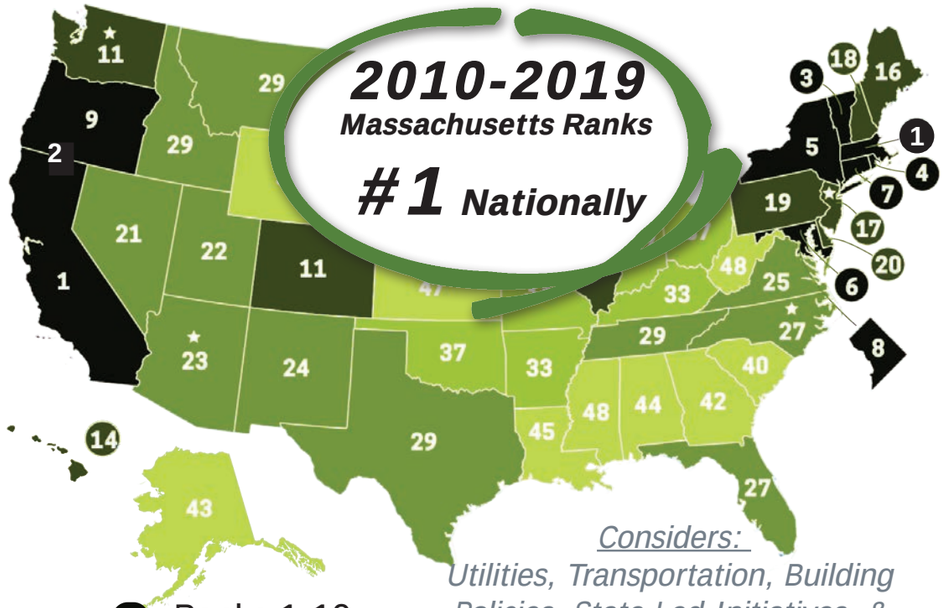
ELEMENTS OF SUSTAi3NABLE DESIGN

Watertown High School...a path to net zero energy

STATUS

2010
Watertown adopts the MA Stretch Energy Code

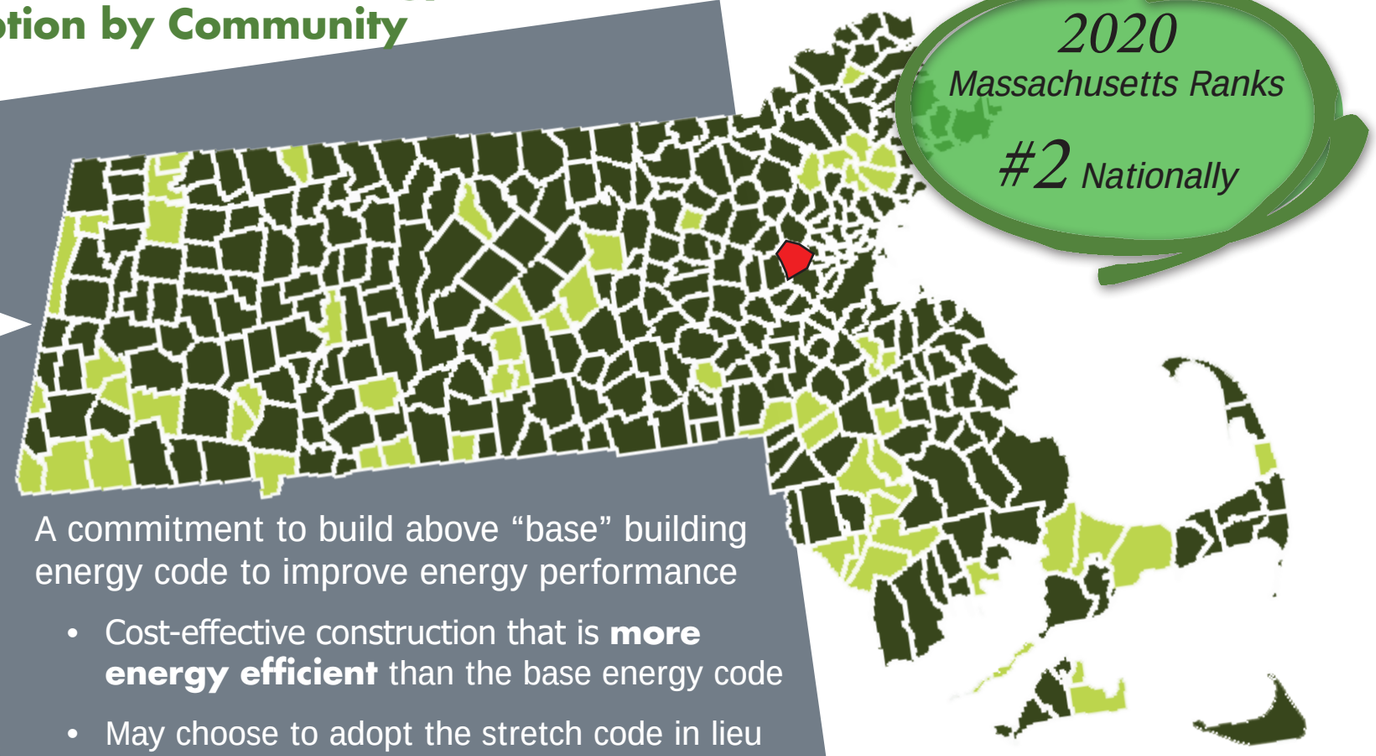
MASSACHUSETTS
2010-2019 Most Energy Efficient State
American Council for an Energy-Efficient Economy (ACEEE)



- Ranks 1-10
- Ranks 11-20
- Ranks 21-30
- Ranks 31-40
- Ranks 41-50
- Rising States

Considers:
Utilities, Transportation, Building Policies, State Led Initiatives, & Appliance Standards per state

Current MA Stretch Energy Code Adoption by Community



A commitment to build above "base" building energy code to improve energy performance

- Cost-effective construction that is **more energy efficient** than the base energy code
- May choose to adopt the stretch code in lieu of the base building energy code

- Adopted the MA Stretch Code (79%)
- Unadopted the MA Stretch Code (21%)

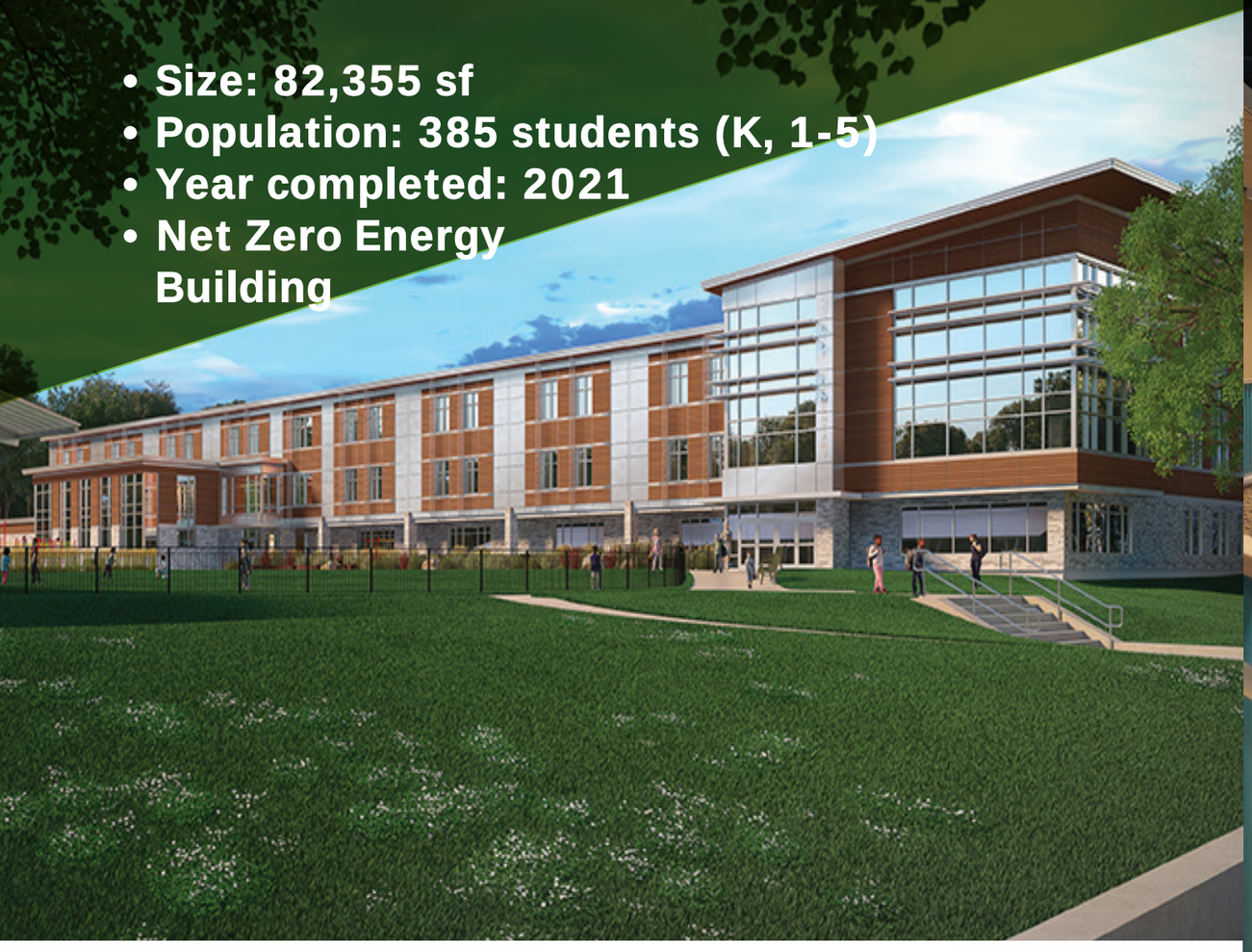
Watertown Regulations

- Adoption of Massachusetts Stretch Energy Code
- Inclusion of Solar renewable Enegy for new Public & Provate developments
- LEED Silver compliance for all large projects
- Energy Modeling required for all developers and designers
- 100% Electric-Based energy use encouraged

