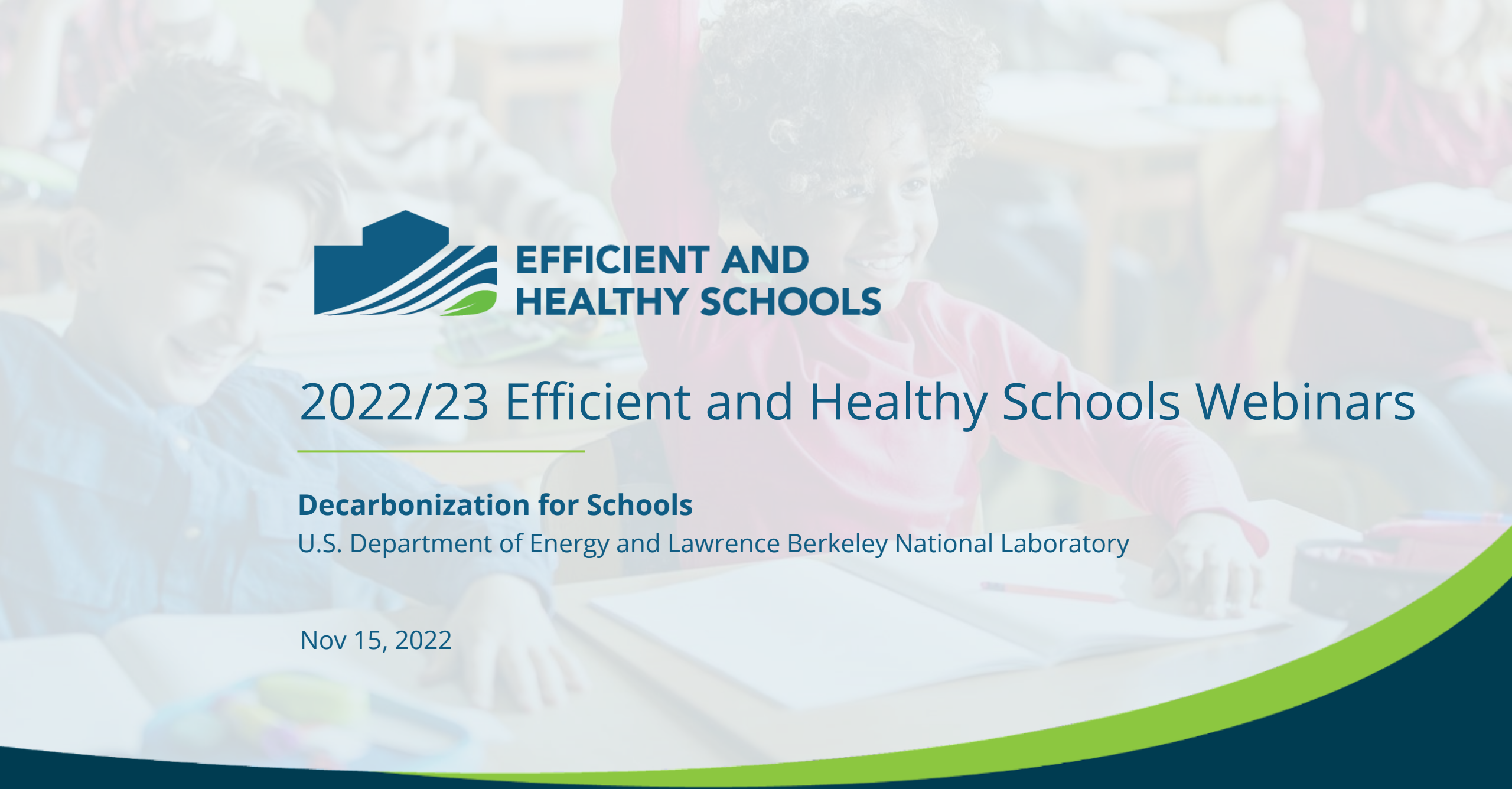


EFFICIENT AND HEALTHY SCHOOLS

2022/23 Efficient and Healthy Schools Webinars

Decarbonization for Schools

U.S. Department of Energy and Lawrence Berkeley National Laboratory

Nov 15, 2022

Efficient and Healthy Schools Campaign Webinar

Welcome!

- Agenda is in the chat
- Webinar is being recorded, and will be posted
- All attendees are muted during this webinar
- Please enter questions into the chat or Q&A at any time
- We will send out the slides and presentation recording shortly after the webinar

Today's Agenda

- Efficient and Healthy Schools Campaign – Alexandra (Allie) Johnson, LBNL
- **Decarbonization for Schools:**
  - Paul Torcellini, Principal Engineer, NREL
  - Jess Farber, Vice President, CMTA
  - Kiersten Washle, Building Science Engineer, CMTA
- Q&A. You can also send questions to EHSC@lbl.gov if we are unable to answer them
- Closing and helpful links - Allie Johnson

Efficient and Healthy Schools Campaign - Overview

- The campaign aims to:
  Improve energy performance, reduce carbon emissions, and promote a healthy learning environment in schools.
- The campaign engages K-12 schools especially those serving low-income student populations and in rural areas.
- This campaign is led by the U.S. Department of Energy with technical support from Lawrence Berkeley National Laboratory.

Organizing partners:

Become a Participant or Supporter

- Campaign participants (such as schools and school districts) can:
  - Access technical assistance and resources on best practices, guidance, case studies, and webinars
  - Receive recognition for their efforts to improve energy performance, health, and resilience

- Campaign supporters (such as contractors and government) are encouraged to share and promote goals and benefits of efficient and healthy schools

Recognition Program: 2022/23 Second Round!

The campaign will recognize solutions and efforts (implementation or planning) by K-12 schools and districts in the following categories:

Energy Efficiency Plus Health - For improving energy efficiency and indoor environmental quality (IEQ: indoor air quality, lighting, thermal comfort, acoustics)

Emissions Reduction and Resilience - For reducing carbon emissions and improving resilience

Title I schools, rural schools, and schools in disadvantaged communities are especially encouraged to apply. Application and more information. Supporters can help schools apply.

Decarbonizing Schools

Paul A. Torcellini, Ph.D., P.E., FASHRAE

Efficient and Healthy Schools Webinar

November 15, 2022

Photo from iStock-627281636

Where are we going?

- What do you think the future of buildings “should” look like?

Trends of Commercial Sector

- Growth is faster than energy efficiency measures
- Every decision has an energy and environmental impact
- Buildings mortgage the energy futures of the world

What are Zero Energy Buildings?

- Conceptually, a building that has no adverse energy [or environmental] impact [because of its operation]
- Energy consumption has been a long-term surrogate for environmental impact

- Boundaries and metrics
- What energy flows to measure

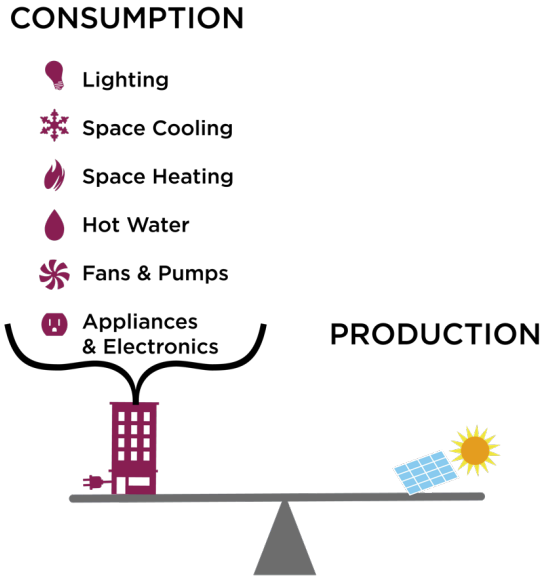
Buildings on a Diet

Goal 1:
Reduce Consumption

Goal 2:

Apply On-site Renewable Energy

BALANCE!

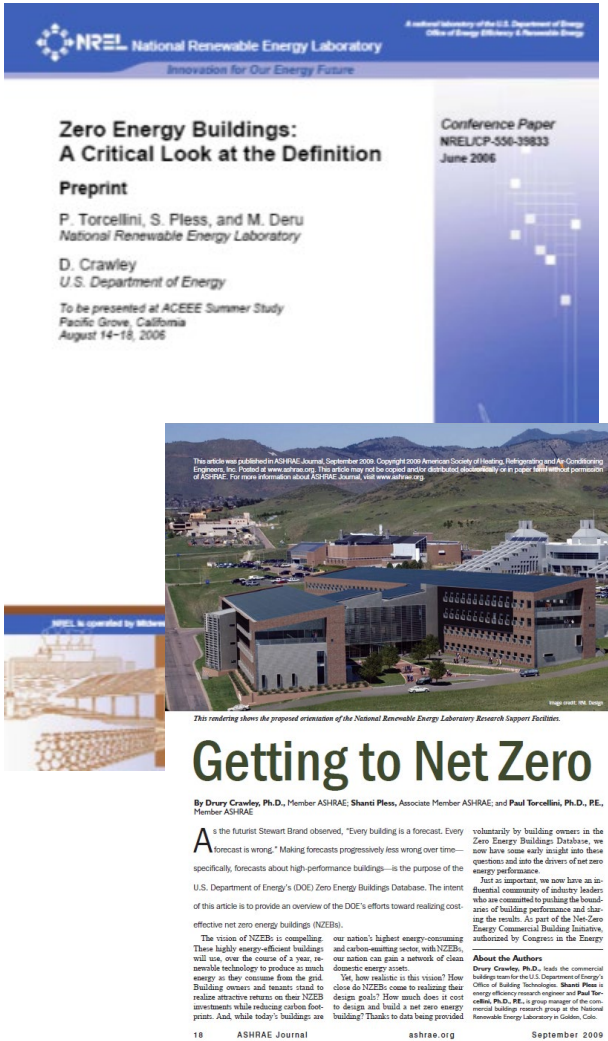


Definitions of ZEB's

- Zero Site Energy
- Zero Source Energy
- Zero Emissions
- Zero Energy Cost

- Boundaries and metrics

The Definition used WILL impact the strategies!



NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Zero Energy Buildings: A Critical Look at the Definition

Preprint

P. Torcellini, S. Pless, and M. Deru
National Renewable Energy Laboratory

D. Crawley
U.S. Department of Energy

To be presented at ACEEE Summer Study
Pacific Grove, California
August 14–18, 2006

Conference Paper
NREL/CP-550-39833
June 2006

This article was published in ASHRAE Journal, September 2009. Copyright 2009 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Posted at www.ashrae.org. This article may not be copied and/or distributed electronically or in paper form without permission of ASHRAE. For more information about ASHRAE Journal, visit www.ashrae.org.

This rendering shows the proposed orientation of the National Renewable Energy Laboratory Research Support Facilities.

Getting to Net Zero

By Drury Crawley, Ph.D., Member ASHRAE; Shanti Pless, Associate Member ASHRAE; and Paul Torcellini, Ph.D., P.E., Member ASHRAE

As the futurist Stewart Brand observed, "Every building is a forecast. Every forecast is wrong." Making forecasts progressively *less* wrong over time—specifically, forecasts about high-performance buildings—is the purpose of the U.S. Department of Energy's (DOE) Zero Energy Buildings Database. The intent of this article is to provide an overview of the DOE's efforts toward realizing cost-effective net zero energy buildings (NZEBs).

The vision of NZEBs is compelling. These highly energy-efficient buildings will use, over the course of a year, renewable technology to produce as much energy as they consume from the grid. Building owners and tenants stand to realize attractive returns on their NZEB investments while reducing carbon footprints. And, while today's buildings are our nation's highest energy-consuming and carbon-emitting sector, with NZEBs, our nation can gain a network of clean domestic energy assets.

Yet, how realistic is this vision? How close do NZEBs come to realizing their design goals? How much does it cost to design and build a net zero energy building? Thanks to data being provided voluntarily by building owners in the Zero Energy Buildings Database, we now have some early insight into these questions and into the drivers of net zero energy performance.

Just as important, we now have an influential community of industry leaders who are committed to pushing the boundaries of building performance and sharing the results. As part of the Net-Zero Energy Commercial Building Initiative, authorized by Congress in the Energy

About the Authors

Drury Crawley, Ph.D., leads the commercial buildings team for the U.S. Department of Energy's Office of Building Technologies. **Shanti Pless** is energy efficiency research engineer and **Paul Torcellini, Ph.D., P.E.**, is group manager of the commercial buildings research group at the National Renewable Energy Laboratory in Golden, Colo.

