ARROWSTREET

DEMYSTIFYING NET ZERO

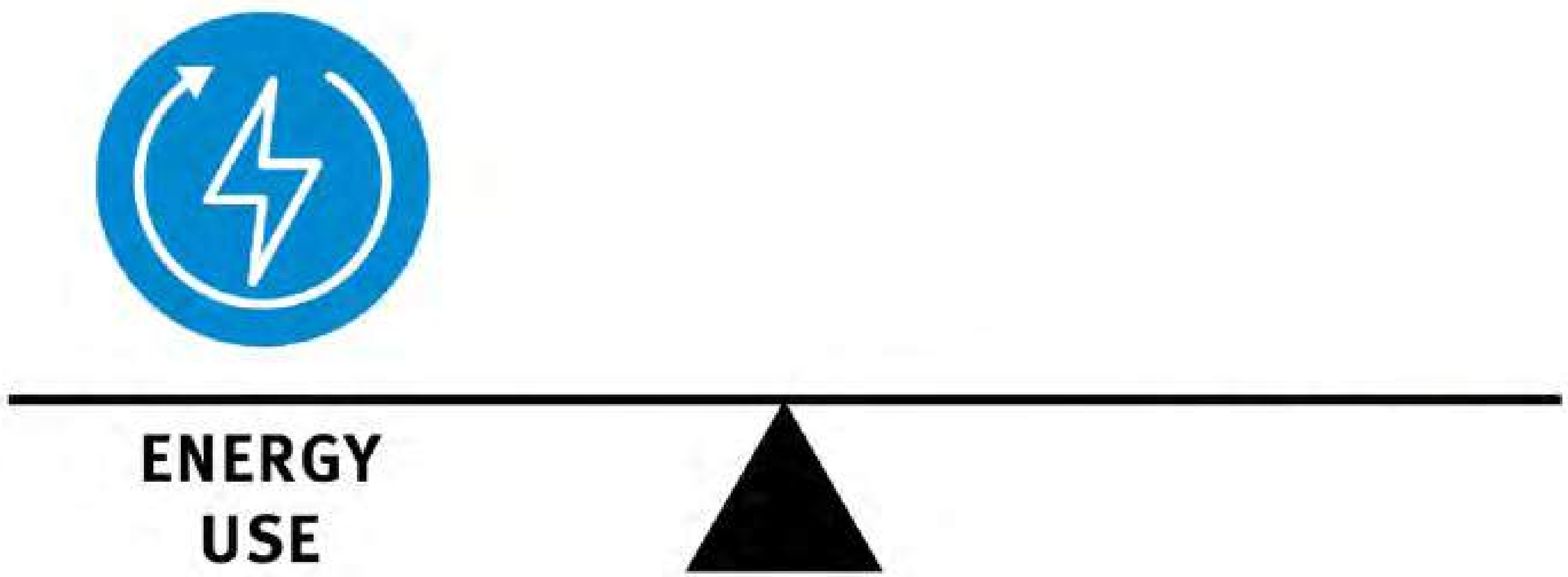
VIRTUAL
27 MAY 2021

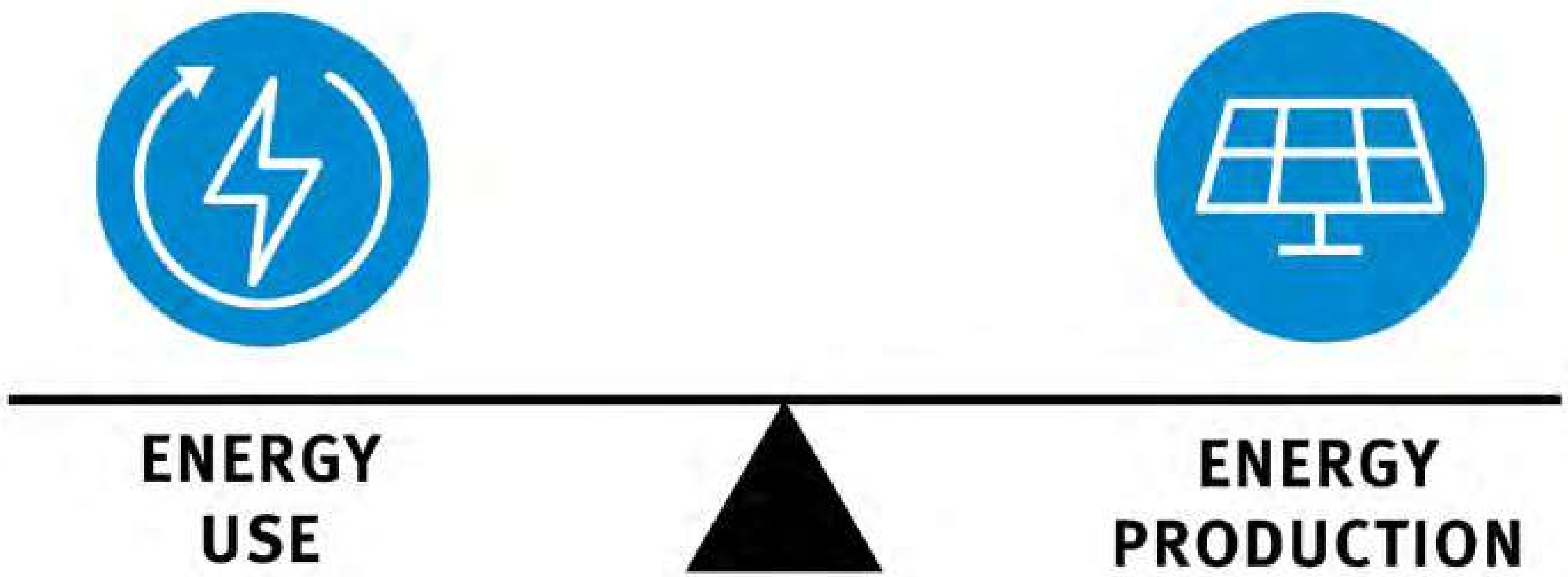
PREPARED FOR

MSBA

DEFINING NET ZERO

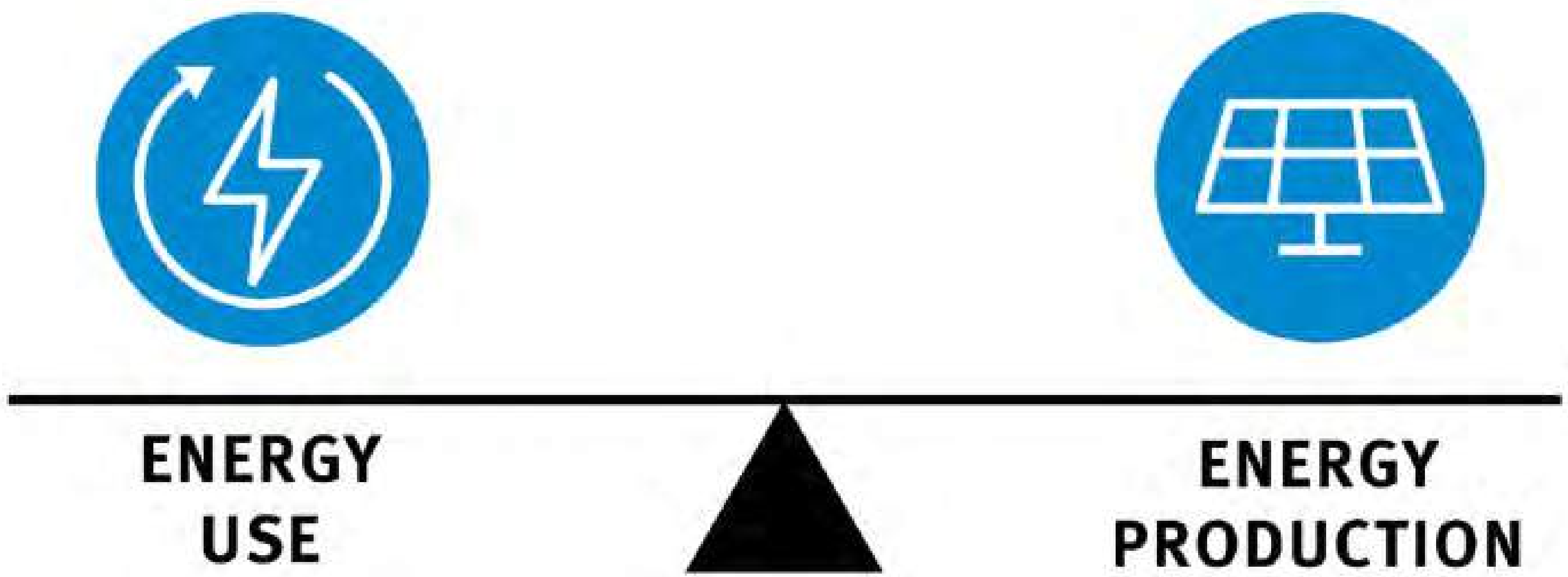
