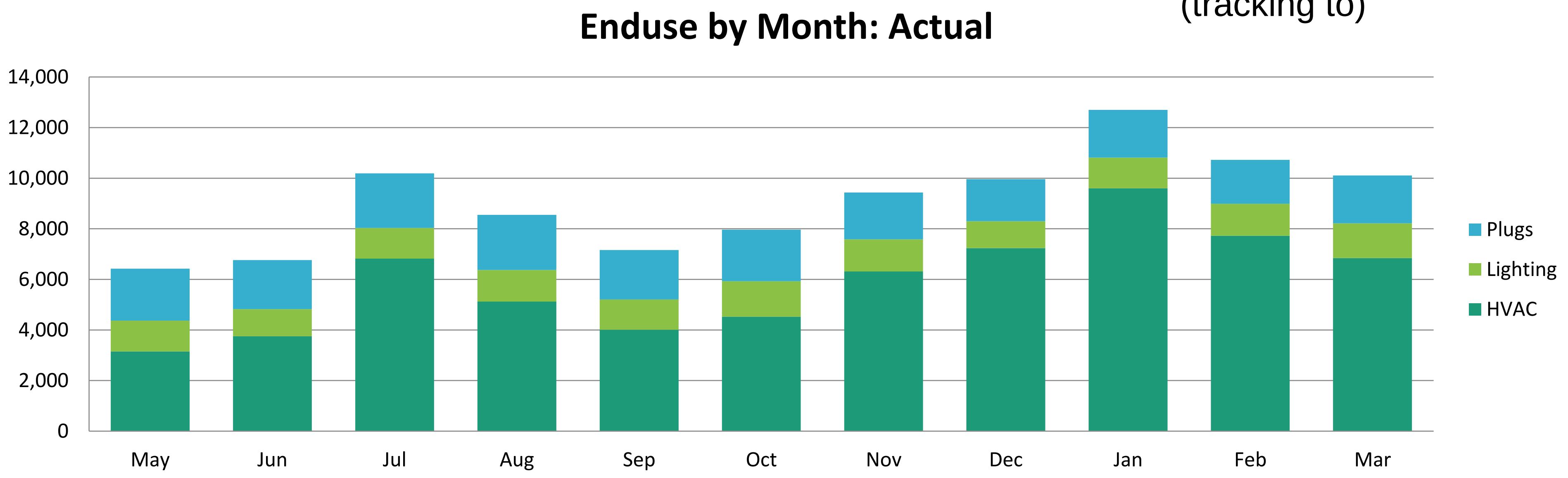
Dashboard Zones

- Anderson Center for Env. Sustainability
- Steinman Foundation Lobby
- Student Affairs and Enrollment Mgmnt
- Shared Space
- Admissions
- Marketing and Communications
- Housing

Building Energy Consumption: Tracking Usage by End Use



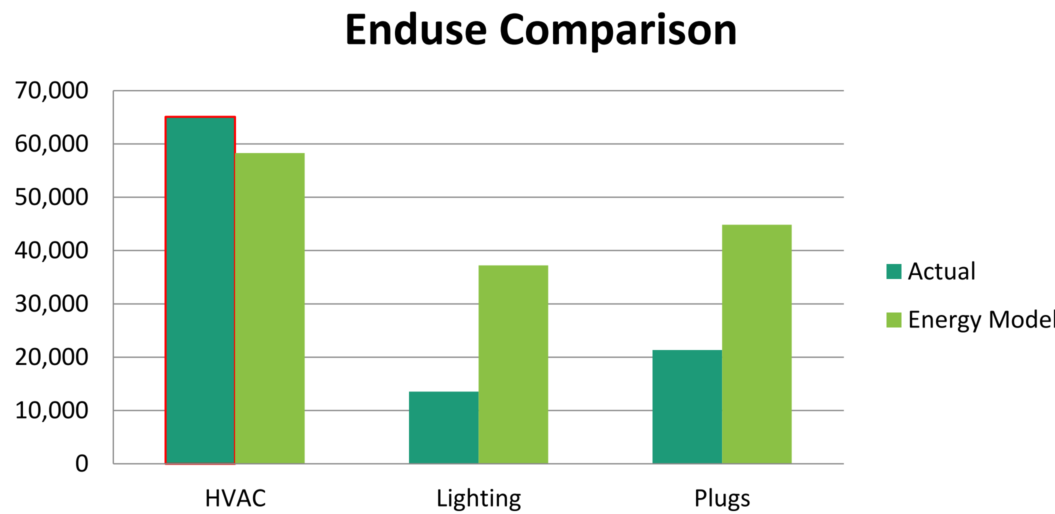
EUI: 26.0 kbtu/sf/yr (tracking to)

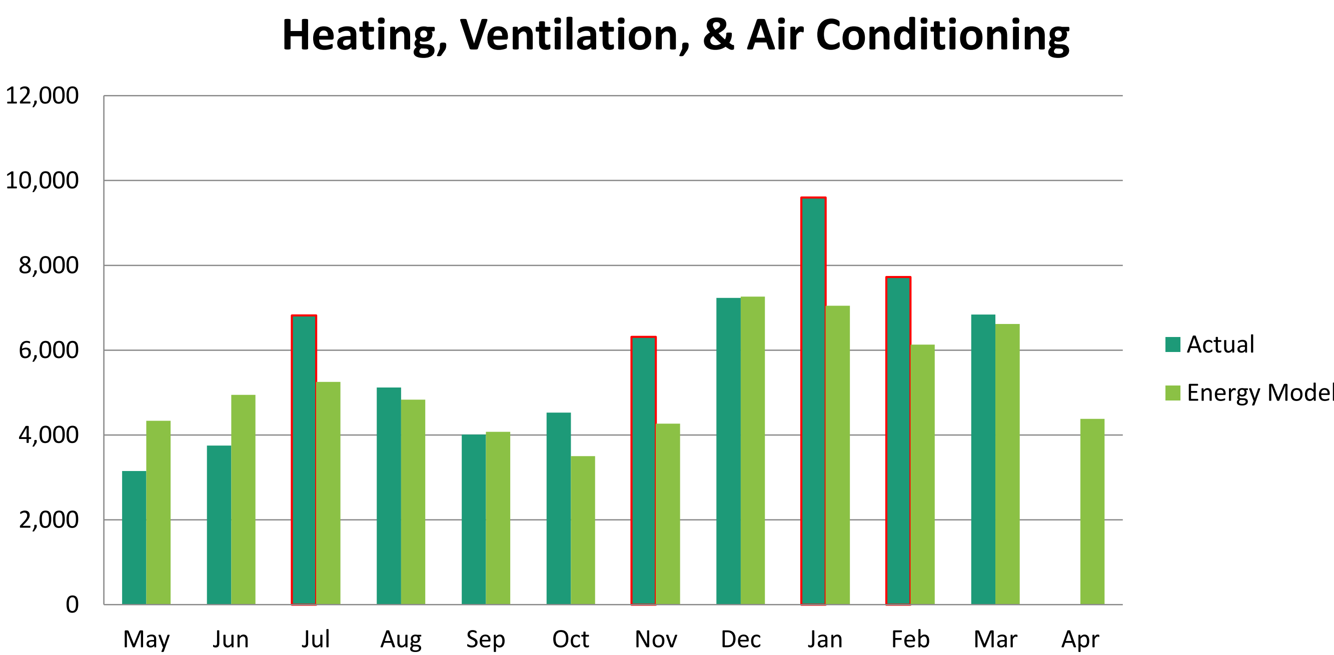


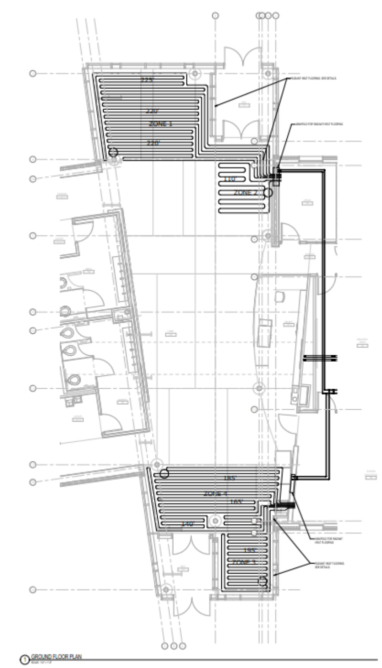
Critical HVAC Trends

- Overall HVAC Consumption
- Indoor Environmental Quality – Air Quality
- Indoor Environmental Quality – Thermal Comfort
  - Zonal VAV Control
  - Zonal Thermal Recovery
- Energy Savings Strategies
  - Zone Standby Temperature Setpoints
  - Resource Room 103 – HP-07; Always Unoccupied
  - Ground-Source Condenser Water Pumps
  - Ground-Source Thermal Persistence
- Indoor Environmental Quality vs. Energy Savings