18 ASHRAE Journal ashrae.org September 2009

http://www.nrel.gov/docs/fy06osti/39833.pdf

Setting Goals

- Measurable goals are better
- From bad to good…
  - I want a green building
  - Design a LEED <rating> building
  - Design a building to use 30% less energy than ASHRAE 90.1-2019
  - Design a building to use less than 25,000 Btu/sqft
  - Design a ZERO ENERGY building
  - Design a ZERO CARBON building

- Influencing purchasing decision—the owner

Zero Energy and Zero Carbon

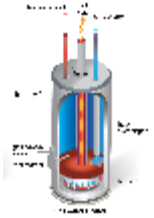
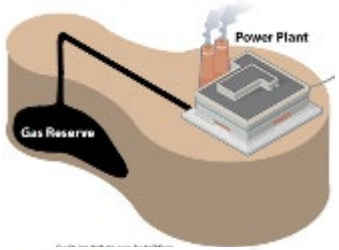
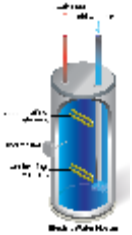
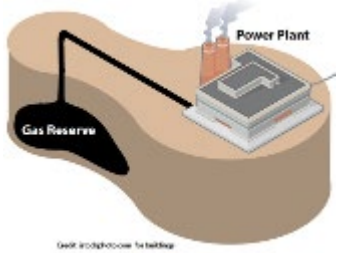
Version 1.0

- To save carbon, you save energy (or use RE)
- Energy Storage comes at a penalty
- Easy to understand and use
- Creates overgeneration scenarios without “penalty”
- The “grid” is the infinite battery

Version 2.0

- Moves towards 100% renewable energy, 100% of the time
- Values storage
- May conflict with utility rate structures
- While saving energy saves carbon, when you save the energy is more important

Electrification

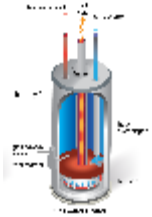
Gas Hot Water Heater	1.74 unit of gas in		→	1.6 unit of gas in	 1 unit of hot water out
Electric (Resist) Hot Water Heater	1.87 unit of gas in		→	1.02 unit of electricity in	 1 unit of hot water out
Heat Pump Hot Water Heater	0.61 unit of gas in		→	0.33 unit of electricity in	 1 unit of hot water out

Energy Flows—Moving towards renewable energy

Gas Hot Water Heater

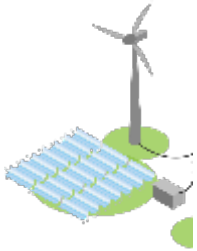
?

1.6 unit of gas in

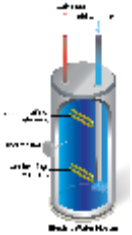


1 unit of hot water out

Electric (Resist) Hot Water Heater



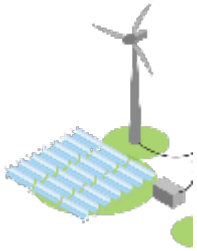
1.02 unit of electricity in



1 unit of hot water out

Heat Pump Hot Water Heater

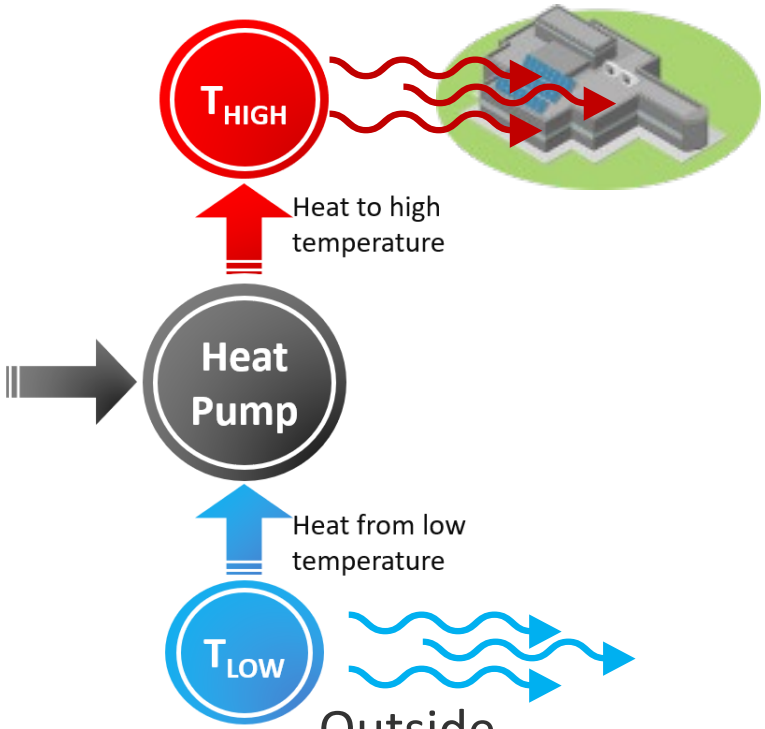
PV Systems (1/3 the size)



0.33 unit of electricity in

1 unit of hot water out

Heat Pumps



- Pull heat from the air—less efficient as the air becomes cooler
  - Heat pumps are rated down to 17°F. Need to ask how much colder a particular heat pump will operate
  - Cold climate heat pumps can work to -20°F which is sufficient for many US Climates
- System types:
  - Ducted Air-source heat pumps (ASHP)
  - Mini-splits (ductless or multi-head)
  - Ground Source Heat Pumps

Action Plans

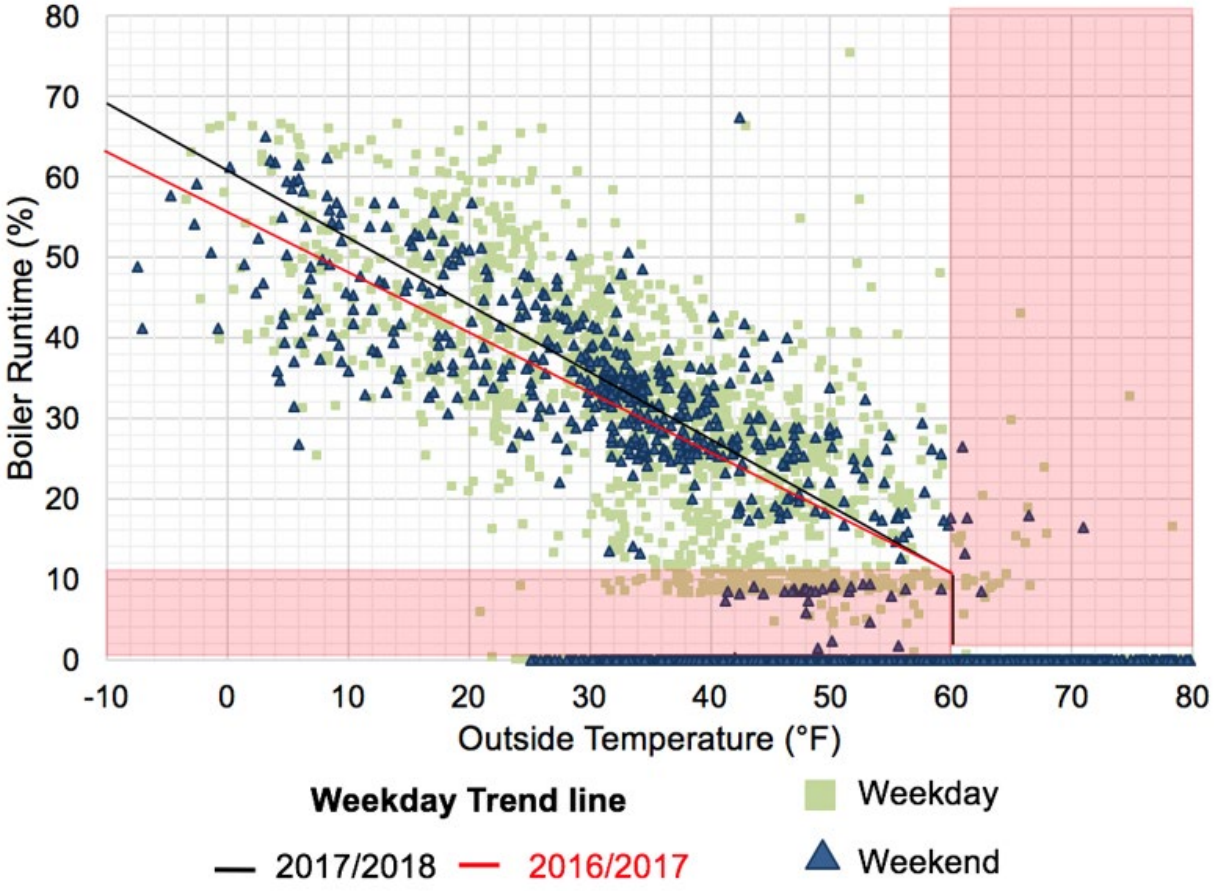
What changes will you make to the building as part of normal business?

What problems does the building have?

If something “dies,” what will you replace it with?

Do you know the actual capacity of equipment?

