Getting the $ and People On-board for a Zero Energy School

November 4th, 1-2pm

Northeast Energy Efficiency Partnerships

"Assist the Northeast and Mid-Atlantic region to reduce building sector energy consumption 3% per year and carbon emissions 40% by 2030 (relative to 2001)"

Mission

We seek to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities.

Vision

We envision the region's homes, buildings, and communities transformed into efficient, affordable, low-carbon, resilient places to live, work, and play.

Approach

Drive market transformation regionally by fostering collaboration and innovation, developing tools, and disseminating knowledge

Massachusetts Achieving Zero Energy (MAZE)

- **<u>Codes</u>**: Provide technical assistance, resources and collective strategic planning with the goal of advancing Massachusetts to a zero energy building code by 2030.

- **<u>Zero Energy Schools</u>**: Continue with Northeast CHPS, provide targeted technical assistance to communities, and convene working group of school building professionals.
  - Goal: Increase the # of zero energy schools in Massachusetts and help make zero energy schools a viable option for more communities

Webinar Overview & Housekeeping Rules

NEEP is hosting this webinar to give stakeholders a different perspective on zero energy schools and pique the interest of those who haven't yet considered a zero energy school for their community.

- Opening poll
- Two 15 min presentations
- Q & A
- Resources
- Closing poll

Opening Poll

Meredith Elbaum

Executive Director of USGBC, MA Chapter

Zero Energy Buildings in Massachusetts: Saving Money from the Start

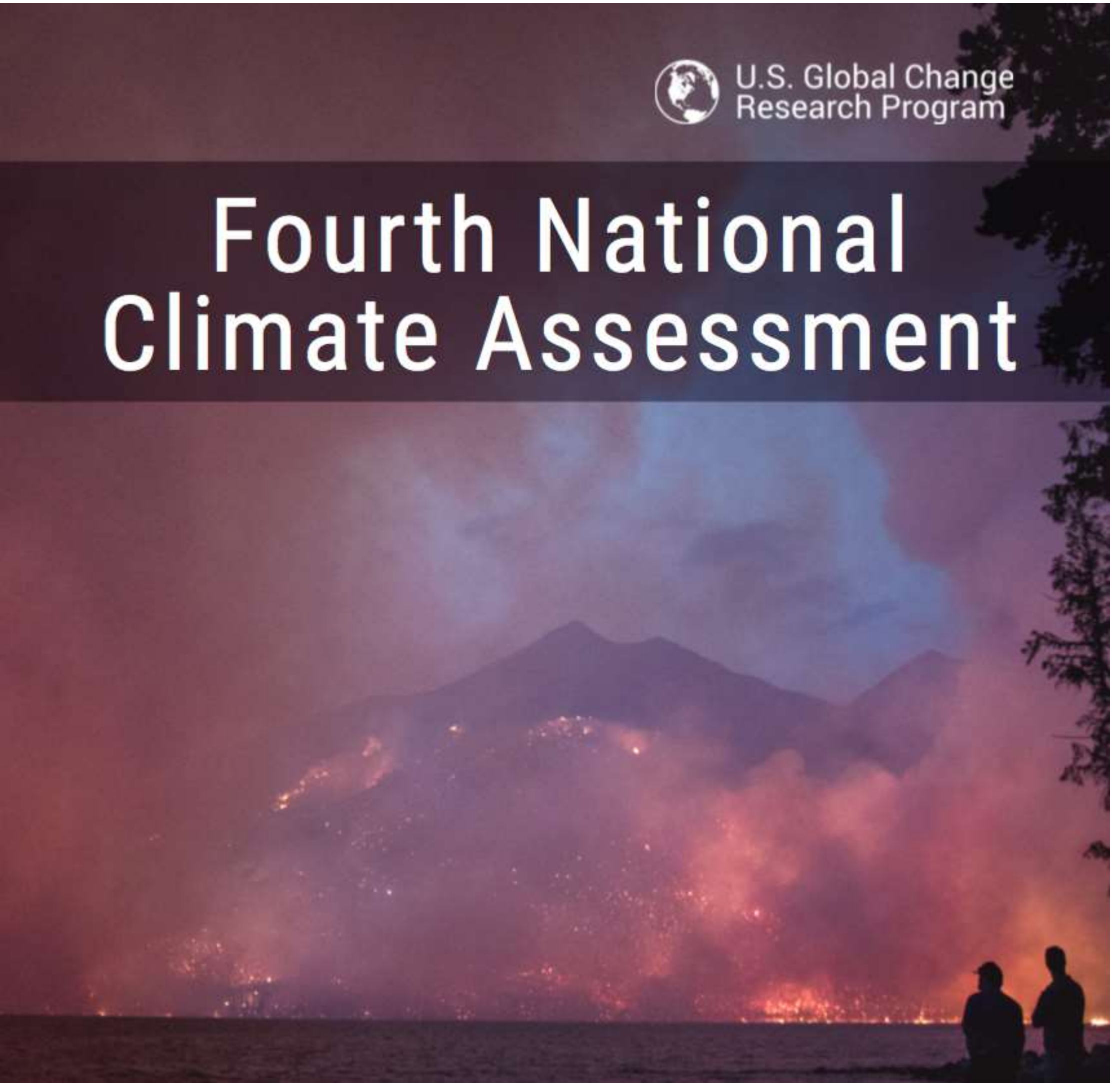
2019 REPORT

USGBC MASSACHUSETTS

Meredith Elbaum, Executive Director

USGBC
MASSACHUSETTS

Driving sustainable and regenerative design, construction, and operations of the built environment.



Global climate continues to change rapidly

Northeastern U.S. is particularly vulnerable

Must reduce greenhouse gas (GHG) emissions and do so as soon as possible.

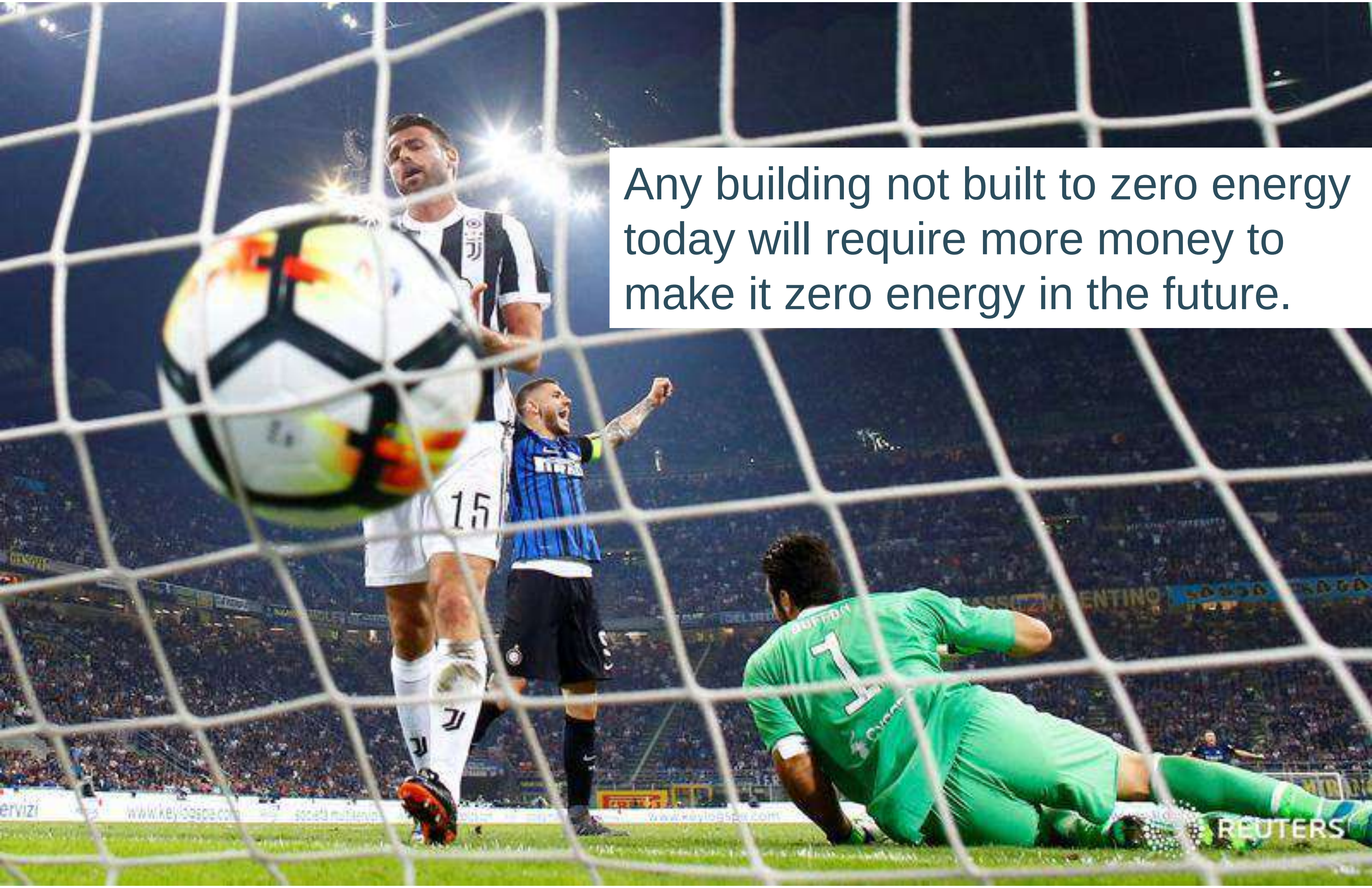
FIGURE 1

Why Buildings?

The buildings and construction sector is a key actor in the fight against climate change: it accounted for 36% of final energy use and 39% of energy and process related emissions in 2017 globally.

SOURCE: https://www.unenvironment.org/resources/report/global-status-report-2018

"….the global building stock is expected to double by 2060, with two-thirds of the building stock that exists today still in existence."

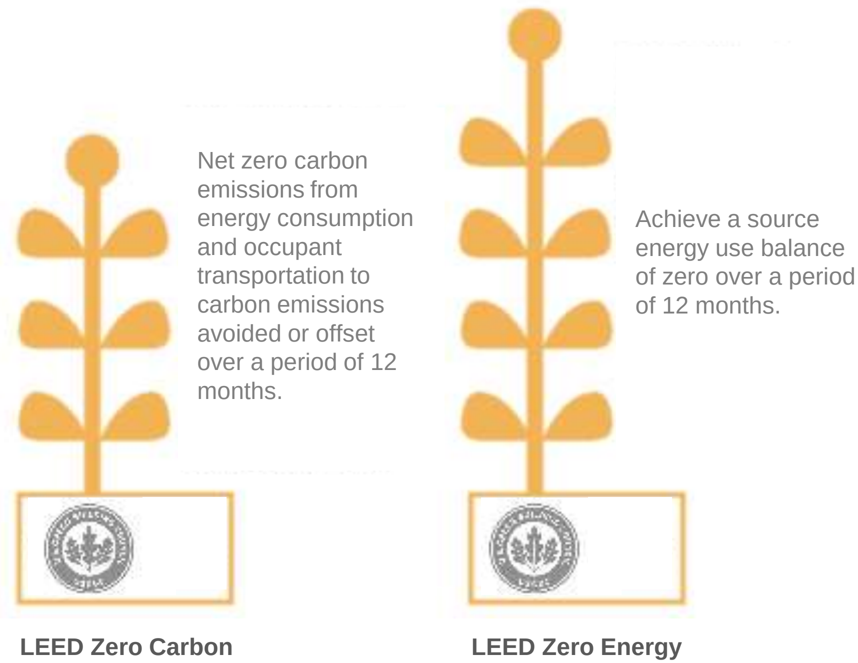


Any building not built to zero energy today will require more money to make it zero energy in the future.