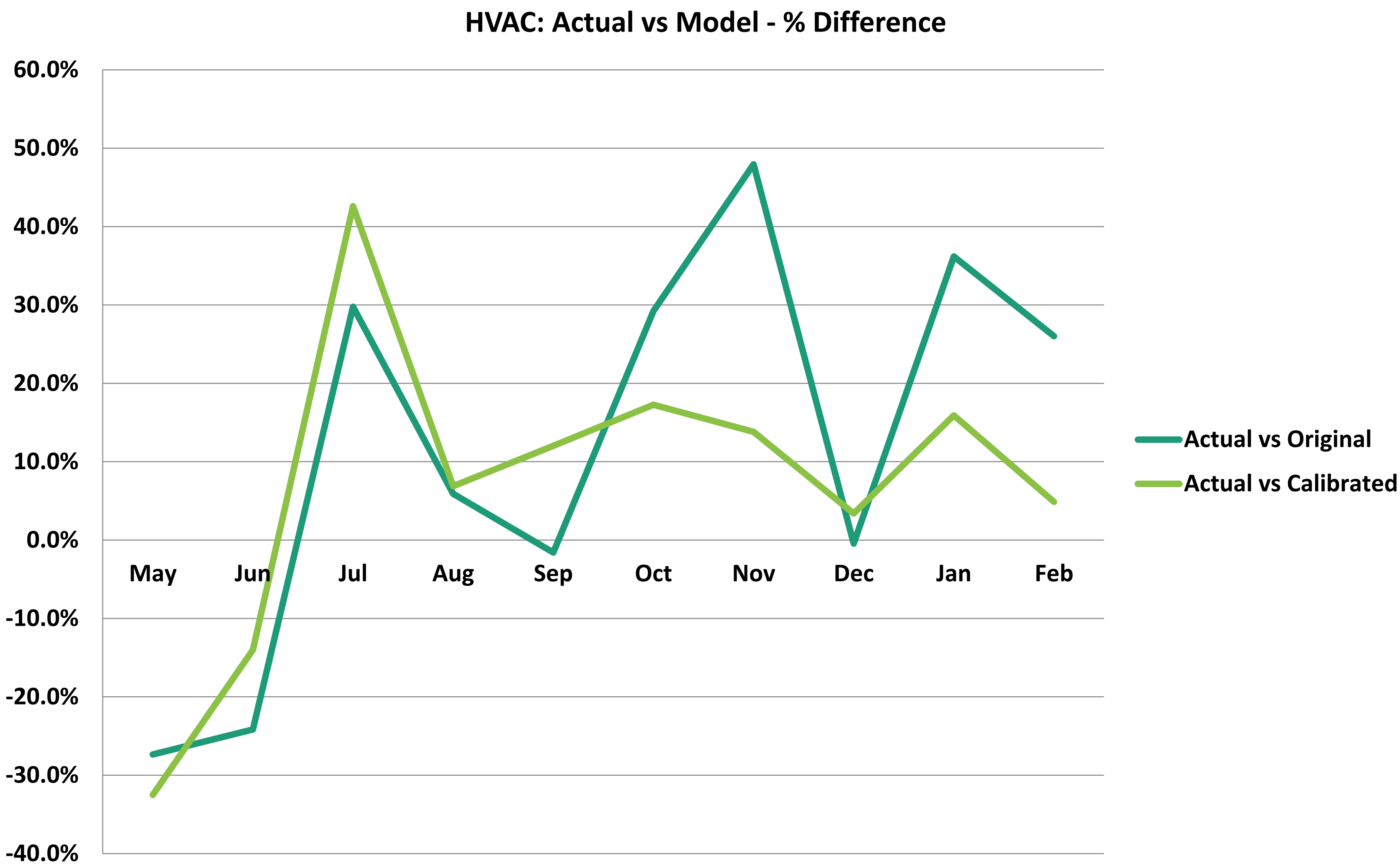
Overall Consumption - HVAC



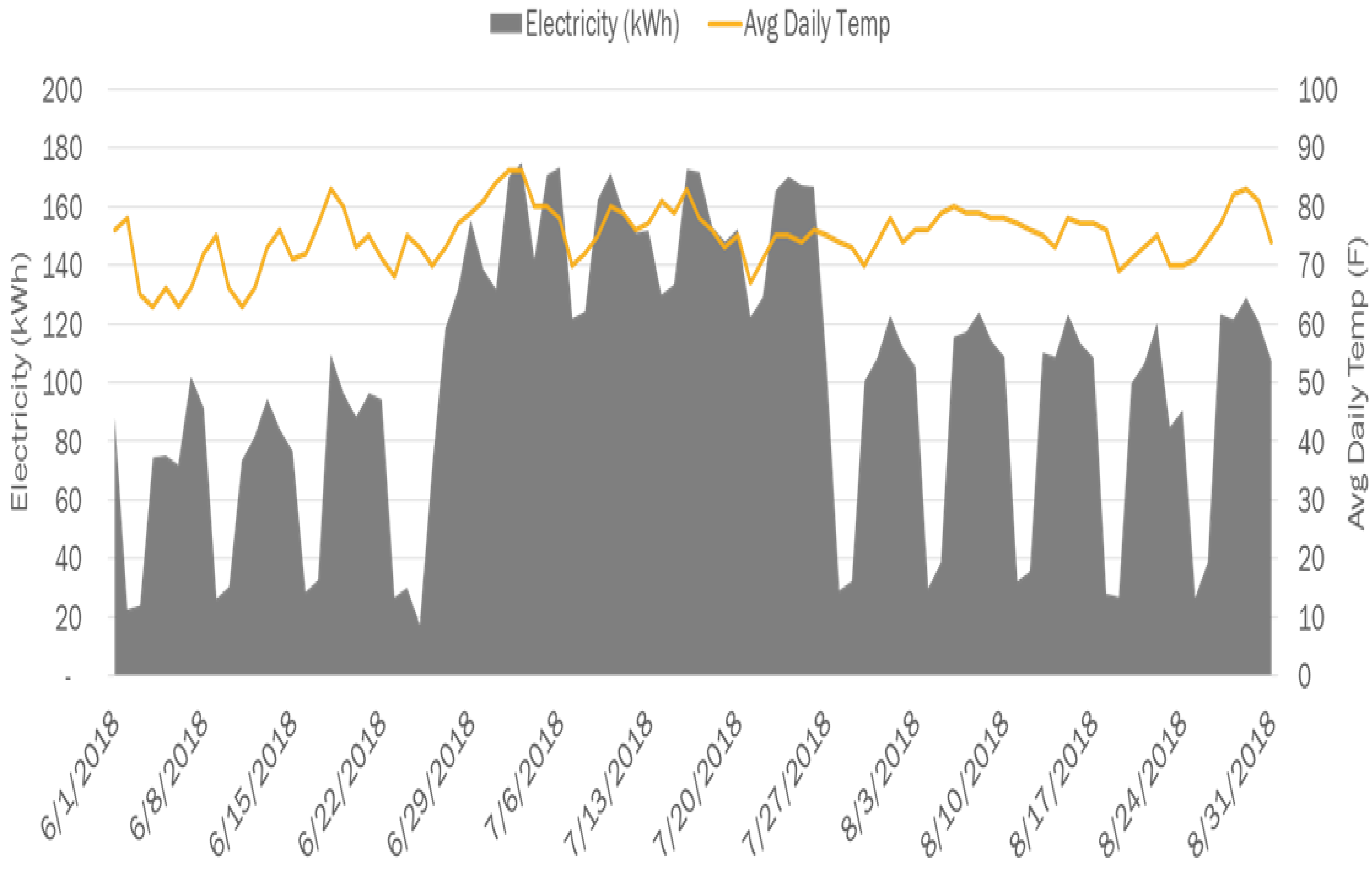




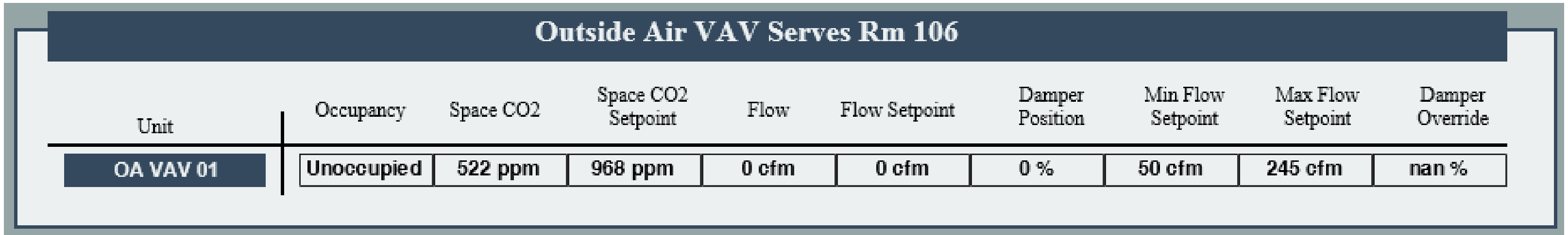
Root Cause Analysis – Model Calibration

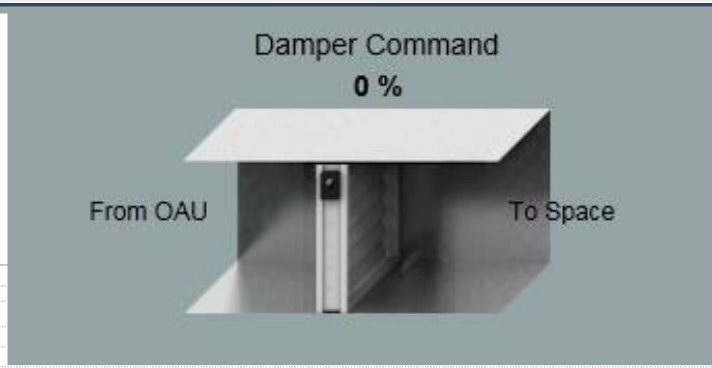


Root Cause Analysis – July 2018