PRECEDENTS

Watertown, Massachusetts
Cunniff Elementary School
EUI = 23.1

- Size: 82,355 sf
- Population: 385 students (K, 1-5)
- Year completed: 2021
- Net Zero Energy Building



Watertown, Massachusetts
Hosmer Elementary School
EUI = 22.4

- Size: 142,500 sf
- Population: 790 (PS, PK, K, 1-5)
- Year completed: 2022
- Net Zero Energy Building

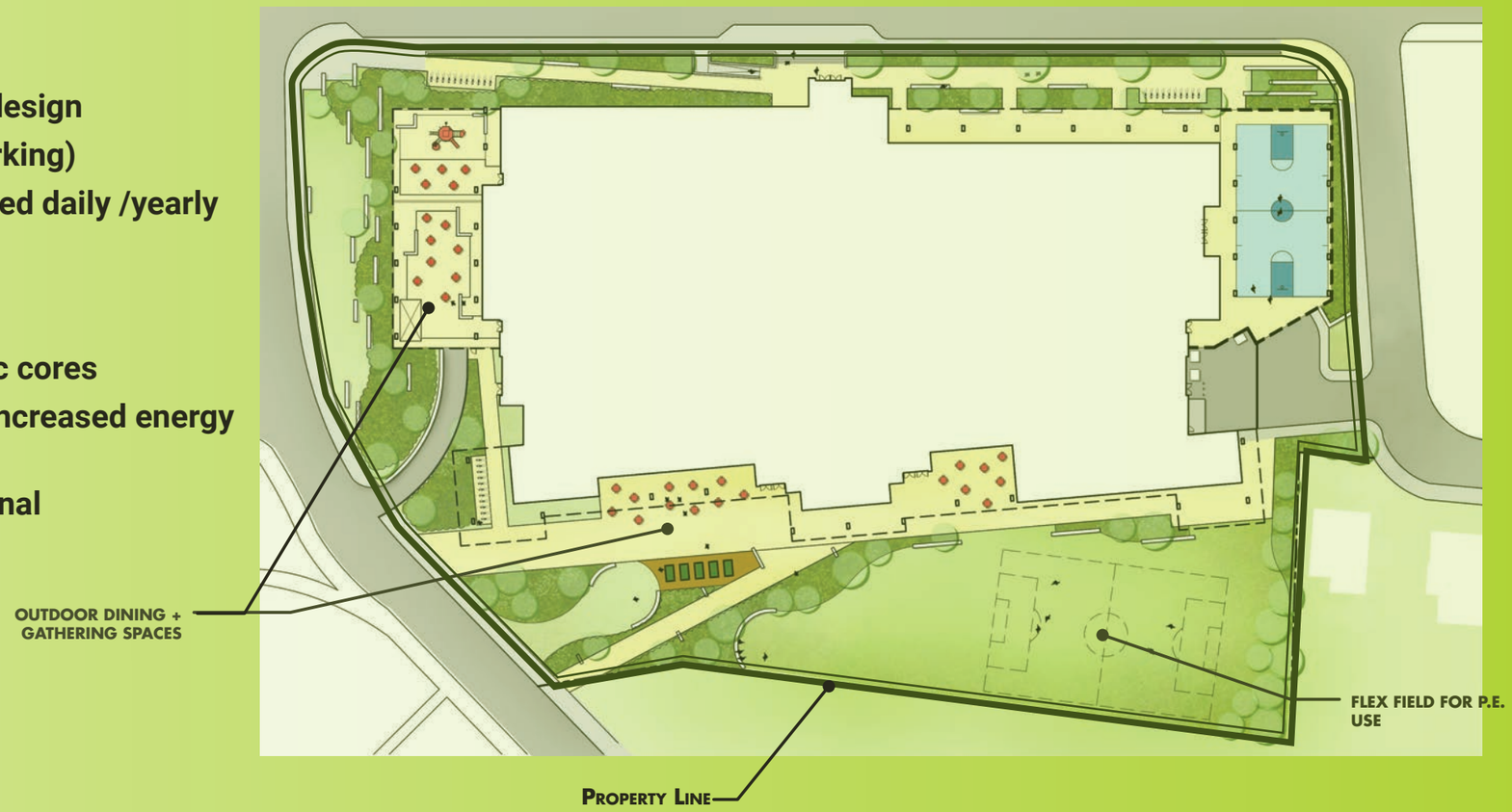
Identifying a Path to Net Zero Energy

Project Challenges:

- **Limited Roof Area for PV due to compact 4-story design**
- **Limited Land area for PV Canpoies (no surface parking)**
- **High EUI typical for High Schools that have extended daily /yearly use beyond the typical school day**

Design Advantages:

- **Building subdivided into Community and Academic cores**
  allowing investigation into Hybrid Systems for increased energy savings
- **Southern exposure and alignment allowing additional**
  PV tecnologies to be investigated