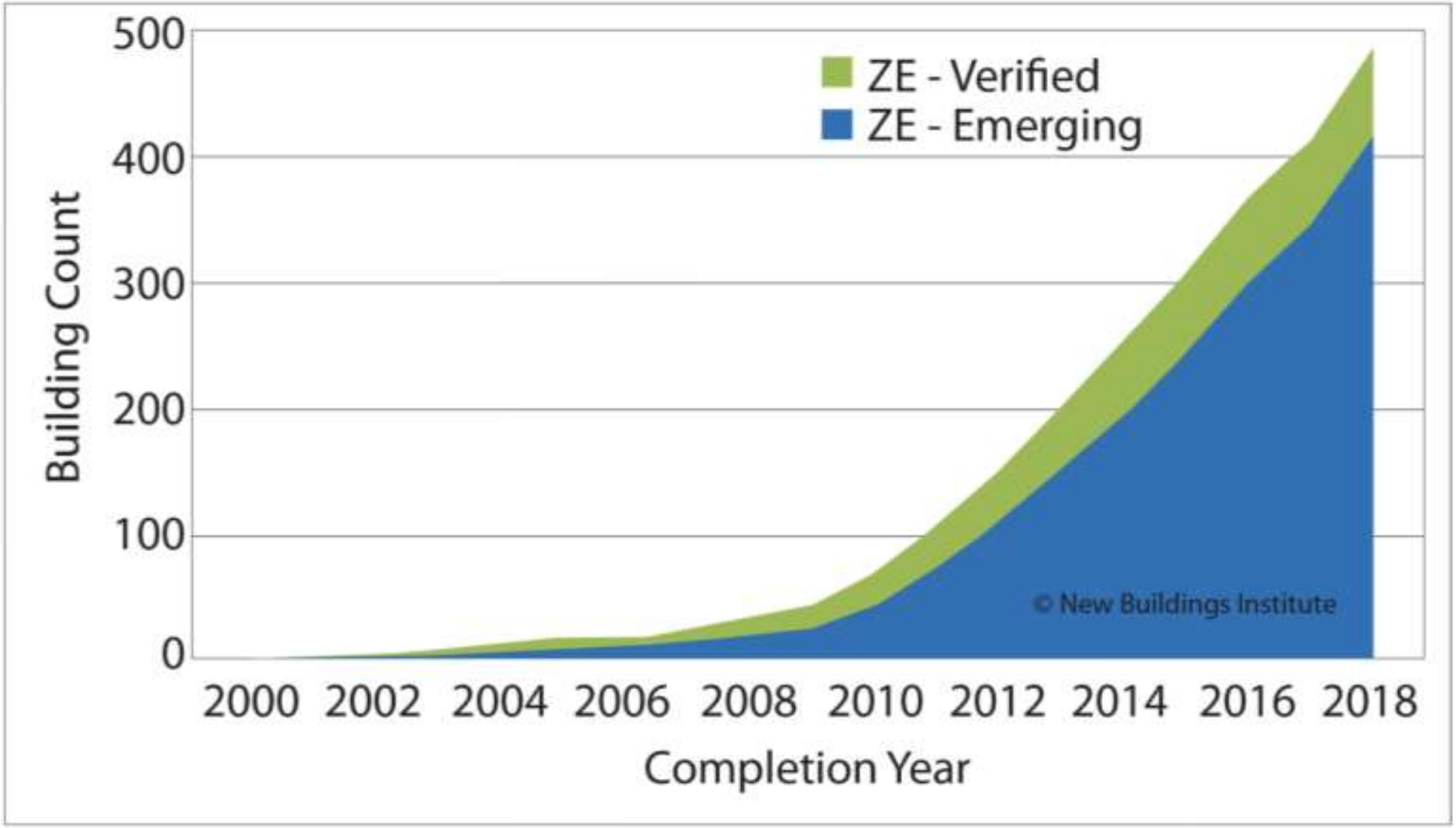
NET ZERO ENERGY = ZERO NET ENERGY = ZERO ENERGY

Various Certifications

ZNE Certifications



Zero Energy Building Growth



Growth by Building Ownership

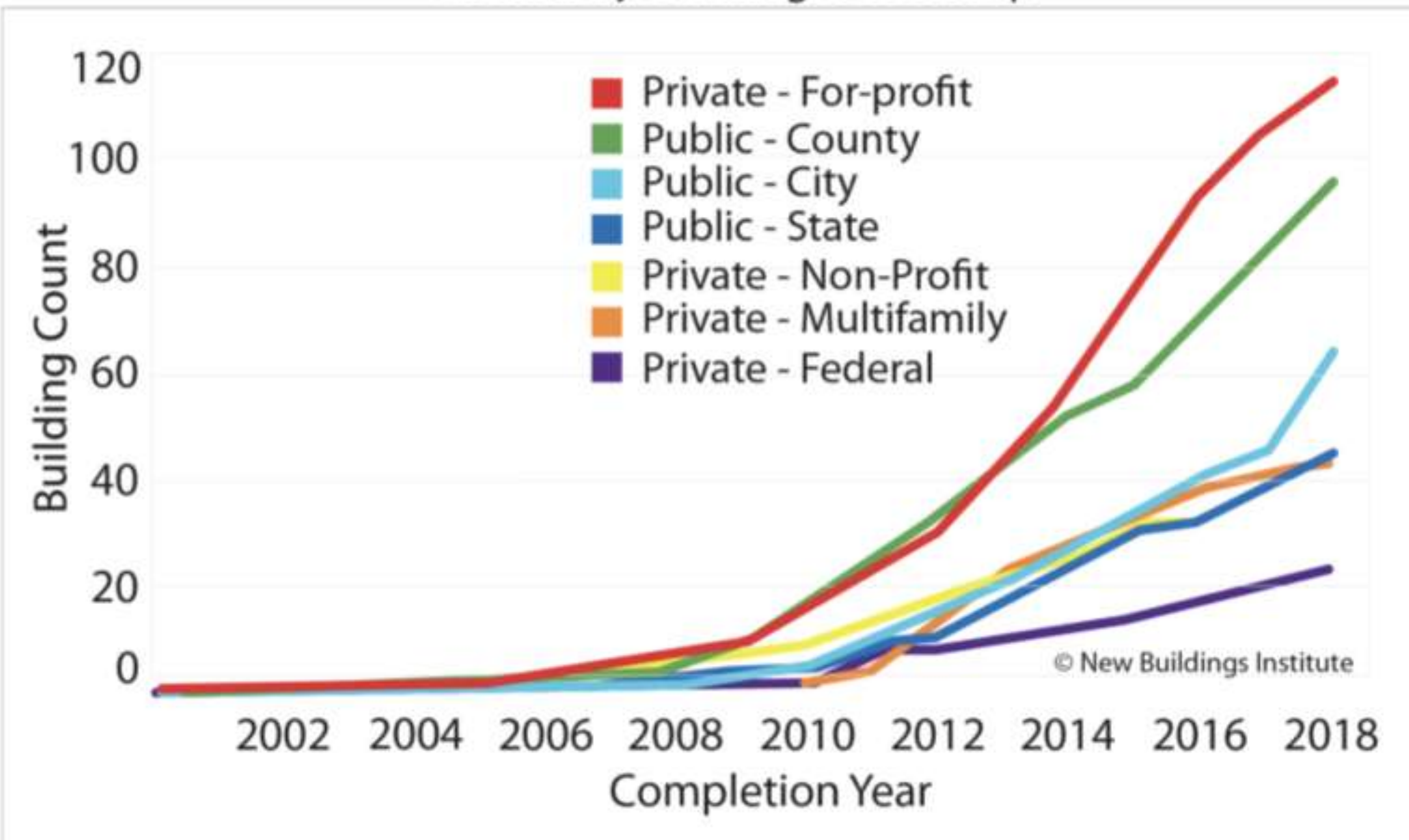
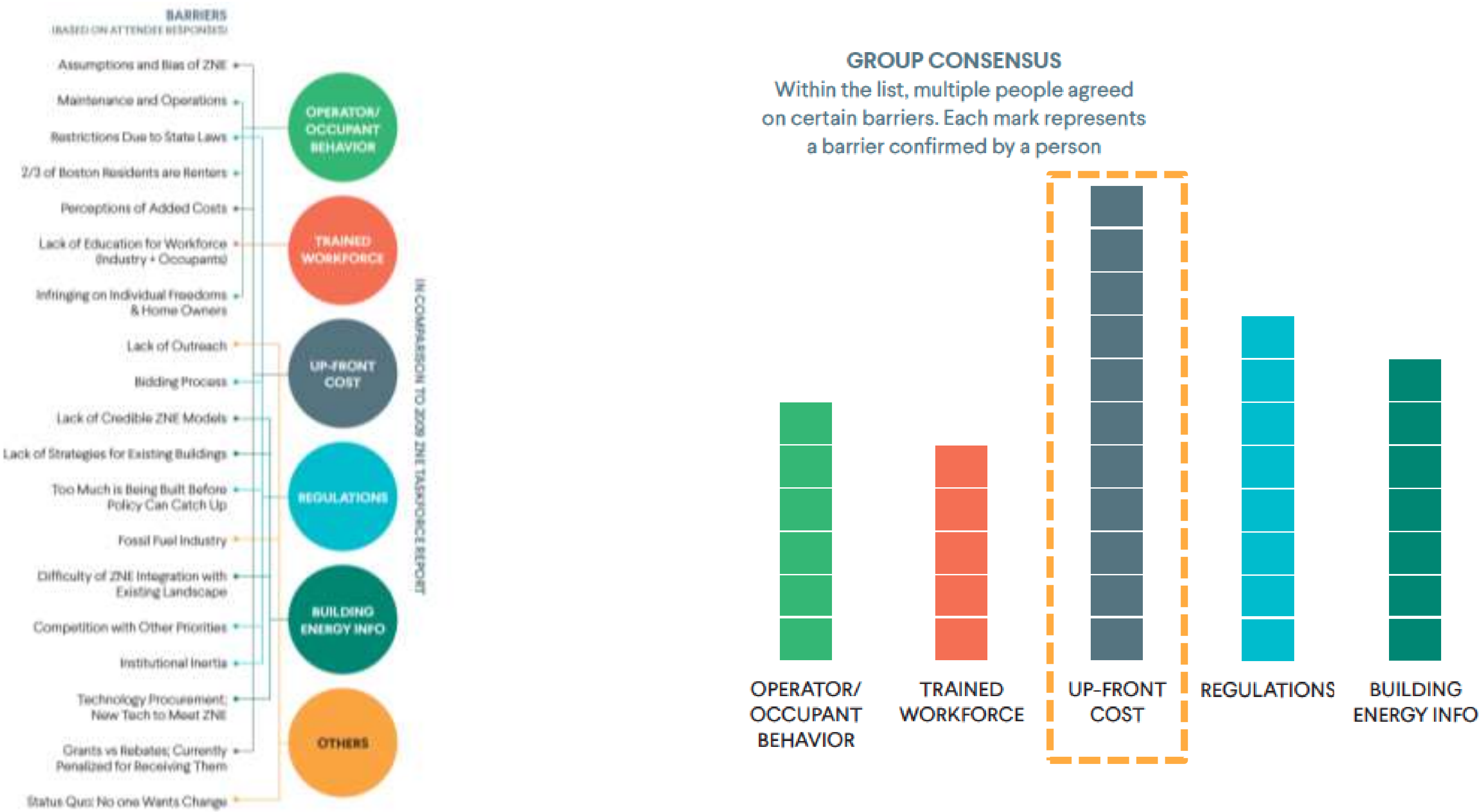


FIGURE 41

Barriers to ZE: “What obstacles are you facing pertaining to ZE?”