Boiler Runtimes



Looking at existing load distribution

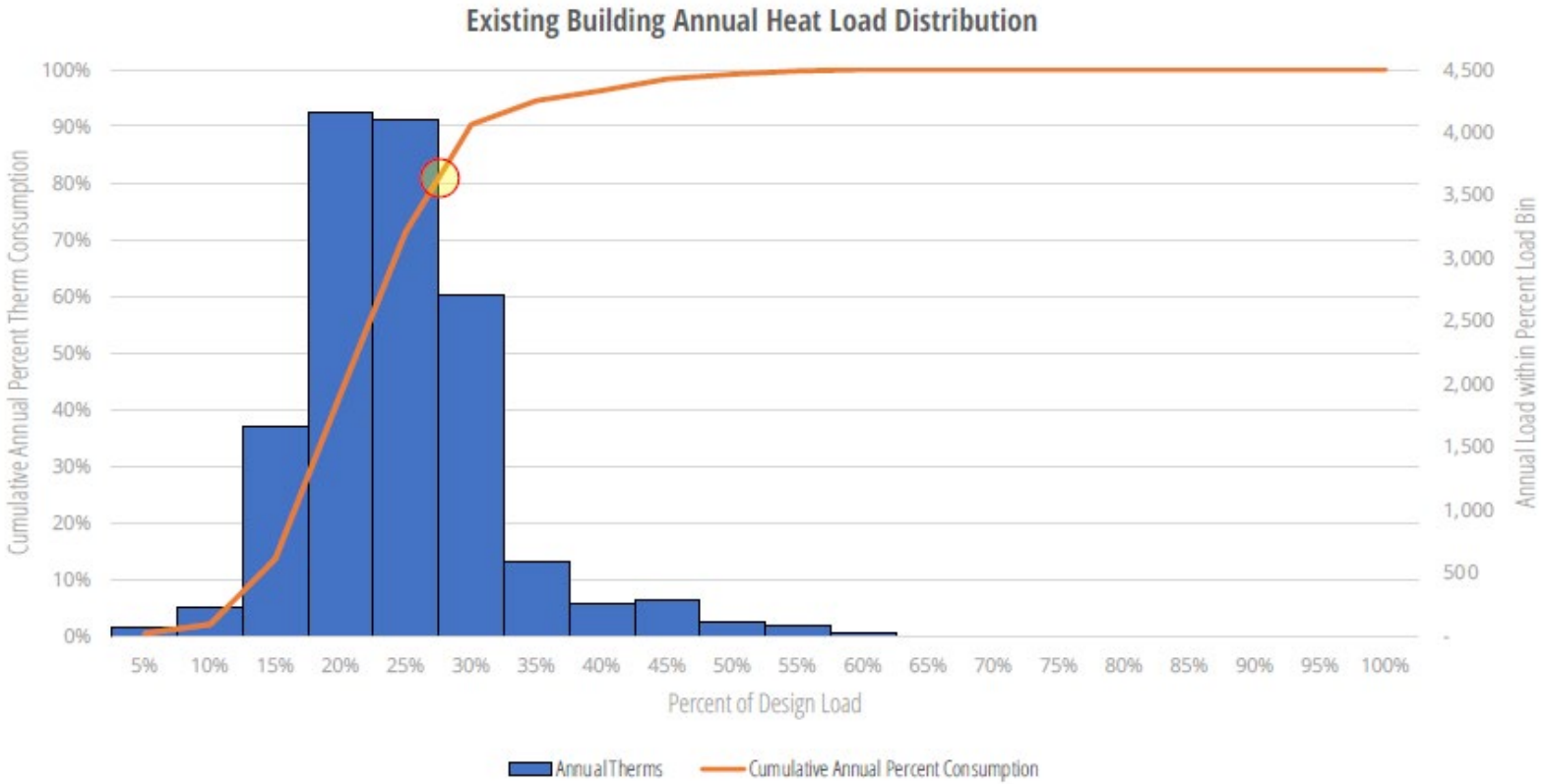


Image courtesy of P2S Engineering

Decarbonization Action Plan in Practice

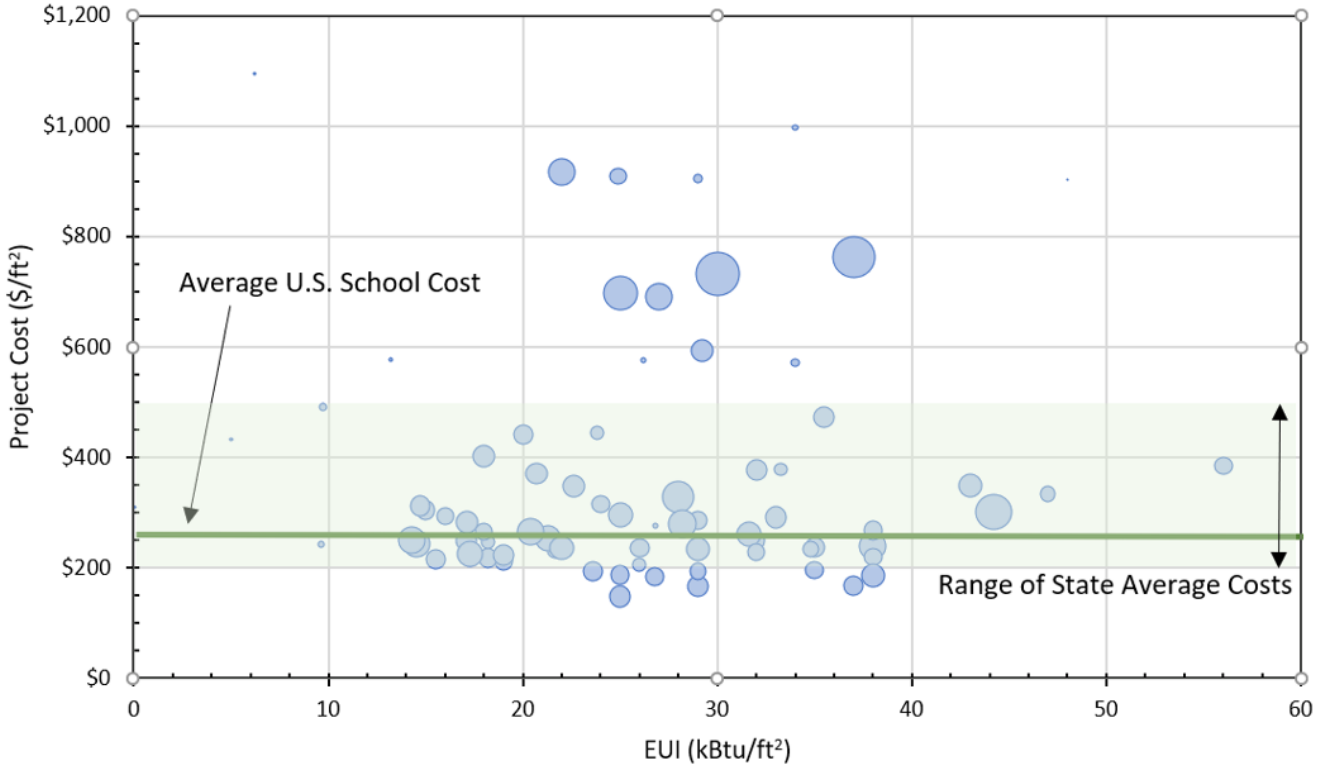
Topic	Strategy to be Accomplished	Issues to Address	Potential Solution for Issue	Next Steps
Envelope	Improve thermal characteristics of windows	Existing window film is failing; thermal comfort issues from single pane windows	Install insulated glazing panels inside existing windows with permanent tinting	Investigate cost of insert panels and ability to solve overheating and energy savings (energy analysis)
HVAC	Electrify building	Do not know which systems and how many use natural gas and if there are electric replacement options	Start an inventory of all natural gas systems and appliances	Reach out to facilities/maintenance teams to create asset inventory
Renewables	Roof mounted PV	Can existing roof structure support ballasted PV system	Install PV on 10,000sqft of roof is roughly 50 kW	Investigate cost of system and determine if concrete roof structure will allow ballasted system installation

Strategies

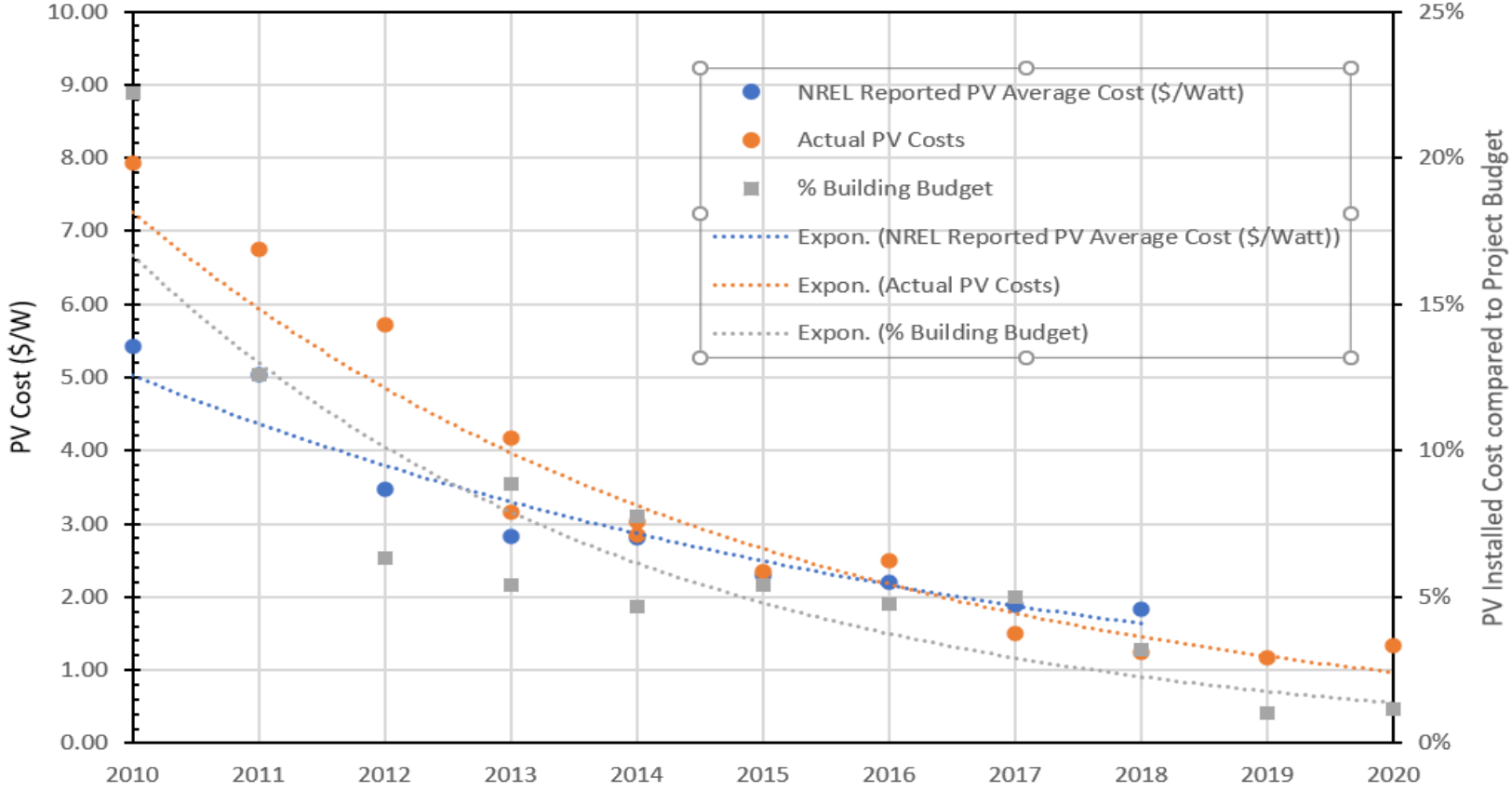
- Strive for 50% energy savings from ASHRAE 90.1-2019.
  - Envelope – Reducing load will downsize equipment and electrical needs
    - Blower door test building and seal leaks. Target 0.10 cfm/ft^2 at 75 Pa
  - Lighting – use the AEDG recommendations. Lighting is often replaced in buildings
  - Plug Loads – Energy Star enabled equipment. Plug load inventories
  - HVAC (to match first three)
- Maximize on-site renewable energy.
- Use as much energy as possible from 10 am to 2 pm … and as little as possible from 5 pm to 9 pm.
- Hydronic loops – how low can you go and still meet loads. Plan for lower loads
- Thermal storage
  - Building materials – Pre-cooling/heating when solar resources are available
  - Hot and cold water and/or ice. Buffer Tanks for HVAC
  - Batteries (but not for HVAC)
  - Ability to flex the building loads
- Create an all-electric building (but minimize electric resistance)

Zero Energy School Costs

https://www.nrel.gov/docs/fy20osti/77414.pdf

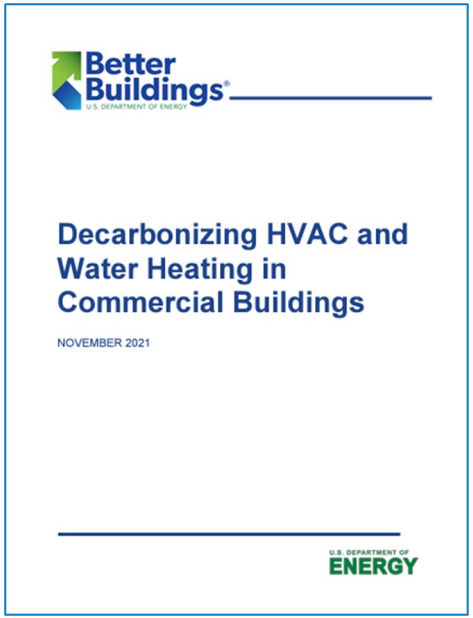


PV Costs Compared to Building Costs (K-12 Schools)



https://www.nrel.gov/docs/fy20osti/77414.pdf

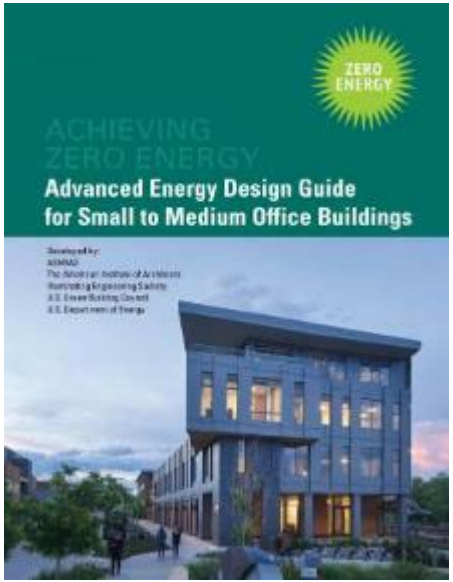
Better Buildings Decarbonizing HVAC

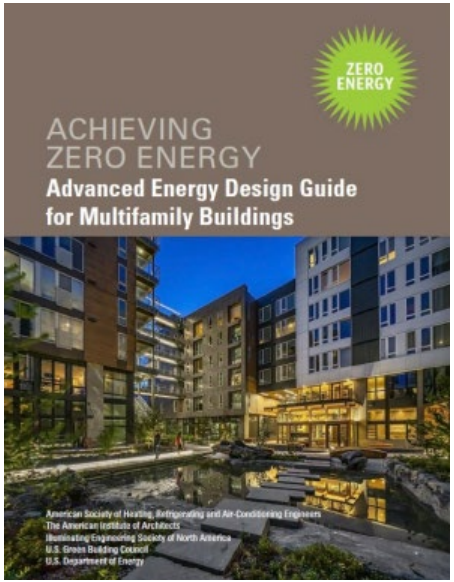


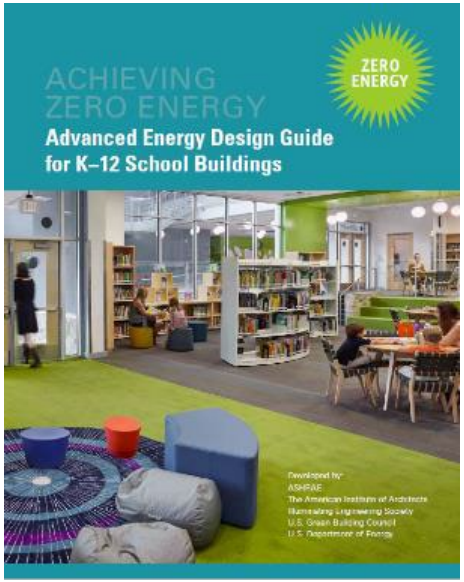
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Decarbonizing%20HVAC%20and%20Water%20Heating%20in%20Commercial%20Buildings%2011.21.pdf

Advanced Energy Design Guides for Zero Energy

- Design guidance by building type and climate zone
    - Supported by case studies and energy modeling
- Developed by leading industry experts
- Looked to for beyond energy code







More information: https://www.ashrae.org/technical-resources/aedgs

Energy Use Intensity Targets for Schools

Climate Zone	SITE ENERGY		SOURCE ENERGY	
	Primary School EUI (kBtu/ft^2-yr)	Secondary School EUI (kBtu/ft^2-yr)	Primary School EUI (kBtu/ft^2-yr)	Secondary School EUI (kBtu/ft^2-yr)
0A	22.5	22.9	69.1	70.5
0B	23.1	23.2	71.4	71.6
1A	21.3	21.1	65.5	65.0
1B	21.7	21.6	66.6	66.6
2A	20.9	21.3	63.8	65.1
2B	19.6	19.9	59.7	60.8
3A	18.8	19.1	56.7	60.8
3B	19.0	19.4	57.3	58.8
3C	17.5	17.6	52.6	52.8
4A	18.8	18.9	56.3	56.7
4B	18.4	18.5	55.1	55.5
4C	17.5	17.6	51.9	52.3
5A	19.2	19.1	57.1	56.9
5B	18.7	19.0	55.6	56.6
5C	17.4	17.6	49.7	52.3
6A	21.1	20.6	62.8	61.2