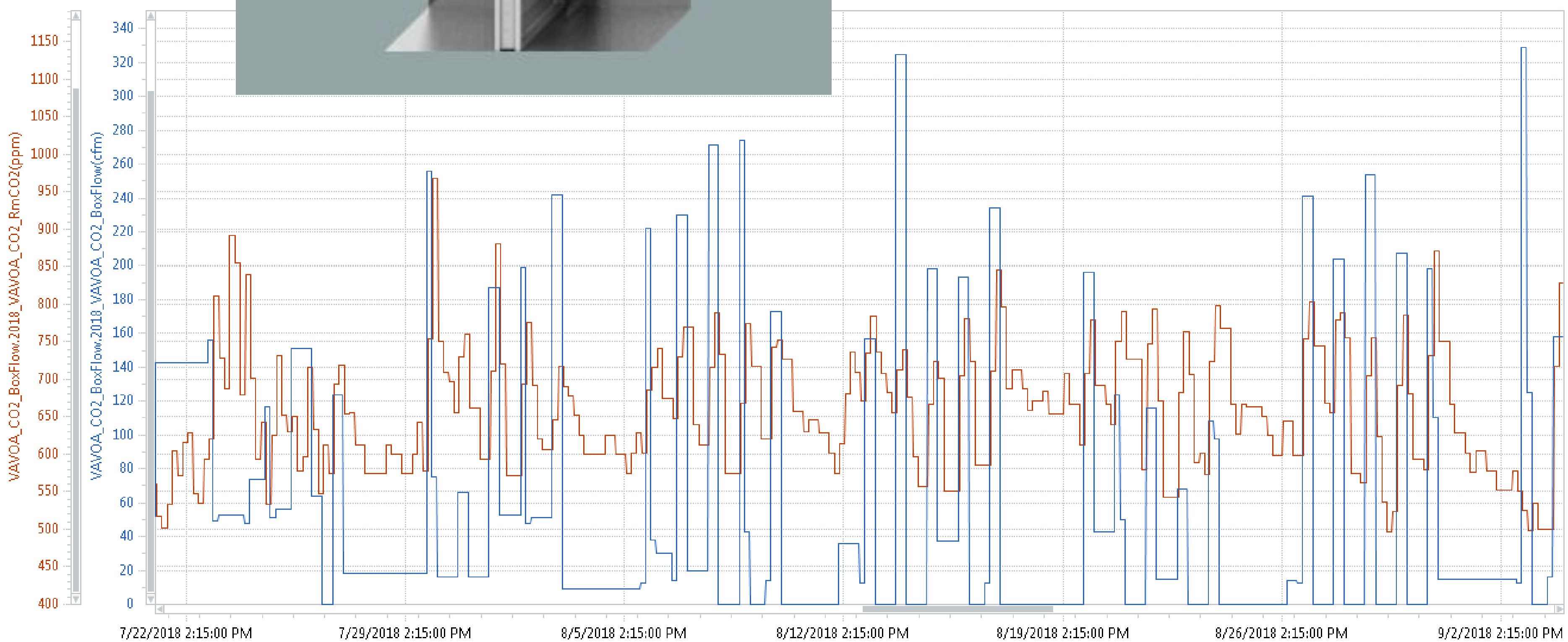


Critical HVAC Trends – Air Quality

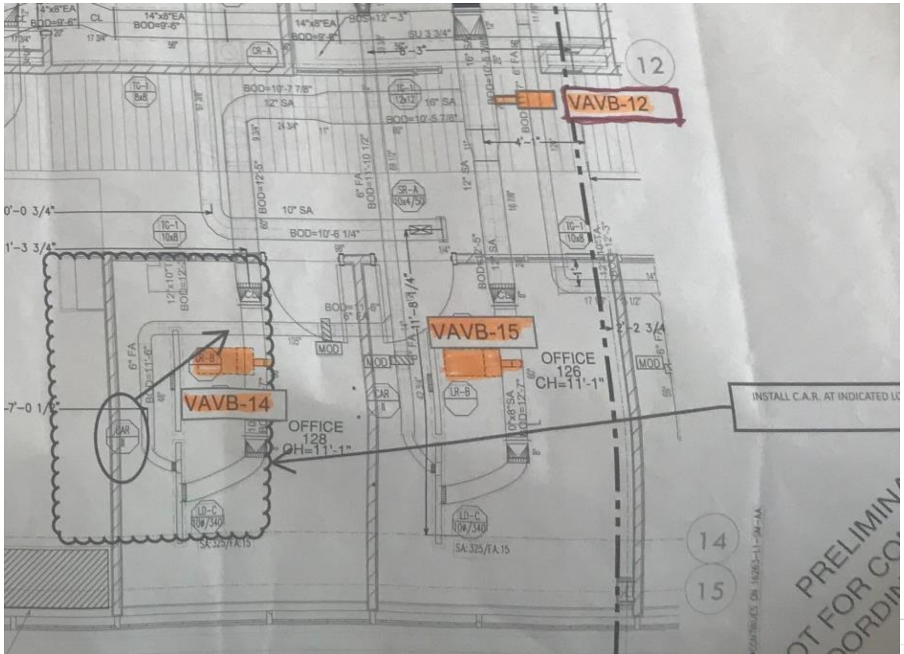


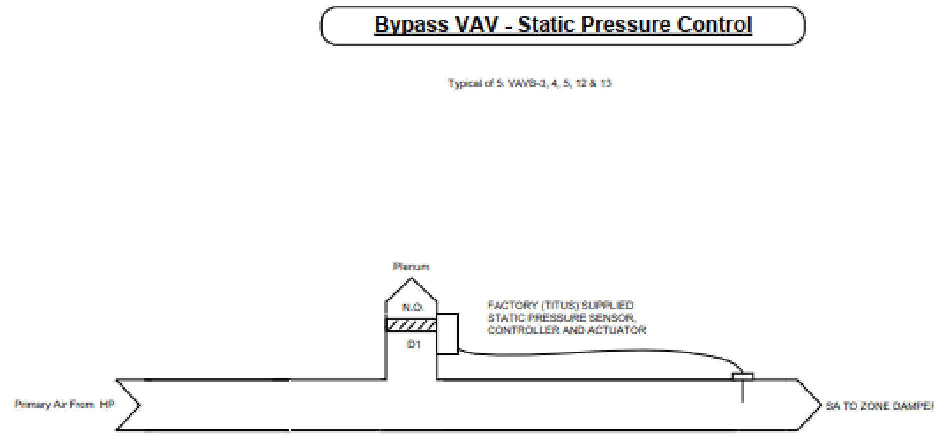


- Zonal Outside Air Dampers
- VAV with CO2 Monitoring for Open Office

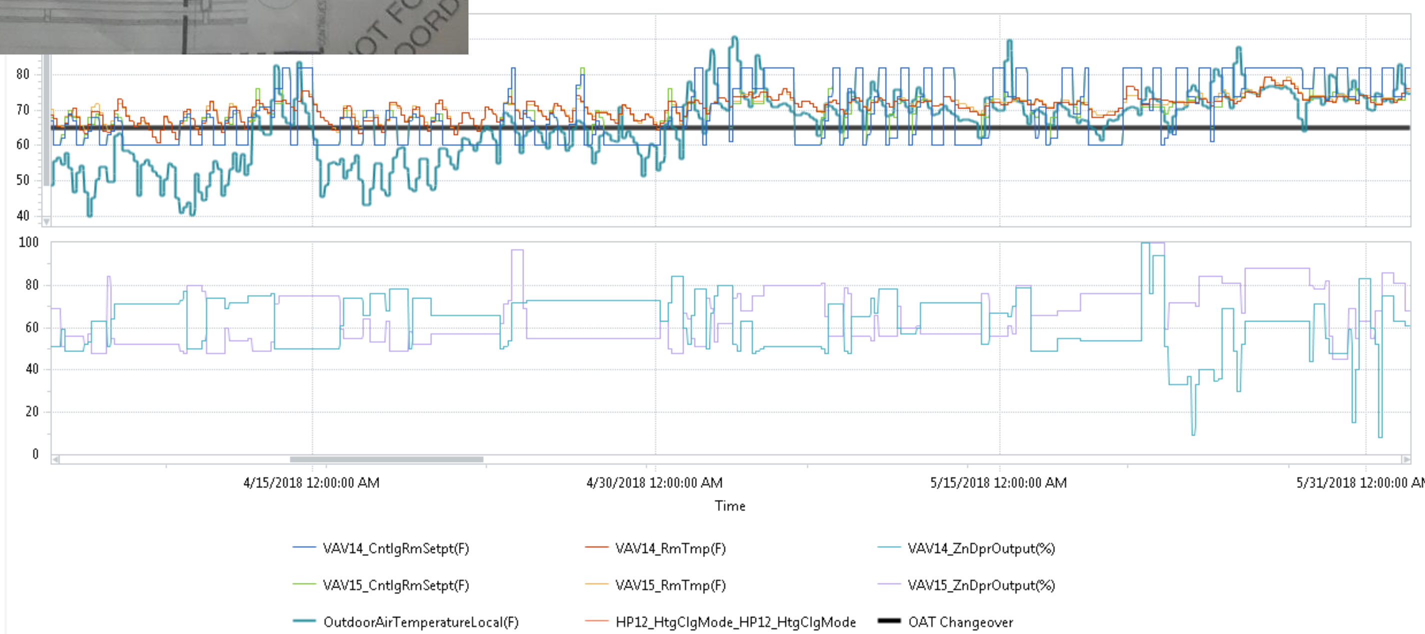