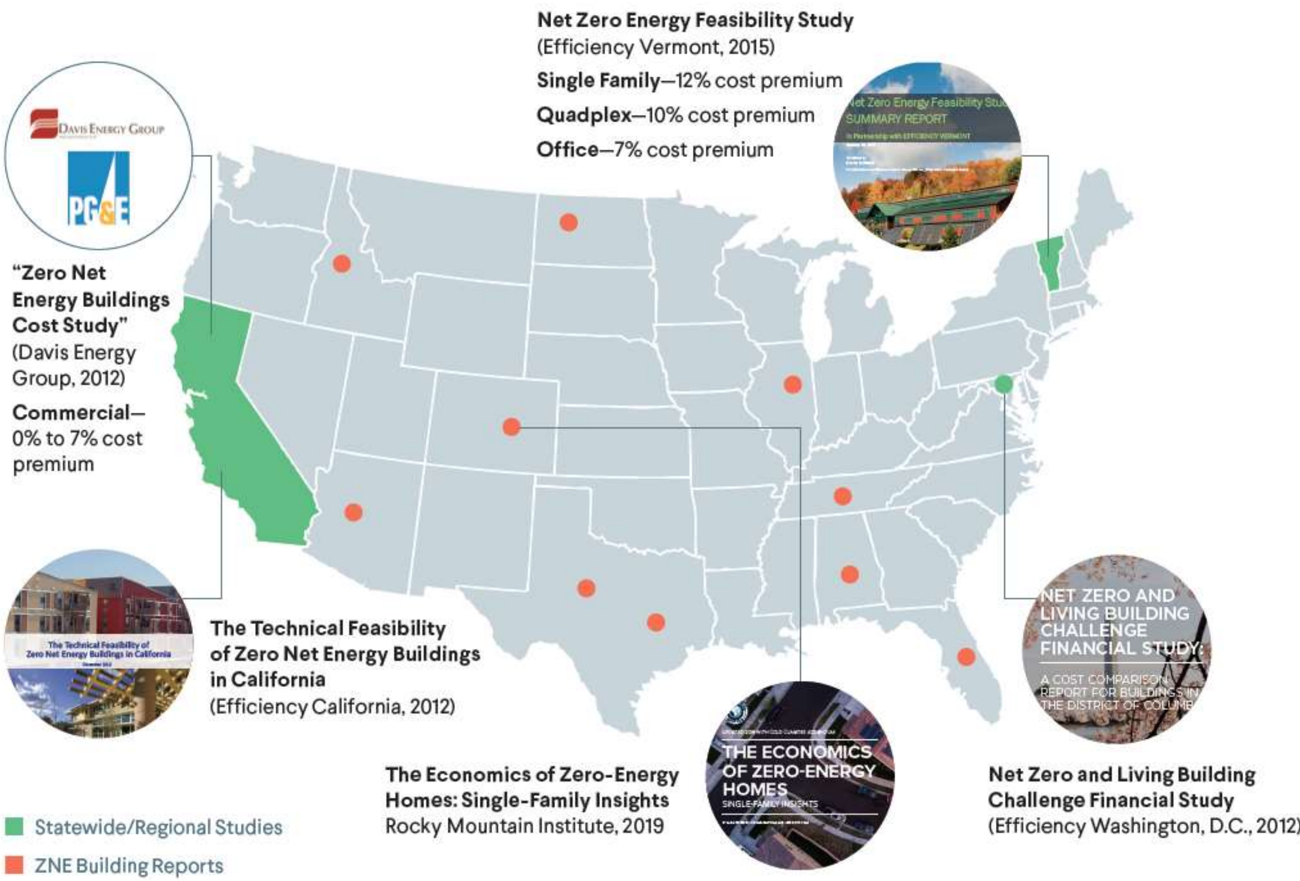
Zero Energy Buildings in Massachusetts: Saving Money from the Start

2019 REPORT

FIGURE 3

ZE Studies in the US

Multiple studies have been conducted around the county on the upfront cost premium of ZE buildings.



Case Studies

King Open/Cambridge Street Upper School

BUILDING TYPE: K-12 School

LOCATION: Cambridge, MA

SIZE: 270,000 sf

Bristol Community College John J. Sbrega Health and Science Building

BUILDING TYPE: Teaching Lab

LOCATION: Fall River, MA

SIZE: 50,600 sf

RW Kern Center

BUILDING TYPE: Welcome Center, School

LOCATION: Amherst, MA

SIZE: 17,000 sf

246 Norwell Street

BUILDING TYPE: Multifamily Residential

LOCATION: Boston, MA

SIZE: 4,518 sf

E+ Marcella Street

BUILDING TYPE: Multifamily Residential

LOCATION: Boston, MA

SIZE: 7,883 sf

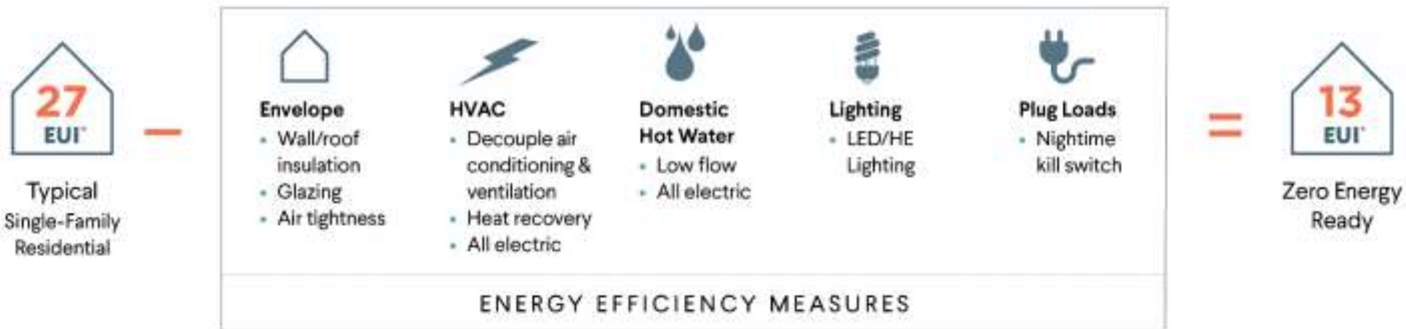
The Distillery North

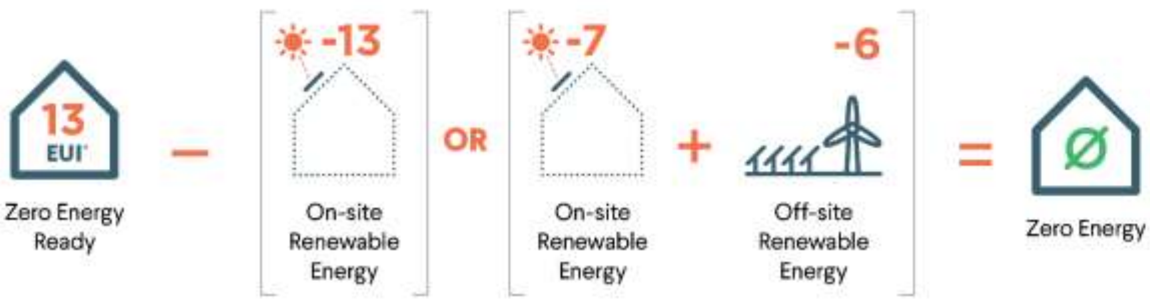
BUILDING TYPE: Multifamily Residential

LOCATION: Boston, MA

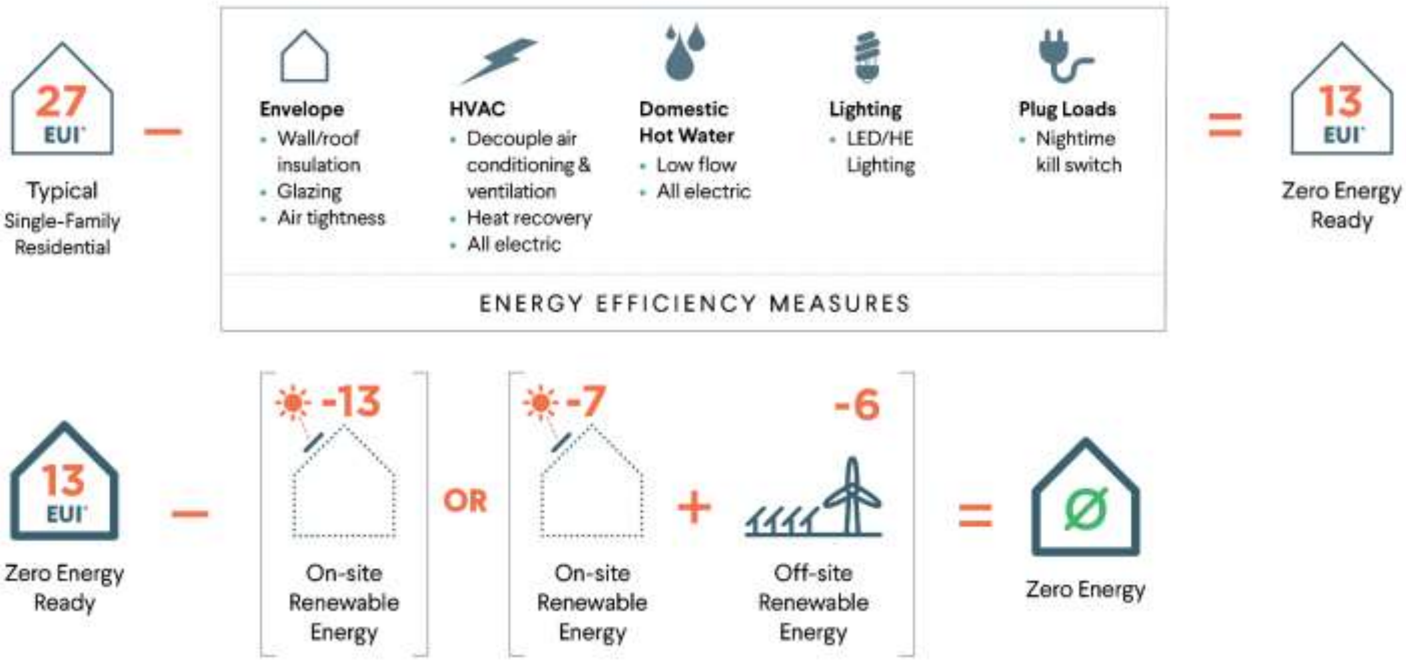
SIZE: 58,800 sf

Source: Oregon Sustainability Center


27
EUI*
Typical
Single-Family
Residential
–
Envelope
• Wall/roof insulation
• Glazing
• Air tightness
HVAC
• Decouple air conditioning & ventilation
• Heat recovery
• All electric
Domestic Hot Water
• Low flow
• All electric
Lighting
• LED/HE Lighting
Plug Loads
• Nightime kill switch
ENERGY EFFICIENCY MEASURES
=
13
EUI*
Zero Energy
Ready



* Energy Use Intensity (kBtu/sf/yr)



* Energy Use Intensity (kBtu/sf/yr)

FIGURE 7

Prototype Model Data

Six different building types were modeled in this study with the parameters identified here.

1 Existing Office	2 New Office	3 K–12 School	4 Mixed Use Retail/Residential	5 Small Multifamily	6 Single-Family Residential
498,588 Sq Ft	498,588 Sq Ft	73,959 Sq Ft	56,241 Sq Ft	10,804 Sq Ft	3,600 Sq Ft
11 Stories	11 Stories	1 Story	5 Stories	3 Stories	2 Stories
9’-00” Floor-to-Floor Height (ft)	9’-00” Floor-to-Floor Height (ft)	13’-00” Floor-to-Floor Height (ft)	16’-10” Floor-to-Floor Height (ft)	8’-6” Floor-to-Floor Height (ft)	8’-6” Floor-to-Floor Height (ft)
38,353 Roof Area (Sq Ft)	38,353 Roof Area (Sq Ft)	73,959 Roof Area (Sq Ft)	22,500 Roof Area (Sq Ft)	3,601 Roof Area (Sq Ft)	1,265 Roof Area (Sq Ft)

METHODOLOGY / BUILDING TYPE / ENERGY

Energy models tell us how much energy we can save and how much renewable energy we need.

