Commissioning Net Zero Schools

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Baumann Consulting

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Course Description

This webinar addresses the role of commissioning in net zero energy (NZE) school projects. The presentation will provide context and trends driving NZE school design and construction nationally and anecdotes from the presenting firm's midwestern and mid-Atlantic home markets. The presenters will review sustainability certifications including net zero energy performance requirements, and how they incorporate building commissioning. Several completed and under-construction case studies will provide attendees with real-world examples from the commissioning process at educational facilities targeting or having achieved NZE performance. Attendees will learn about mechanical, plumbing, and electrical systems commonly encountered in NZE school design and lessons learned during functional performance testing. The presentation will also discuss the role of airtightness in NZE school design concepts and important enclosure testing to specify and verify during the envelope commissioning process to achieve building airtightness targets. The presenters will finally address the commissioning provider's role and strategies for success in achieving and verifying net zero energy performance during the post-occupancy performance verification period.

Learning Objectives

1. Recognize how commonly sought sustainability certifications incorporating verified net zero performance requirements can impact the commissioning process.

2. Understand the functional performance testing process for commonly encountered MEP systems in net zero school designs.

3. Identify important enclosure testing to specify and verify during the net zero schools building enclosure process.

4. Learn the role of post-construction occupant engagement and operational monitoring and diagnostics in verifying net zero performance.

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Overview

1. Why net zero energy schools?
2. Common zero energy standards & their requirements
3. The role of energy modeling in net zero energy schools commissioning process
4. Lessons learned commissioning net zero energy school enclosures
5. Lessons learned commissioning common net zero energy school MEP systems
6. Lessons learned verifying net zero energy school performance

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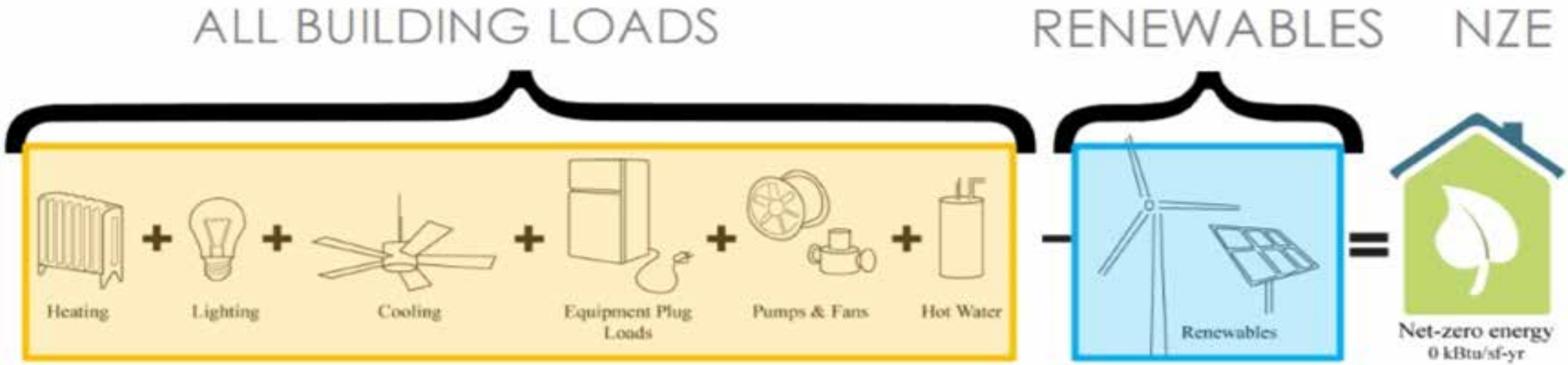
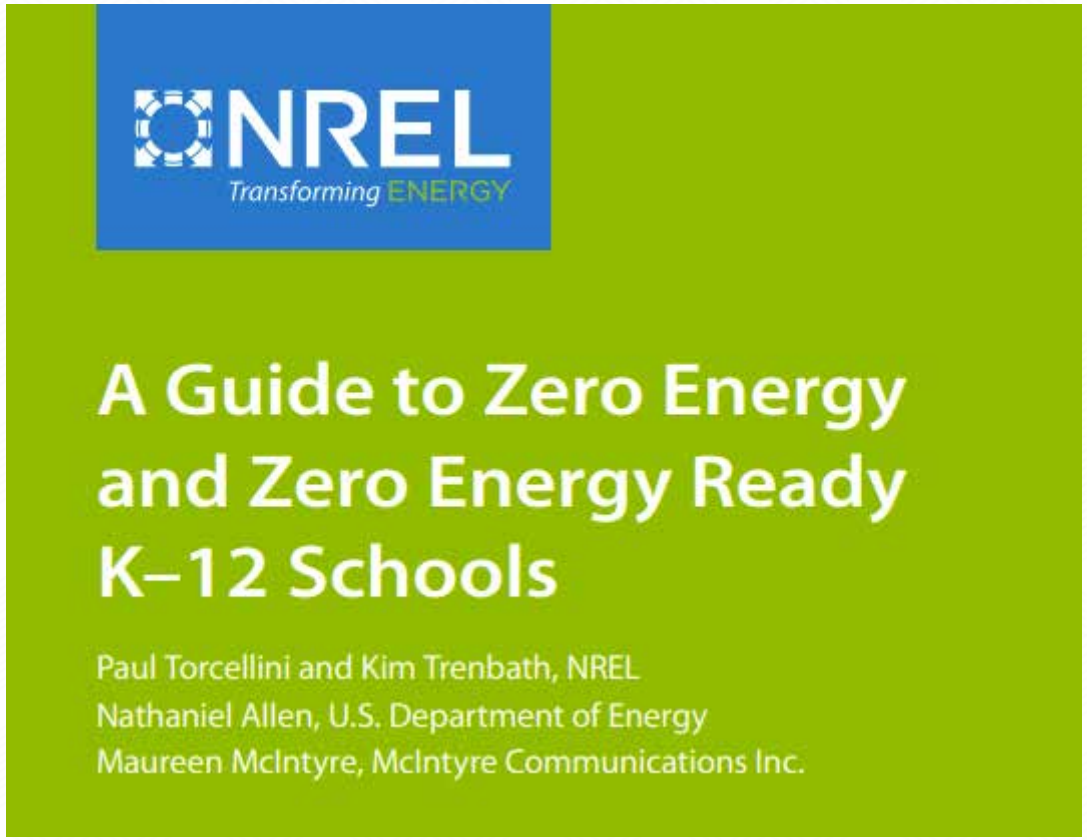
What is a Verified NZE School?



For 12 consecutive months, within a given "performance period" (often 18 months)

Why Net Zero Energy Schools?



- Schools represent the third largest sector of commercial building energy usage in the United States.
- Students and staff will spend 1,000 hours a in their school year (Center for Public Education).
- Sustainabile schools – better outcomes: classrooms natural light show 20-26% improvement on test scores compared to artificially lit environments.
- Students across the world are demanding climate action.
- Schools offer an opportunity to showcase in every community in that building efficiency, electrification, green and resilient school facilities and grounds, are possible

(…and there's more public funding for schools… and most schools shut down for the summer…!)