Critical HVAC Trends – VAV Bypass Control

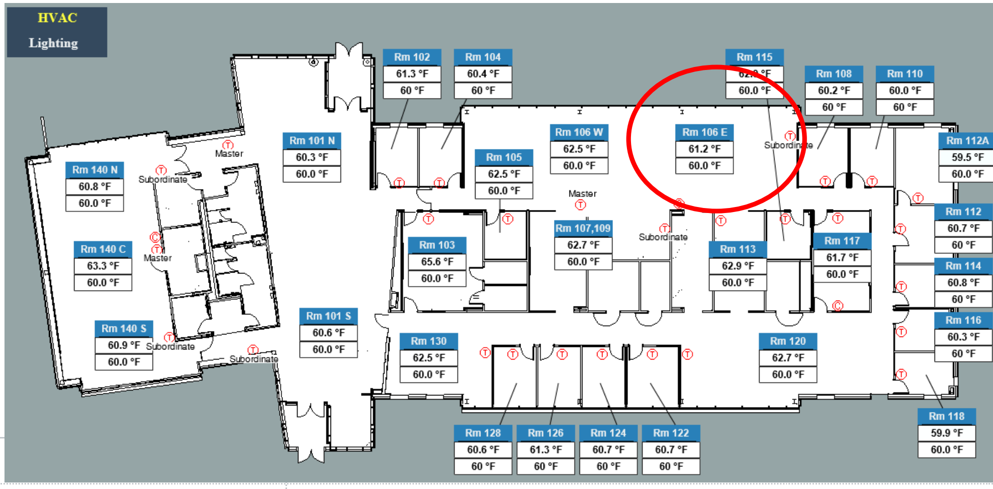


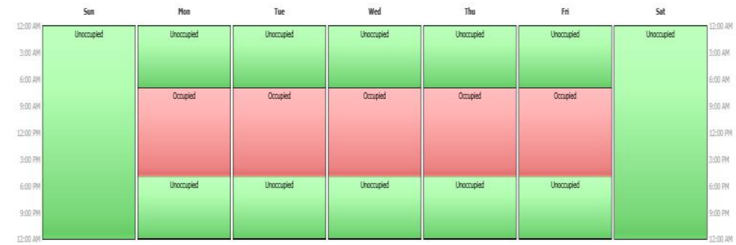


65F Outside Air Temperature Changeover

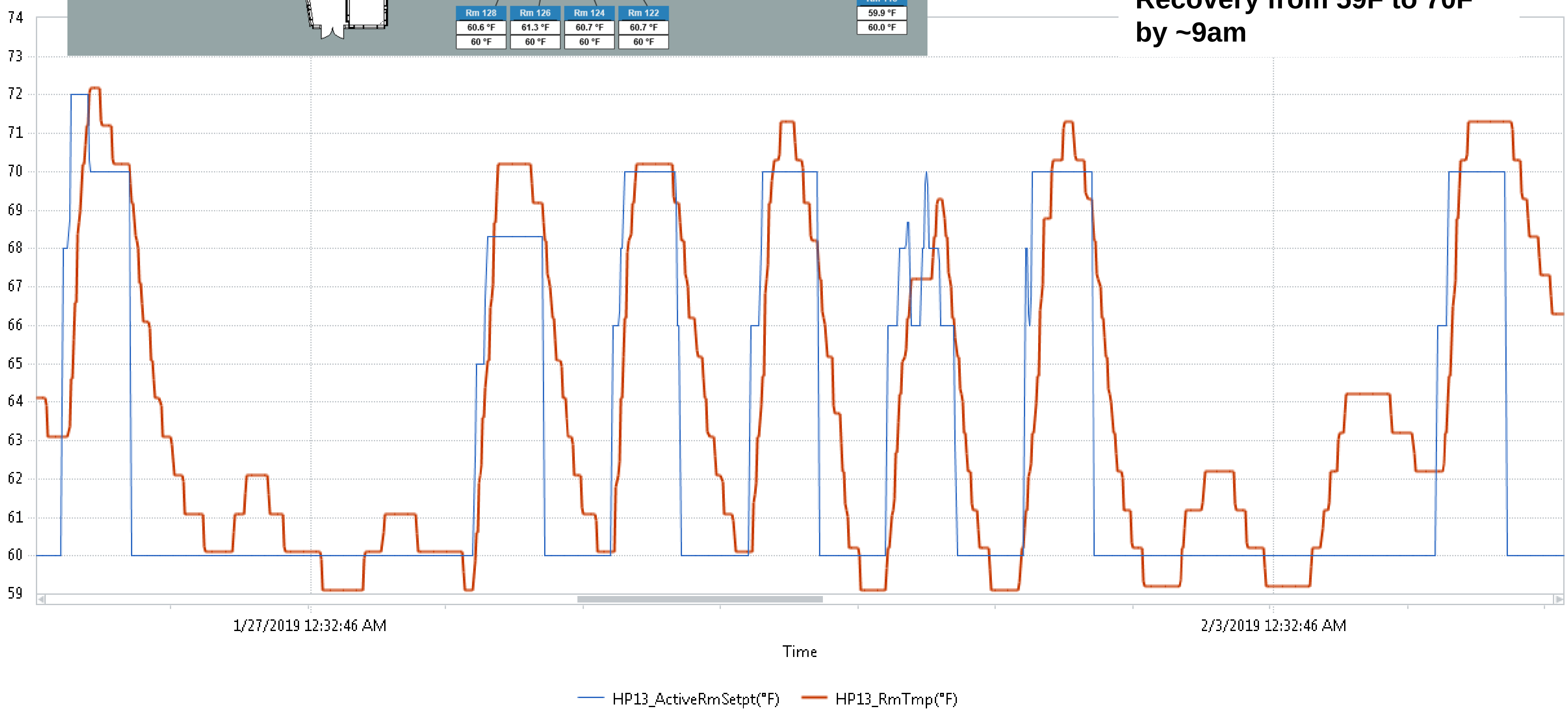


Critical HVAC Trends – Zonal Thermal Recovery



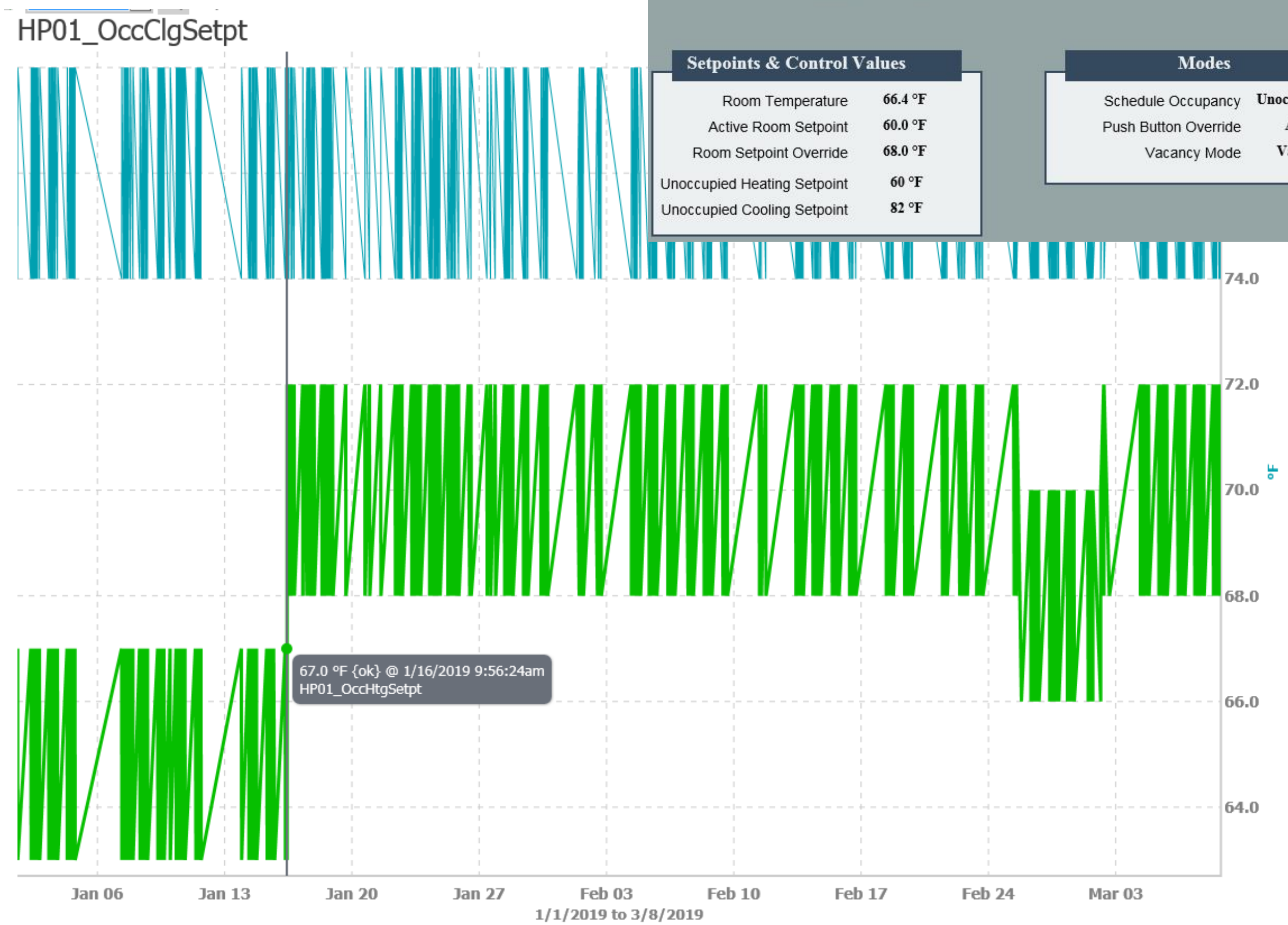