FIGURE 8

Energy Efficiency Measures for ZE Design

Many different energy efficiency measures were utilized for the zero energy ready designs.

Envelope
- Increased wall/ roof insulation
- Improved glazing
- Improved air tightness

HVAC
- Decoupled conditioning and ventilation
- Heat recovery ventilation
- All electric HVAC (heat pumps)

Domestic Hot Water
- Low flow fixtures
- All electric DHW (heat pumps)

Lighting
- LED/high efficiency lighting
- Daylighting & occupancy controls

Plug Loads
- Nighttime kill switch

METHODOLOGY / LIFE CYCLE COST (30 YEAR)

Life-Cycle Cost Assessments tell us how much money we will save and how soon we will see a return on investment.

LIFE-CYCLE COSTS (30 YEAR)

$ Typical	$ Zero Energy Ready	$ Renewables on/and off-site	$ Savings	$ Zero Energy
We began with typical construction costs.	We added a conservative 5% for ZER. In practice we found the actual range to be 0-7%.	Based on energy needs established in the models, we added costs for renewable energy.	We subtracted energy savings and available incentives and rebates.	We calculated the breakeven year and the amount of money saved for each building type.

TABLE 2

Baseline Upfront Costs Provided by Daedalus Projects, Inc.

Building Type	Price ($/sf)
Existing Office	$195.00
New Office	$500.00
K-12	$365.00
Mixed-Use	$290.00
Small Multifamily	$325.00
Single Family	$250.00

K–12 SCHOOL BUILDINGS

FIGURE 15

Energy Consumption—K-12 School

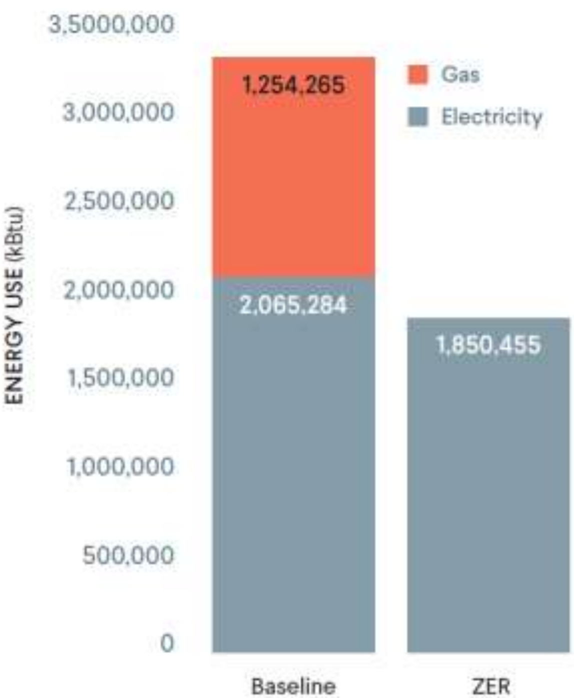
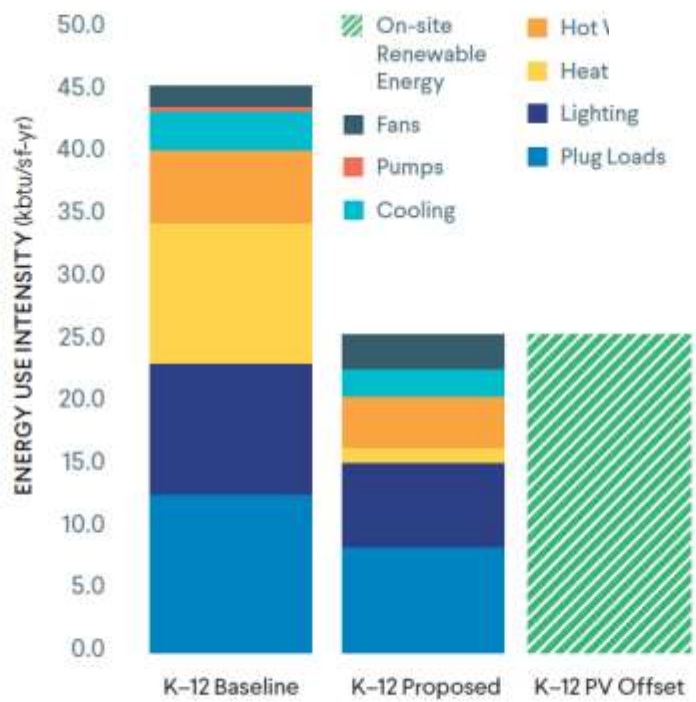


FIGURE 16

EUI Breakdown and PV—K-12 School

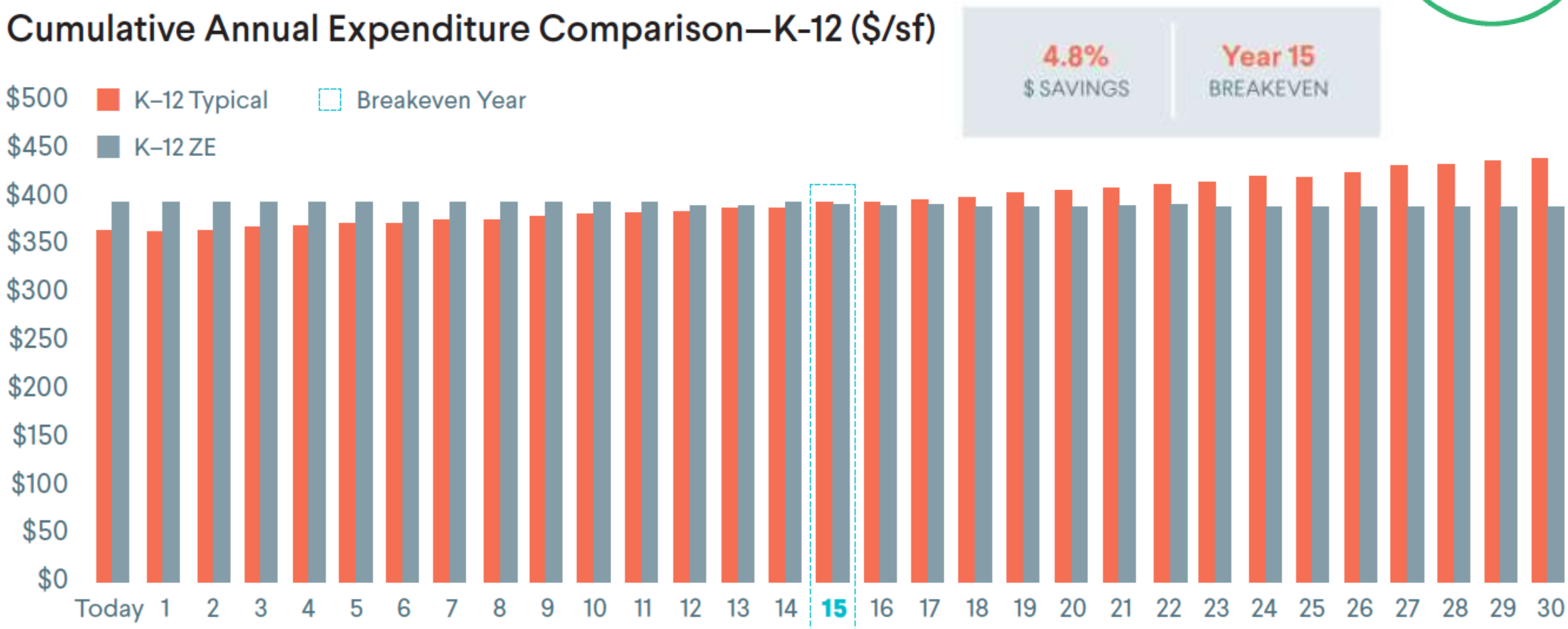


44.9 kBtu/sf BASELINE	100% % PV ON-SITE
25 kBtu/sf ZE READY	44% ENERGY SAVINGS

K–12 SCHOOL BUILDINGS

FIGURE 27

Cumulative Annual Expenditure Comparison—K-12 ($/sf)