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Brock Environmental Center

Size: 10,500 SF
Opened: November 2014
Location: Virginia Beach, VA
Owner: Chesapeake Bay Foundation
Architect: SmithGroup
MEP Engineer: SmithGroup
GC: Hourigan Construction
Project Role: Energy Modeling

LEED NC Platinum & Living Building Challenge - **Certified**

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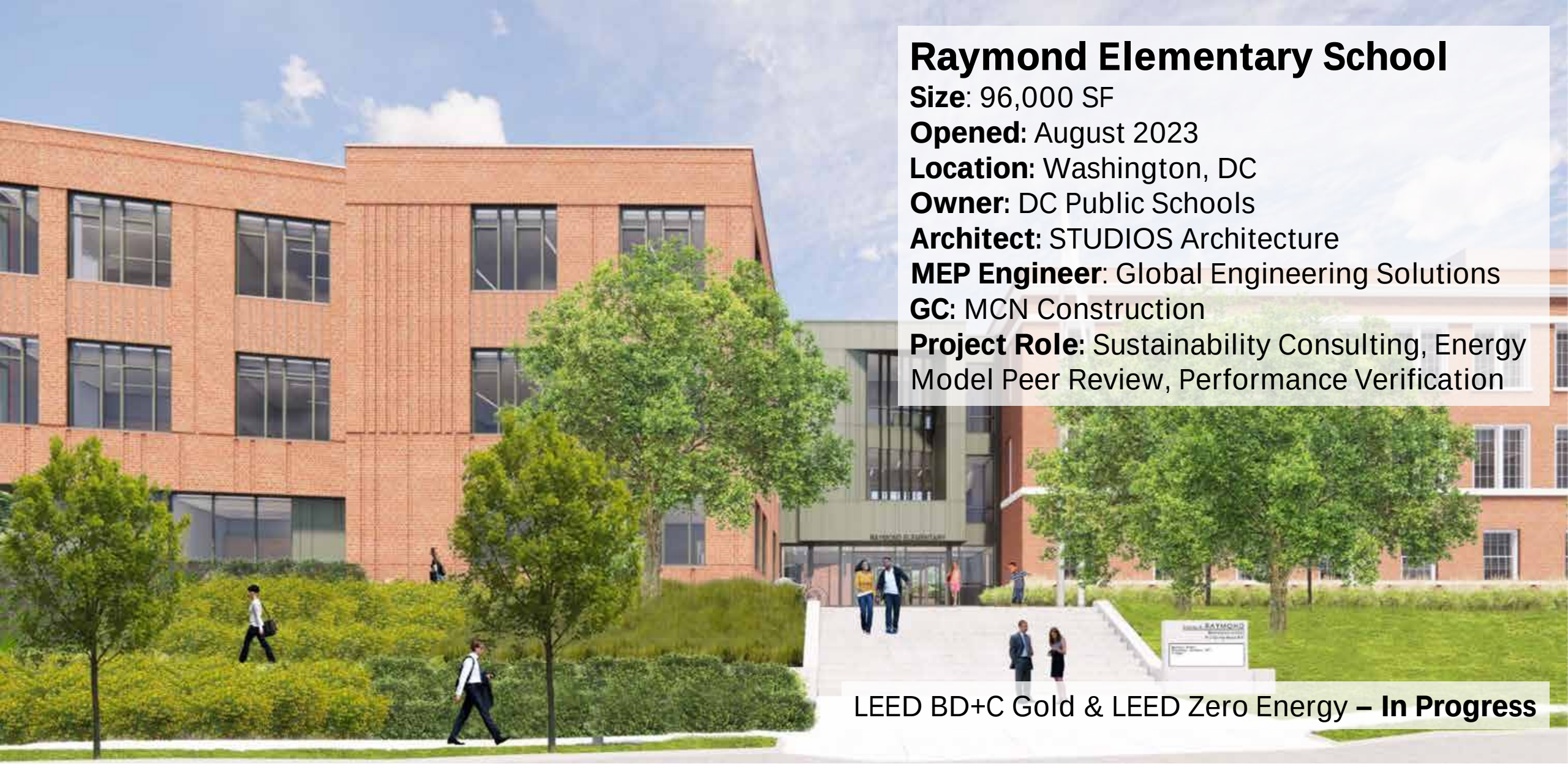

Raymond Elementary School

Size: 96,000 SF
Opened: August 2023
Location: Washington, DC
Owner: DC Public Schools
Architect: STUDIOS Architecture
MEP Engineer: Global Engineering Solutions
GC: MCN Construction
Project Role: Sustainability Consulting, Energy Model Peer Review, Performance Verification

LEED BD+C Gold & LEED Zero Energy **– In Progress**

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Academy for Global Citizenship

Size: 72,000 SF
Opened: September 2023
Location: Chicago, IL
Owner: Cultivate Collective
Architect: Farr Associates
MEP Engineer: dbHMS
GC: Power Construction
Project Role: MEPCx, BECx, Energy

Model Peer Review, Performance Verification

Living Building Challenge & PHIUS Commercial **– In Progress**

Agricultural Complex

Size: 30,000 SF
Planned Opening: January 2024
Location: Normal, IL
Owner: Heartland Community College
Architect: Legat Architects
MEP Engineer: dbHMS
GC: River City Construction
Project Role: MEPCx, BECx, Energy Modeling, Performance Verification

IFLI Zero Energy Certification **– In Progress**

Common NZE School Sustainability Certifications

ZERO ENERGY CERTIFICATION

LEED Zero

Illinois Clean Energy community foundation

LIVING BUILDING CHALLENGE℠

phius

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Setting a Site Energy Performance Target

Rooftop Size Estimator

Click the map below to draw the area to be occupied by the array. The size estimate is based on the area of a horizontal polygon. It does not account for roof tilt and azimuth, or shading.

System Capacity: 50.3 kWdc (335 m2)

RESULTS

Print Results

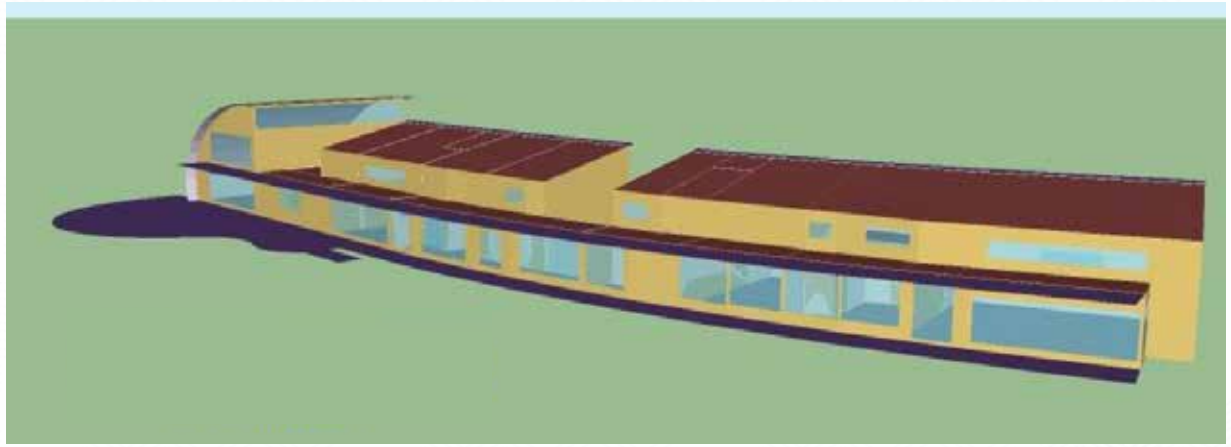
71,041 kWh/Year*

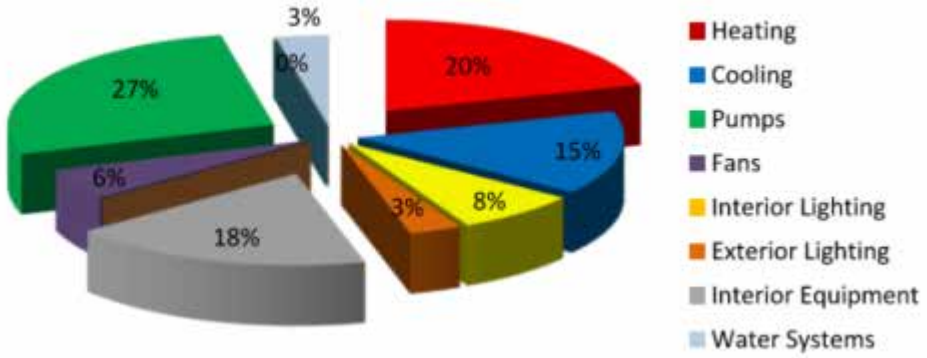
System output may range from 67,908 to 72,376 kWh per year near this location.
Click HERE for more information.