Example School

Windows did not meet fire egress requirements.
70-year-old steam system was failing
30-year-old hot water system for gym
Wanted to put PV on gym roof (but could not support the weight)

Solution Pathway

- New low-e windows (now steam system was way over capacity)
- Replaced Gym roof with EDPM and tripled insulation amount (now that boiler was over capacity)
- Reduced roof weight allowed for PV for 60% of electrical load at 70% electrical cost savings – no money up-front
- Started replacing radiators with low temperature fin tube on return from gym boiler
- Retired steam boiler (1.5 MMBtu/hr) and now running entire school on 0.6 MMBtu/hr boiler. Added provisions for adding heat pumps

Next Steps…

- Create your action plan
  - Track energy performance
  - Focus on energy efficiency. Makes the pathway to electrification easier.
  - Identify on-site fossil equipment. Develop pathways to electrify
  - Avoid electric resistance
- Join the DOE Better Climate Challenge

Questions and Comments

Paul Torcellini
paul.torcellini@nrel.gov

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the Buildings Technology Office, U.S. Department of Energy. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Photo from iStock-627281636

NREL
Transforming ENERGY

EFFICIENT AND HEALTHY SCHOOLS

2022/23 Efficient and Healthy Schools Decarbonization
Case Study | Buckley Elementary School

November 15, 2022

CMTA
A LEGENCE Company

CMTA

Your Presenters

Jess Farber
PE, WELL AP
Vice President | Mechanical Engineer
jess@cmta.com

Kiersten Washle
LFA, CEM, LEED Green Associate
Building Science Engineer
kwashle@cmta.com

CMTA Overview

National Zero Energy Expert

9.9+ Million

Square Feet of Zero Energy / Carbon Facility Design

175+ Zero Energy Capable Projects

Operating Under 35 kBtu/sf/yr

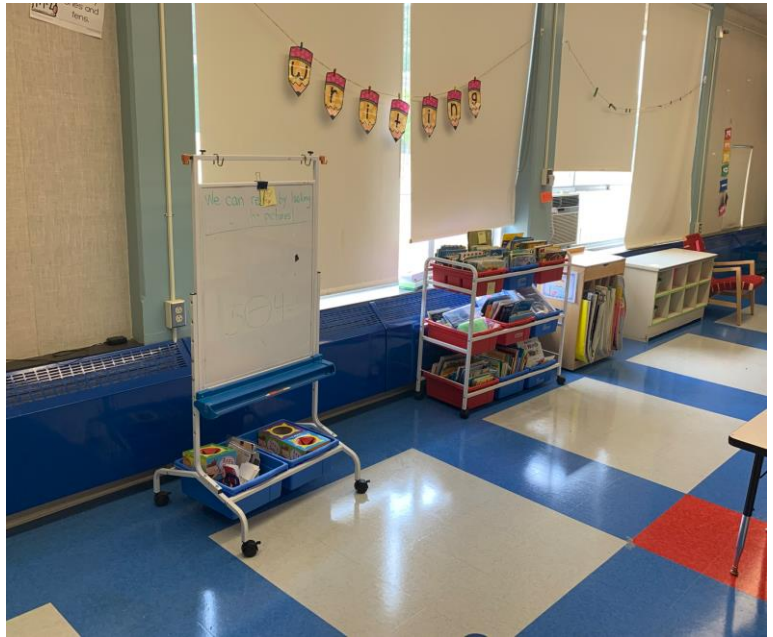
200+ ENERGY STAR Projects

69 with Perfect 100 Scores

75+ Megawatts

Renewable Power Designed / Installed

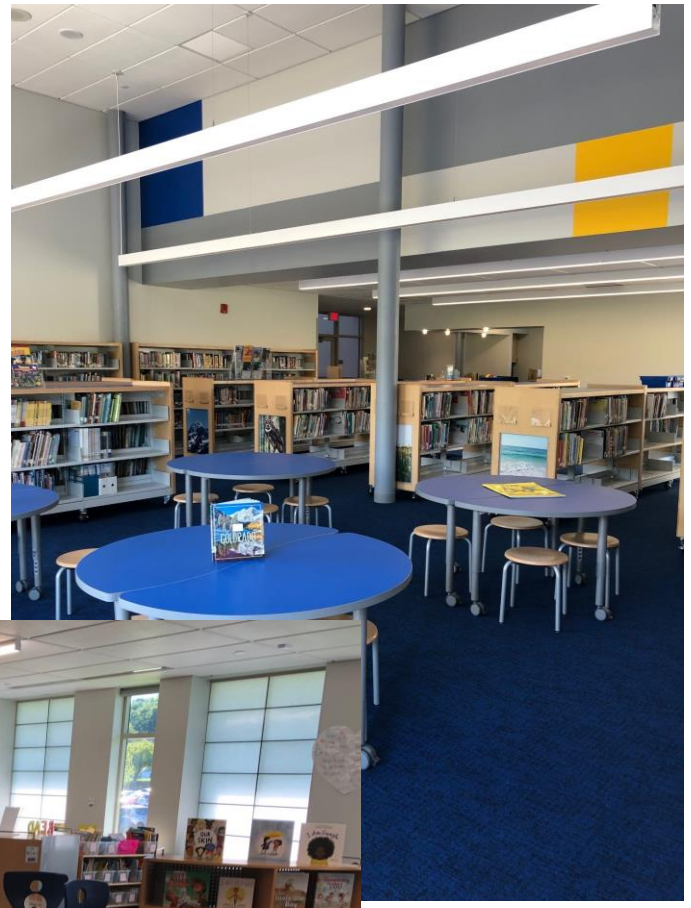
Buckley Elementary School – Manchester CT



Buckley ES "Before" Stats

- ✓ 58,600 sf
- ✓ 1950's vintage
- ✓ Poor Building Envelope
- ✓ Natural Gas Heating Steam Boilers
- ✓ Limited A/C
- ✓ No Mechanical Ventilation

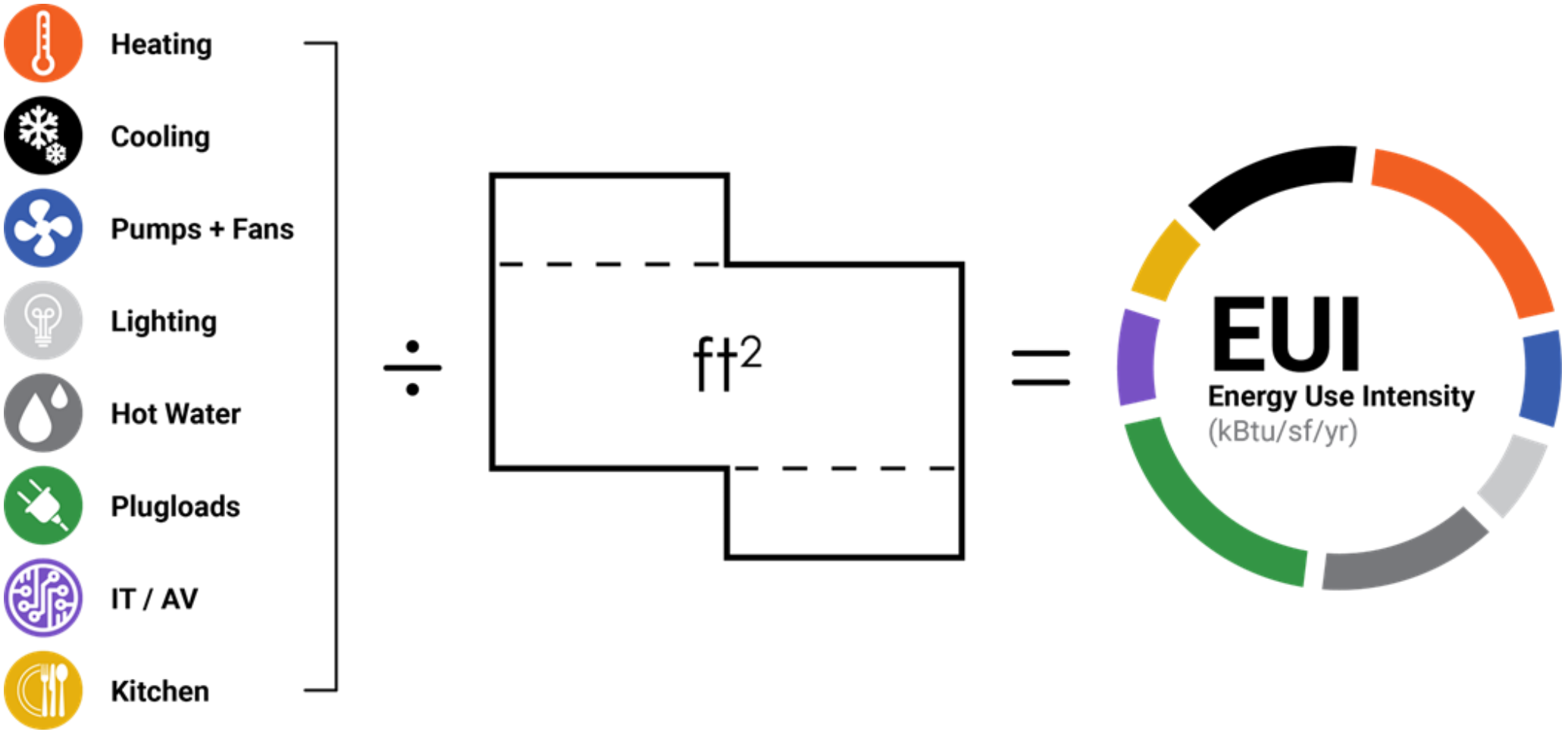
Buckley Elementary School – Manchester CT



Buckley ES Goals

- ✓ 21st Century Learning w/ 9,000 sf of additional program space
- ✓ Renovate-As-New
- ✓ Net Zero Energy w/ EUI < 25 kbtu/sf/yr
- ✓ Provide Excellent IAQ and Daylighting
- ✓ Electrification and Renewal of Systems
- ✓ Upgrade Building Envelope

What is Energy Use Intensity?



What is Net Zero Energy?

Measured for 365 days

Heating

Plug Loads

Lighting

Cooling

Pumps + Fans

Hot Water

Energy Consumption

-

On-Site Production

=

0

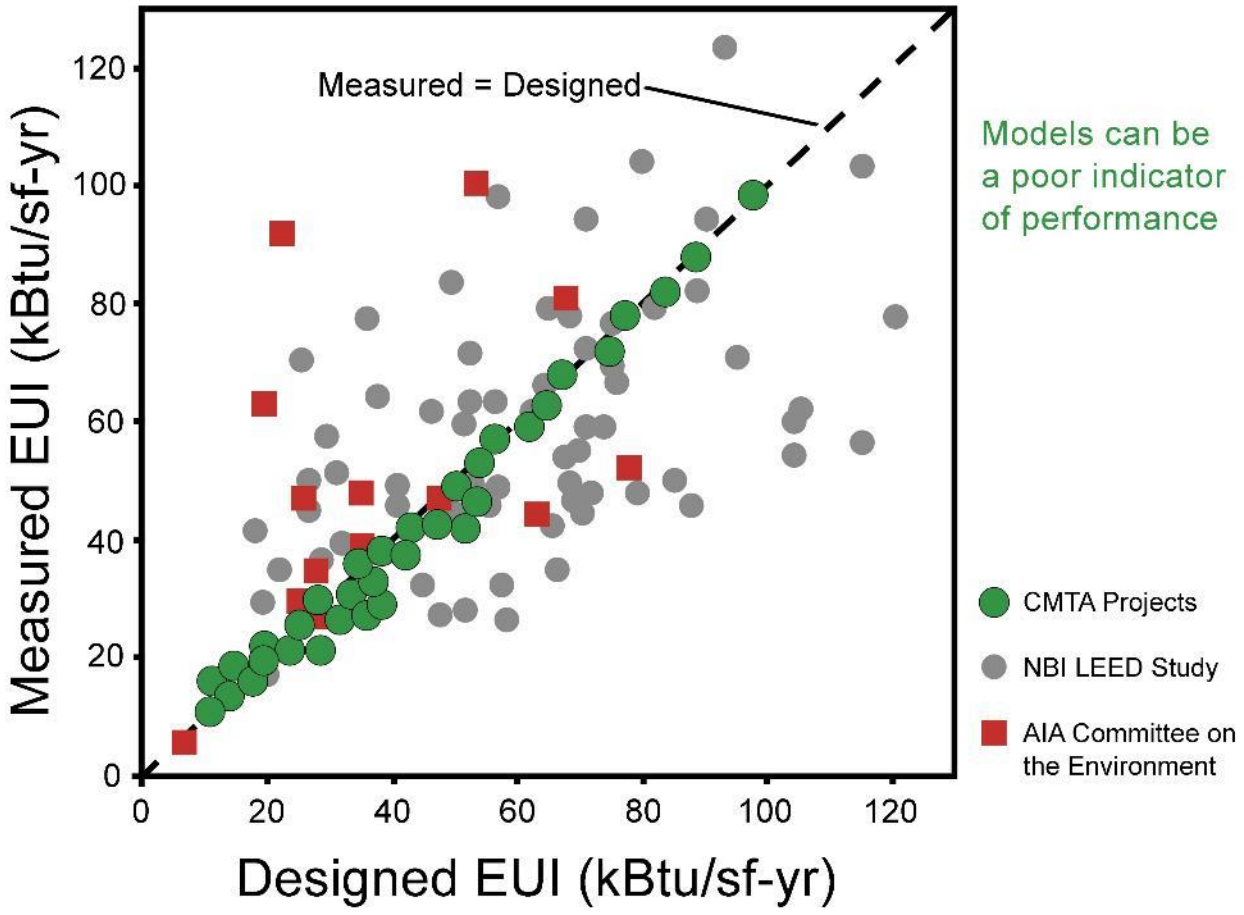
(kBtu / Year)