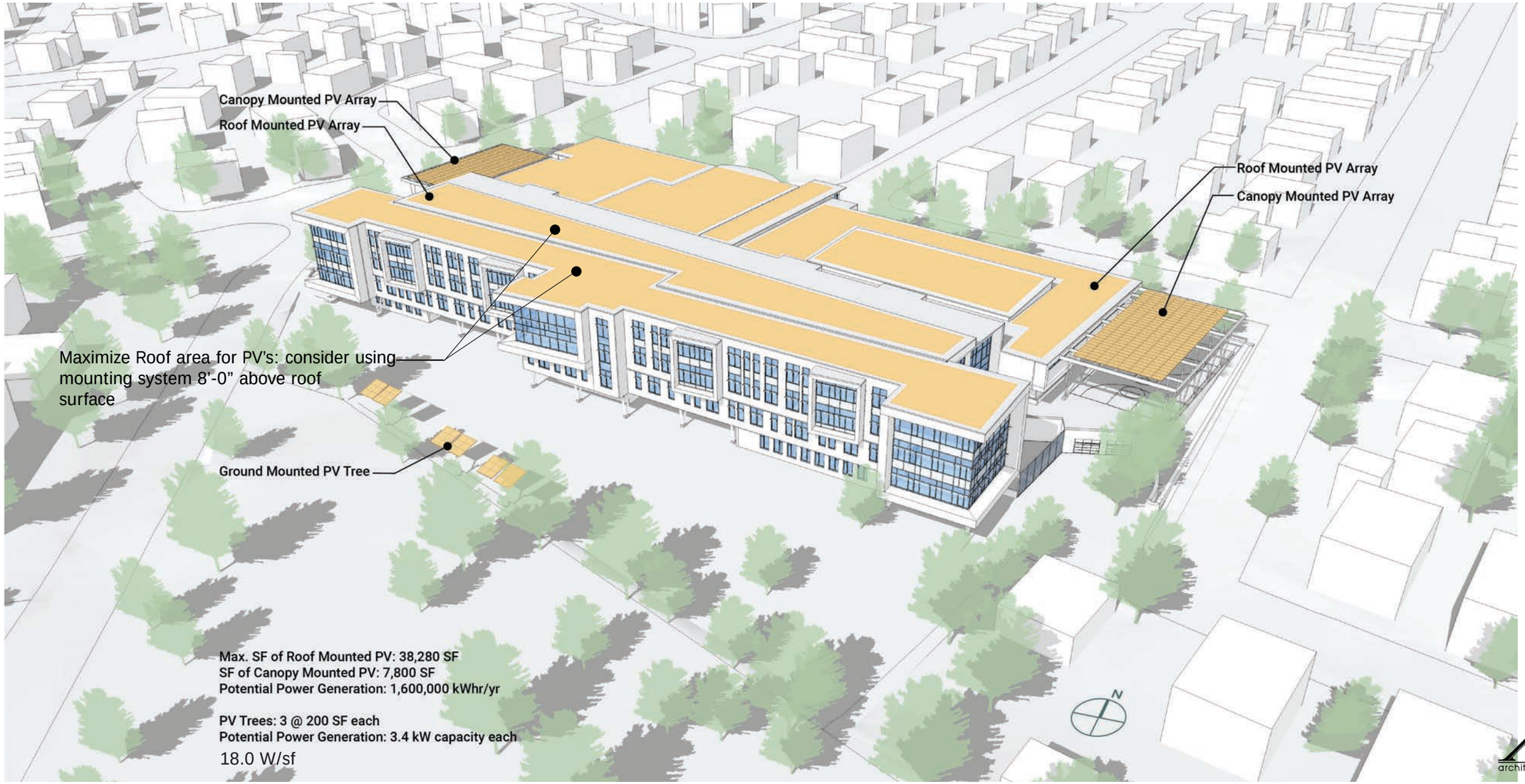


Energy **USED** on site/year ≤ Energy **PRODUCED** on site/year

EUI 25 = 1,422,927 kWh ≤ 1,423,000 kWh

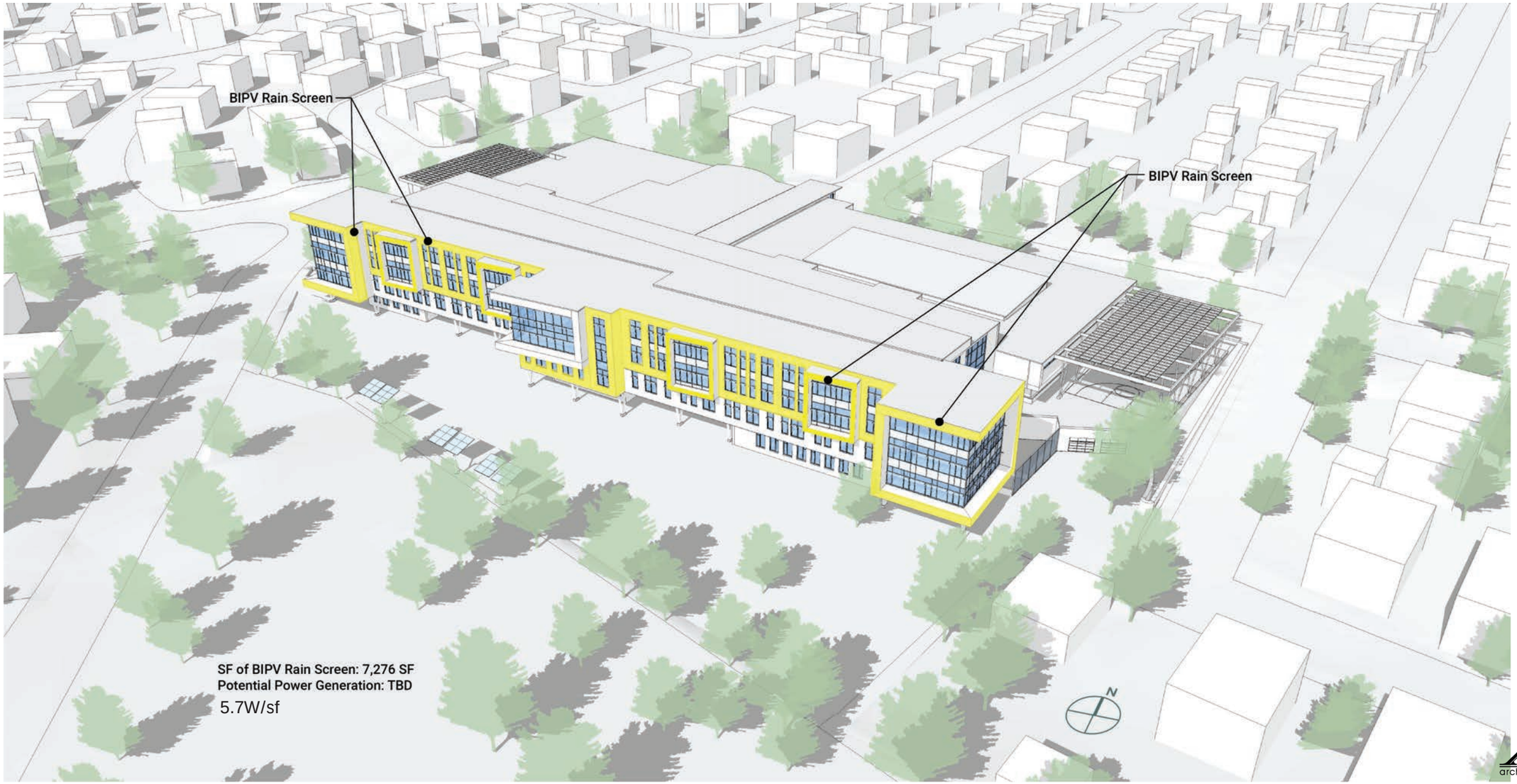
WHS Path to NZE

Photovoltaic Arrays



WHS Path to NZE

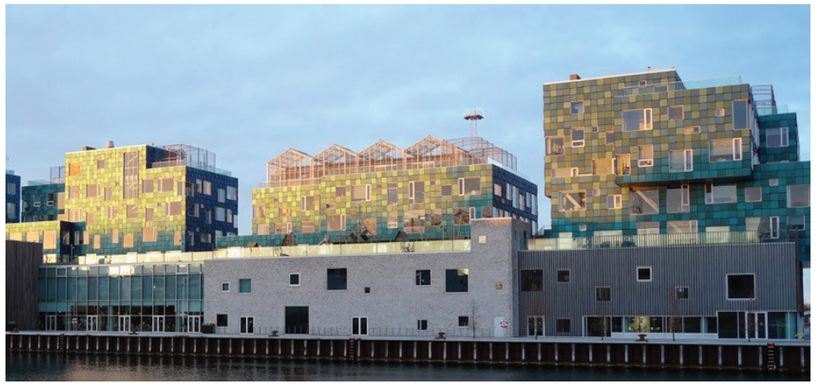
Building Integrated Photovoltaics (BIPV)

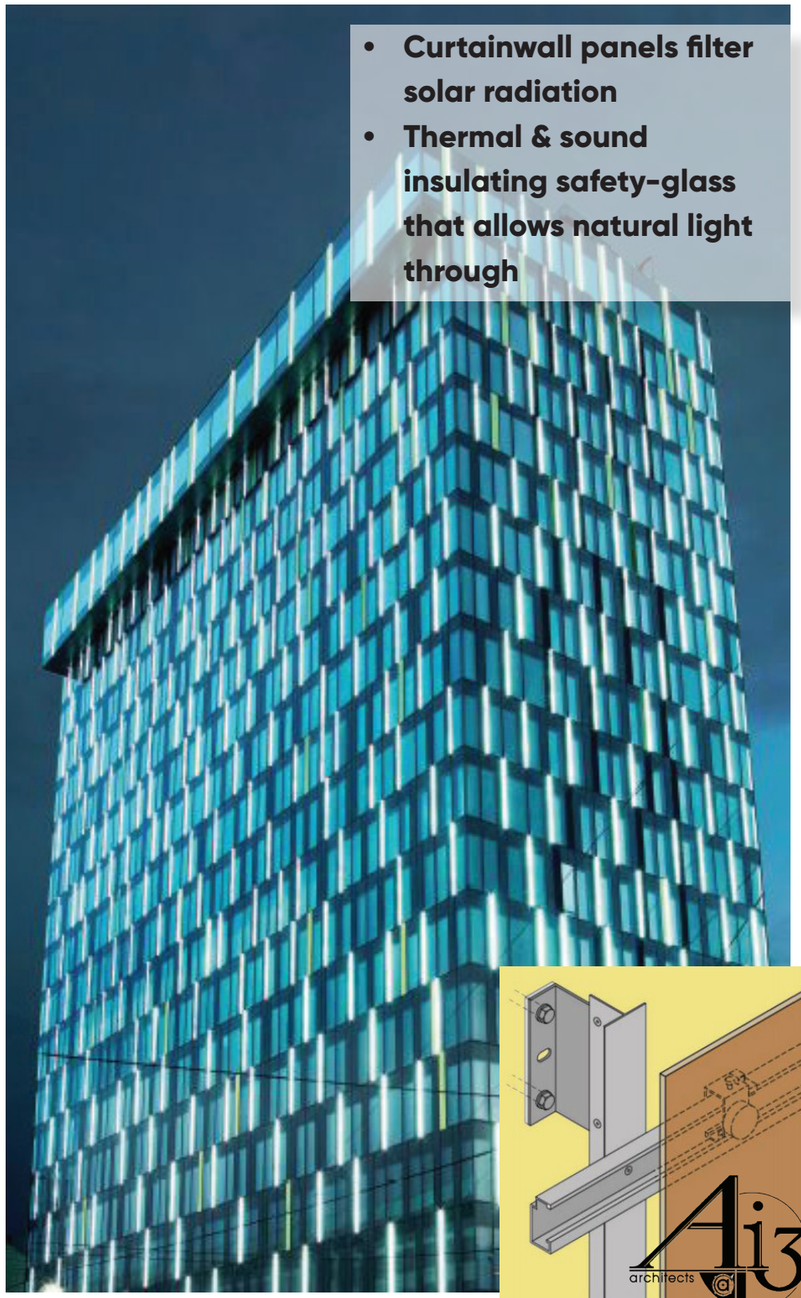


BiPV

Building Integrated Photovoltaics

- **Custom colors**, laminated, insulating, matt, coated, and curved glass available
- **Combination of active panels** containing photovoltaic cells & **inactive panels** that look identical to allow design continuity
- Designed to install in the same method as a traditional rainscreen system, with **natural air ventilation**

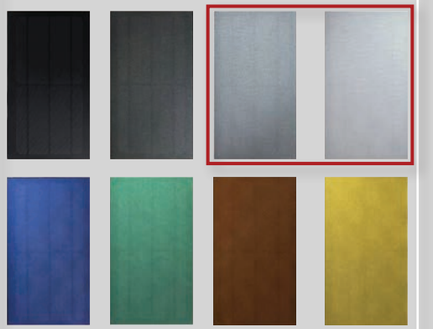




- **Curtainwall panels filter solar radiation**
- **Thermal & sound insulating safety-glass that allows natural light through**