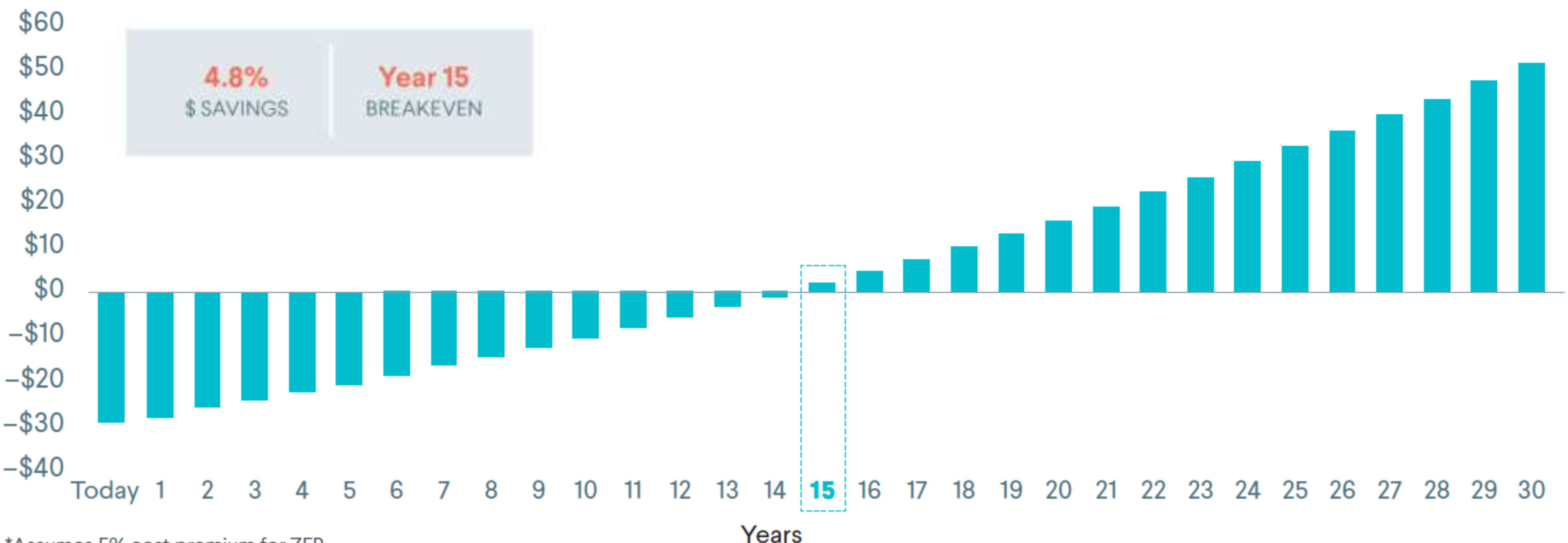


*Assumes 5% cost premium for ZER

K–12 SCHOOL BUILDINGS

FIGURE 28

Cumulative Annual Cost Difference Between ZE and Typical—K-12 ($/



*Assumes 5% cost premium for ZER

SENSITIVITY ANALYSIS / PAY BACK PERIOD (YEARS) WITH DIFFERENT COST PREMIUMS FOR ZE

FIGURE 38

Payback Periods for Different First Cost Premiums

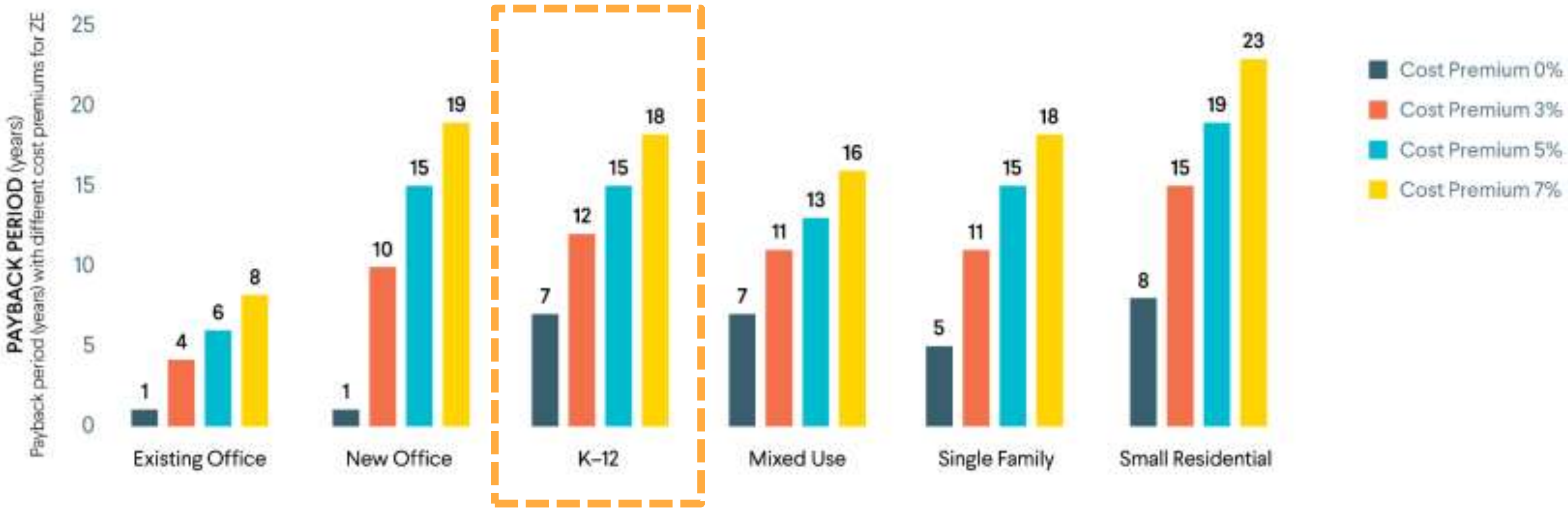
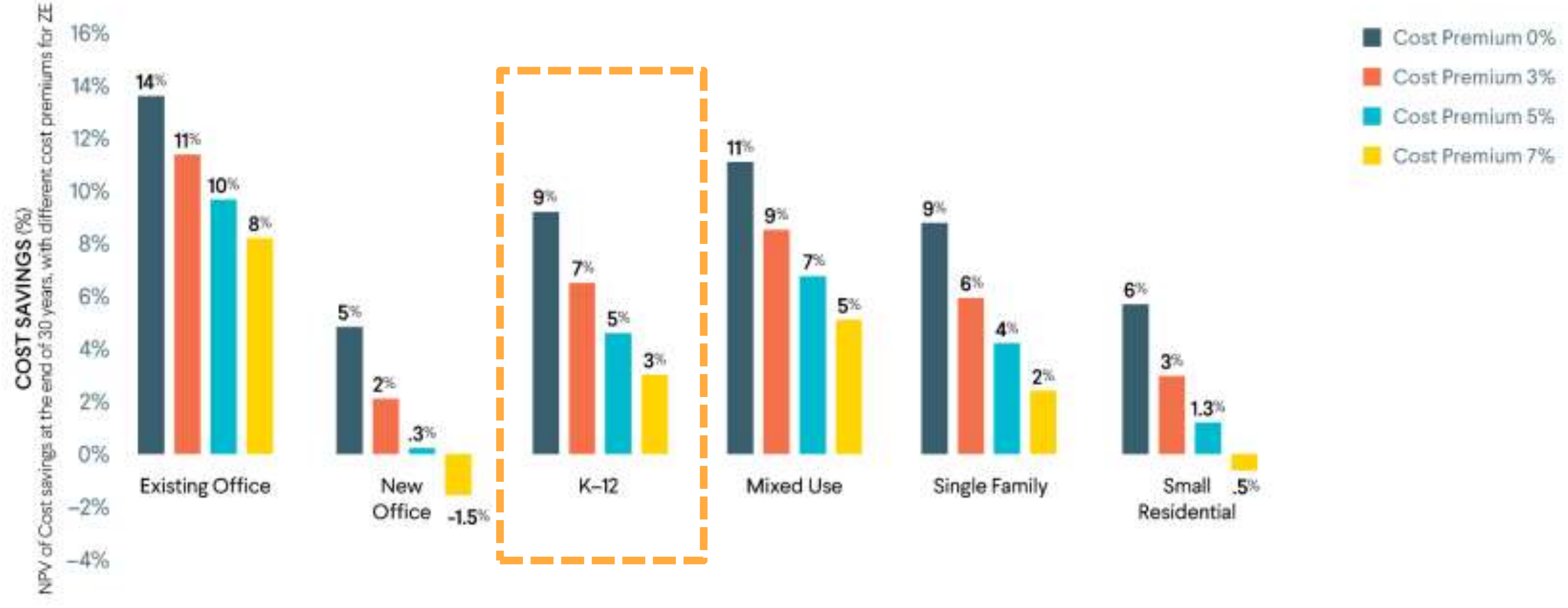


FIGURE 39

Percent Cost Savings for Different First Cost Premiums

NPV of cost savings at the end of 30 years,



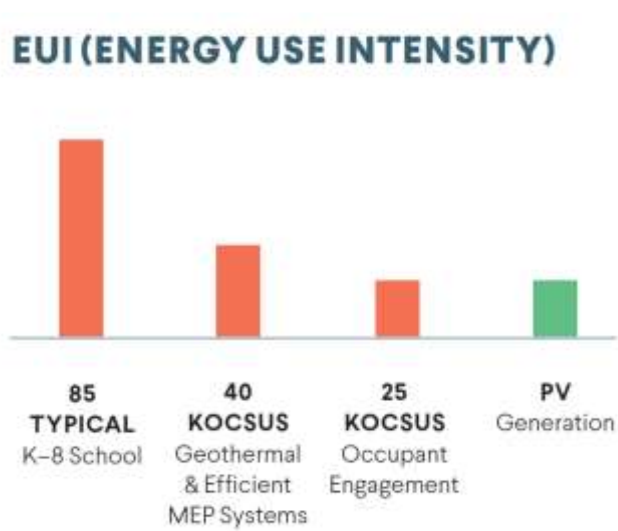
Dr. MLK Jr. School & Putnam Ave School, Cambridge, MA.

EUI 24kBTU/sf/yr
$365/sf
PV = 45-50% energy

After three years of operation, the Dr. Martin Luther King, Jr. School & Putnam Avenue School in Cambridge, MA, is operating at a site EUI of 24 kBTU/sf/yr and outperforming this report's predicted energy models for K-12 Schools of 25 kBTU/sf/yr. The construction costs without photovoltaics were only 1% more than our baseline of $365/sf. Photovoltaics on the roof provide 45-50% of the school's energy. Owner: City of Cambridge, Architect: Perkins Eastman, Mechanical Engineer: AKF, Photo credit: Sarah Mechling, Perkins Eastman.

King Open / Cambridge Street Upper School, Cambridge, MA.

EUI 25kBTU/sf/yr
$480/sf
1,300 MWh PV



CASE STUDY: King Open/Cambridge Street Upper School

Saving Energy Through Occupant Engagement

Cambridge, MA
270,000 sq. ft.
2019 (planned)
Public elementary and middle schools, public library
Arrowstreet & William Rawn Associates
Garcia, Galuska, Desousa
LeMessurier
Nitsch
Copley Wolff Design Group
InPosse
CDM Smith
Soden Sustainability
$130 Million

The occupants of ZE buildings can have critical impacts on a project's ability to achieve zero energy goals. Occupants directly impact energy use in many ways, from cooking, to use of electronic devices, to hot water consumption. In Cambridge, Massachusetts, almost every classroom within the original King Open School and Cambridge Street Upper School had its own mini-kitchenette with a microwave, coffee maker, and mini-fridge, increasing plug load and energy costs. In 2015, the city developed its own net zero emissions action plan. This school complex, known as the King Open/Cambridge Street Upper Schools and Community Complex, is the first project to meet the action plan.

During the feasibility study for the new complex, the design team asked teachers why they felt they needed kitchen equipment in every classroom and listened to the answer: there was only one staff room and it was too far away—up to 700 feet in some cases. The teachers needed to be near the classrooms they supervised, but the school schedule did not allow them to get to the one staff room. They wanted their new school to be a building that fosters collaboration among the staff despite working in different classrooms. To meet this vision, the school's design includes small clusters of classrooms with a central "Team Room" for collaboration and building community. The Team Room also provides a kitchenette that is nearby and easily accessible for all staff in that cluster, eliminating excess equipment. The result is a reduction in both cost and energy consumed within the building.

Modeled impact of some of the user engagement strategies:

- Shared Staff Team Rooms = 7% Energy Savings
- Temperature Ranges = 2% Energy Savings
- Building Organization by Use = 13.6% Energy Savings

$480/sf COST/SF
ANNUAL ENERGY SAVINGS
PV OUTPUT

Belmont Middle and High School

EUI 30 kBTU/sf/yr
Cash positive year one
100% renewable energy (on and off-site)

The Belmont Middle and High School is a 445,100 sf four-story building that is anticipated to achieve Class D Zero Net Energy. The building has a predicted site EUI of approximately 30 kBtu/sf*yr and is designed to rely on 100% renewable electricity (from on-site and off-site sources), eliminating fossil fuel consumption. Because the reduction in building operating costs is greater than the bond payments associated with the ZNE-enhancements, the net cash flow is positive from year one. Therefore, the payback is immediate. Owner: Town of Belmont, Architect: Perkins+Will, Mechanical Engineer: BALA. Image credit: Perkins and Will.

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MASSACHUSETTS

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Saving Money from the Start

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https://usgbcma.org/zero-energy-buildings/