Floor area (SF)

Data Driven Process

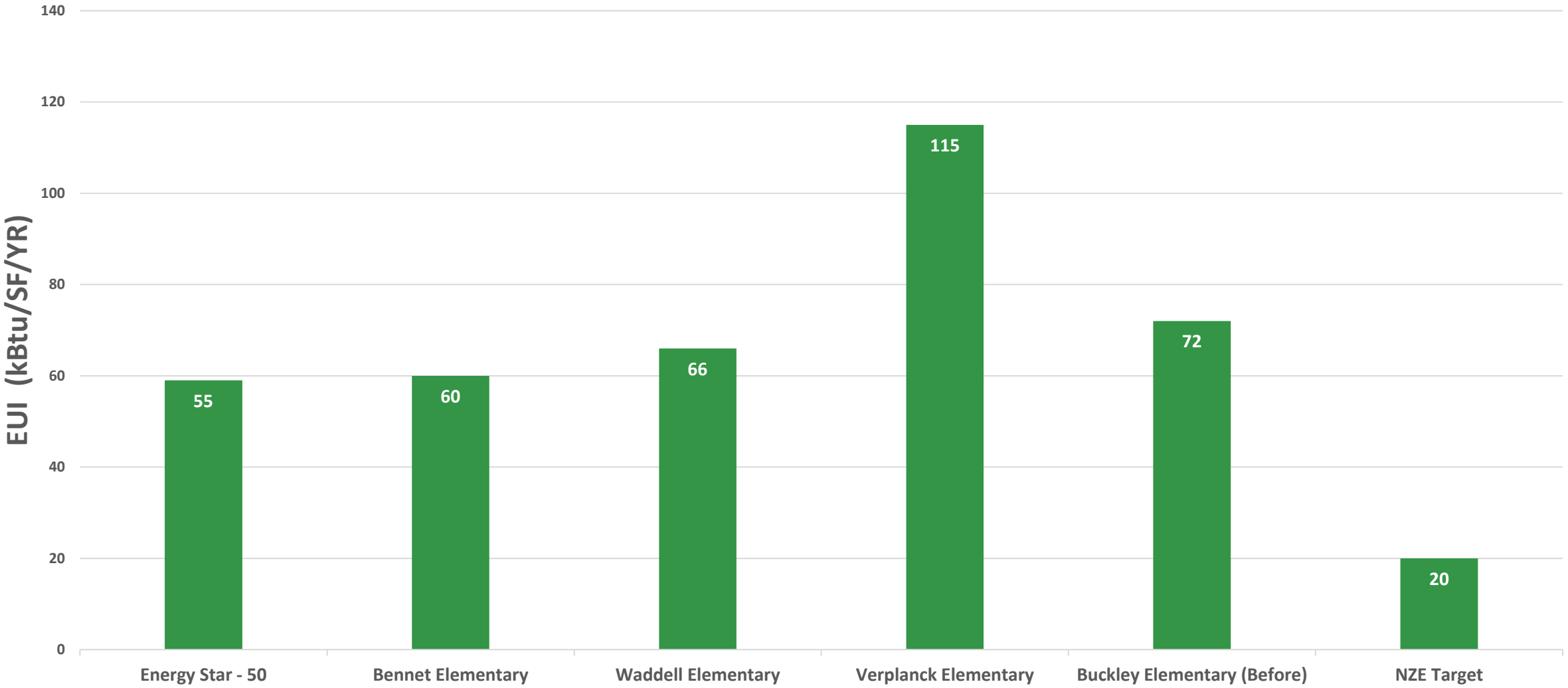
"You cannot manage what you do not measure."

– W. Edwards Deming



Benchmarking

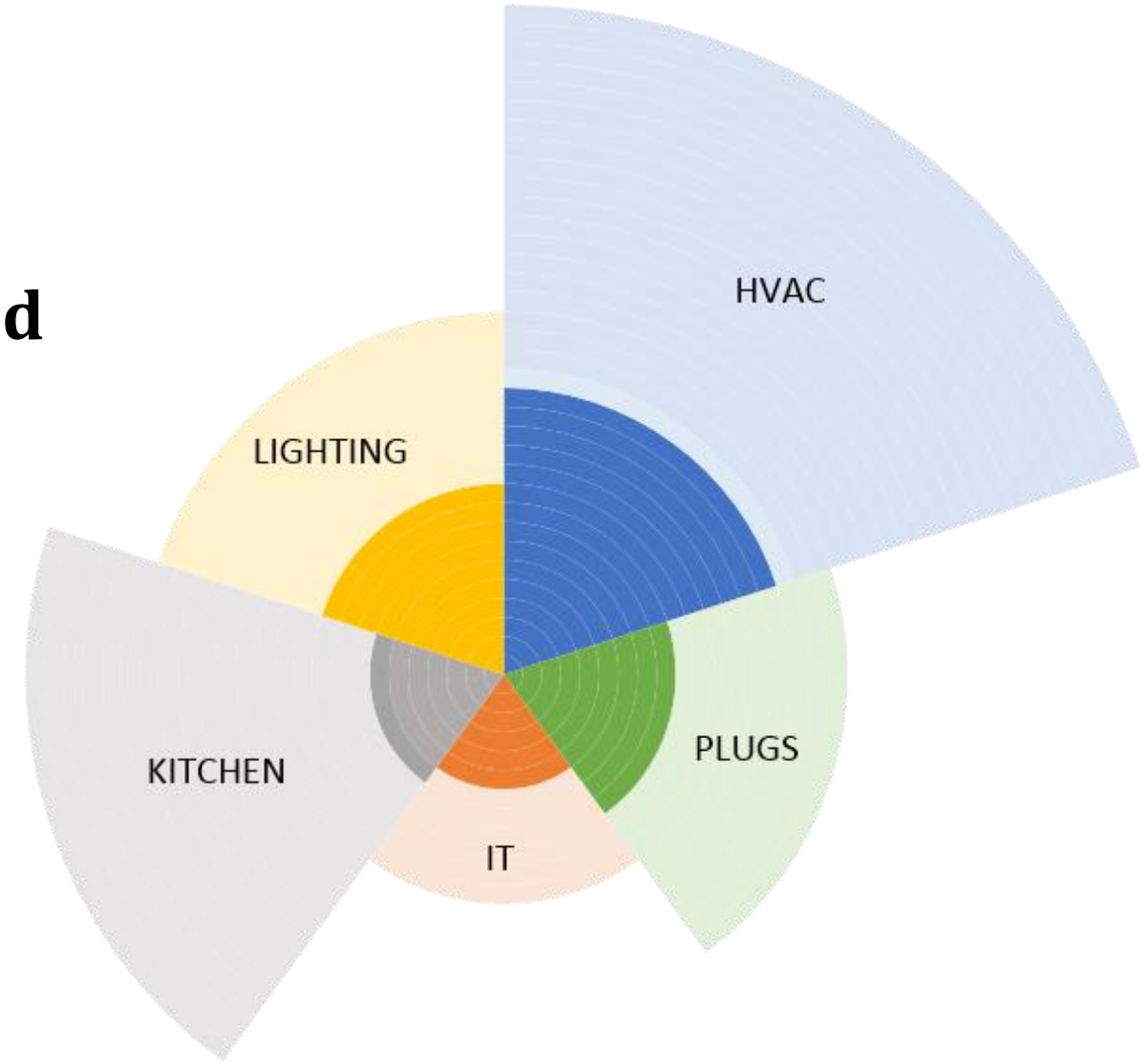
PARTIAL SCHOOL DISTRICT ENERGY USE INTENSITY



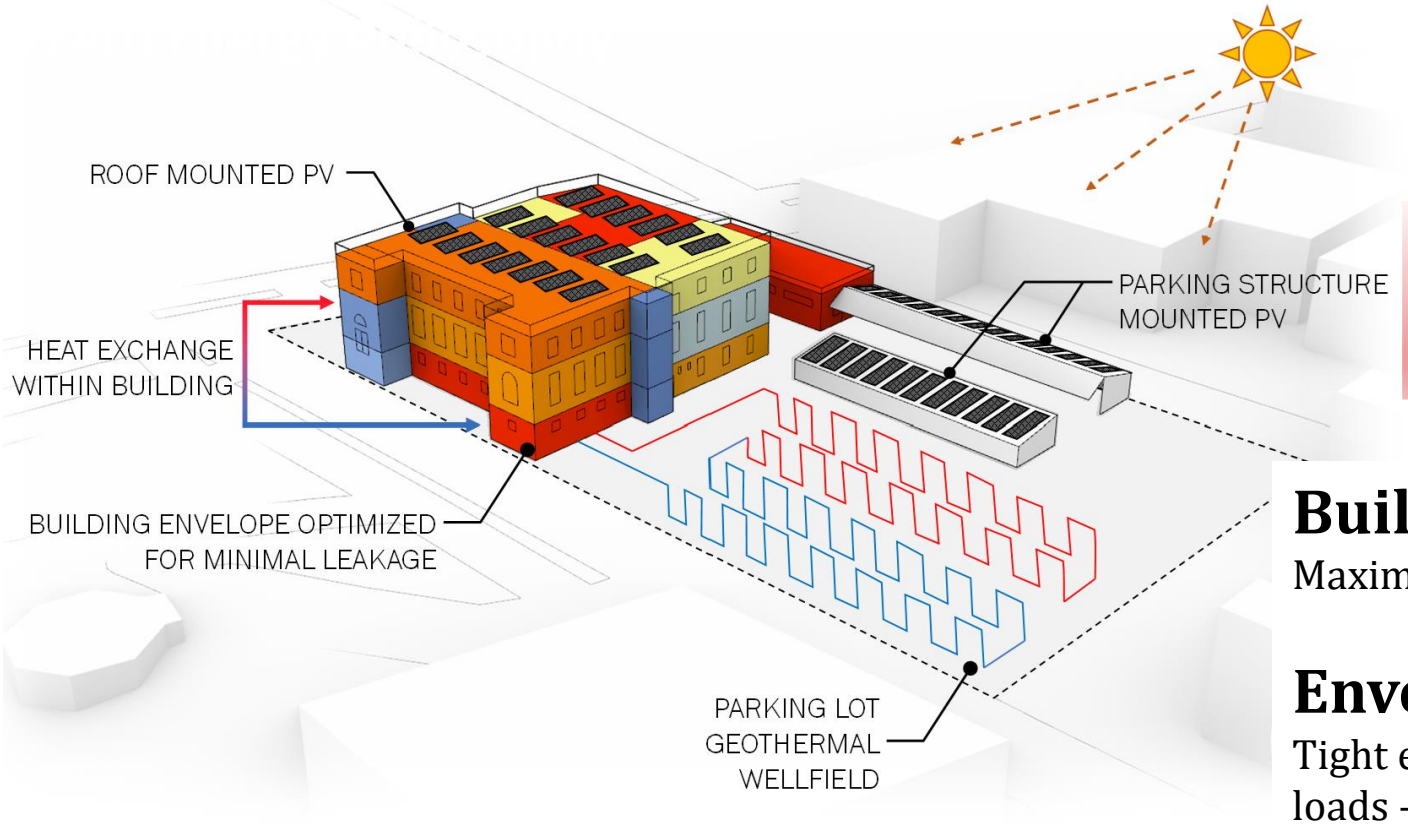
Follow the Energy

Drastic Energy Reduction is Needed

- **HVAC ~45%**
- **Kitchen ~20%**
- **Lighting ~20%**
- **Plug Loads ~10%**
- **IT ~5%**



What's the Process for Net Zero Energy?