Options for style & texture

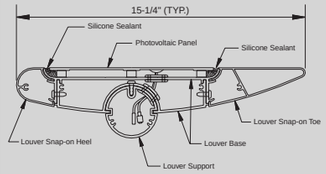
Ertex - Color Options



Metalics

Digital Patterns/ Prints

LOUVER CROSS SECTION WITH PHOTOVOLTAIC PANEL

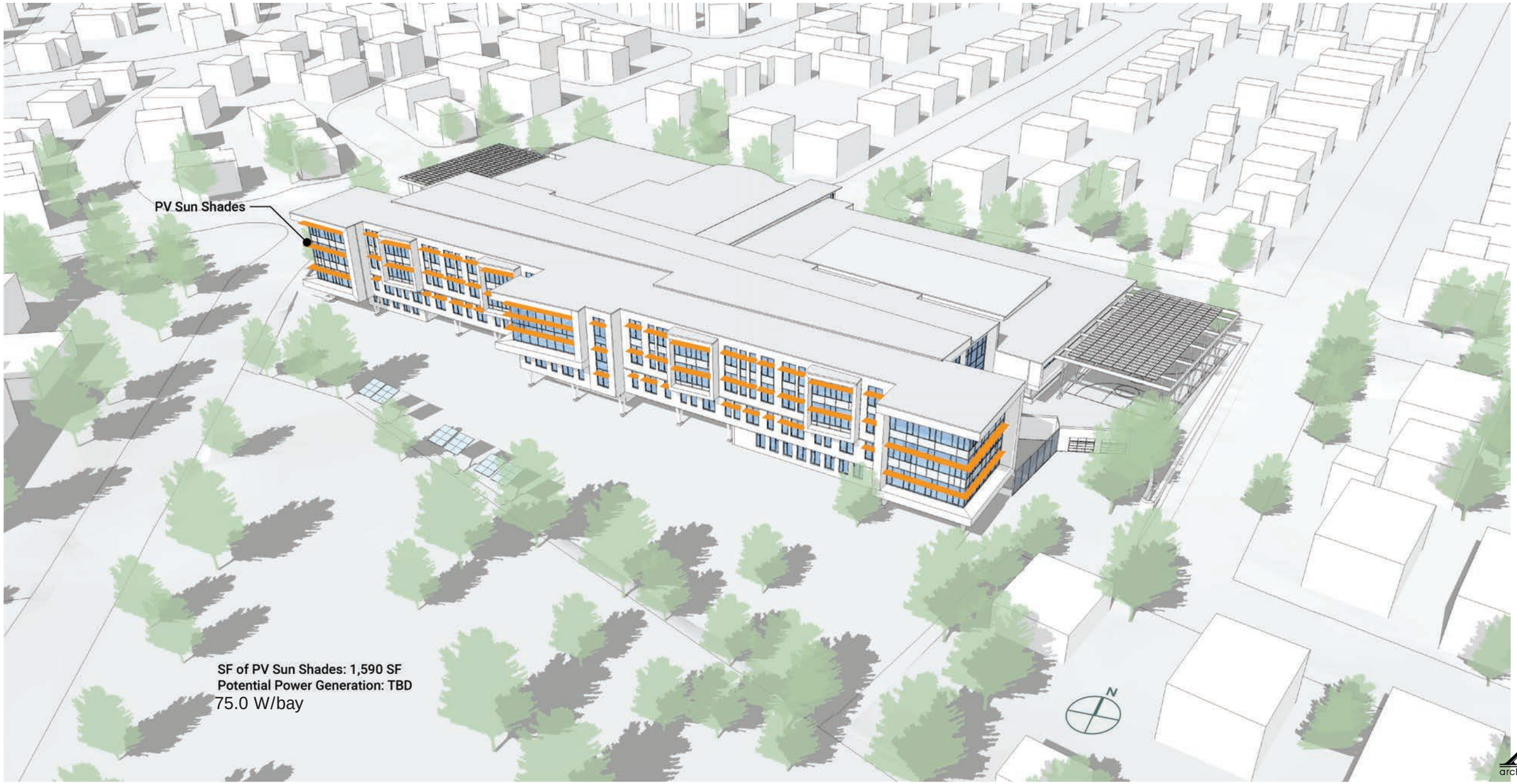


Onyx - Color Options

Ertex
Light Grey

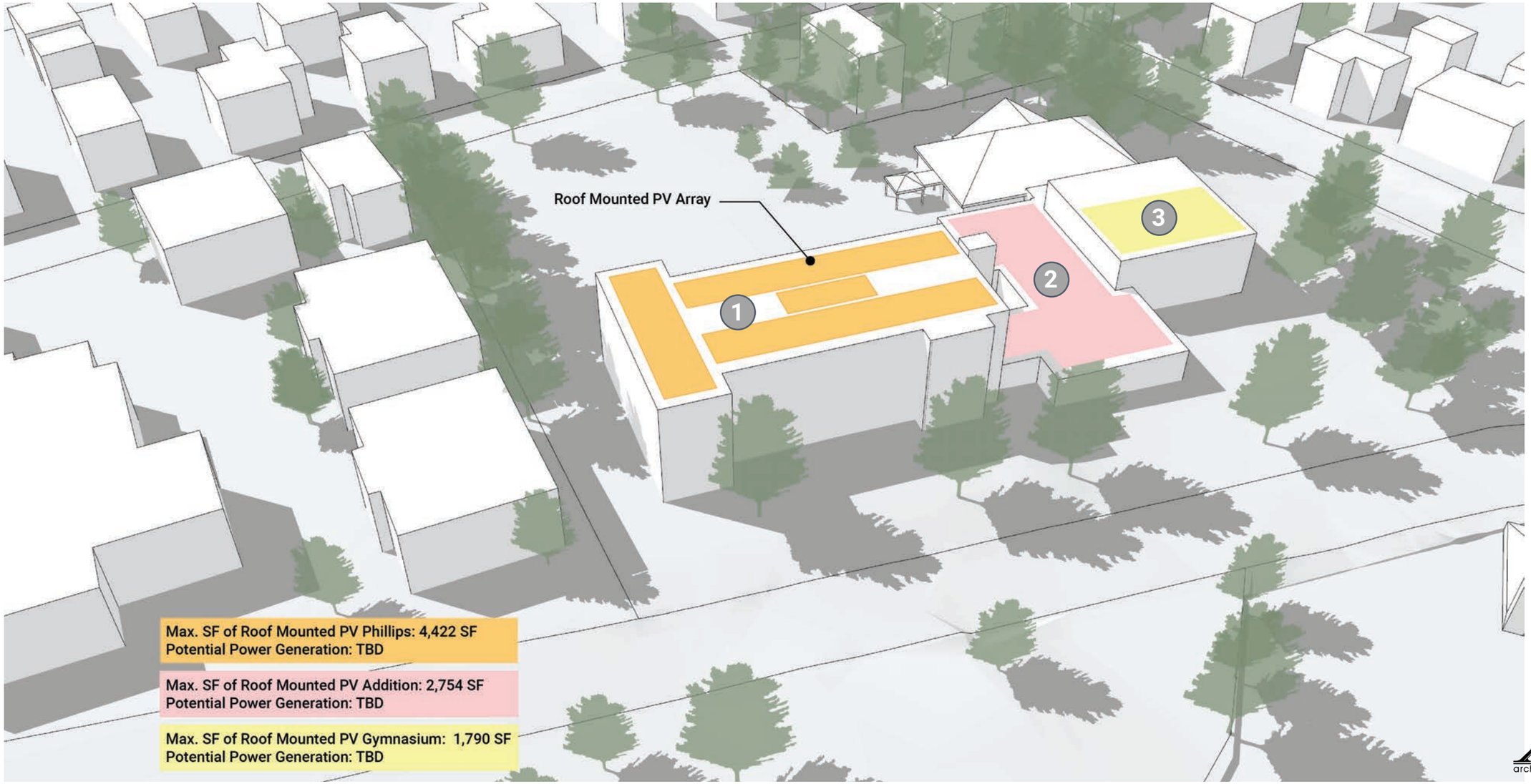
WHS Path to NZE

Building Integrated Photovoltaic Sun Shades



WHS Path to NZE

Photovoltaic Arrays on Phillips Building Roof



Roof PV		
Watertown HS Roof*	49,850	sf
Phillips Bldg Roof 1	4,422	sf
Phillips Bldg Roof 2	1,790	sf
Total Roof Area	56,062	sf
Assumed PV Capacity	*18*	*w/sf*
Max output of Roof PV	**1,009**	**kW**
Max annual production	**1,242,230**	**kWh**

*based on discussion on Tuesday 6/29, does not quite align with images received later in day on 6/29

Canopy PV		
Canopy 1	7,800	sf
Assumed PV Capacity	*18*	*w/sf*
Max output of Roof PV	**140**	**kW**
Max annual production	**175,465**	**kWh**

Solar Trees		
PV Trees	600	sf
Assumed Max Output	*18*	*W/sf*
Max output	**10.80**	**kW**
Max annual production	**13,536**	kWh

Total Max Output (all systems)	**1,210**	**kW**
Total Max annual production (all)	**1,478,638**	**kWh**

All results subject to change

PV Shade (Kawneer 1600 PowerShade)		
BIPV Shade (linear feet)	909	ft
Max Bay Size (linear feet)	8	ft
Number of Bays	113	Bays
Assumed Max Output (per Bay)	*75*	*W/Bay*
Max output system	**8.5**	**kW**
Max annual production	**10,867**	**kWh**

BIPV Façade (South)*		
BIPV Panels 1	6,276	sf
Assumed Max Output	5.7	W/sf
Max output	**35.8**	**kW**
Max annual production	**32,619**	**kWh**

*need to confirm basis of design product

BIPV Façade (East)*		
BIPV Panels 3 (East)	500	sf
Assumed Max Output	*5.7*	*W/sf*
Max output	**2.85**	**kW**
Max annual production	**1,979**	kWh

BIPV Façade (West)*		
BIPV Panels 4 (West)	500	sf
Assumed Max Output	*5.7*	*W/sf*
Max output	**2.85**	**kW**
Max annual production	**1,942**	kWh

Summary		
Target Site EUI	25	kBtu/sf annually
Building Area	194,196	sf
Target Energy Consumption (kBt	4,854,900	kBtu annually
Target Energy Consumption (kW	1,422,890	kWh annually
Estimated Energy Production	1,478,638	kWh annually