Kate Crosby, Energy Manager & JD Head, Director of School Operations

Acton-Boxborough Regional School District

Acton-Boxborough Regional School District
Acton, Massachusetts

JD Head, Director of School Operations

Kate Crosby, Energy Manager

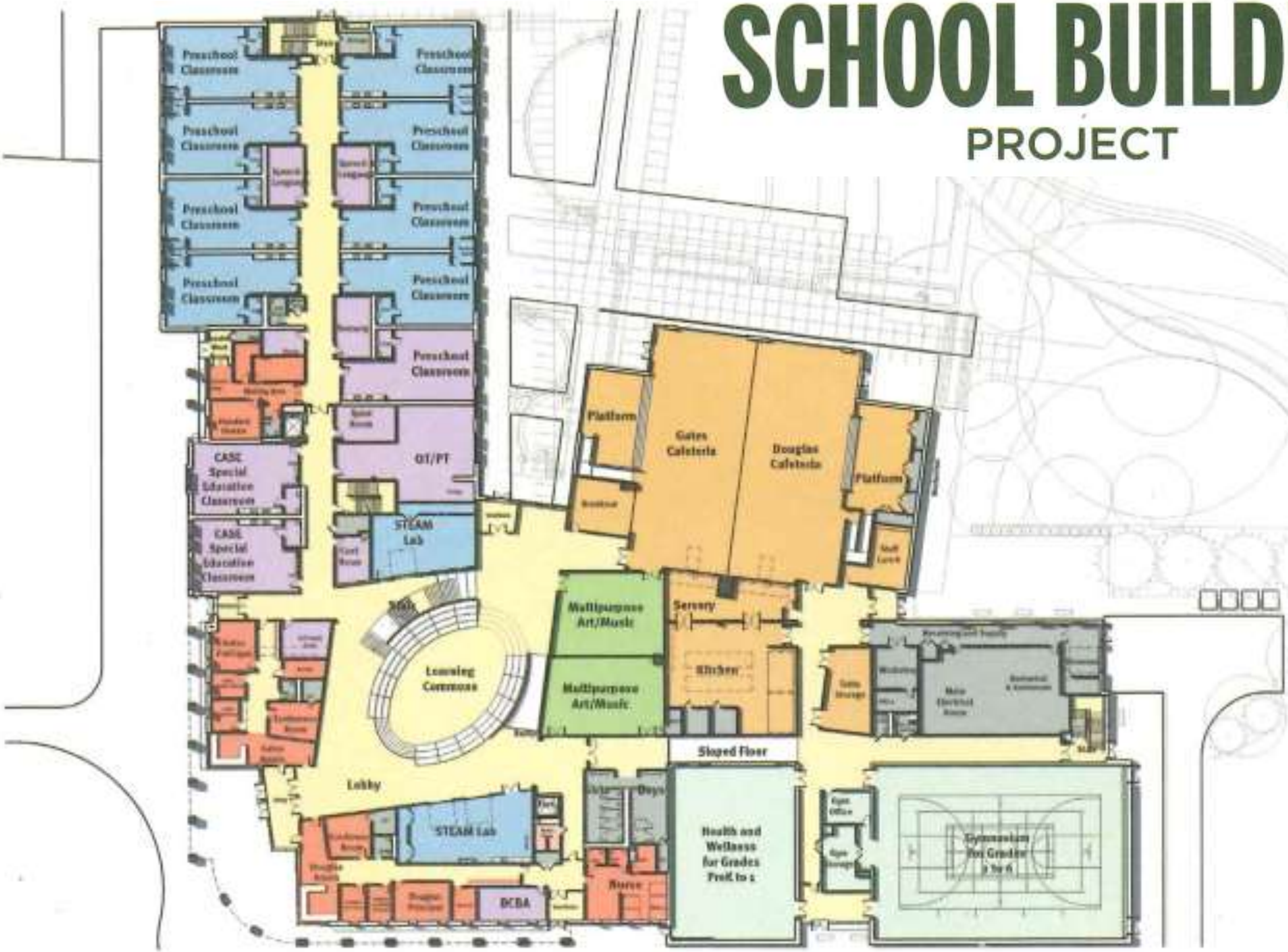
To develop engaged, well-balanced learners through collaborative, caring relationships

WELLNESS • EQUITY • ENGAGEMENT

ACTON-BOXBOROUGH

SCHOOL BUILDING

PROJECT



ABRSD SKANSKA ARROWSTREET

Critical to set **<u>EUI energy target</u>** early in the planning process – either before or as design team is assembled.

Early support in setting an EUI target received from Eversource (Kim Cullinane) and NGRID via the **Accelerate Performance Demonstration Program** (as well as ongoing support with modeling and energy target).

Energy Use Intensity = kBtu/square foot

Path to Net Zero

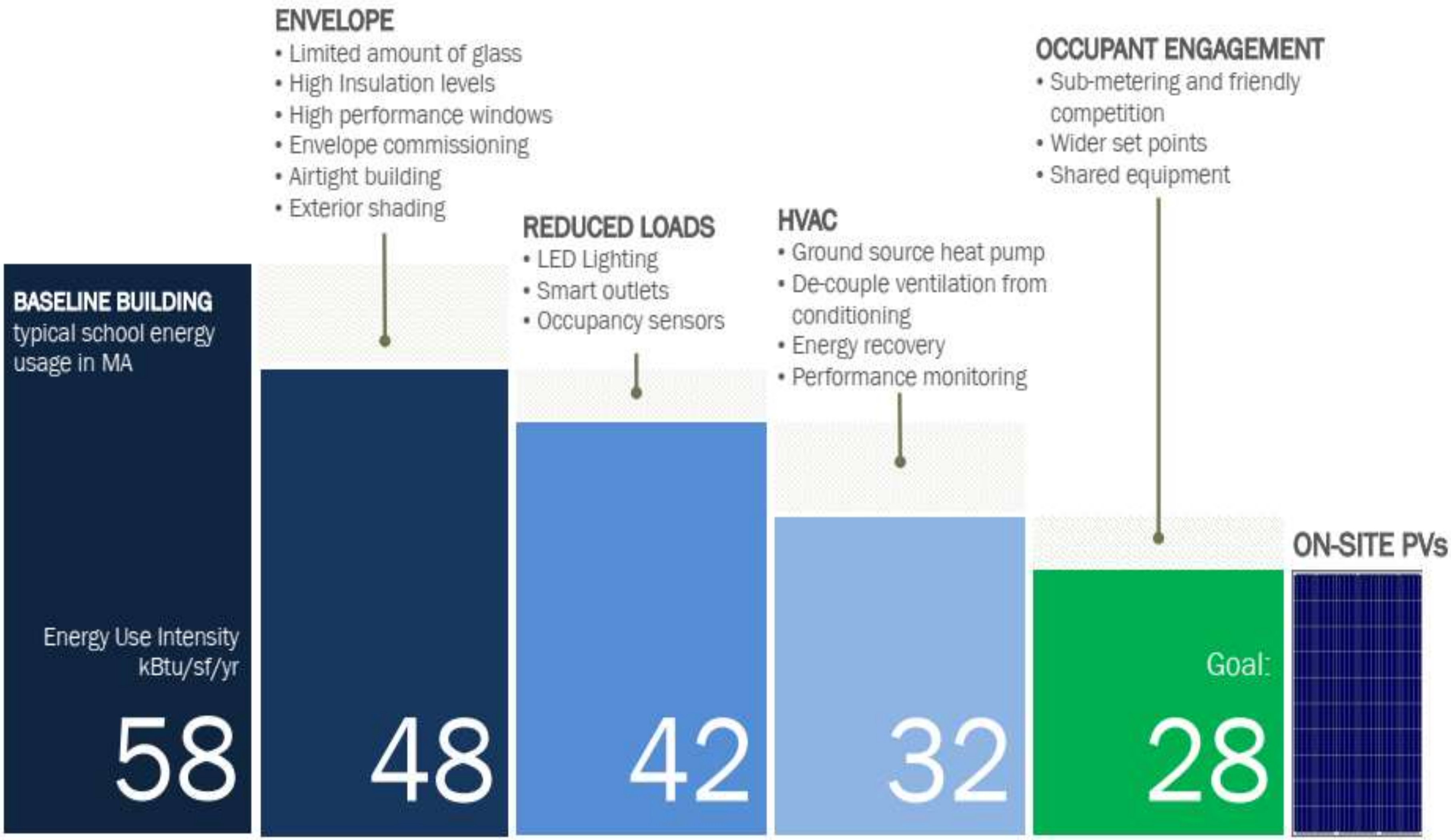


Image provided courtesy of Arrowstreet Architects

ARROWSTREET Thornton Tomasetti

Energy balance for Net Zero building

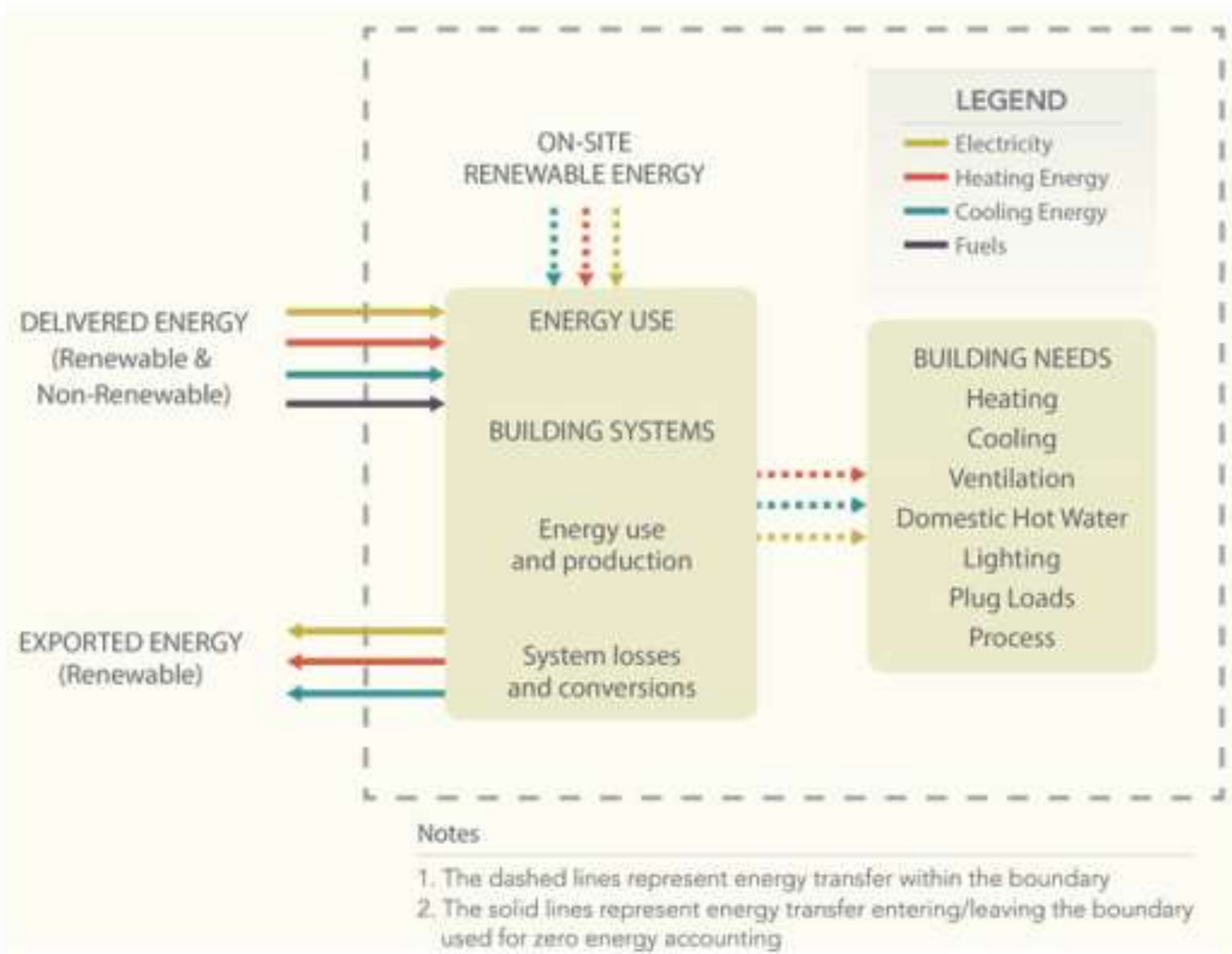


Figure 3-4 Energy balance diagram.
Source: *A Common Definition for Zero Energy Buildings* (DOE 2015)

Life Cycle Analysis ~ Douglas Gates School Building Project
Acton-Boxborough RSD
(50-year study period)

GARCIA • GALUSKA • DESOUSA
Consulting Engineers Inc.