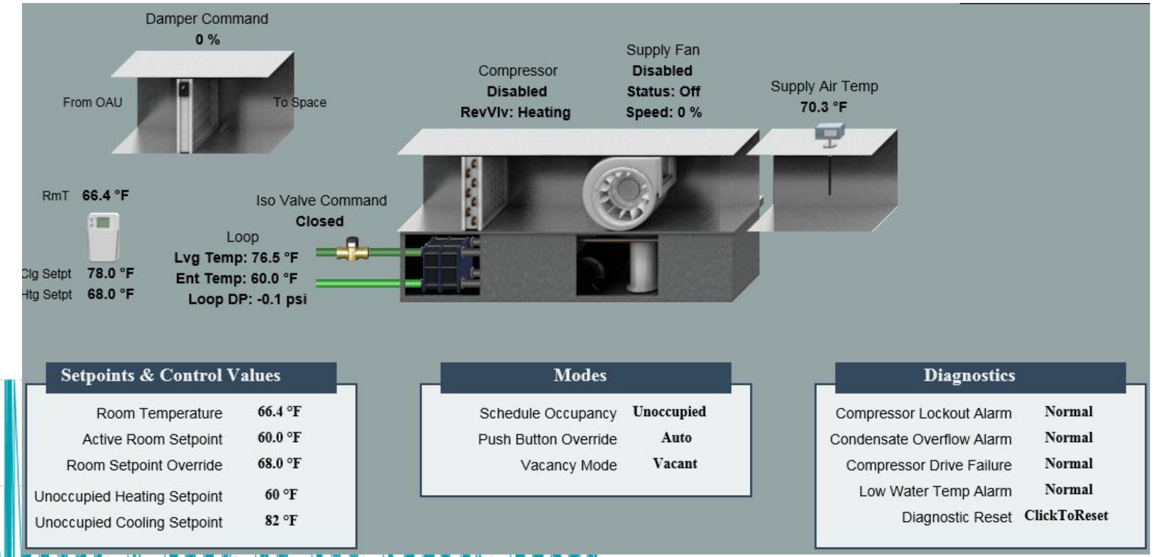
Recovery from 59F to 70F by ~9am

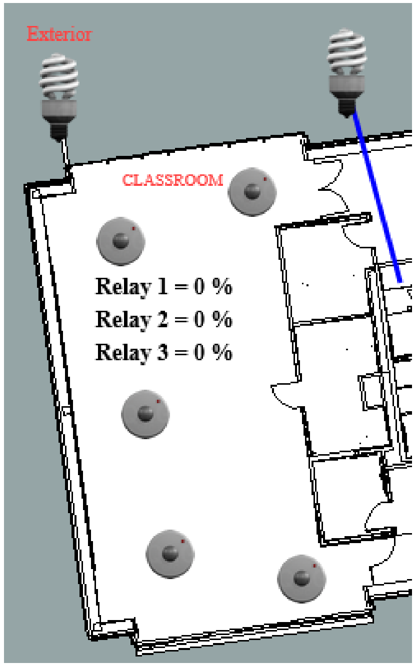


Critical HVAC Trends – Zonal Standby Setpoints

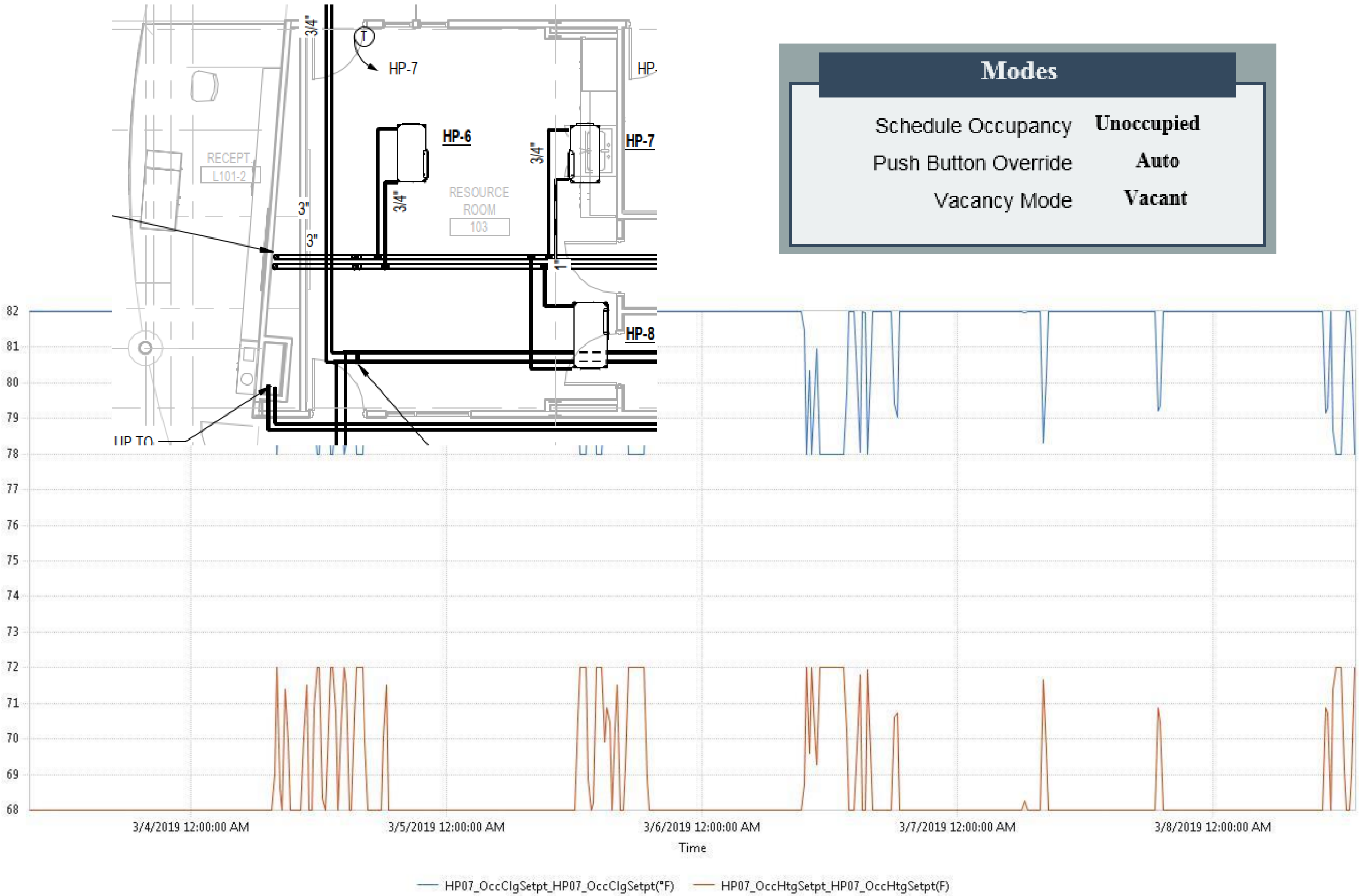
- **Lighting Occupancy Sensor Integration**
- **Standby Setpoints**