Watertown High School

PV Options

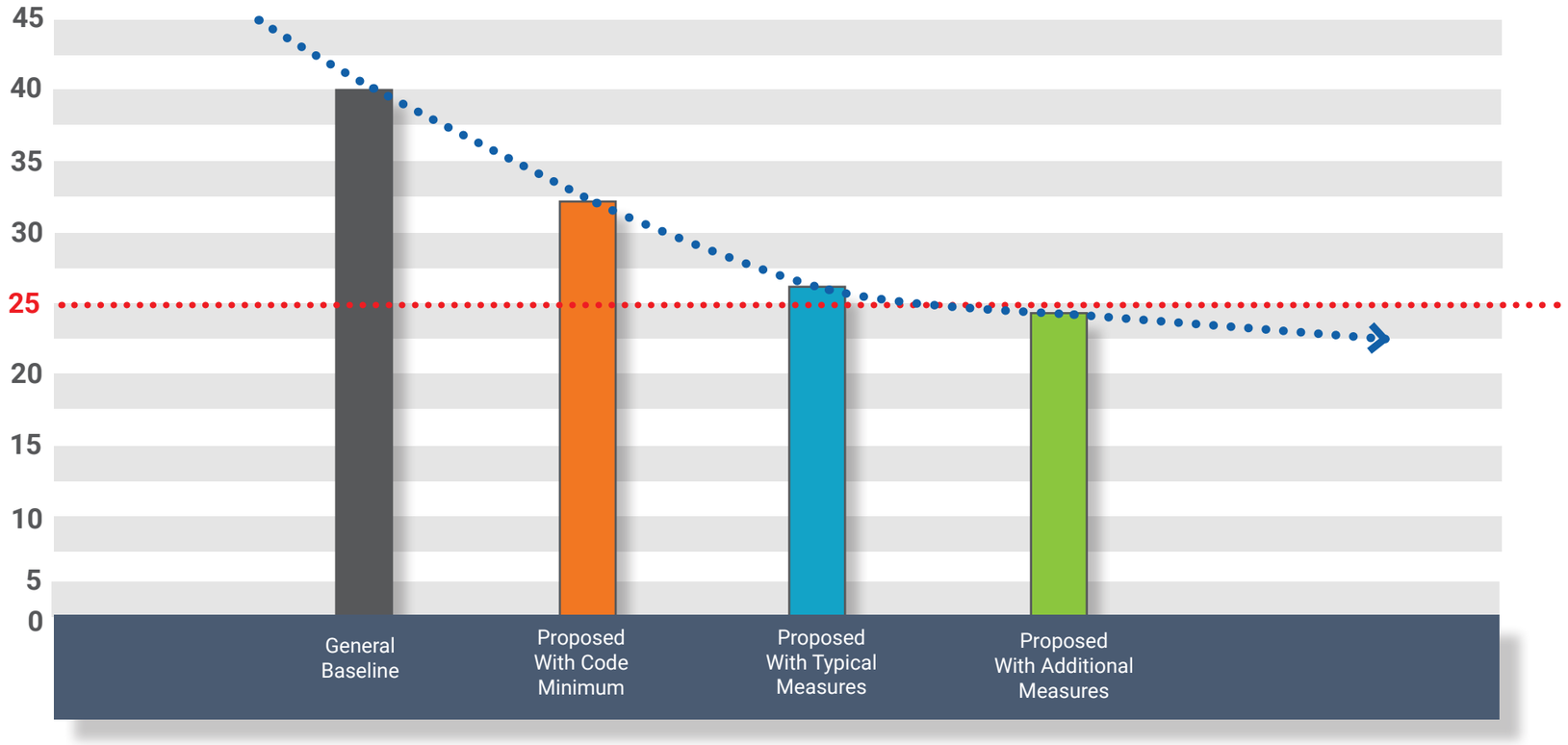
Roof Mounted PV	1,242,230 kWh
Canopy Mounted PV	175,465 kWh
Solar Trees	13,536 kWh
PV Sun Shades	10,867 kWh
BiPV South Facade	32,619kWh
BiPV East facade	1,979 kWh
BiPV West Facade	1,942 kWh
TOTAL OUPUT	**1,478,638 kWh**
TARGET CONSUMPTION	1,422,890 kWh
ABOVE TARGET	55,748 kWh

ELEMENTS OF SUSTAi3NABLE DESIGN

Watertown High School...targeting a low EUI

Focusing on EUI of 25 or Lower

▶ Adopt measures that can provide further energy savings lowering the EUI

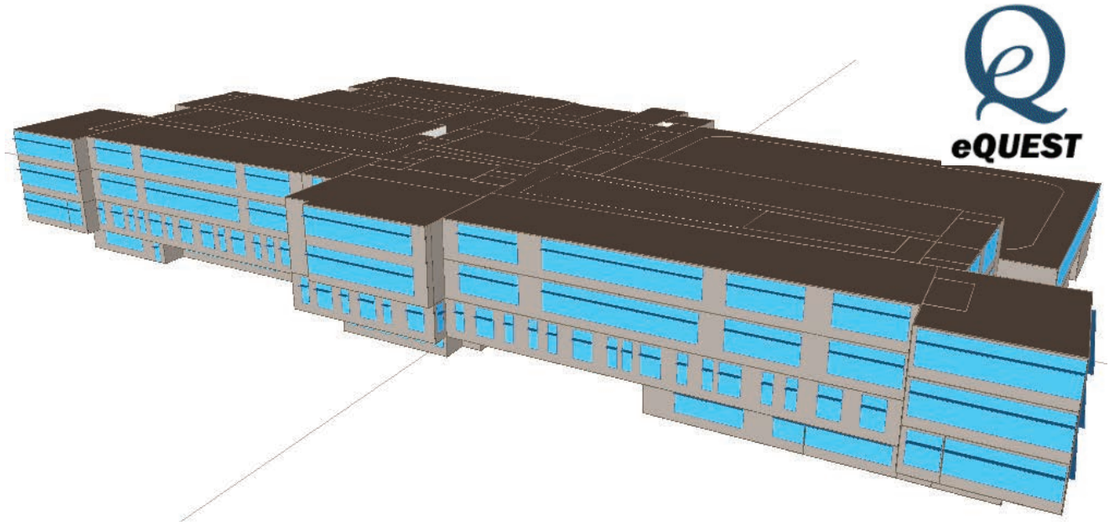


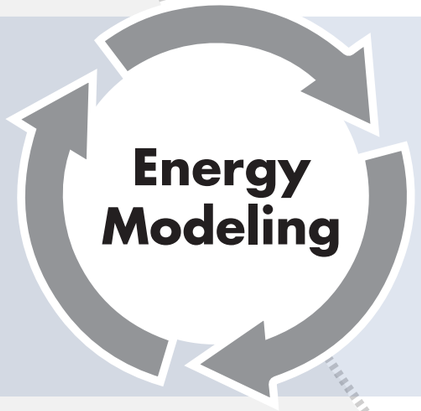
1 Building Analysis Program: eQUEST

A flexible program that permits modeling of a variety of building types and components, including:

- Complex architectural geometry
- Lighting systems
- Heating, ventilation, & air conditioning (HVAC) systems
- Central Plan Equipment
- Utility rate structures

Energy Consumption is calculated on an annual basis (8,760 hours per year).

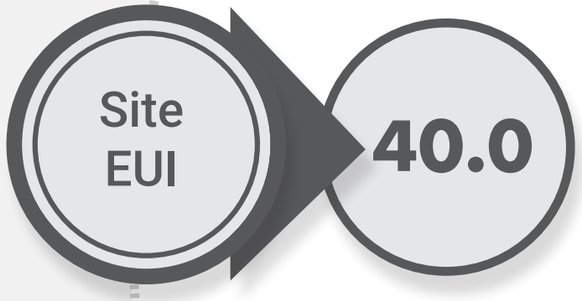




2 General Process for Developing Early Stage Energy Model

- Building architecture
- Building use
- Planned mechanical
- Planned lighting
- Planned plumbing
- Utility data
- Weather data

Focusing on EUI of 25 or Lower



General Baseline Building

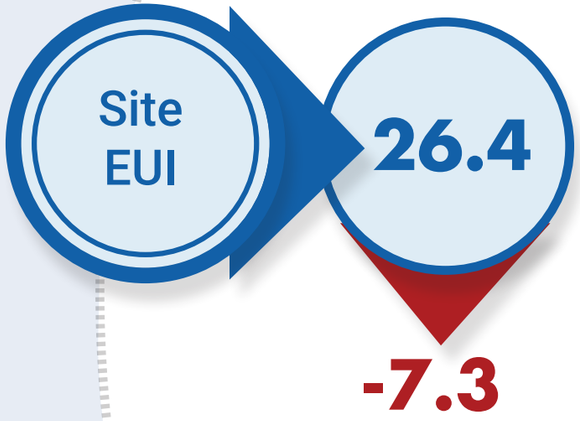
- As designed architectural geometry
- Typical traditional mechanical and plumbing system types found in New England, including chillers and natural gas-fired heating hot water boiler, with minimum heating and cooling efficiency and controls per code*
- Overall lighting system with maximum allowable lighting power density (LPD) and minimum controls per code

*Code: ASHRAE 90.1-2016 with Massachusetts Amendments

Proposed Building with Code Performance

- As designed architectural geometry
- As-designed mechanical and plumbing system types, with minimum heating and cooling efficiency and controls per code*
- Overall lighting system with maximum allowable lighting power density (LPD) and minimum controls per code

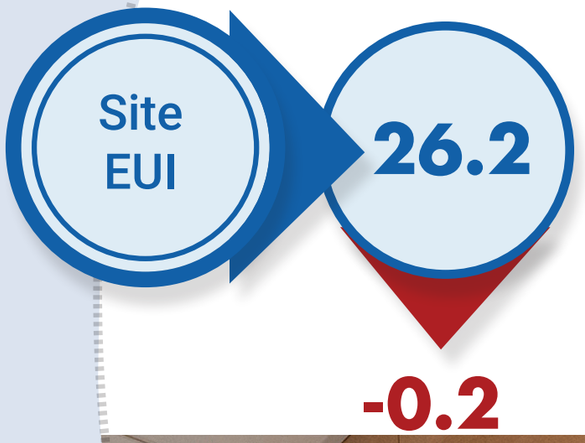
*Code: ASHRAE 90.1-2016 with Massachusetts Amendments



Proposed Building with Typical Measures Implemented

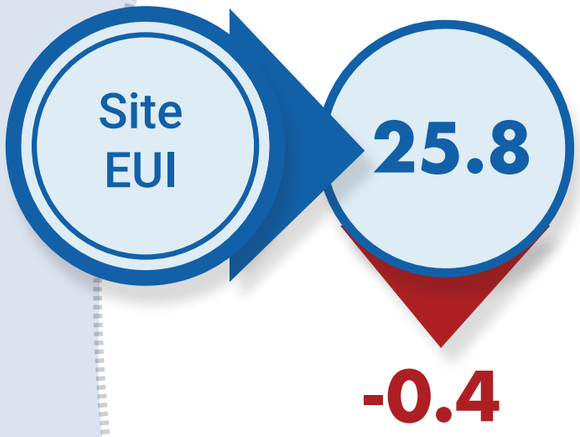
Watertown High School incorporates the following energy efficiency improvements....