Douglas Elementary School - Mechanical System Payback Summary

Baseline	System	Gross Capital Investment*	Annual Elec. Cons. (kWh)	Annual Gas Cons. (MBTU)	Annual Electric Cost	Annual Gas Cost	Combined Utility Cost	Annual Utility $/s.f.	Annual kBTU/s.f. (EUI)	Annual Maint. Cost	15 Year Exterior Equipment Replacement Cost	Annual CO2 Emissions (mTONS)*******	Combined Annual Expense	Combined Expense Savings**	Total Life-Cycle Savings***	Discounted Payback (Years)****
-	1. Hot water coil heating/chilled water coil cooling VAV AHU system with energy recovery and terminal VAV boxes with hot water reheat coils 2. Code-efficient gas-fired non-condensing boiler plant 3. High-efficiency (code) water-cooled chiller plant with cooling tower	$10,843,800	2,020,046	2,865,0	$242,405	$36,051	$278,456	$1.57	55,1	$46,710	$175,000	960,0	$325,166	-	-	-

Option	System	Gross Capital Investment*	Annual Elec. Cons. (kWh)	Annual Gas Cons. (MBTU)	Annual Electric Cost	Annual Gas Cost	Combined Utility Cost	Annual Utility $/s.f.	Annual kBTU/s.f. (EUI)	Annual Maint. Cost	15 Year Exterior Equipment Replacement Cost	Annual CO2 Emissions (mTONS)*******	Combined Annual Expense	Combined Expense Savings**	Total Life-Cycle Savings***	Discounted Payback (Years)****
1	1. Displacement ventilation diffusers with passive chilled beam cooling/heating radiation 2. Hot water coil heating/chilled water cooling VAV ventilating units with energy recovery with terminal VAV boxes with CO2 controls 3. Geothermal wells with high-efficiency water-to-water source heat pump chillers	$12,838,650	1,409,139	0,0	$169,097	$0	$169,097	$0.96	27,2	$35,460	$0	563,7	$204,567	$120,609	$2,732,400	20
2	1. Displacement ventilation diffusers with passive chilled beam cooling/heating radiation 2. Gas-fired heating/dx cooling VAV ventilating units with energy recovery with terminal VAV boxes with CO2 controls 3. High efficiency gas-fired condensing boiler plant 4. High efficiency air-cooled chiller plant	$9,073,210	1,239,201	1,624,0	$148,704	$22,954	$171,658	$0.97	34,2	$37,460	$175,000	592,5	$209,118	$116,048	$4,635,005	Instant*****
3	1. Variable refrigerant flow (VRF) terminal evaporator units with air-cooled condensing units 2. Air-cooled dx heat pump heating/cooling 100% O.A. ventilating units with energy recovery with terminal VAV boxes with CO2 controls serving VRF units 3. Air-cooled dx heat pump heating/cooling VAV AHU systems with energy recovery with terminal VAV boxes with CO2 controls serving the cafetorium	$9,331,350	1,704,508	0,0	$204,541	$0	$204,541	$1.16	32,9	$75,960	$1,900,000	981,8	$280,501	$44,665	-$1,360,213	N/A
4	1. Displacement ventilation diffusers with passive chilled beam cooling/heating radiation 2. Hot water coil heating/chilled water cooling VAV ventilating units with energy recovery with terminal VAV boxes with CO2 controls 3. Geothermal wells with high-efficiency water-to-water source heat pump chillers 4. Supplemental electric boiler plant	$12,208,150	1,426,031	0,0	$171,124	$0	$171,124	$0.97	27,5	$36,960	$0	570,4	$208,084	$117,062	$3,237,454	15

* Gross capital investment based upon in-house cost estimate utilizing cost data from similar past projects and industry standard estimating references. Costs have been estimated for system comparison purposes only and do not incorporate all supplemental/independent HVAC system costs which would be required for all systems studied (i.e., kitchen exhaust, overhead and profit).
** Combined expense savings is the difference between the combined annual expense of the baseline and system in comparison.
*** Total life-cycle savings is based on a 50 year study period.
**** Discounted payback years is based upon BLCC5 Life Cycle Analysis.
***** Discounted payback never reached within 50 year study period.
****** Discounted payback never reached because system is more efficient and/or less expensive than baseline system.
******* Annual CO2 emissions does not account for renewable generation.

Link for download: https://drive.google.com/open?id=18Ru1v2-qNTHoXnPaeeGCa_zVSsh8mdIs

Option	System
1	1. Displacement ventilation diffusers with passive chilled beam cooling/heating radiation 2. Hot water coil heating/chilled water cooling VAV ventilating units with energy recovery with terminal VAV boxes with CO2 controls 3. Geothermal wells with high-efficiency water-to-water source heat pump chillers
2	1. Displacement ventilation diffusers with passive chilled beam cooling/heating radiation 2. Gas-fired heating/dx cooling VAV ventilating units with energy recovery with terminal VAV boxes with CO2 controls 3. High efficiency gas-fired condensing boiler plant 4. High efficiency air-cooled chiller plant
3	1. Variable refrigerant flow (VRF) terminal evaporator units with air-cooled condensing units 2. Air-cooled dx heat pump heating/cooling 100% O.A. ventilating units with energy recovery with terminal VAV boxes with CO2 controls serving VRF units 3. Air-cooled dx heat pump heating/cooling VAV AHU systems with energy recovery with terminal VAV boxes with CO2 controls serving the cafetorium
4	1. Displacement ventilation diffusers with passive chilled beam cooling/heating radiation 2. Hot water coil heating/chilled water cooling VAV ventilating units with energy recovery with terminal VAV boxes with CO2 controls 3. Geothermal wells with high-efficiency water-to-water source heat pump chillers 4. Supplemental electric boiler plant

Evaluating results of Life Cycle Analysis

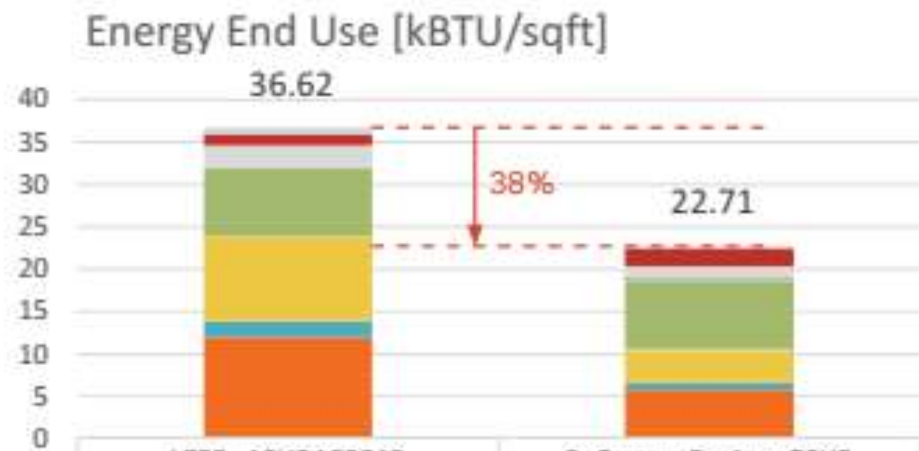
		EUI	Gross Capital Investment (initial)	Gross Capital Investment (initial) delta vs Option 2	Total Life Cycle Savings (50 years) vs Baseline	Total Life Cycle Savings (50 years) delta vs Option 2
	Baseline	55.1	$10,643,800	x	x	x
Option 1	Geothermal	27.2	$12,838,650	**$3,765,440**	$2,732,400	**-$1,902,605**
Option 2	Efficient gas boiler + chiller	34.2	$9,073,210		$4,635,005	
Option 3	Air Source Heat Pump	32.9	$9,331,350	**$258,140**	-$1,363,213	**-$5,998,218**
Option 4	**Geothermal + electric boiler**	**27.5**	$12,208,150	**$3,134,940**	$3,237,454	**-$1,397,551**

$3,134,940 more initial cost vs Option 2

$3,237,454 more over 50 year analysis vs Baseline

$1,397,551 less over 50 year analysis vs Option 2

EUI 22.71 = current energy modeling for proposed building



	LEED_ASHRAE2013	0_CurrentDesign_GSHP
Water Systems	0.36	0.36
Heat Rejection	0.25	-
Pumps	1.36	2.01
Fans	2.71	1.53
Exterior Equipment	-	0.18
Interior Equipment	8.08	8.08
Exterior Lighting	0.18	0.18
Interior Lighting	9.81	3.71
Cooling	1.86	0.85
Heating	12.01	5.80
TOTAL	36.62	22.71
REDUCTION %		38.0%

ARROWSTREET

Thornton Tomasetti

Based on current assumptions, the design indicates 38% energy consumption savings from an ASHRAE 90.1-2013 Baseline. In the Baseline, approximately 22% of the total energy use comes from equipment loads, which remains energy saving neutral in the as design case, and makes it difficult to have large amount of savings.

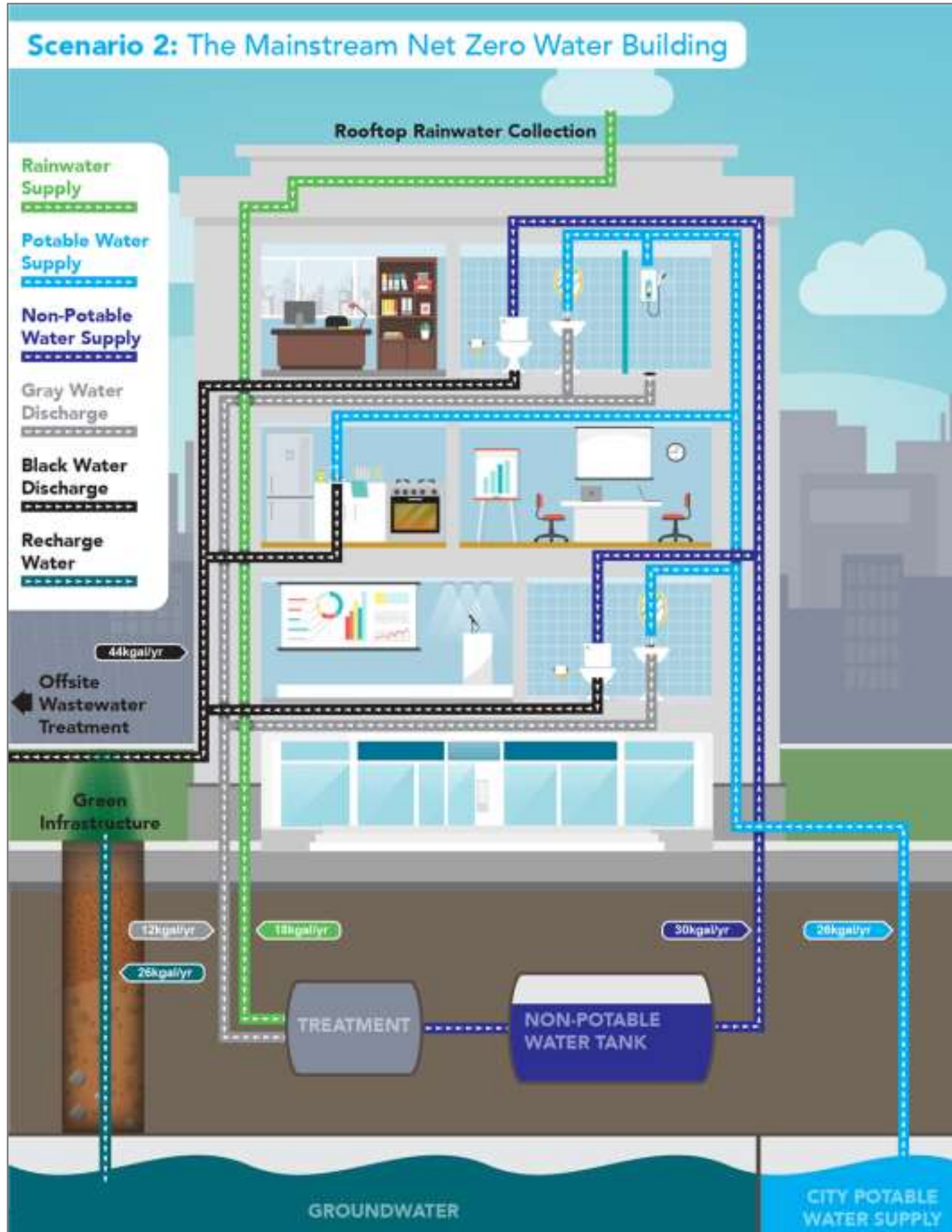
RESOURCES

- New Buildings Institute – Zero Energy hub and Zero Buildings Database
  https://newbuildings.org/hubs/zero-energy/
- Advanced Energy Design Guide for K-12 School Buildings - free download at
  https://www.ashrae.org/technical-resources/aedgs/zero-energy-aedg-free-download
- CHPS & NE-CHPS (NEEP)
- USGBC & USGBC-MA