Critical HVAC Trends – Resource Room 103

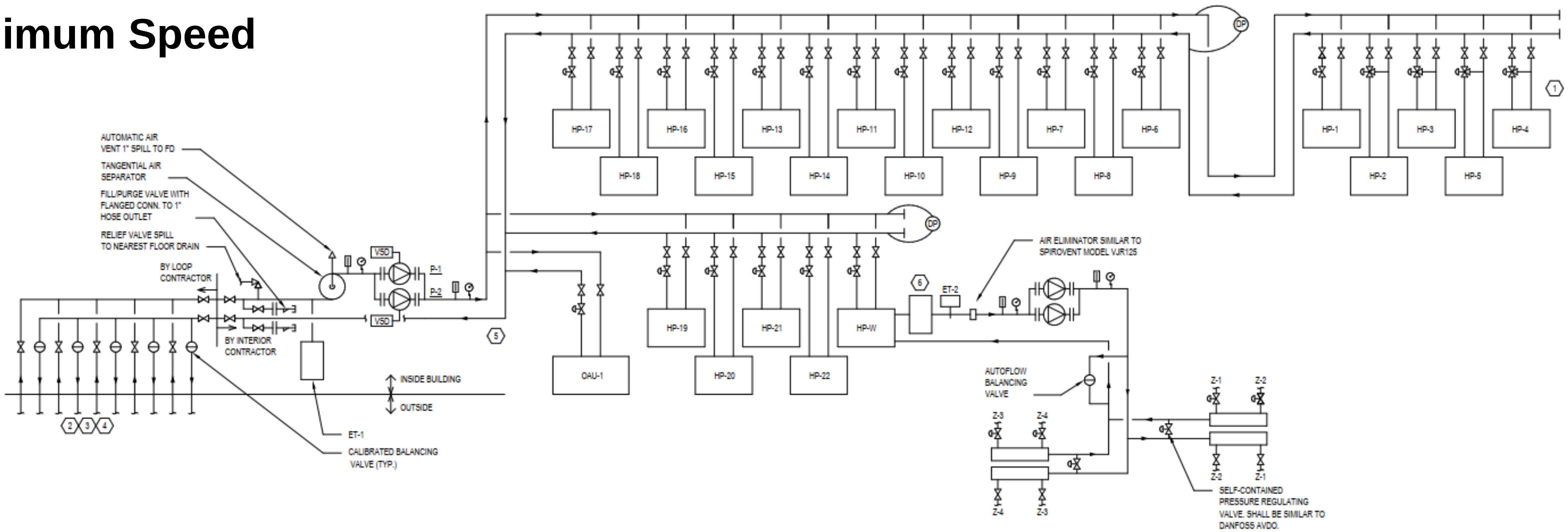


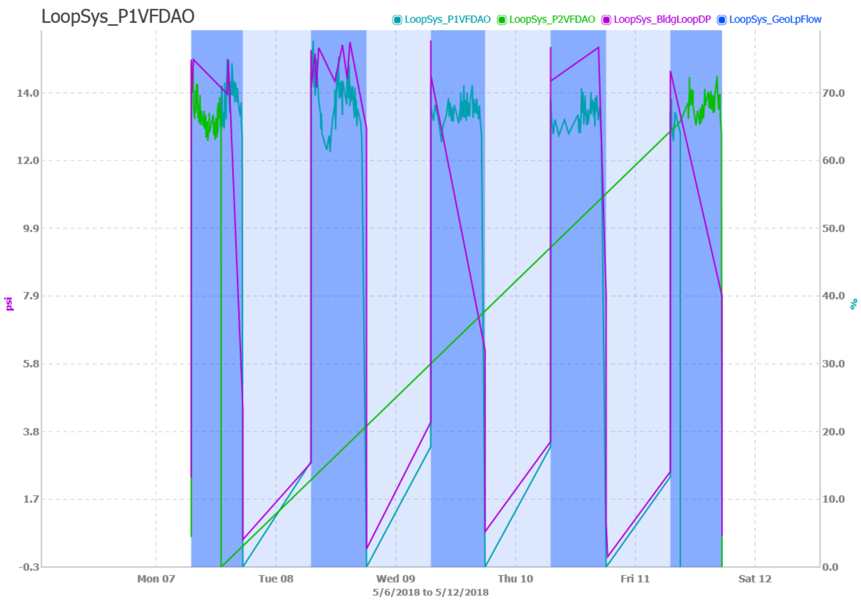
Modes

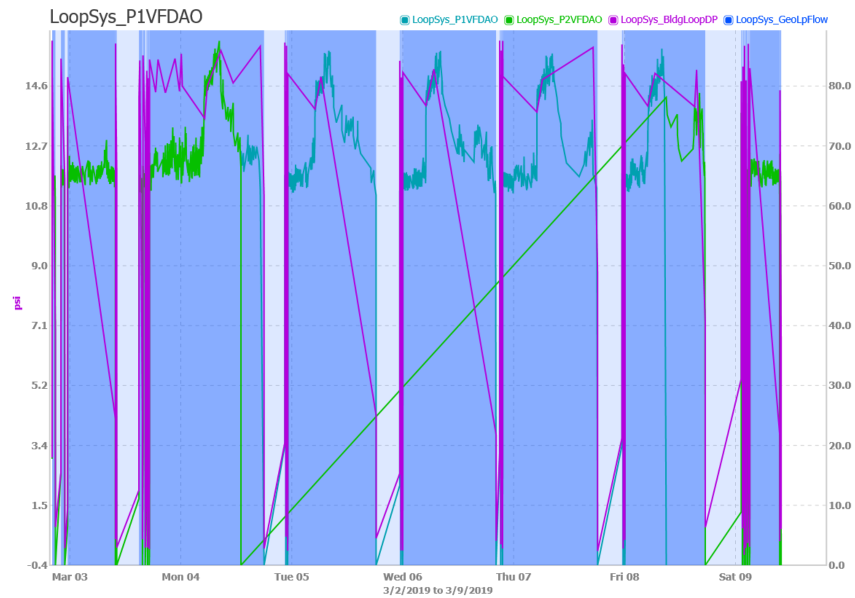
Schedule Occupancy	**Unoccupied**
Push Button Override	**Auto**
Vacancy Mode	**Vacant**