- 404,752 kWh Electric Savings
- Improved Roof Insulation
- Improved Window Thermal Performance
- Demand Controlled Ventilation for Gym, Cafeteria, Classrooms, Administration
- Variable Airflow Indoor Variable Refrigerant Flow (VRF) Units
- Exhaust Air Enthalpy Wheels with 65% Effectiveness
- High Efficiency VRF Air Source Heat Pumps



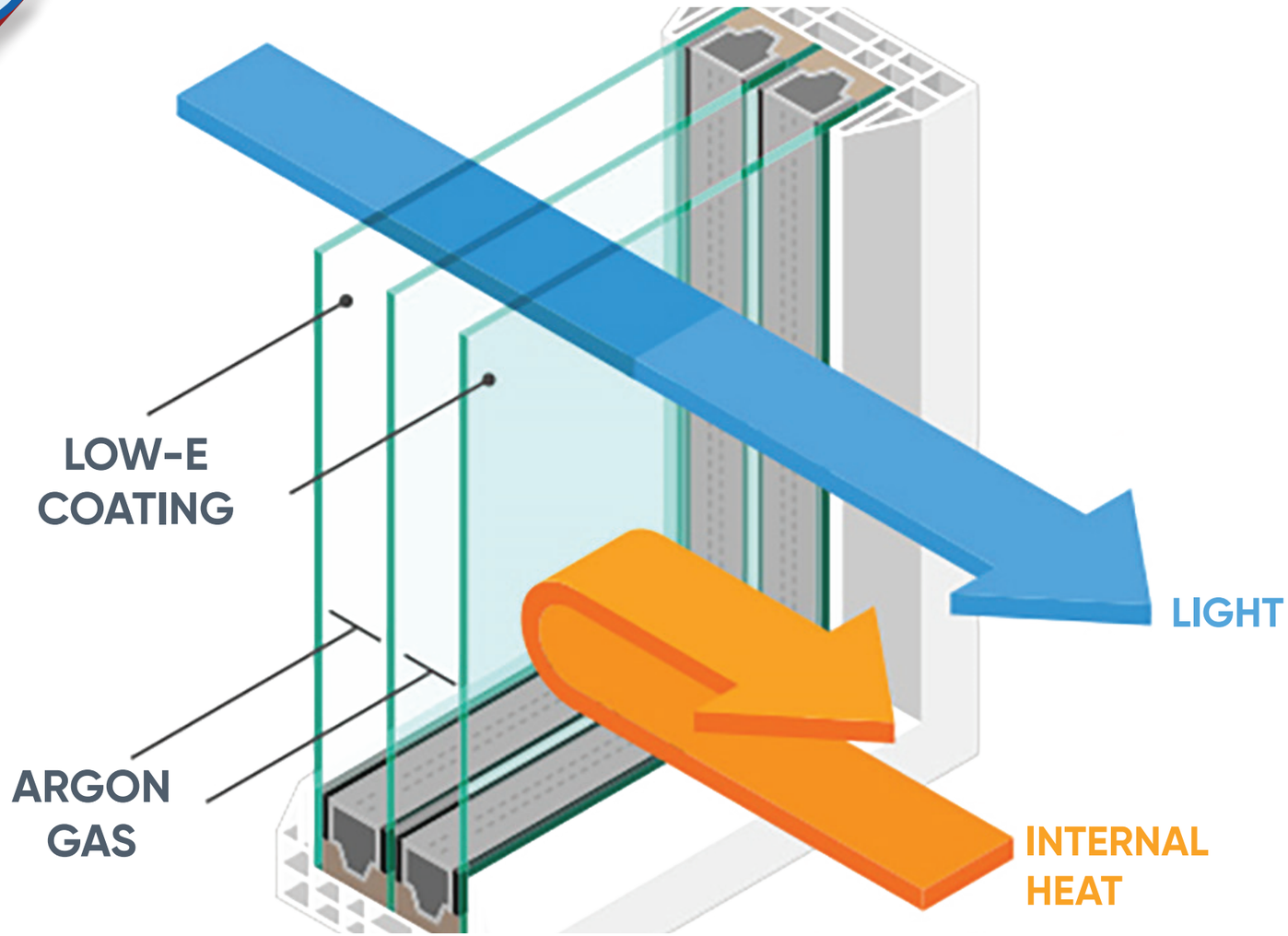
Lighting Power Density

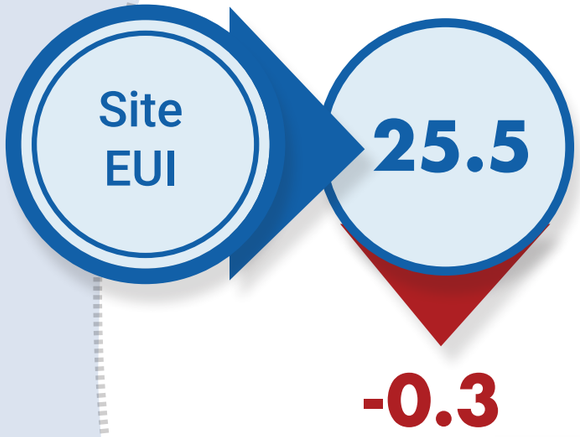
- 12,396 kWh Electric Savings
- (LPD) 0.425 W/sf



Triple Glazing
(Assembly Thermal Performance u-0.23, SHGC 0.19)

- 24,768 kWh Electric Savings

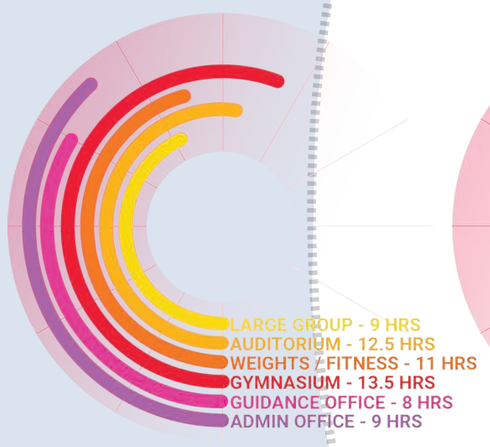




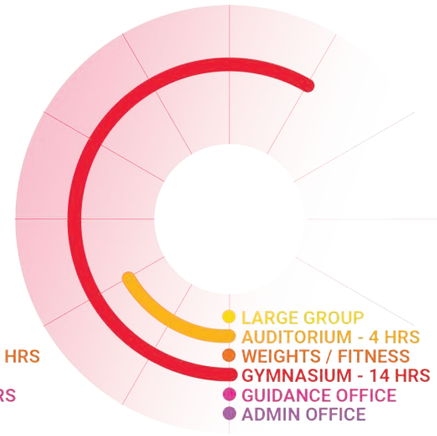
Reduce Total Glazing Area

- 16,489 kWh Electric Savings
- 25% Reduction in Galzing Area

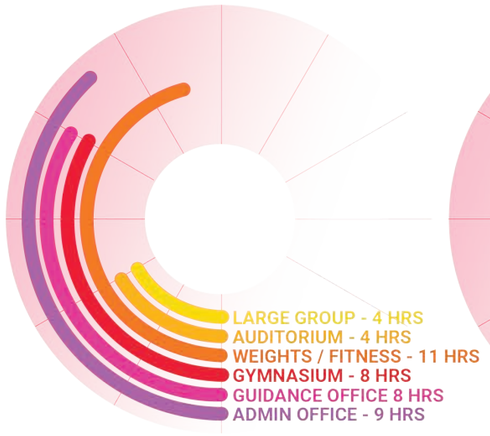
Understanding the Building Hours of Operation & Program Use



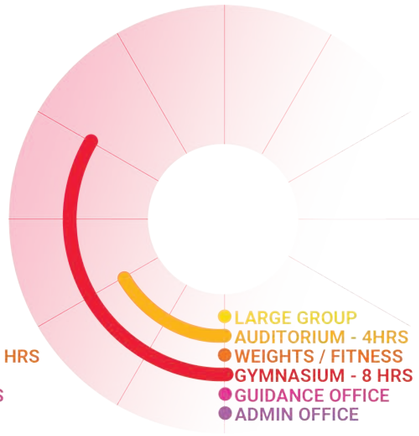
SCHOOL YEAR
COMMUNITY CORE HOURS - **WEEKDAY**