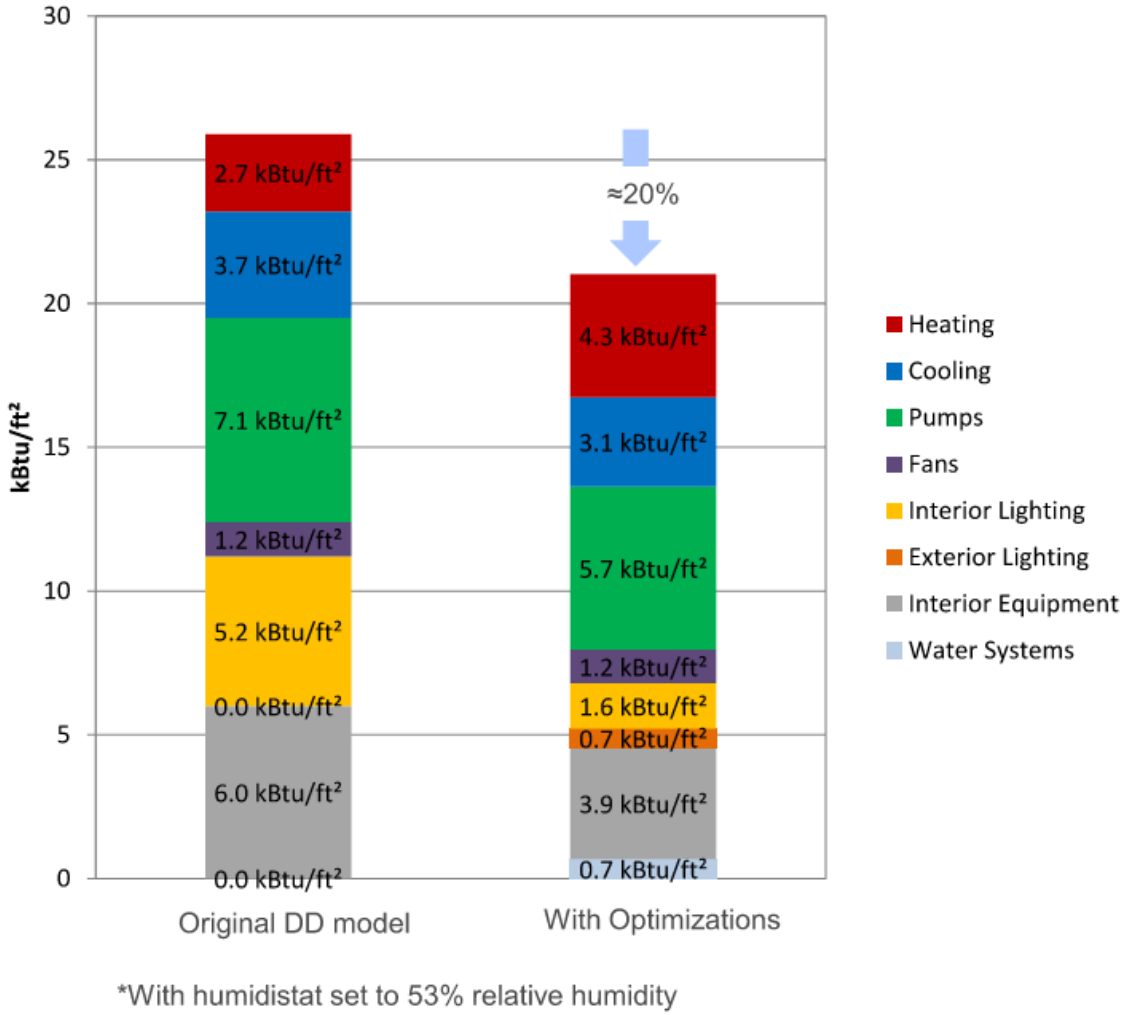
Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	3.31	4,314
February	4.18	4,913
March	4.88	6,175
April	5.74	6,811
May	6.06	7,254
June	6.37	7,216
July	6.25	7,282
August	5.90	6,850
September	5.03	5,832
October	4.54	5,612
November	3.96	4,868
December	3.00	3,912
Annual	4.94	71,039

Brock Environmental Center site energy usage target setting

Energy Modeling: Inform Design to Meet NZE Target







*With humidistat set to 53% relative humidity

Brock Environmental Center Energy Model Results

The Role of Energy Modeling during NZE School Development

Design Modeling Cycles

1 Simple Box Modeling
2 Conceptual Design Modeling
3 Load Reduction Modeling
4 HVAC Selection Modeling
5 Design Refinement
6 Design Integration and Optimization
7 Energy Simulation-Aided Value Engineering

Construction and Operations Modeling Cycles

8 As-Designed Energy Performance
9 Change Orders
10 As-Built Energy Performance

Postoccupancy Modeling Cycles

11 Postoccupancy Energy Performance Comparision

A Preconcept (Benchmarking / Climate and Site Analysis / Energy Charrette)
B Conceptual Design
C Schematic Design
D Design Development
E Construction Documents
F Bidding
G Construction
H Postoccupancy
I Twelve-Months of Occupancy

Source: https://danieloverbey.blogspot.com/2018/09/clarifying-energy-simulation-aided.html

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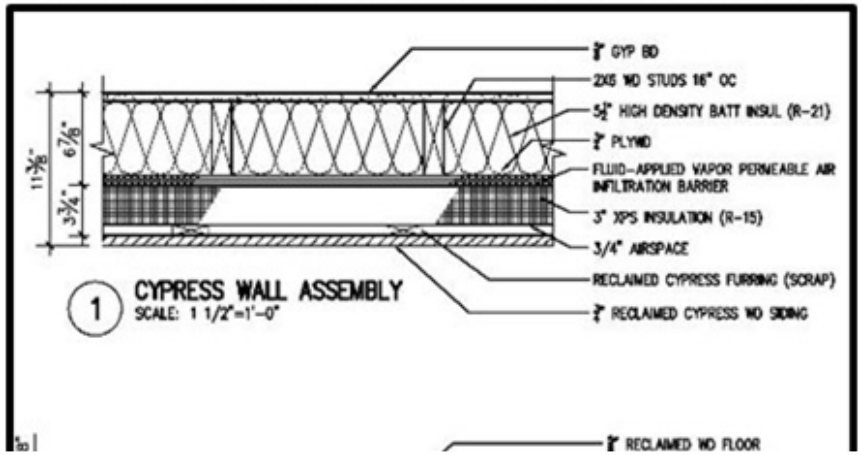
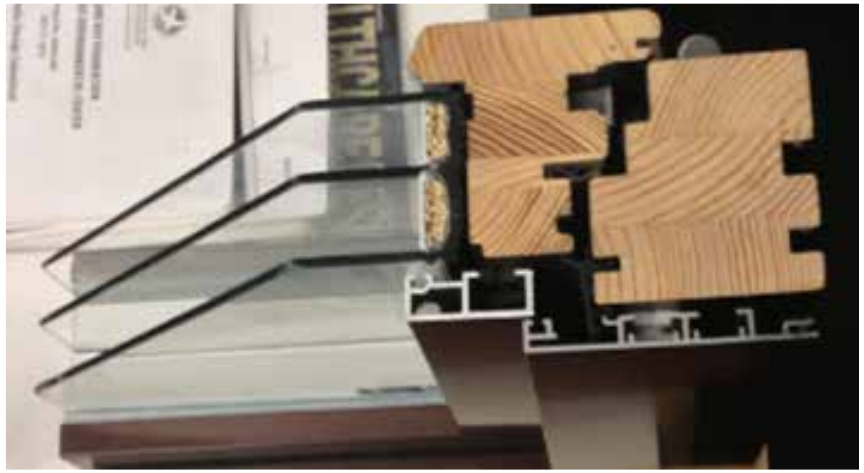
SD Decision: Insulation Thickness



Insulation Cost Premium	**$22,204**
Energy Savings	27,000 kbtu/yr
# of PV Panels Saved	35 PV panels
	11.2kW
Reduced PV Cost Savings	**$44,800**

Brock Environmental Center Energy Model Results

DD Decision: Glazing Thermal Specification



Triple Glazing (U-0.20) energy savings relative to double glazing (U-0.30)	19,000 kbtu/yr
Triple Glazing Cost Premium	**$26,235**
Equivalent PV Required	25 PV panels
	8.0 kW
Equivalent PV Cost	**$32,000**

The CxP's Energy Model Review Checklist

1. Does the model use appropriate weather data?
2. Are envelope systems modeled with accurate thermal properties and MEP systems with accurate capacity, rated efficiencies, and performance curves?
3. Are temperature, pressure, water, and airflow setpoints and setback are modeled consistently with the design – and your pre-functional checklist?
4. Are automatic lighting and HVAC controls are modeled consistently with the design sequences of operation – and your functional performance test script?
5. Does the energy model report include an EUI target limited by available site renewable energy generation capacity?