Passive & Active Strategies

Building Orientation
Maximize daylighting and control solar heat gain

Envelope
Tight envelope for low infiltration, reduced heating and cooling loads – to a point

High Performance MEP Systems
Quality equipment, right-sized design

On-Site Renewable
Off set energy consumption with PV

Building Envelope

Orientation can't change but,

Increase Roof Insulation

--- R-35.3

Increase Exterior Wall Insulation

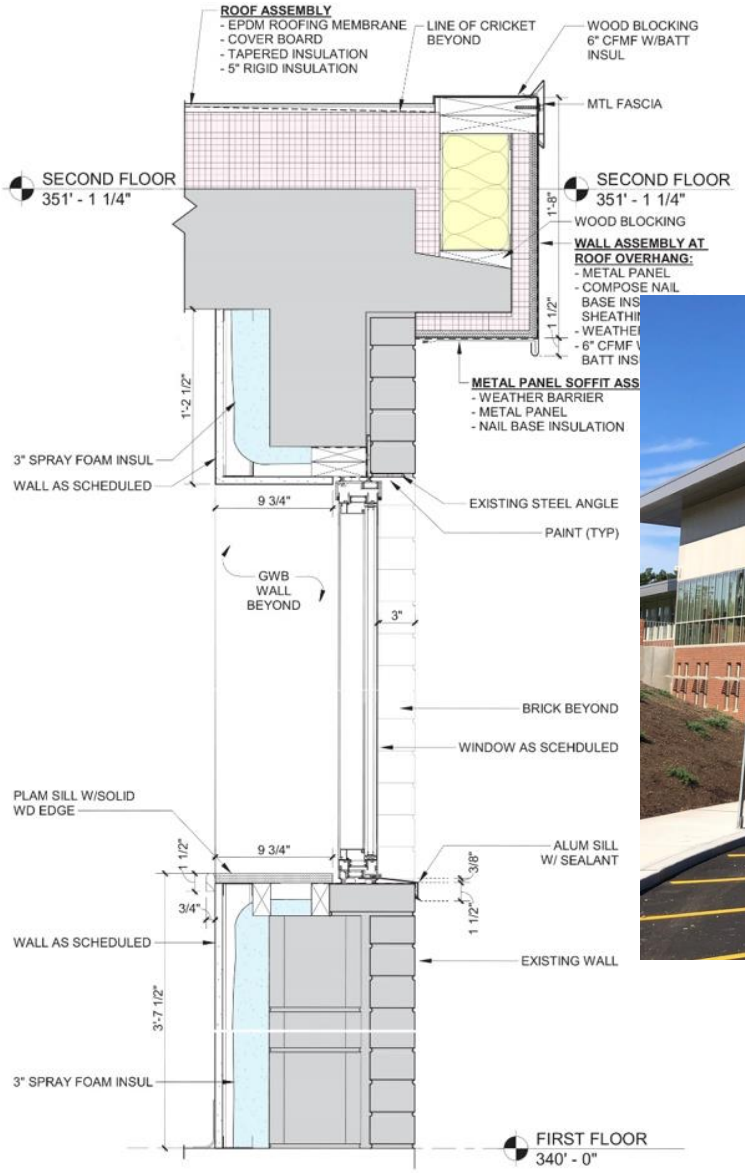
--- R-19 + R-12.6 c.i.

Improved Glazing

--- U-0.38 & SHGC 0.40

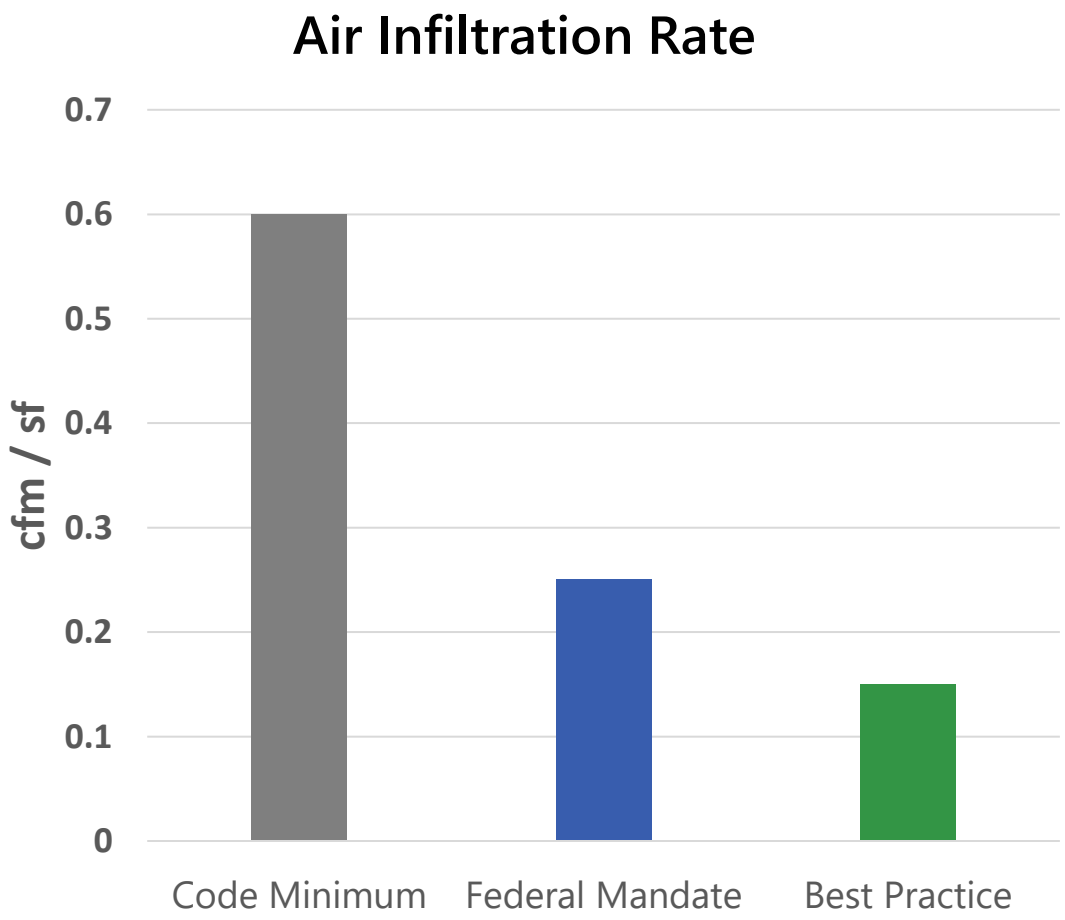
--- Double-Paned

REDUCE Infiltration!



Building Envelope Testing is Critical!

Pressure Testing Standards



Air Infiltration

- Code Minimum
- Federal Mandate
- Industry Standard

Testing Standards

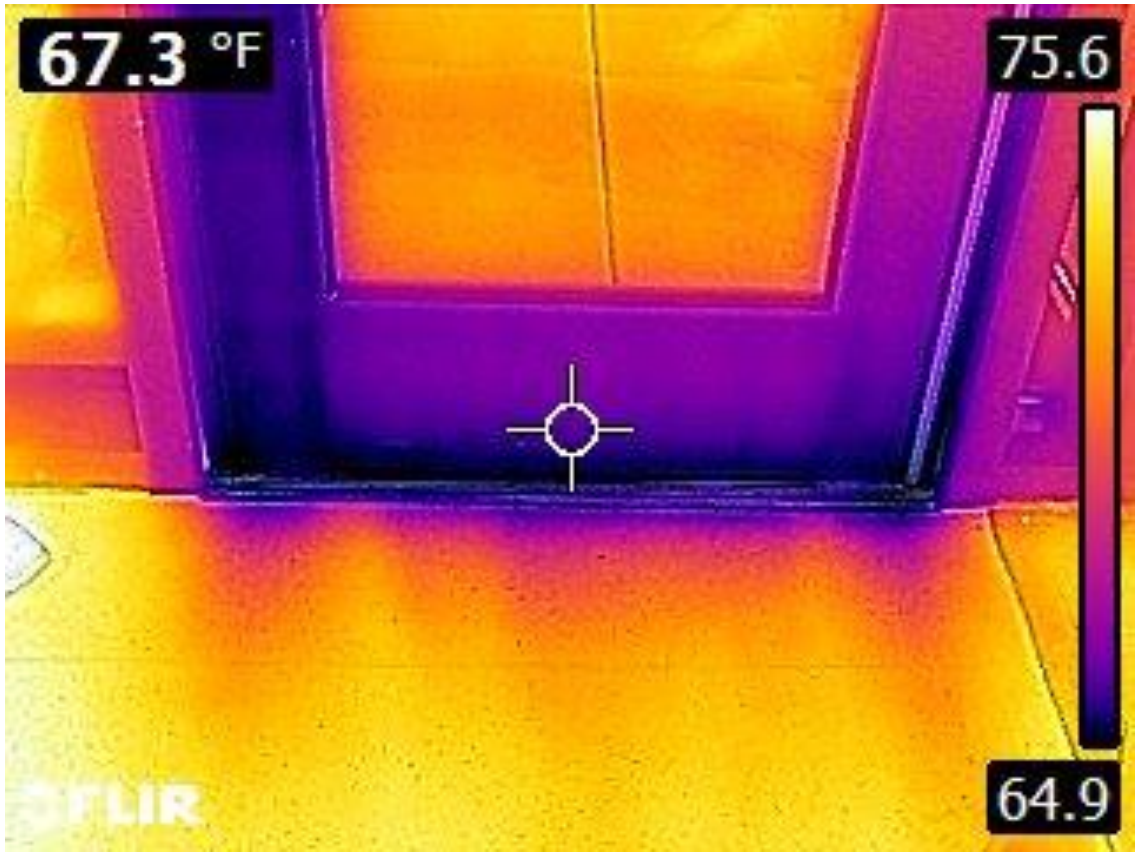
- ASTM E779
- ASTM E1827

Building Envelope Testing is Critical!

Blower Door Pressure Testing

Building Envelope Testing is Critical!