Critical HVAC Trends – Condenser Water Pump Operation

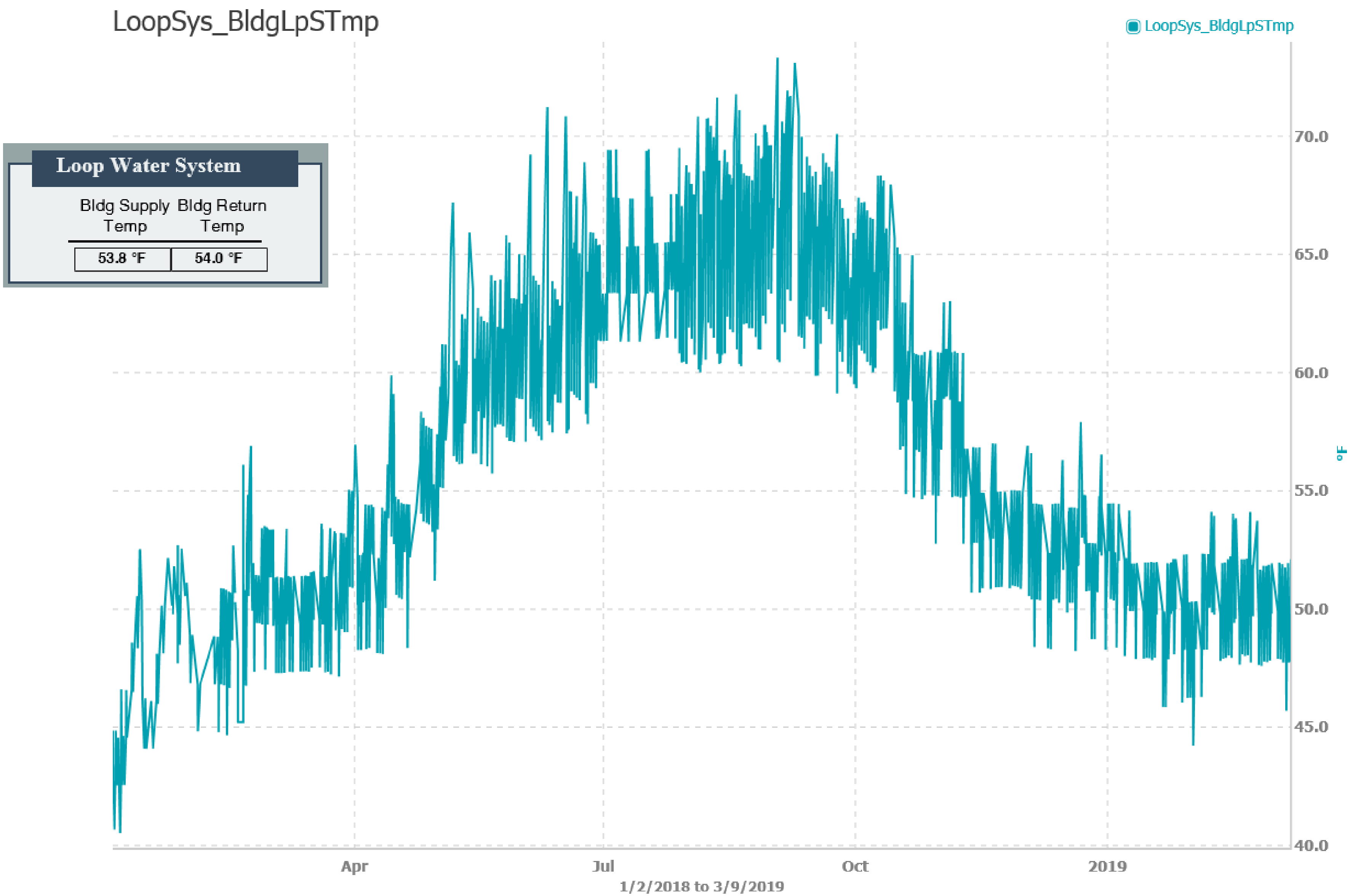
- **Off Time**
- **Pump Minimum Speed**



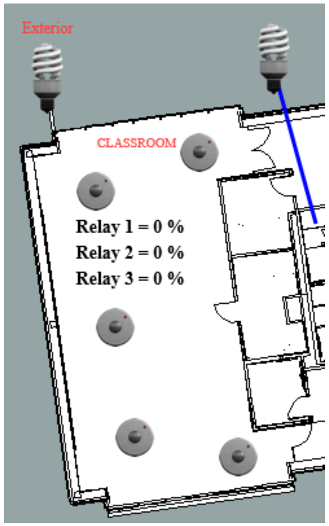


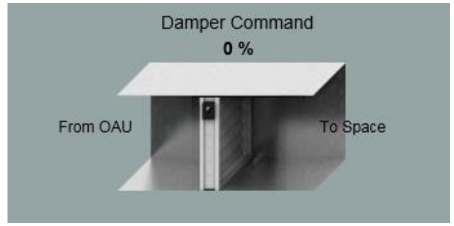


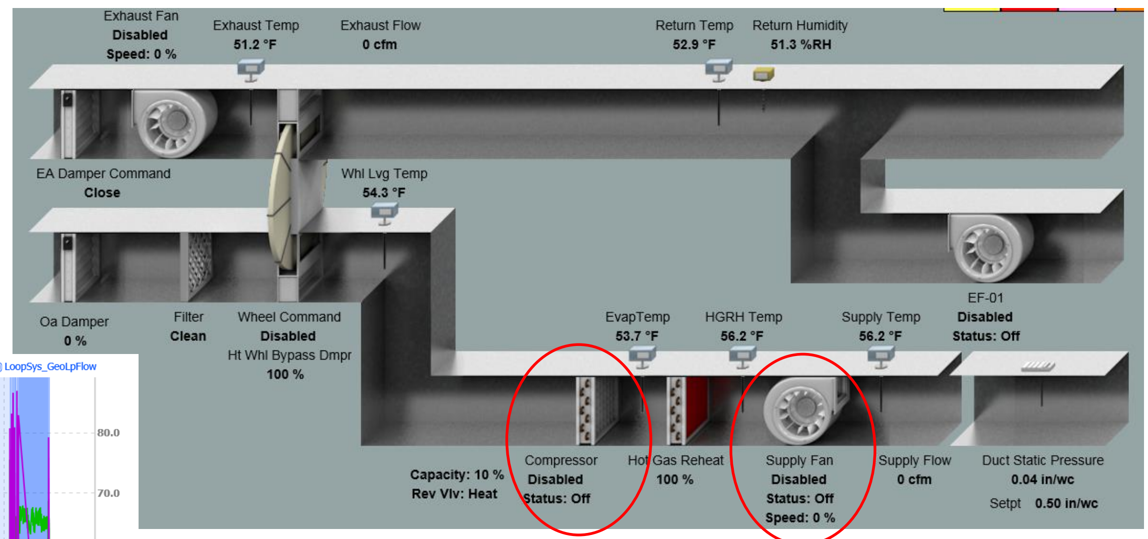
Critical HVAC Trends – Well Persistence

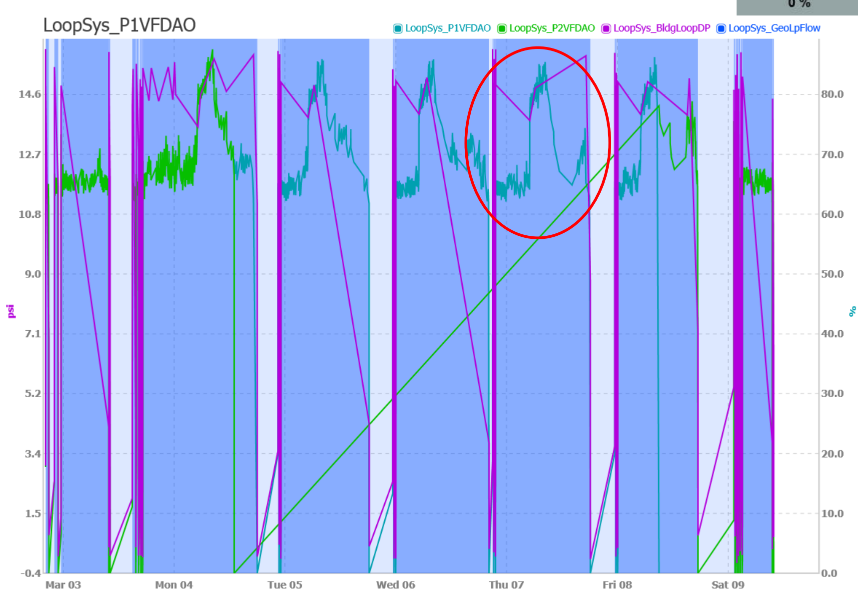


Critical HVAC Trends – IEQ vs Energy Savings

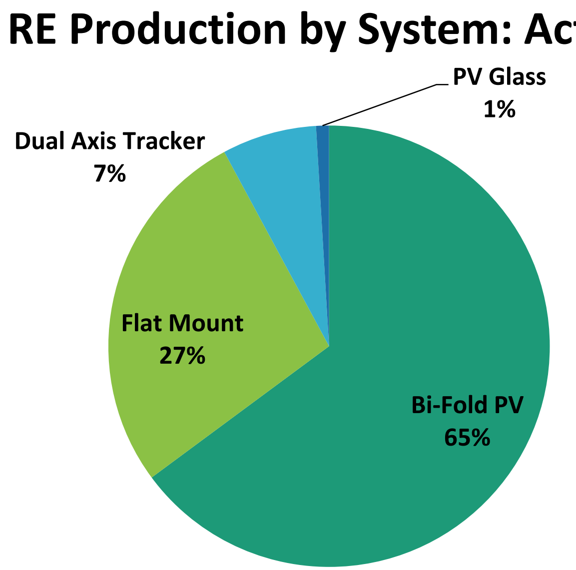


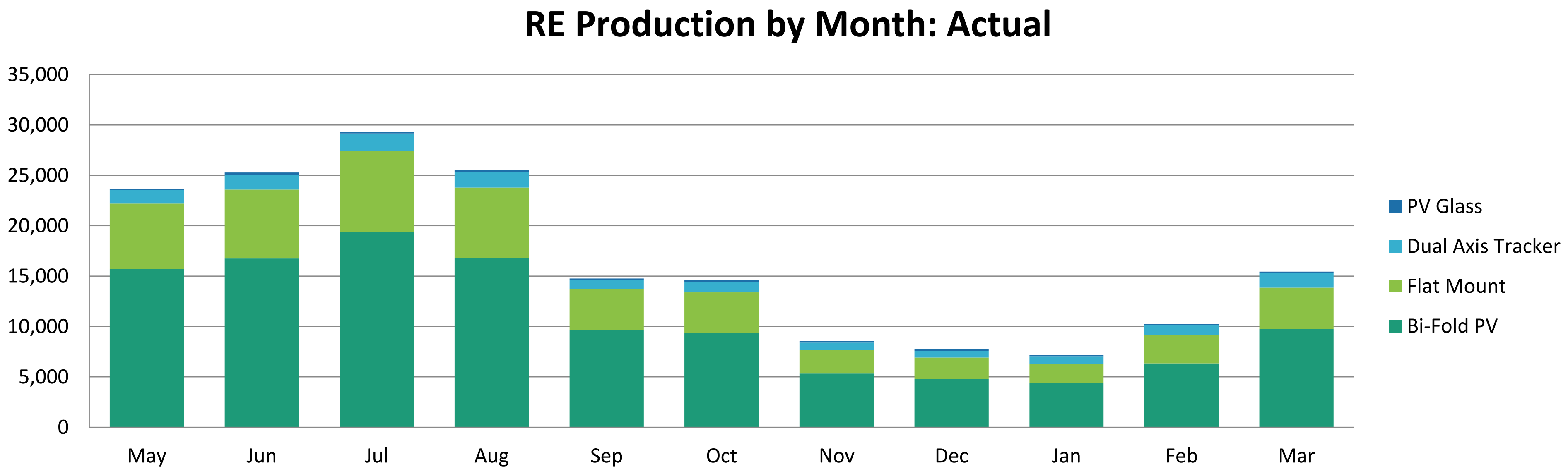






Renewable Energy Production: Tracking by System



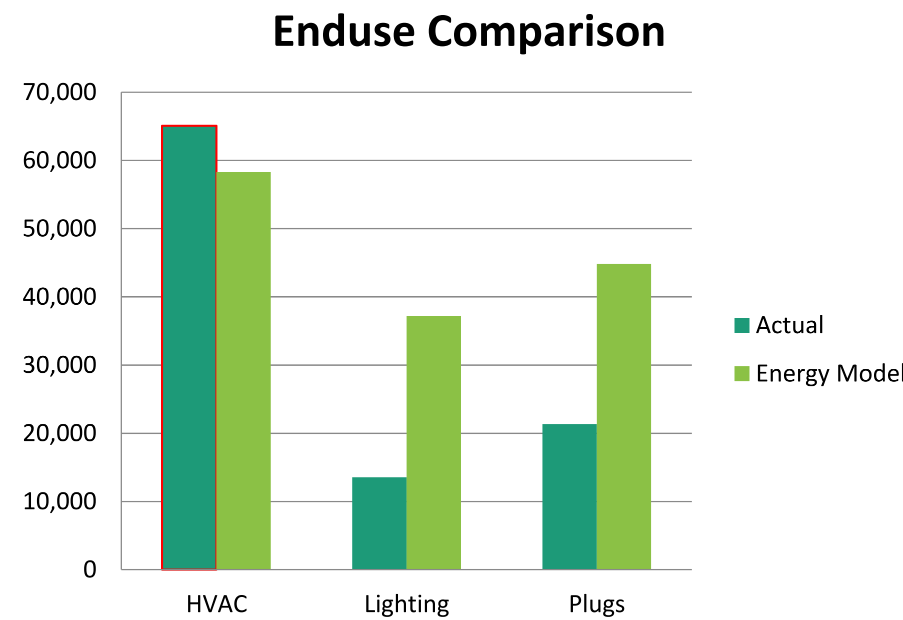


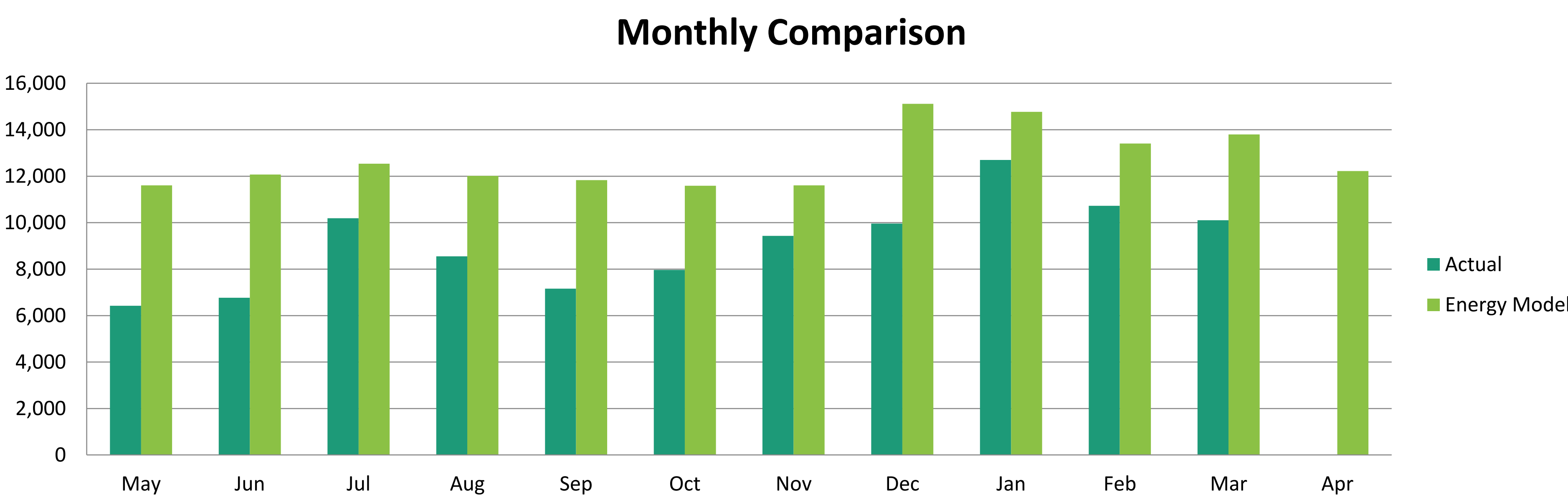
Revisiting our Predictions…

- Building Energy Consumption
- Renewable Energy Systems Production
- Net Positive