SCHOOL YEAR
COMMUNITY CORE HOURS - **WEEKEND**

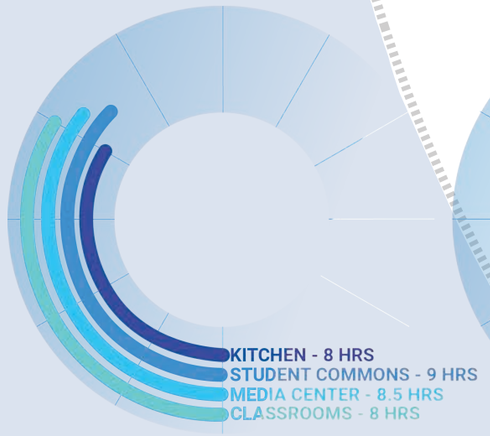


SUMMER BREAK
COMMUNITY CORE HOURS - **WEEKDAY**

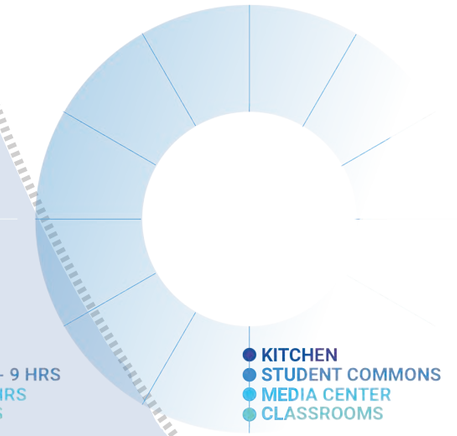


SUMMER BREAK
COMMUNITY CORE HOURS - **WEEKEND**

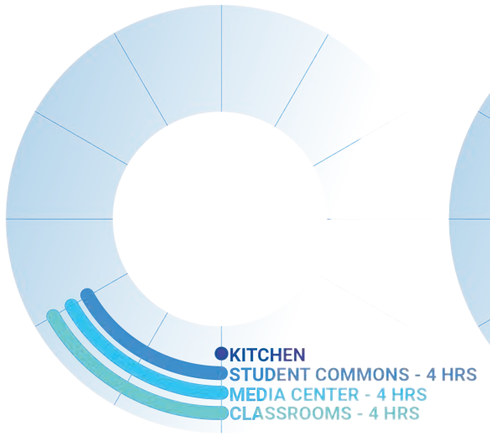
SCHOOL VACATION WEEKS
COMMUNITY CORE HOURS



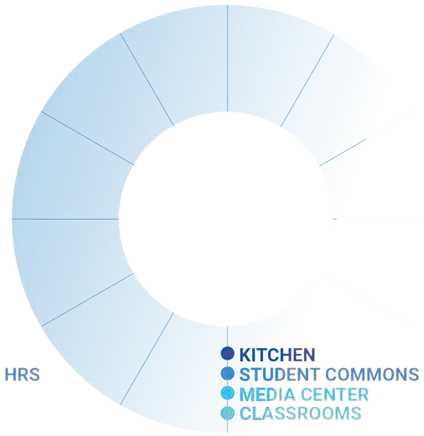
SCHOOL YEAR
ACADEMIC CORE HOURS - **WEEKDAY**



SCHOOL YEAR
ACADEMIC CORE HOURS - **WEEKEND**



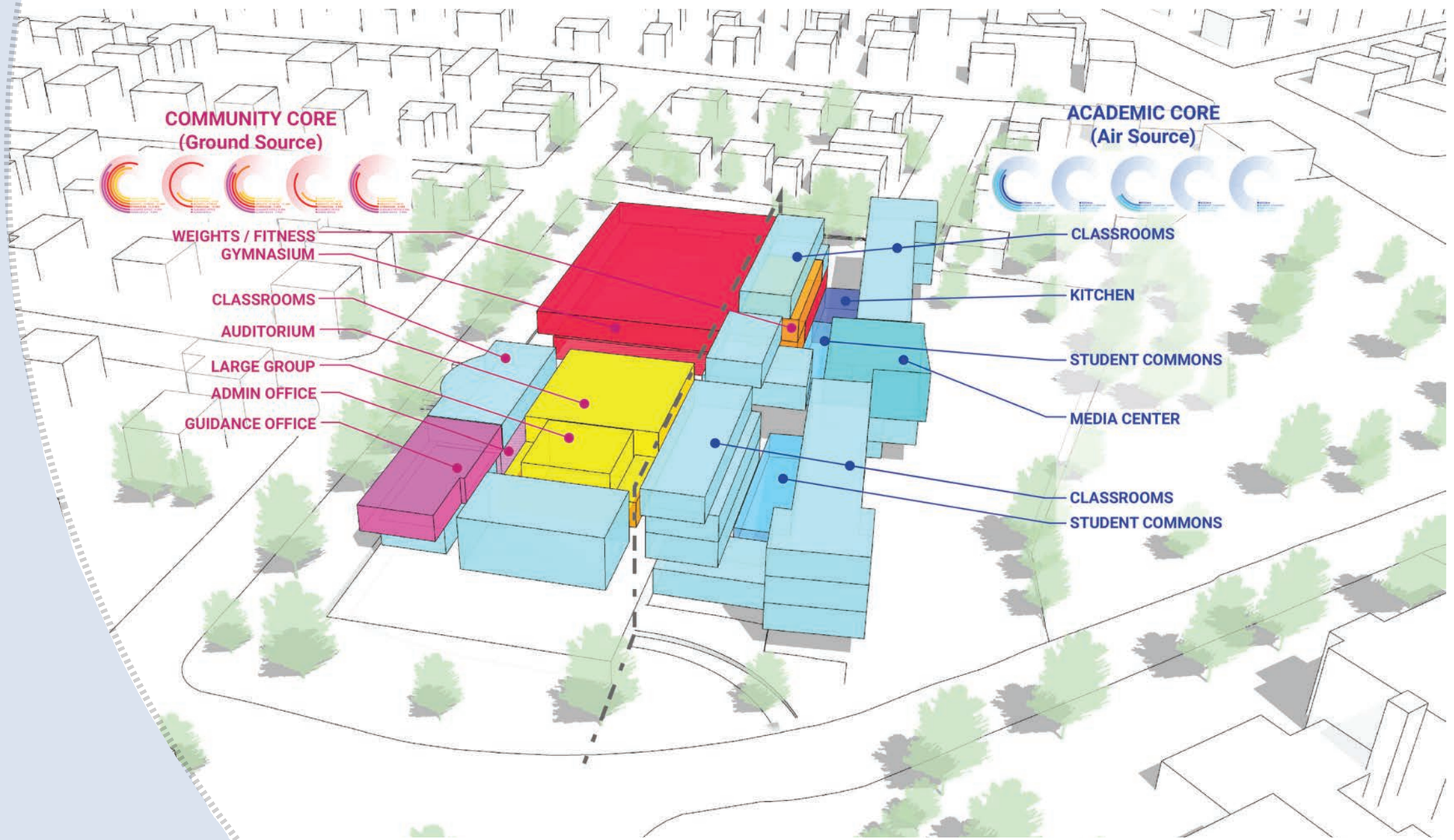
SUMMER BREAK
ACADEMIC CORE HOURS - **WEEKDAY**



SUMMER BREAK
ACADEMIC CORE HOURS - **WEEKEND**

SCHOOL VACATION WEEKS
ACADEMIC CORE HOURS

Hybrid HVAC System: Ground Source and Air Source



Site EUI **24.8**

-0.7

Ground Source Heat System

▶ 38,308 kWh Electric Savings

Steps to achieve NZE for Watertown HS

1 Select a method of electricity generation using **renewable energy** (practical in MA):

- — Solar
- — Geothermal
- — Wind

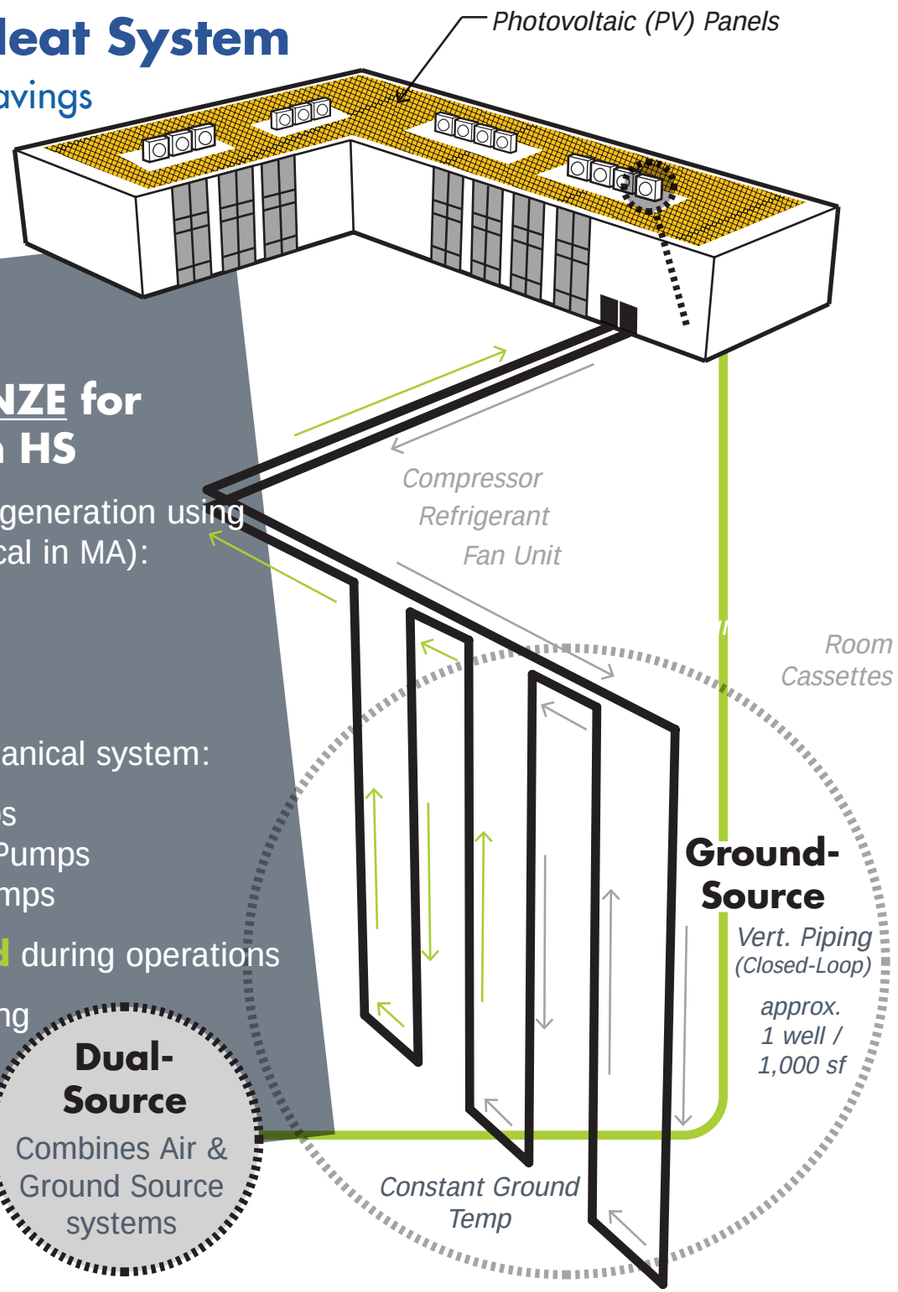
2 Select an **all-electric** mechanical system:

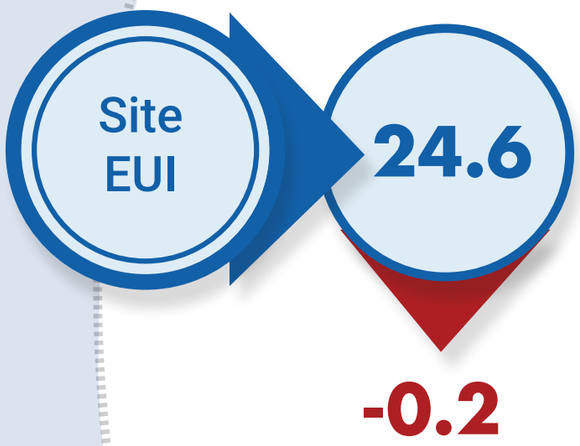
- — Air-Source Heat Pumps
- — Ground-Source Heat Pumps
- — Dual-Source Heat Pumps

3 Monitor/**reduce demand** during operations

- — Metering & Monitoring
- — Occupant Behavior
- — Reduce Plug Loads

Dual-Source
Combines Air & Ground Source systems





Low Flow Faucets and Shower Heads

- 10,587 kWh Electric Savings

REDUCED HOT WATER DEMAND = ENERGY SAVINGS

Faucet
if the faucet is run for
4 minutes a day...

Normal Fixture

4,000 gal/yr

Low Flow Fixture

3,000 gal/yr

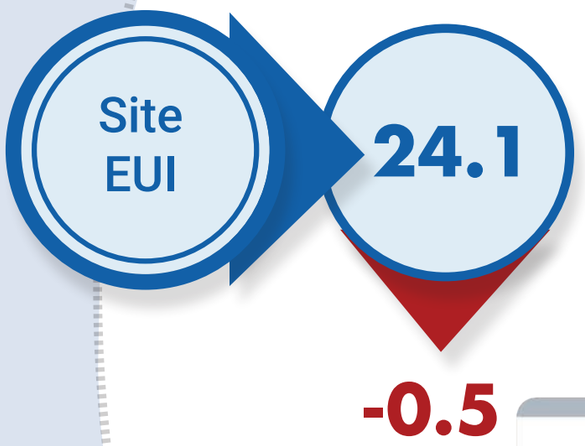
Shower Head
average family uses
40 gallons a day...

Normal Fixture

14,600 gal/yr

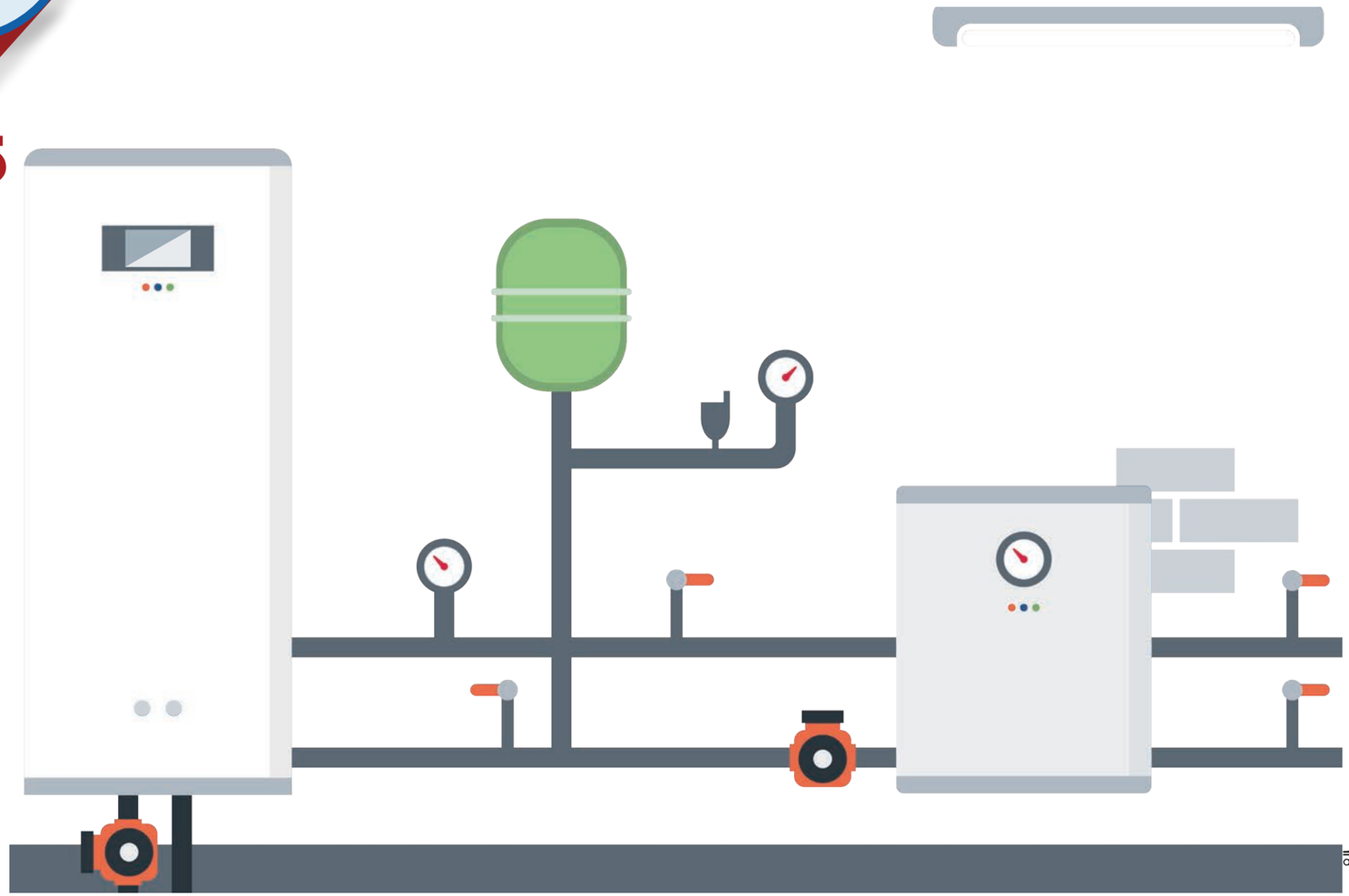
Low Flow Fixture

10,200 gal/yr

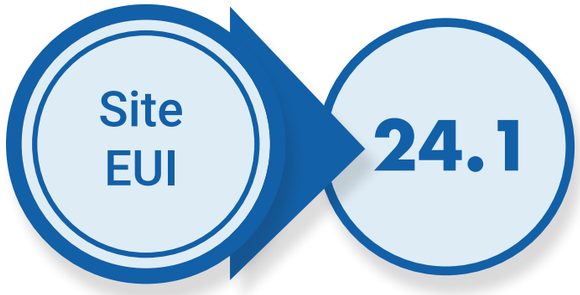


Heat Pump for Domestic Hot Water Heating

- 28,941 kWh Electric Savings



Focusing on EUI of 25 or Lower



Proposed Measures

Description	Electric Savings kWh	Site Energy Savings kBtu / sf	Site Energy Savings %	Total Annual Site Energy kBtu / sf
Proposed Building with typical Energy Efficiency Measures	404,752	7.3	22%	26.4
ADD: Building Average Lighting Power Density (LPD) of 0.40 W / sf	12,396	0.2	1%	26.2
ADD: Triple Glazing (Assembly Thermal Performance U-0.23, SHGC 0.19)	24,768	0.4	1%	25.8
ADD: Reduced Total Glazing Area by Approximately 25% of Current Design	16,489	0.3	1%	25.5
ADD: Ground Source System for Community Core Programs	38,308	0.7	2%	24.8
ADD: Low Flow Faucets and Shower Heads	10,587	0.2	1%	24.6
ADD: Heat Pump for Domestic Hot Water Heating	28,941	0.5	2%	24.1


WHS