Local school building projects with ZE targets and/or incorporating geothermal:

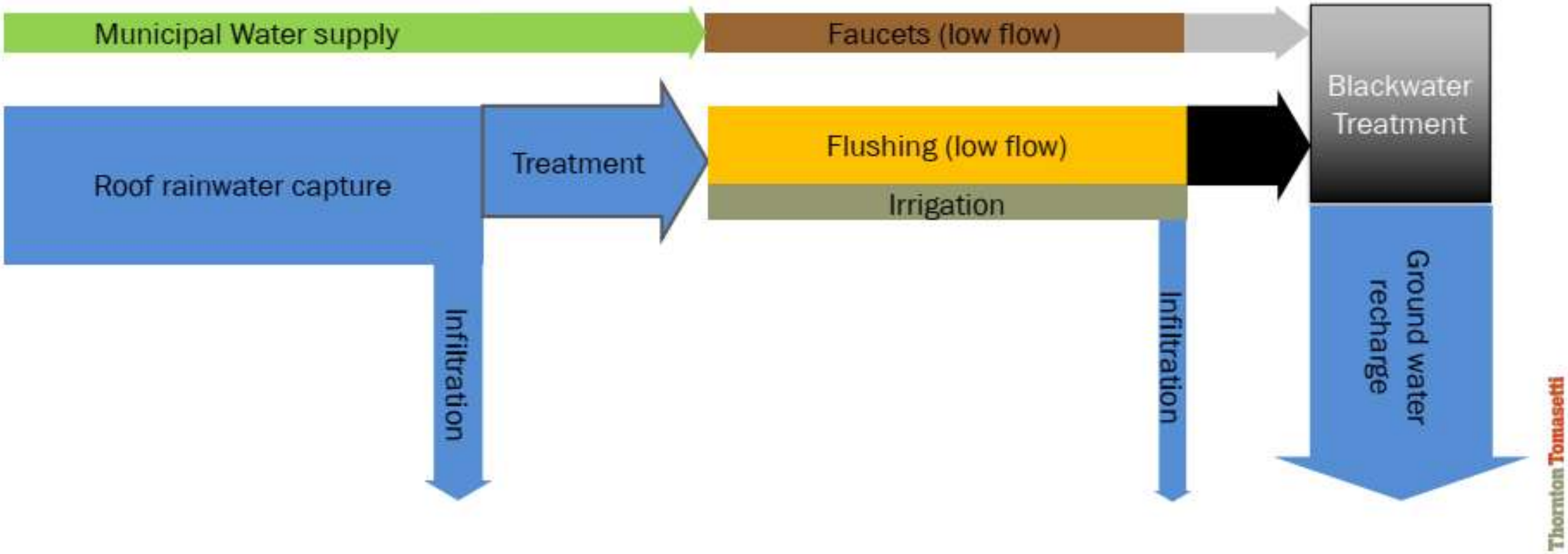
- Cambridge
- Worcester
- Brookline
- Lexington
- Westborough
- Belmont
- Lincoln
- Arlington
- Wellesley
- Sharon
- Concord

Goal: Net Zero Water

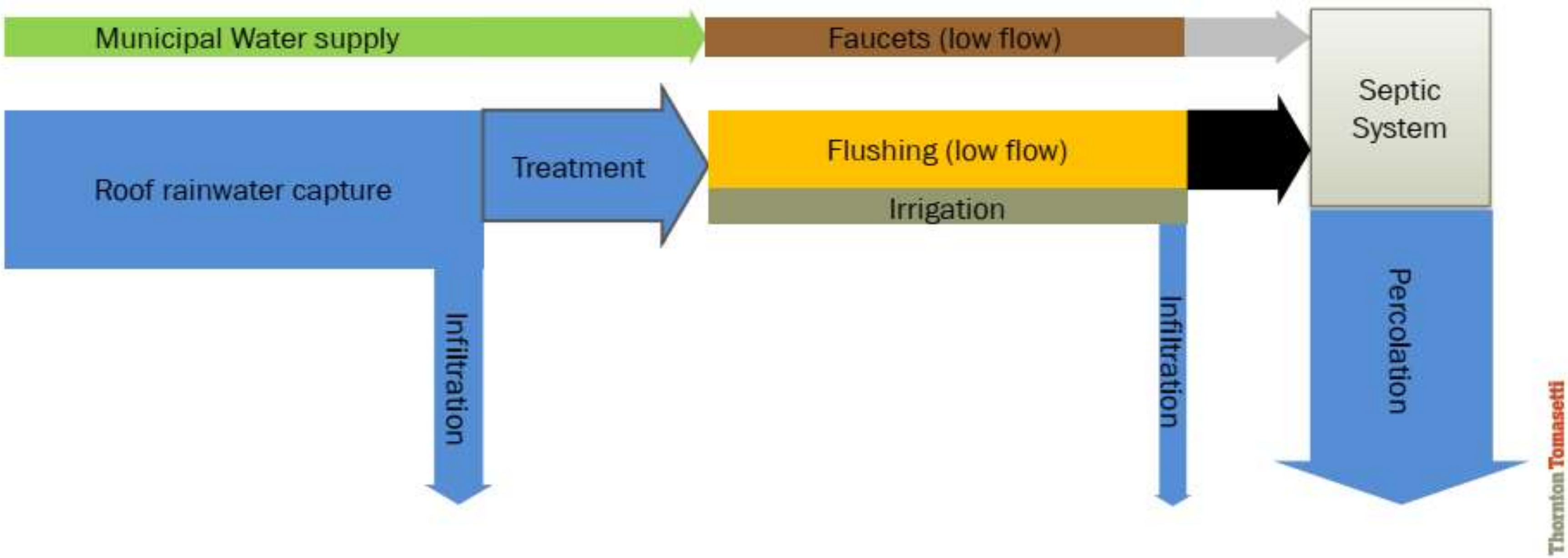


www.energy.gov

Key Strategies - No Septic



Key Strategies - Septic



Goal: Net Zero Waste

Net Zero Waste Construction

- Project will require the LEED/CHPS construction waste management:
    - Divert at least 75% of construction waste by weight.
    - Develop a comprehensive Waste Recovery Plan for reuse / salvage within 1,000 miles.

Net Zero Waste Operations

Definition – USGBC

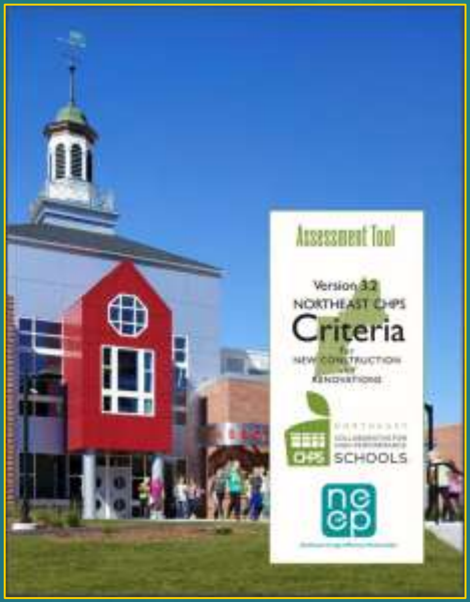
An average of 90 percent or greater overall diversion from landfill, incineration (waste-to-energy) and the environment for solid, non-hazardous waste for the most recent 12 months.

Question & Answer

Please type your questions into the chat box

Resources to Improve EE in Schools

New Construction and Major Renovations



Northeast-CHPS

*A **complete building criteria** that provides students with **premium educational environments***

Priorities

- *Indoor Environmental Quality*
- *Energy Efficiency*
- *Ease of O & M*
- *Occupant Comfort*

Resources for Existing Buildings

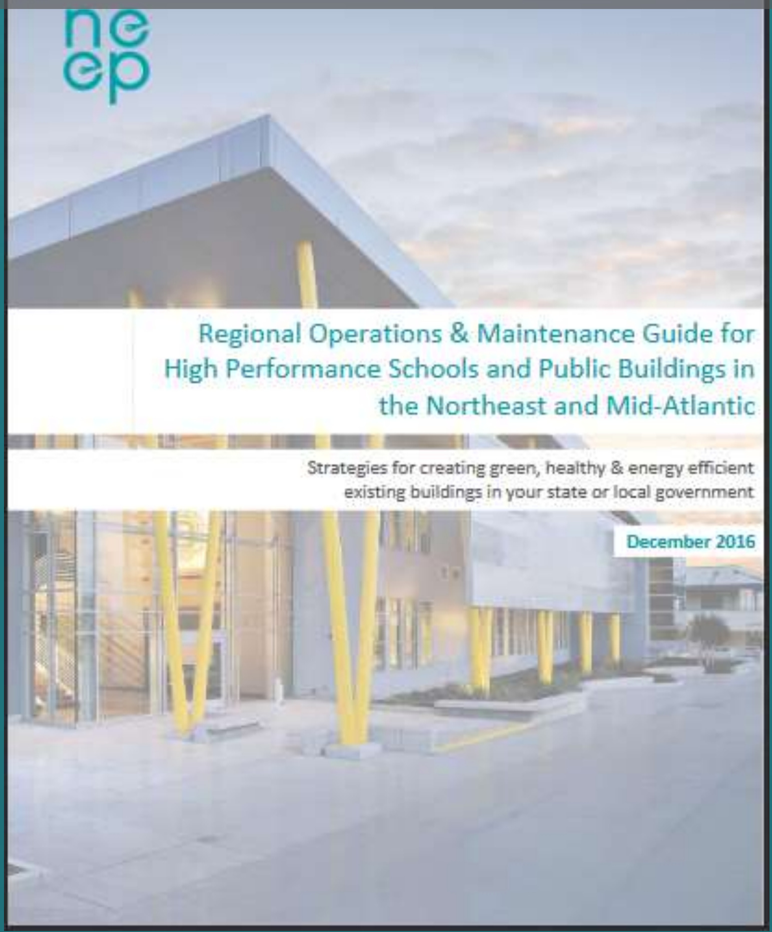
NEEP's O&M Guide

– A pathway to reach high performance in public buildings
– Best practices, checklists and more for improving energy efficiency and health in schools / public buildings

NEEP's O&M Guide

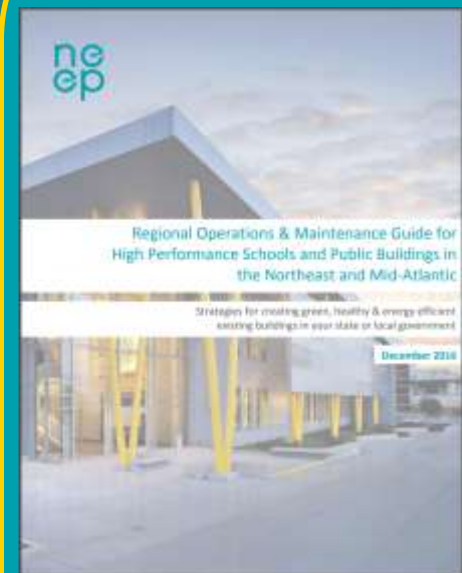
Establishing Operations and Maintenance Policies
Indoor Environmental Quality
Integrated Pest Management
Energy Efficiency
Alternative and Renewable Energy Systems
Commissioning and Retro-Commissioning
Transportation
Water Efficiency
Materials Selection and Specification
Recycling
Landscaping to Reduce "Heat Island Effect"
Innovative Financing Options
Cafeteria Practices
Zero Energy Buildings
Specialized Building Types

O&M targeting EE can save 5-20% on energy bills



Other Free NEEP Resources

(click an image below to be redirected to the webpage)



Air Source Heat Pumps – Renters Checklist – Home Energy Management Systems NEEP Blog – Strategic Electrification – Building Energy Labeling

Visit us at NEEP.org for these resources and more

Closing Poll

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