Thermal Scanning & Imaging

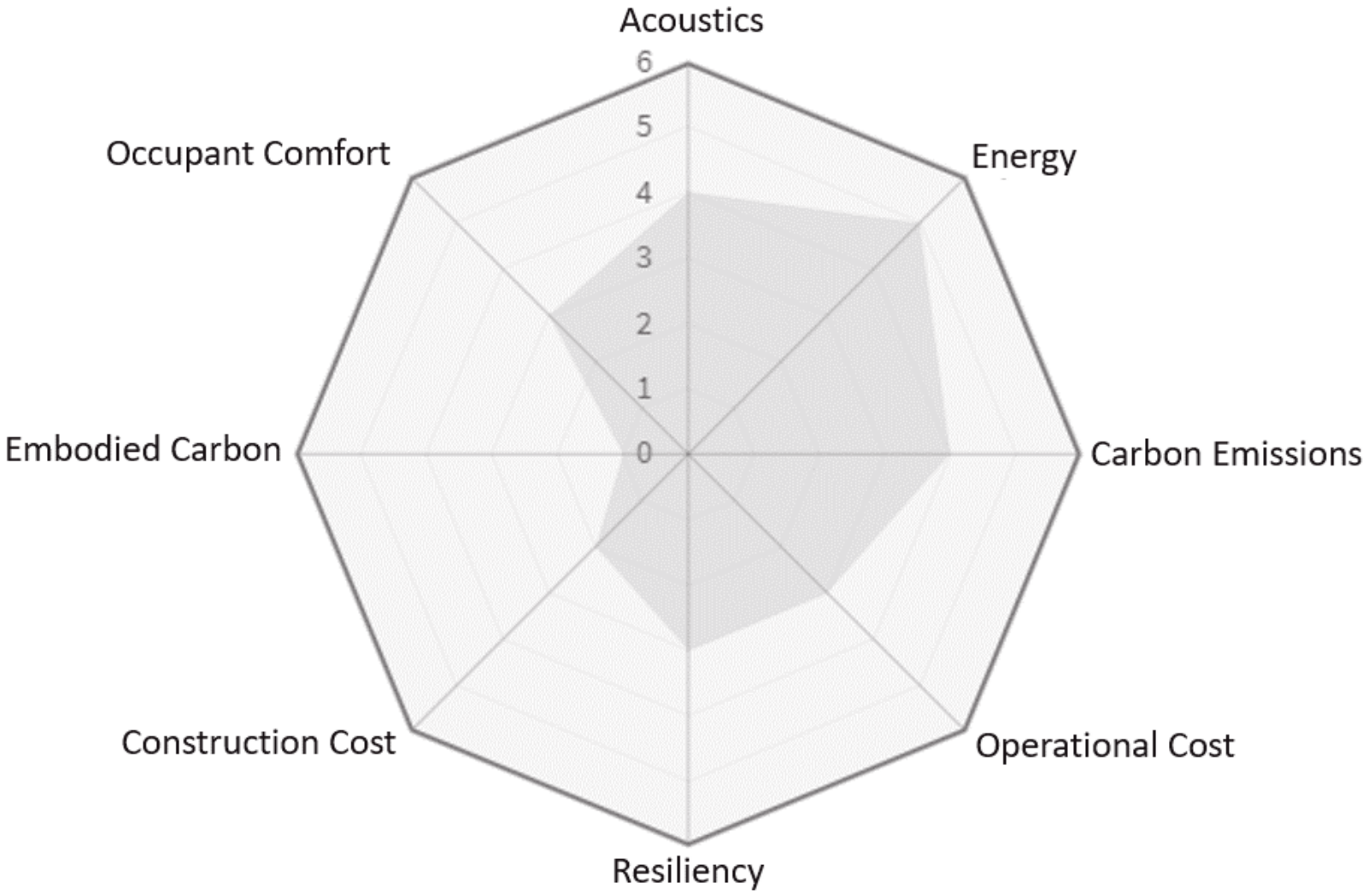


High Performance MEP Systems – Focus on HVAC

COMPETING PRIORITIES

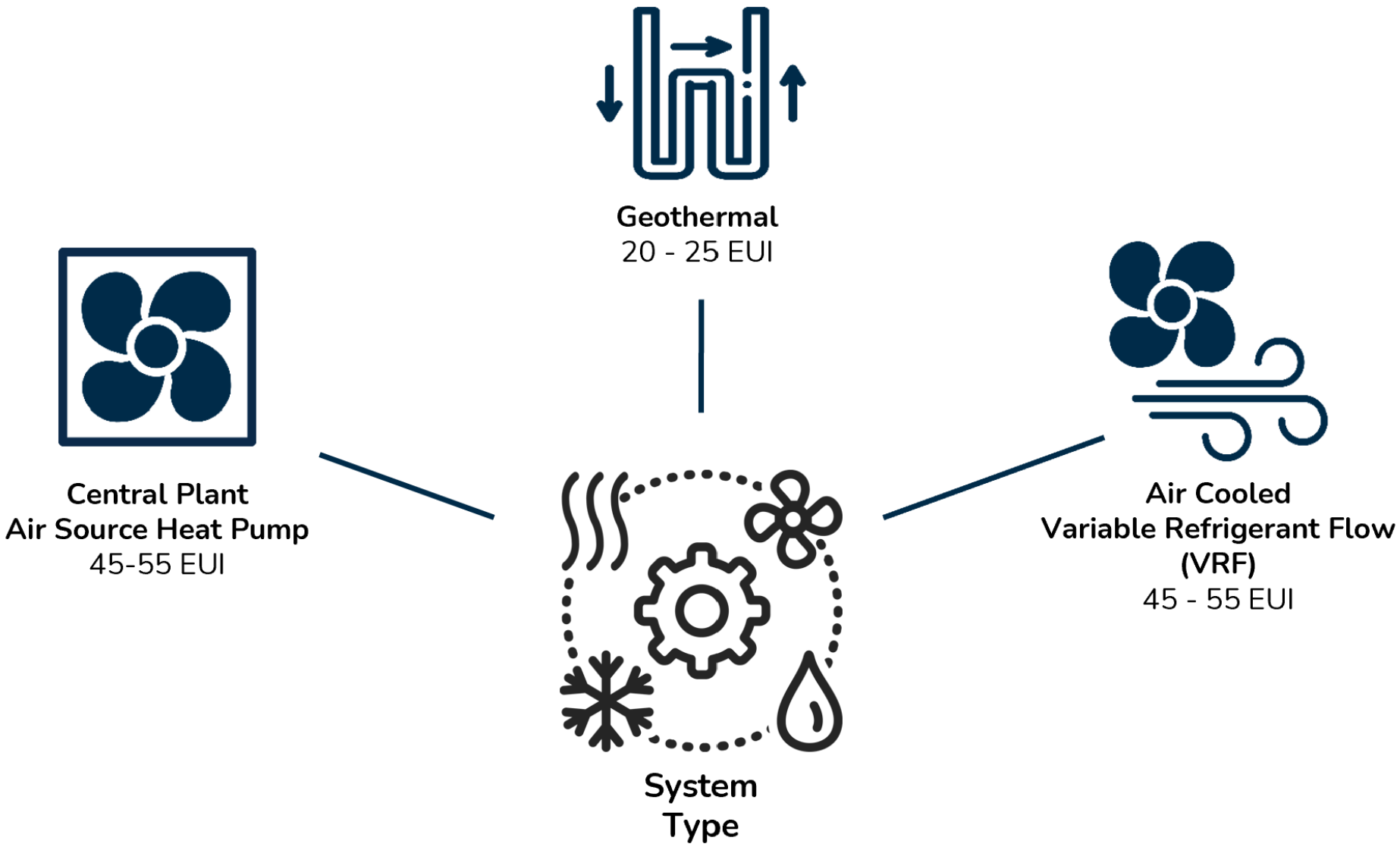
Selection Criteria

- ✓ Acoustics
- ✓ Emissions Implications
- ✓ Fewer Compressors
- ✓ First Cost
- ✓ Future Adaptability
- ✓ Individual Zoning
- ✓ Indoor Air Quality
- ✓ Low EUI
- ✓ Low Life Cycle Cost
- ✓ Minimal Space Implications
- ✓ Operating Cost
- ✓ PV Installation Size
- ✓ Refrigerant GWP
- ✓ Simplicity
- ✓ Speed of Construction



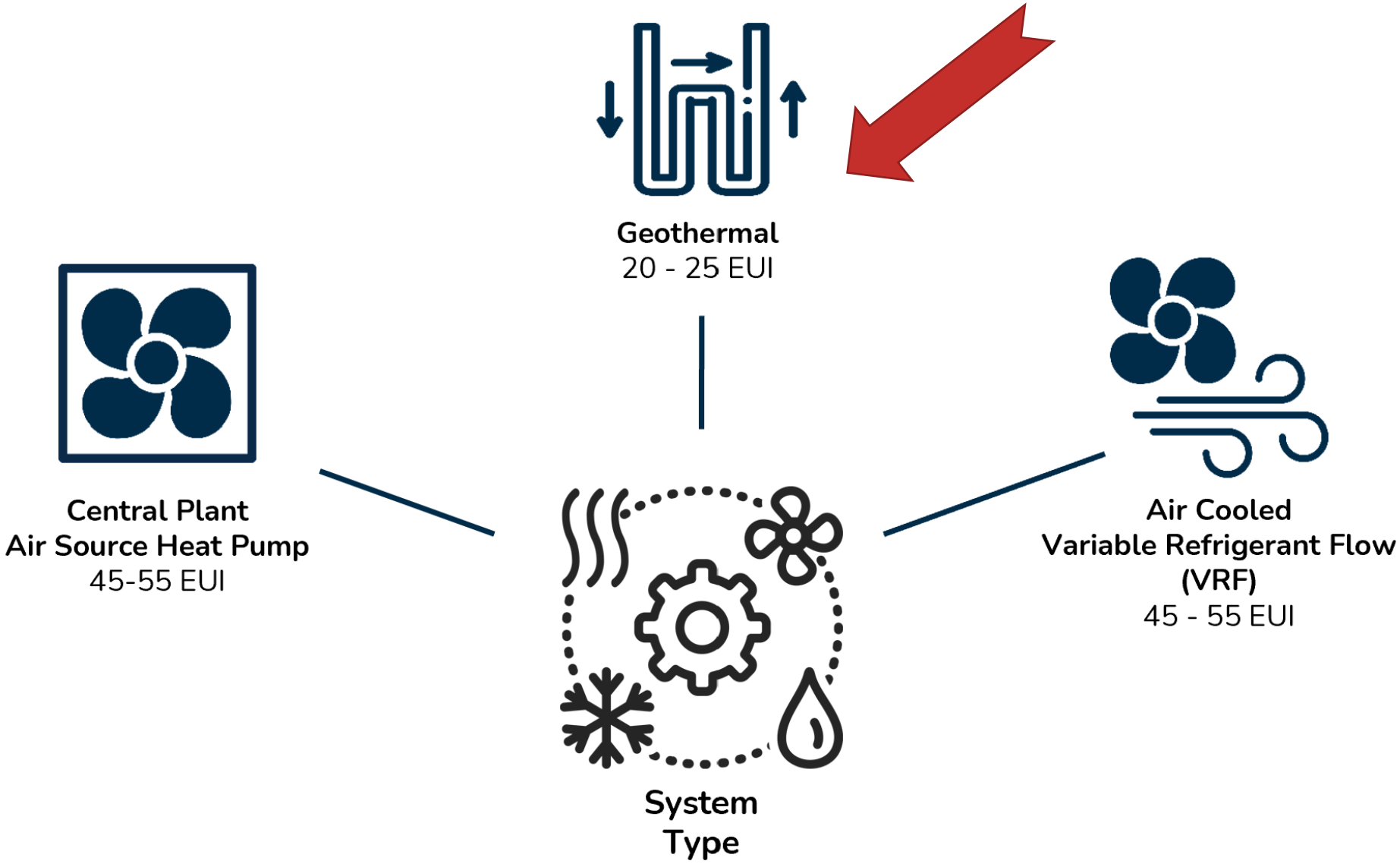
High Performance MEP Systems – Focus on HVAC

ELECTRIFICATION



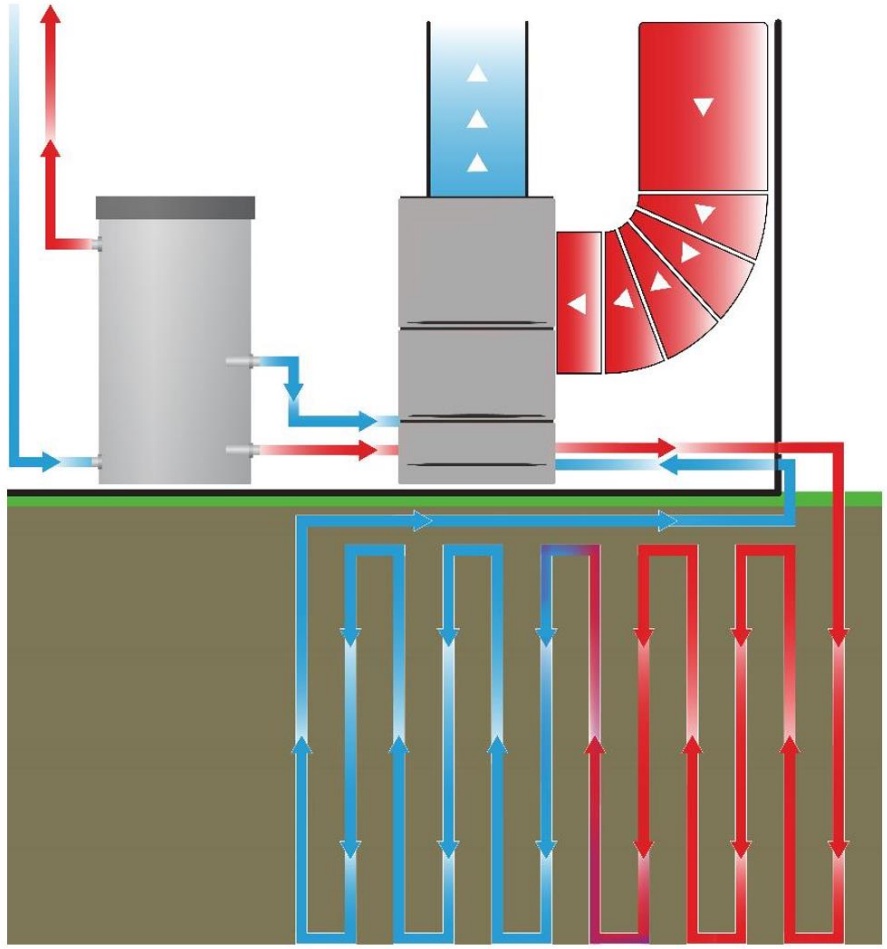
High Performance MEP Systems – Focus on HVAC

ELECTRIFICATION



High Performance MEP Systems – Focus on HVAC

GEOTHERMAL HVAC – WELLFIELD & PUMPING



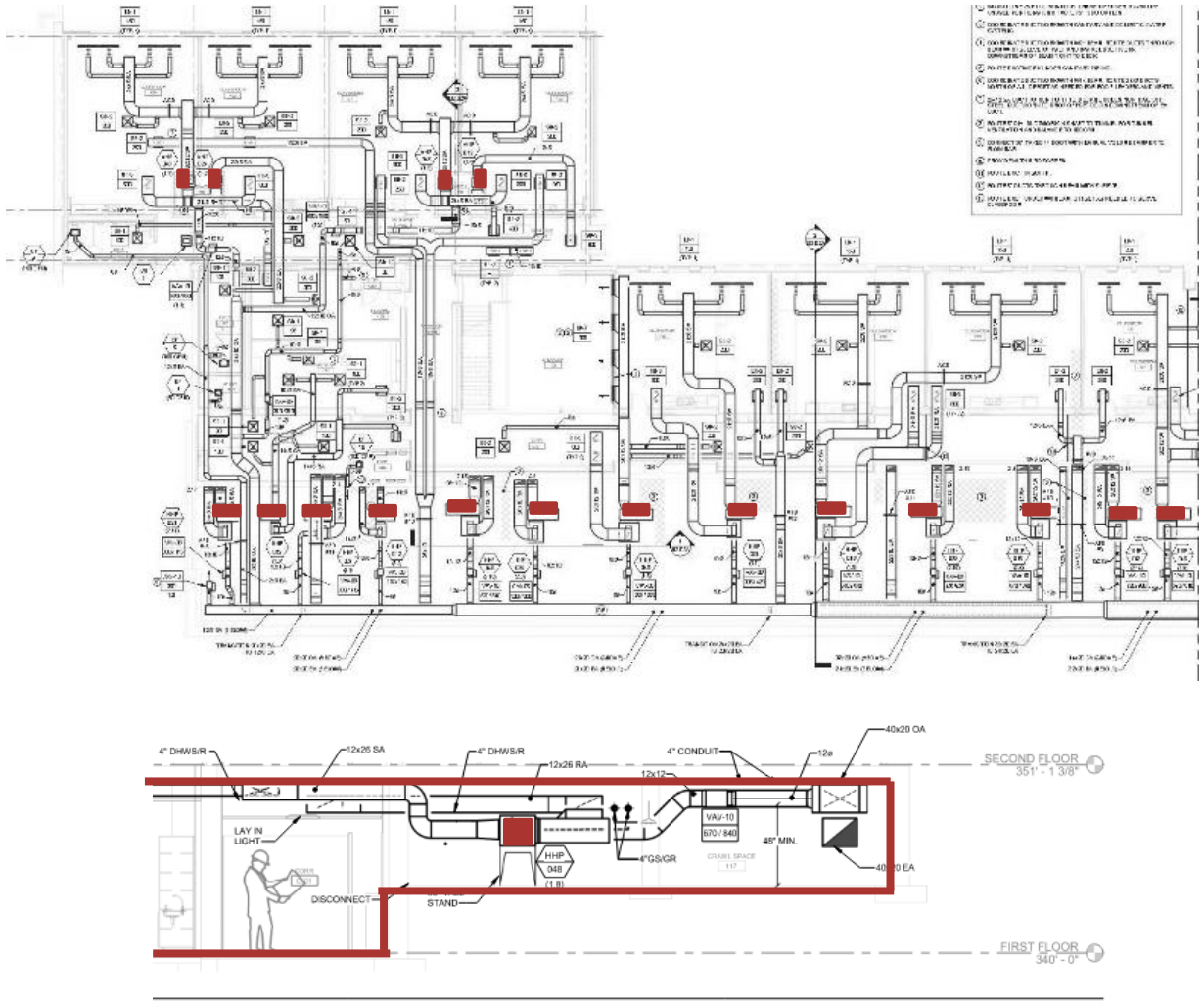
High Performance MEP Systems – Focus on HVAC