The CxP's Energy Model Review Checklist

6. Does the energy model compare predicted energy use with the target, and provide a breakdown showing ALL end uses? Don't forget exterior lighting, EV chargers, elevators, and irrigation systems!
7. Does the project's submetering concept provide sufficient granularity to validate the energy model predictions at the end-use level?
8. Do the space & water heating, cooling, lighting, pump, and fan energy peak demand results align with the selected MEP system capacities?
9. Do the space & water heating, cooling, lighting, pump, and fan equivalent full load hours (EFLH = annual energy/annual peak demand) make sense given the building's expected use patterns?
10. Does the energy model report include a sensitivity analysis to predict how energy use is impacted by factors outside of the design team's control (e.g. plugged-in equipment usage, class schedule changes, **or workmanship?**)

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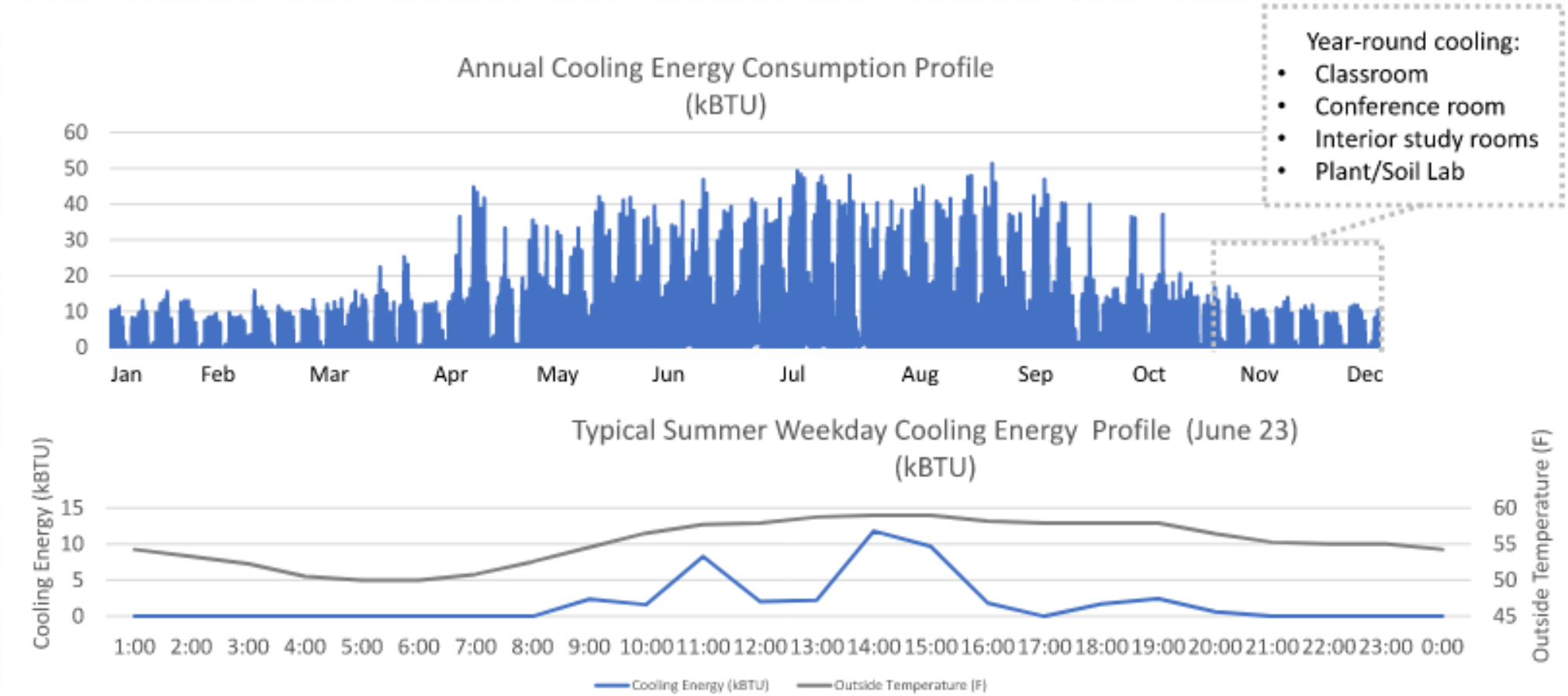
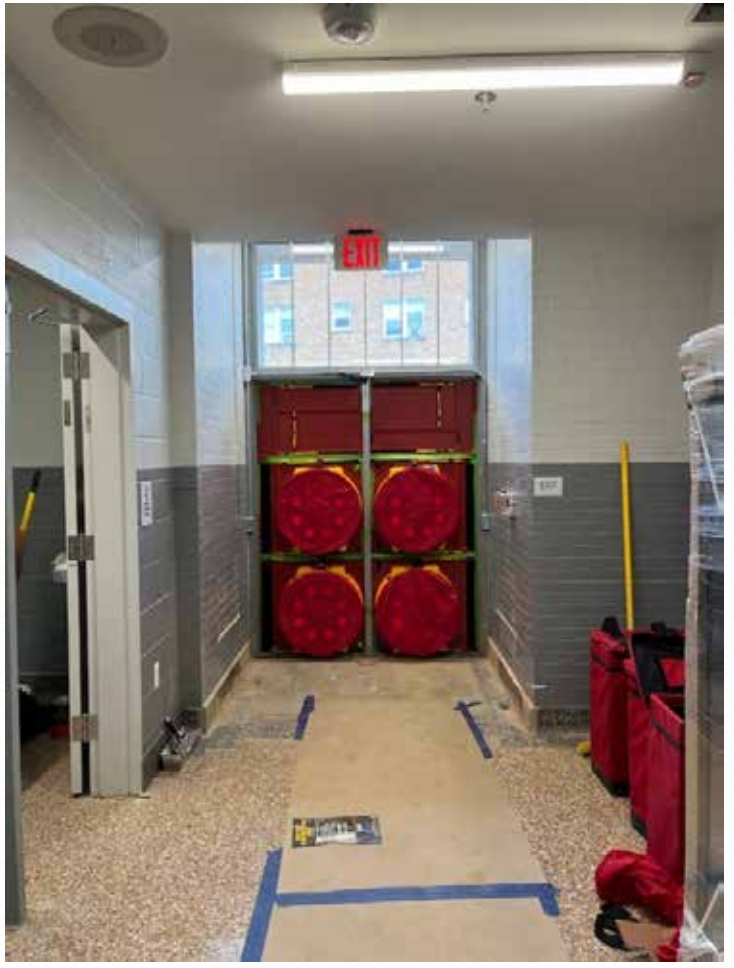
If it doesn't make sense - ask for the trends!