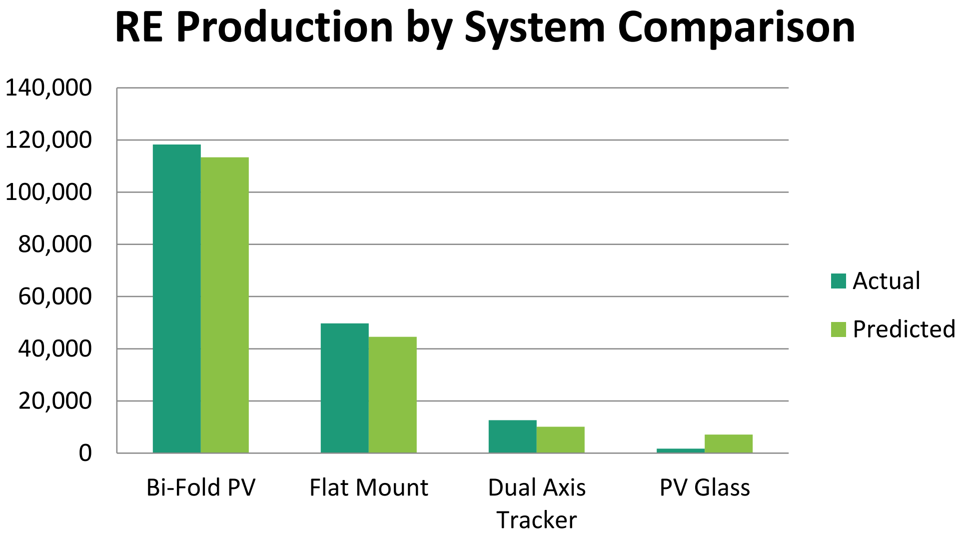
Tracking Progress To Net Positive Energy – Building Consumption

Consumption is ~71% of Energy Model
EUI (tracking to): 26.0 kbtu/sf/yr

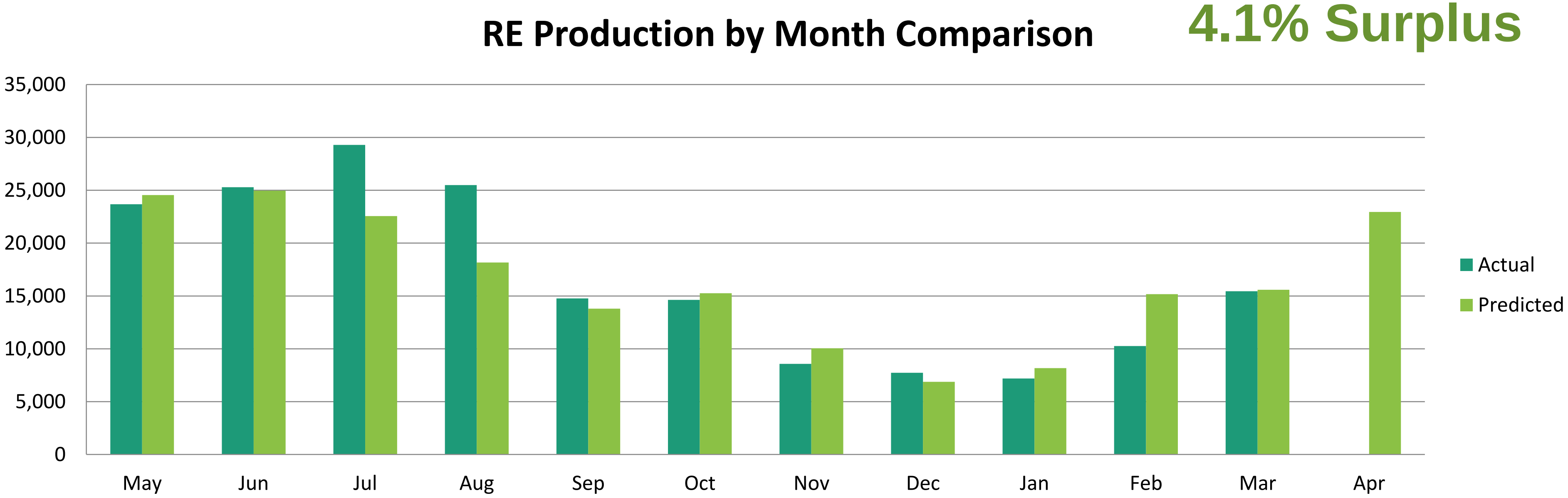




Tracking Progress To Net Positive Energy – Renewable Energy Production



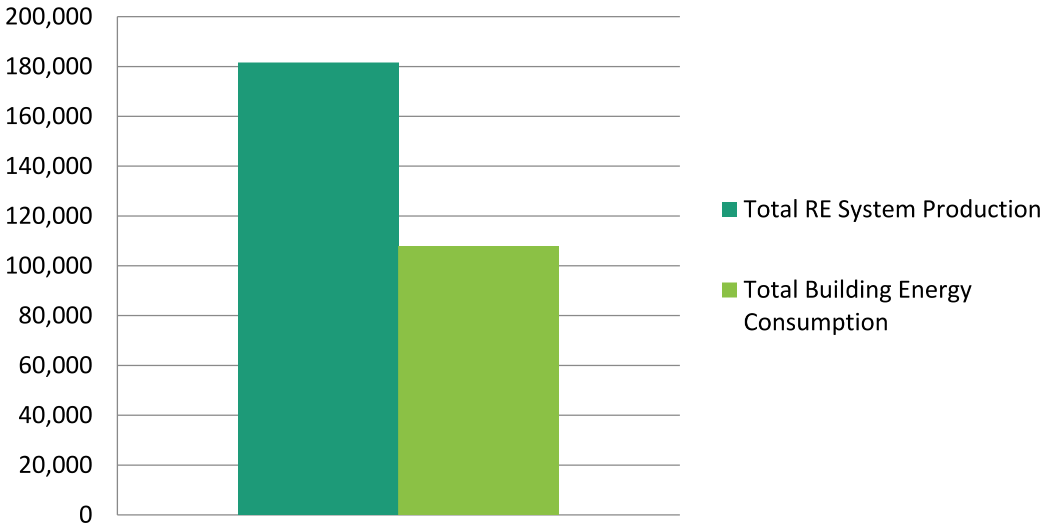
4.1% Surplus



Tracking Progress To Net Positive Energy

Tracking Net Positive!
~68% surplus for 11 months

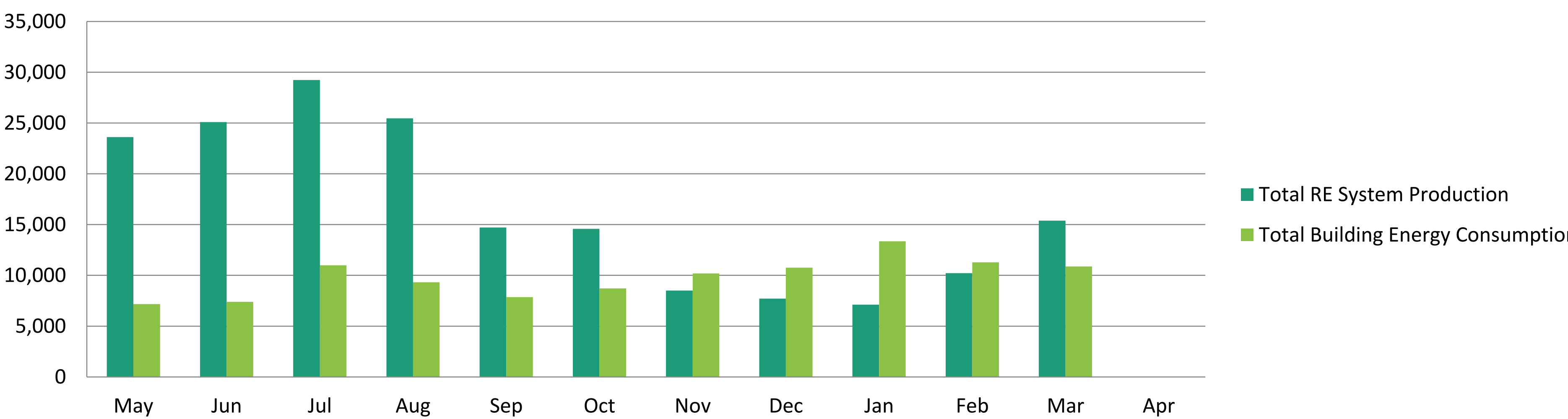
Production vs. Consumption (11 mo.)



ZERO ENERGY CERTIFICATION

INTERNATIONAL LIVING FUTURE INSTITUTE

Monthly Production vs. Consumption



This concludes The American Institute of Architects Continuing Education Systems Course

Contact Information