GEOTHERMAL HVAC – HEAT PUMP UNITS & DOAS

High Performance MEP Systems – Focus on HVAC

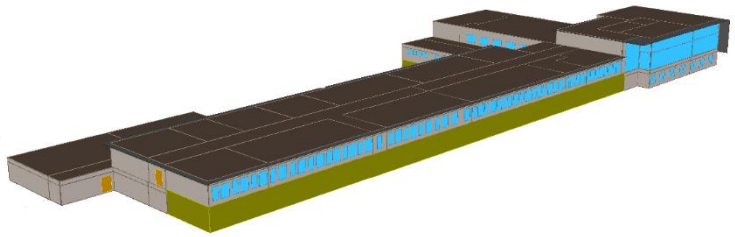
GEOTHERMAL HVAC

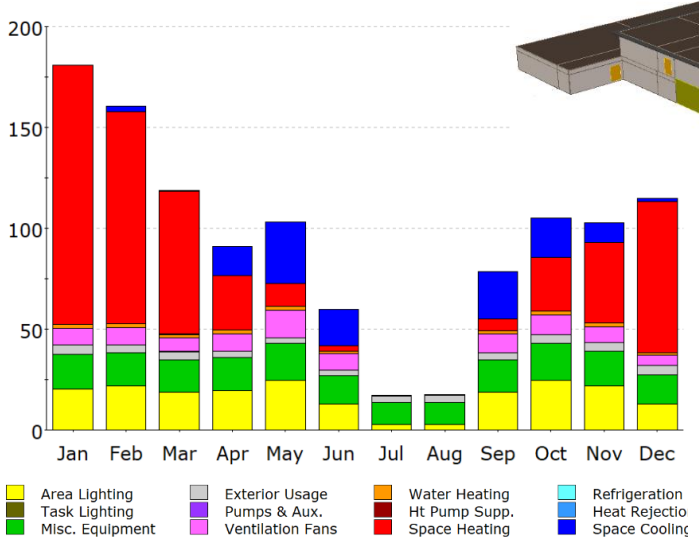
- ✓ Distributed Heat Pump Units throughout – took advantage of existing crawlspace
- ✓ Dedicated OA System with Demand Control Ventilation
- ✓ MERV 13 Filtration & UV Lighting



Renewable Energy – Solar PV

- ✓ 391 kw PV -> 18 EUI
- ✓ All on the Roof
- ✓ Predictive Energy Model Needed





What did it Cost?

Owner's Total Budget

$24,392,000 $360/SF

Actual Bid Results

Building	**$20,920,000**	**$309/SF (Feb.2021)**
PV Array	**$1,100,000**	**$17/SF (Nov.2021)**
Total	**$22,020,000**	**$326/SF**

Don’t forget about Utility Incentives!

EVERSOURCE

October 21, 2021

Christopher Till
Town of Manchester
P.O. Box 191, 321 Olcott Street
Manchester, CT, 06045

Reference: Energy Efficiency Project # CT20-P00072533 **REVISED**
Buckley Elementary School, 250 Vernon Street,Manchester, CT, 06042

Dear Christopher Till:

Congratulations on choosing to make your business energy-efficient! Eversource is pleased to present you with the details of your energy incentive for the upcoming project at your **Manchester, Connecticut facility.**

Should you decide to move forward with the project as submitted, you are eligible for a financial incentive of **$266,789.00.**

This packet includes the following documents:

Energy Efficiency Services Letter of Agreement – Please review the document, sign both copies, and return one copy to my attention at the address noted below. **To reserve your incentive as stated, return the signed Agreement within 30 days of the signature date on the Agreement.**

Standard Terms and Conditions – In order to claim your incentive, you will need to agree to these terms.

W-9 Form – This form is necessary to process your incentive payment. Submit this completed form with your Energy Efficiency Services Agreement.

Exhibit A – The upgrades included in your project are outlined here. Information includes the energy and dollar savings estimated for each individual measure.

If you have any questions regarding this letter or the documents contained in the packet, please contact me.

Sincerely,

Jordan Schellens
Energy Efficiency Consultant - New Construction
Eversource
107 Selden Street
Berlin, CT 06037
jordan.schellens@eversource.com
860-665-3749

- ✓ **Leverage Available Incentives**
- ✓ **Contact Utility Company Early in Process**
- ✓ **Inflation Reduction Act Potential**
- ✓ **$266,789 Incentive for the Owner**

THANK YOU

CMTA.COM

Q&A

Contact us at EHSC@lbl.gov

Resources - Decarbonization

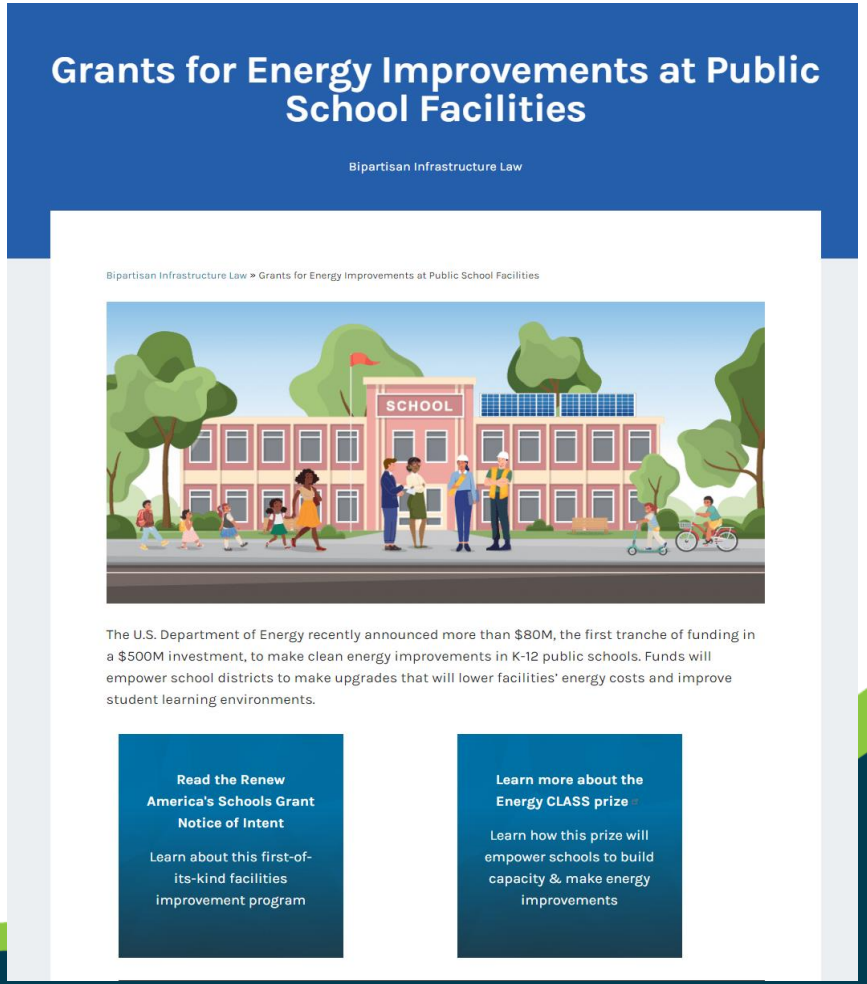
Check out the campaign site's resource pages, including decarbonization all in one place. Decarbonization examples:

- Zero Energy Schools Accelerator
- Low Carbon Technology Strategies guidance
- NREL Advanced Energy Retrofit Guide
- … and more!

Upcoming Funding

- Check out this page for exciting new funding opportunities.
  - America's Schools Grant Notice of Intent
  - Energy CLASS prize

See our webinar recording from November 8th to learn more!



Grants for Energy Improvements at Public School Facilities

Bipartisan Infrastructure Law

Bipartisan Infrastructure Law » Grants for Energy Improvements at Public School Facilities

The U.S. Department of Energy recently announced more than $80M, the first tranche of funding in a $500M investment, to make clean energy improvements in K-12 public schools. Funds will empower school districts to make upgrades that will lower facilities' energy costs and improve student learning environments.

Read the Renew America's Schools Grant Notice of Intent

Learn about this first-of-its-kind facilities improvement program

Learn more about the Energy CLASS prize

Learn how this prize will empower schools to build capacity & make energy improvements

Webinars (for schools and districts) interested in recognition, planning track:

- Emissions Reduction and Resilience

Jan 24th: Electrification Readiness for School Districts

February 28: Understanding Greenhouse Gas Tracking and Reporting in School Districts

March 28: Take Action on Climate! Planning for Climate Vulnerability and Resiliency in Schools

- Energy Efficiency Plus Health

Jan 10th: What's in Your Kit? Tools to Save Energy and Improve IEQ in Schools

Feb 14: Understanding Your Building Stock: Energy Benchmarking and IEQ Assessments for Schools

Mar 14: Building Assessment Tools for School Energy Retrofits

~~Recognition~~ Program: Planning Track Timeline

Webinar Series

Interested schools and districts will participate in a webinar series between **January and March 2023.**

Final Submission

Schools and districts will complete a final submission by **May 1, 2023** to summarize key learnings and describe how tools or approaches can be applied in their school facilities.

Preparation

Schools and districts will prepare their materials for final submission.

Announcement

Schools and districts receiving recognition will be invited to attend an in-person celebration in **June 2023.**

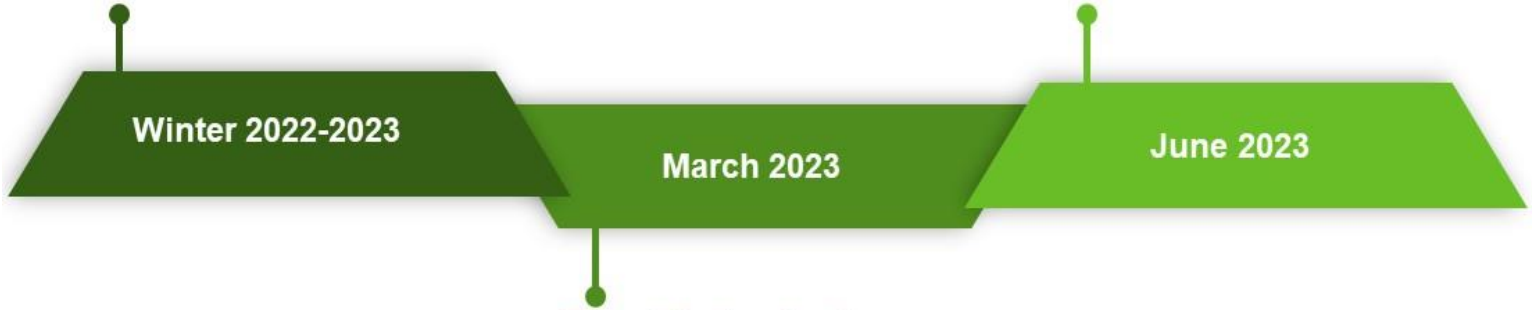
Recognition Program: Implementation Track Timeline

Preparation

Interested schools and districts will fill out a recognition application and request assistance from the campaign if needed.

Announcement

Schools and districts receiving recognition will be invited to attend an in-person celebration in **June 2023.**



Final Submission

Schools and districts will complete and send the application together with supporting materials by **March 1, 2023.**