Commissioning NZE School Building Enclosures



Enclosure testing @ Raymond Elementary

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Common Enclosure Field Tests for NZE Schools

Adhesion Tests

- ASTM C1521 Standard Practice for Evaluating Adhesion of Installed Weatherproofing Sealant Joints
- ASTM D 4541 Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

Opening Airtightness tests

- ASTM E 783 Field Measurement of Air Leakage Through Installed Exterior Windows and Doors ASTM E 1186 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems.

Watertightness Tests

- AAMA 501.1 Standard Test Method for Water Penetration of Windows, Curtain Walls and Doors using Dynamic Pressure
- AAMA 501.2 Field Check of Metal Storefronts, Curtainwalls, and Sloped Glazing Systems for Water Leakage.
- ASTM E 1105 Field Determination of Water Penetration of Installed Exterior Windows, Curtainwalls and Doors by Uniform Static Air Pressure Difference.
- ASTM D7877 Standard Guide for Electronic Methods for Detecting and Locating Leaks in Waterproof Membranes

Whole Building Airtightness Tests

- **ASTM E 779 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization**
- **ASTM E 3158 Standard Test Method for Measuring the Air Leakage Rate of a Large or Multizone Building**

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Test Early... Test Often

Performance Mockup Testing @ HCC Agricultural Complex

Final (& Midterm Exam): The Blower Door Test

Blower Door Testing @ Academy for Global Citizenship – 0.059 CFM/SF @ 50 PA achieved (but not at mid-construction…)

Lessons Learned Specifying - BECx Testing for NZE Schools

1. Include a BECx specification section; either specify enclosure tests here or include section references to spec sections containing tests, coordinating with the architect as needed.
2. Specify who is responsible for enclosure testing & pre-test site prep (if not you!)
3. Specify that the general contractor make available water and electricity needed, and otherwise facilitate testing.
4. Specify who bears the cost of correcting deficiencies, repairs, and retesting after a failed test.
5. Specify a requirement to test early, performing out-of-sequence work if needed -> require a performance mockup and a mid-construction blower door.

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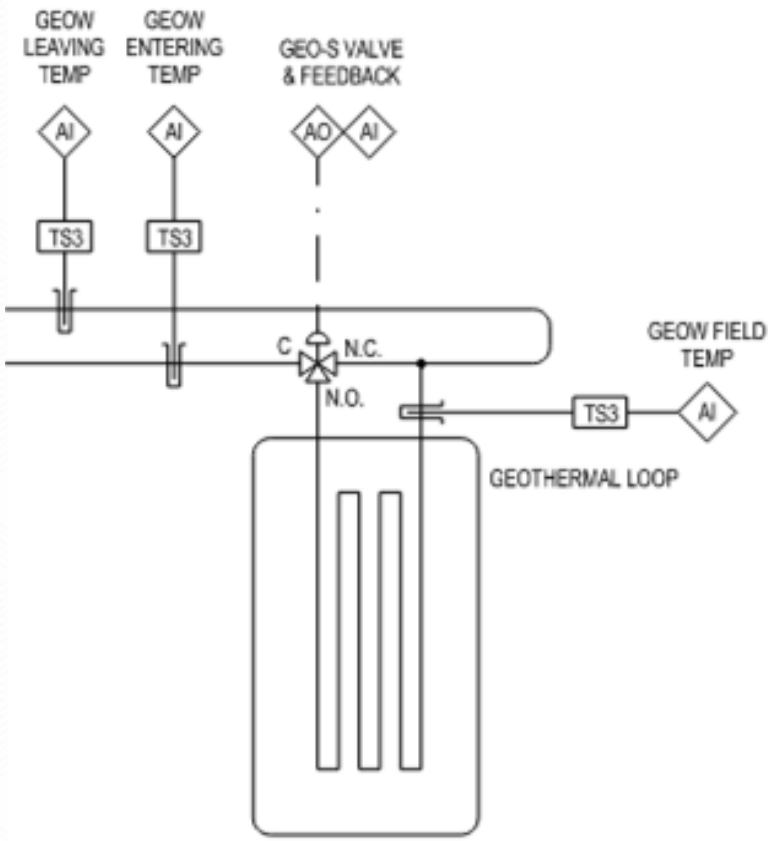
Lessons Learned Specifying - BECx Testing for NZE Schools

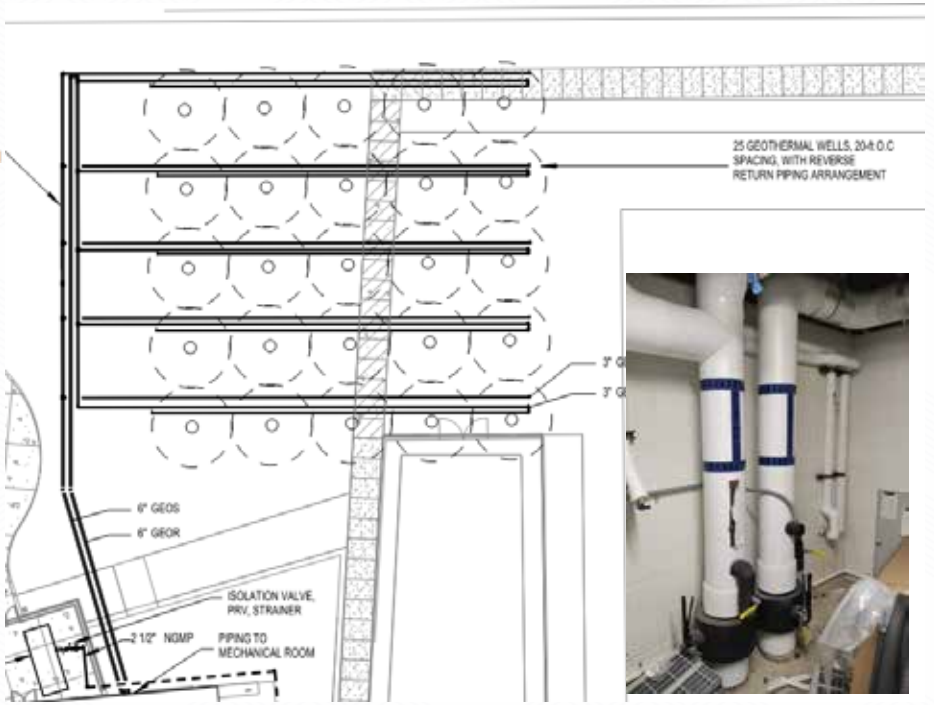
6. Specify that the general contractor include testing in the construction schedule.
7. Specify quantity/locations of proposed enclosure tests.
8. Specify pass/fail criteria and test conditions to ensure contractor understanding
9. Specify criteria informed by the energy model requirements, not just code.
10. In addition to specifications, document BECx testing in a BECx Plan prior to the start of construction – make sure contractors & sub on the same page as you!

Commissioning Common NZE School MEP systems

Mechanical Room @ HCC Agricultural Complex

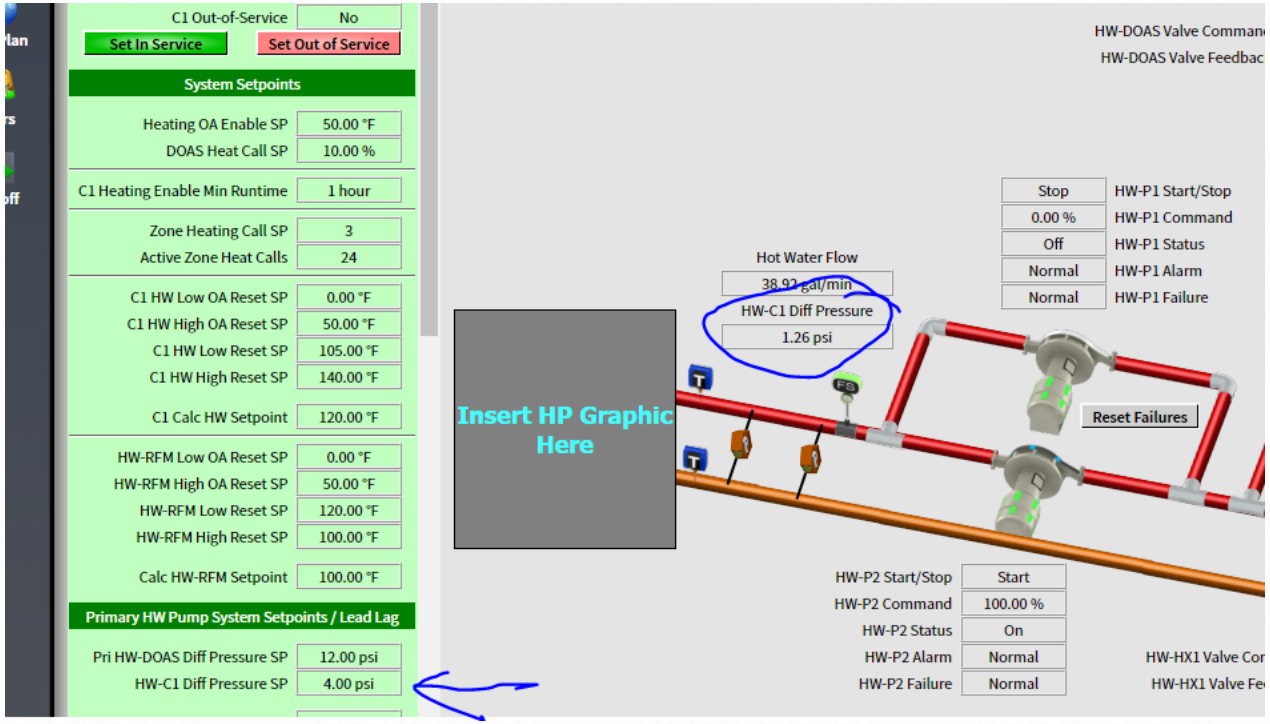
Ground-Source Heat Pumps





Geo-exchange Borefield Drilling @ HCC Agricultural Complex

Typical Issues:



Water pressure not meeting setpoint caused by blown strainer & expansion tank left at factory settings without onsite configuration

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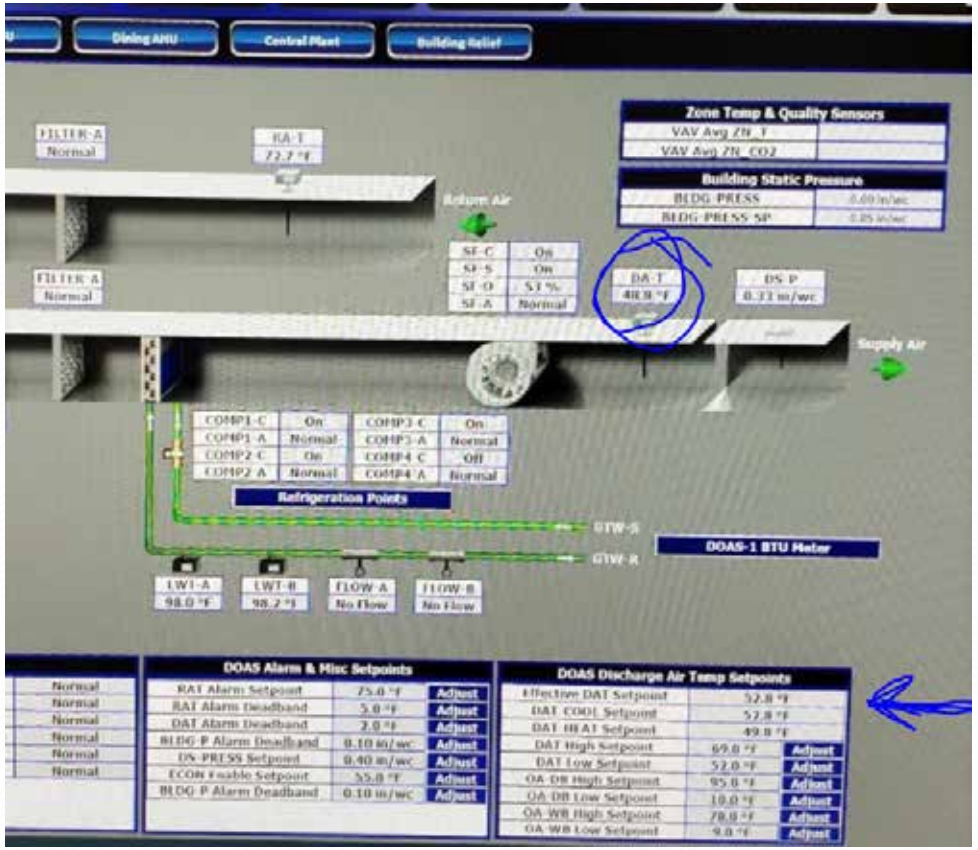
Independent Space Conditioning & Energy Recovery Ventilation Systems

Ground-Source VRF @ Brock Center (Top)

Terminal GSHP @ Raymond Elementary (Bottom)

Radiant Slab & Geothermal Heat Recovery Chiller @ Academy for Global Citizenship

Encountered Issues:



DOAS overcooling DAT past ERV discharge and DAT SP, causing WSHPs to run in full heating in late summer

Slab Sensor too long for maintenance by pulling thru manifold

Encountered Issues:

DCKV system improperly balanced- conditioning more OA than required

Heat Pump Service Water Heating Systems

ASHP DHW @ Raymond Elementary

Composting Toilets @ Brock Environmental Center

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Encountered Issues:

Excess refrigerant length beyond manufacturer's allowance caused refrigerant acidity & repeated compressor failure.

Smart Device Controls

OCCUPANCY CONTROLLED RECEPTACLES

OCCUPANCY CONTROLLED HVAC SETBACK

Encountered Issues:

Daylight-controlled blinds stuck halfway, unresponsive to flashlight

Occupancy-controlled receptacle stays on despite 30 min lack of motion

Daylight-controlled lights: one on, one off while daylit

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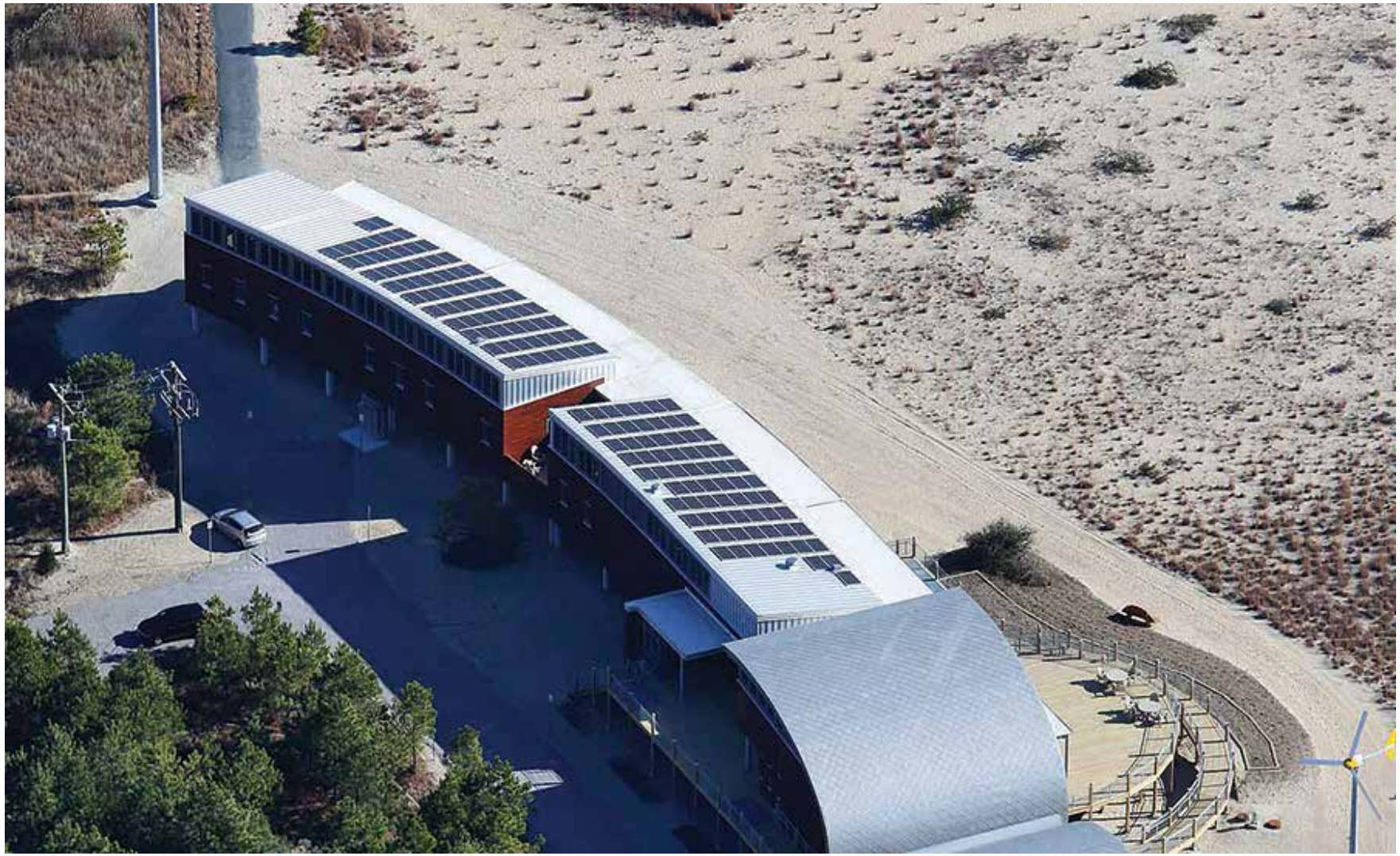
Solar Photovoltaic Arrays



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Lessons learned from NZE Schools MEP Cx Issues Logs

1. Properly specify & witness to ground-exchange borefield backfill and flush/fill operations to prevent ground loop flow issues…
2. Don’t forget to properly configure your hydronic appurtenances before plant equipment startup!
3. Ensure sensor accessibility for in-slab systems before they’re ordered
4. Double-check lockouts on economizers and ERVs
5. Investigate simultaneous heating and cooling conflicts between independent ventilation and space conditioning systems.

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Lessons learned from NZE Schools MEP Cx Issues Logs

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Cx & Performance Verification in NZE Schools

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Engaging Stakeholders

What is this book?

Congratulations on moving into your new building! The Heartland Community College Agriculture Complex building has been in development in various forms since the college completed its latest master planning effort in 2020. The design and construction teams are thrilled to welcome you to the state of Illinois' first native-Net Zero college campus building.

The Net Zero Building User Manual provides end users and occupants of the building with a simple, quick, and easy guide to the everyday functions of the building in order to ensure a safe and healthy work environment, while complementing the efficient operation of the building to the full potential provided by the design.

This document is split into three parts.

- Part 1, the User Guide, will focus on information relating to the management of people and how they interact with the building.
- Part 2, the Building Manual, will focus on information that is relevant to building operations and facilities management.
- Part 3, the Glossary and Index, is intended to be a repository for terms and definitions used throughout the book, as well as an educational resource for users.

With the gap that often exists between the design concept and the operators' understanding of how the building works, this User Guide and Building Manual offers the opportunity to close this gap, and in doing so reduce excessive energy use and increased maintenance costs, while meeting the building's Net Zero goals.

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The Green Team

- Form a “green team” of interested champions from the following groups to hold responsibility for achieving the net zero goal during the performance verification period
  - Admin
  - Facilities
  - Students
  - Teachers
- Walk the site monthly, looking for changes to settings, setpoints, usage patterns, and plugged-in equipment; record all changes to discuss at next meeting with performance verification consultant/ongoing CxP
- Schedule monthly calls with performance verification consultant/ongoing CxP
  - Review past month’s energy performance compared to predictions
- Schedule quarterly in-person reviews with performance verification consultant/ongoing CxP
  - Review monitoring-based Cx findings & recommendations
  - Schedule follow-up actions with green team’s facilities staff representatives

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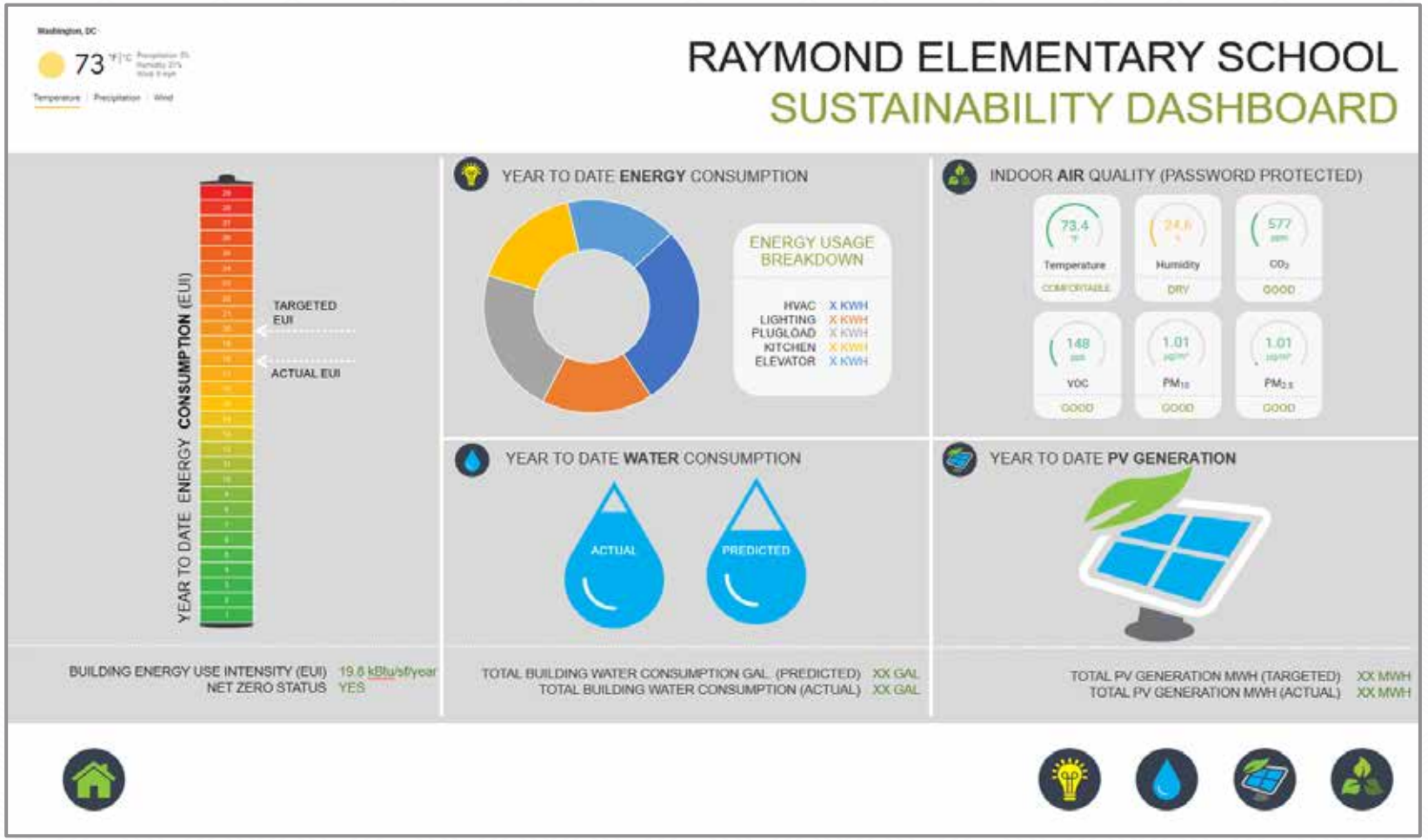
Maintaining Transparency:
Energy Performance Monitoring Dashboard



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Validating & Calibrating the Energy Model

BUILDING LEAKAGE TEST Page 3 of 4

Date of Test: 4/8/23 Test File: AGC MC BD - Depressurization with all vents on roof taped off, except DOAS

Depressurization Test:

Environmental Data

	Indoor Temperature (°F)	Outdoor Temperature (°F)	Altitude (ft)
Pre-Test	47.0	47.0	
Post-Test	47.0	47.0	
Average	47.0	47.0	595.0

Data Points - Data Entered Manually (TTE 5.0.8.4)

Nominal Building Pressure (Pa)	Baseline adjusted Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow (cfm)	Adjusted Flow (cfm)	% Error	Fan Configuration
0.0	n/a	n/a				
-50.0	-50.0	239.6	7342	7251	0.0	Open
0.0	n/a	n/a				

Efficiency Valuation Organization

IPMVP® INTERNATIONAL PERFORMANCE MEASUREMENT & VERIFICATION PROTOCOL

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A Selection of Equipment Schedules

	6 meeting and huddle room EQUIPMENT																							
Through	12/31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
For:	Weekdays Wi	0%	0%	0%	0%	0%	0%	0%	0%	38%	50%	50%	38%	0%	25%	25%	0%	38%	0%	0%	0%	0%	0%	0%	0%
	Saturday	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Sunday	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	AllOtherDays	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
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	Saturday	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Sunday	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	AllOtherDays	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Office EQUIPMENT																							
Through	12/31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
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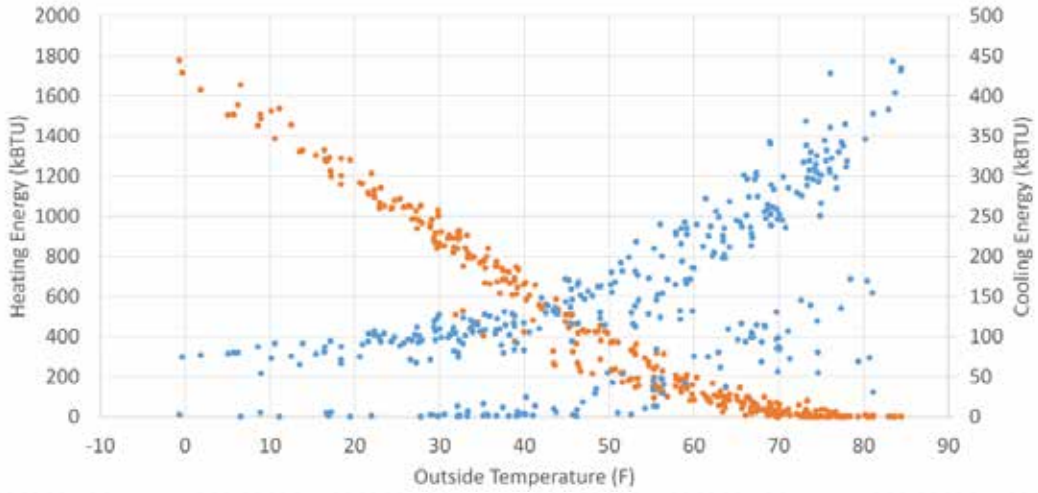
	Saturday	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	12%	12%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Sunday	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	12%	12%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	AllOtherDays	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	12%	12%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

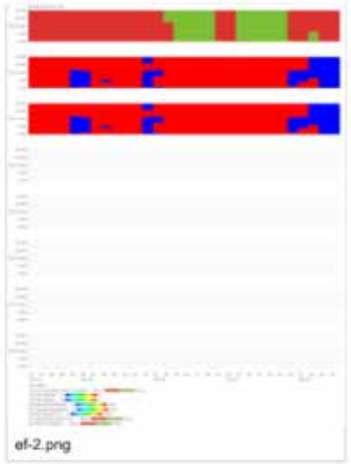


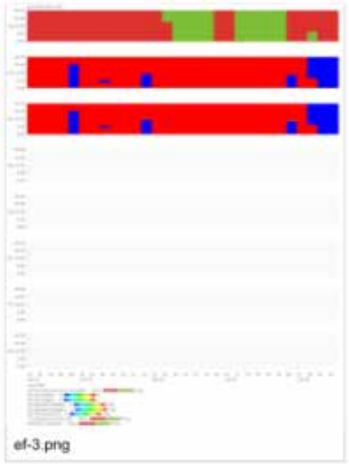
Incorporating Monitoring-Based Commissioning

FO-20-3 OPEN MODERATE

It does appear EF-2 & EF-3 are not running based off of occupancy schedule. Honeywell to investigate

Assigned To	Honeywell Building Solutions (Controls)
Asset	EF-2
Discipline	Controls
Due Date	11/10/2023
Created By	Preetham Mannem
Identified On	10/27/2023 12:14 PM

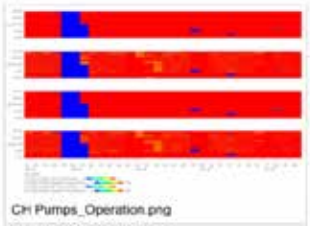

ef-2.png


ef-3.png

FO-16-2 OPEN MODERATE

Chilled water pumps did not rotate their positions on a weekly basis. Per trends, both pumps are running simultaneously. Per executed FPTs, these pumps should swap their positions every Monday at 9 am.

Assigned To	Honeywell Building Solutions (Controls)
Asset	CHWP-1
Discipline	Controls
Due Date	11/13/2023
Created By	Preetham Mannem
Identified On	10/30/2023 11:45 AM


CH Pumps_Operation.png

FO-17-3 OPEN MODERATE

Fan never turned off in the month of August. This fan should be disabled when associated RTUs are off.

Assigned To	Honeywell Building Solutions (Controls)
Asset	EF-7
Discipline	Controls
Due Date	11/10/2023
Created By	Preetham Mannem
Identified On	10/27/2023 11:03 AM


ef-7.png

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NZE School Performance Verification: Lessons Learned

1. Hold a kickoff meeting with all users including faculty, administration, support staff, and students to explain project goals, building systems, user responsibilities, and next steps
2. Form a green team to champion net zero energy performance during the performance period
3. Provide visible means for all building users to track energy performance as a habit
4. Establish communication protocol for building users to report comfort and energy issues to the green team
5. Calibrate the energy model at least quarterly based on weather and green team findings and observations regarding modified settings, setpoints, and usage patterns

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NZE School Performance Verification: Lessons Learned

6. Identify end-uses exceeding calibrated energy model predictions,
7. Use monitoring-based commissioning approach to identify potential causes for energy end-uses exceeding calibrated energy model breakdowns
8. Meet green team in person on a quarterly basis and remotely on a monthly basis to keep building performance on track during the performance period
9. Work with green team to implement and verify operational modifications, behavioral programs, and faulty system repairs
10. Submit building utility and renewable energy system production data for net zero verification!

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Conclusions

1. Schools pursue net zero energy goals as community inspiring and educational facilities, and benefit from public funding and partial-year operation.

2. Energy modeling is critical to achieving schools' net zero energy performance goals; commissioning proivders are well-suited and well-positioned to delivering energy modeling services, or at least providing energy modeling peer review

3. Properly reviewing net zero energy school projects' architectural details and specifying enclosure testing with clearly defined methodology, pass criteria, test conditions, frequency, and follow-up responsibility is essential to hitting performance targets.

4. North American net zero energy school projects frequently feature geothermal HVAC systems, separate ventilation and space conditioning sytems, heat pump water heating, smart building controls,

5. Lessons learned verifying net zero energy school performance

Questions?

Today's Presenter:

Ajit Naik, PE, BEMP, CCP

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