NET ZERO ENERGY

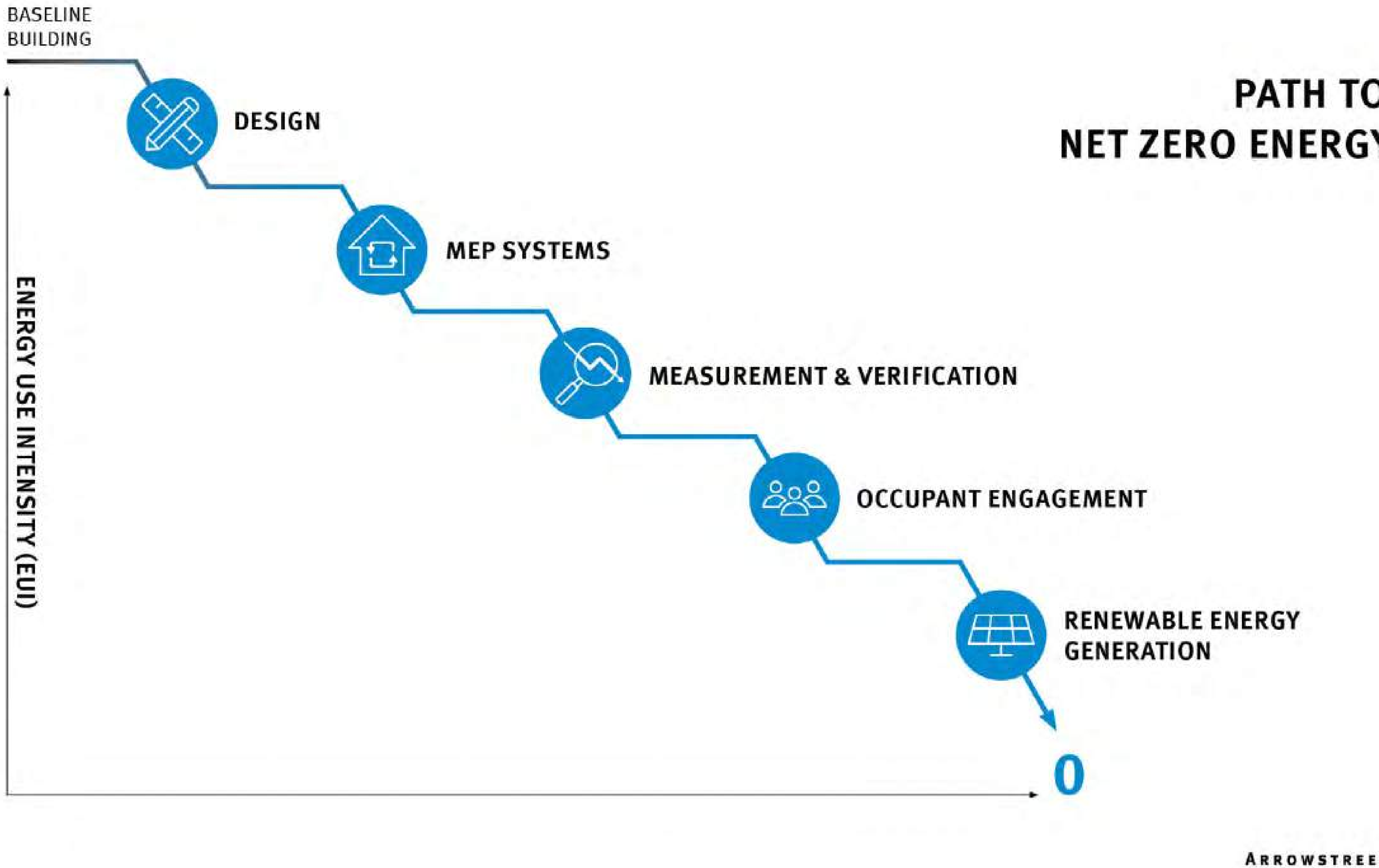

ENERGY
USE

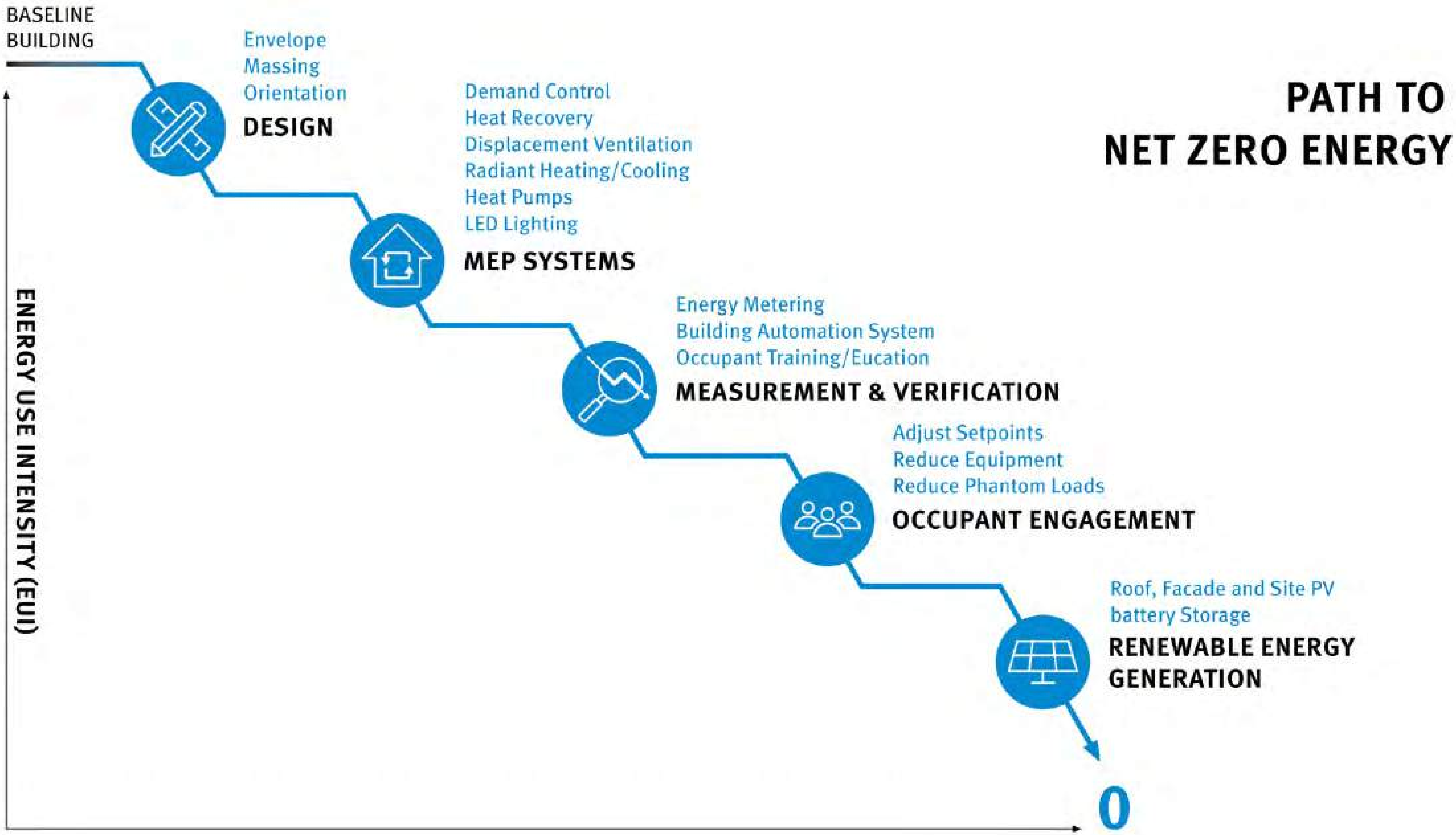

ENERGY USE
ENERGY PRODUCTION

NET ZERO ENERGY DEFINITION

A building, that has an ultra low EUI, whose annual energy use is equal or less than the amount of on-site or off-site new renewable energy.




BASELINE
BUILDING
PATH TO
NET ZERO ENERGY
DESIGN
MEP SYSTEMS
MEASUREMENT & VERIFICATION
OCCUPANT ENGAGEMENT
RENEWABLE ENERGY
GENERATION
ENERGY USE INTENSITY (EUI)
0
ARROWSTREET



ARROWSTREET

energy use intensity: EUI

kBtu* / SqFt / Year

energy / area / time

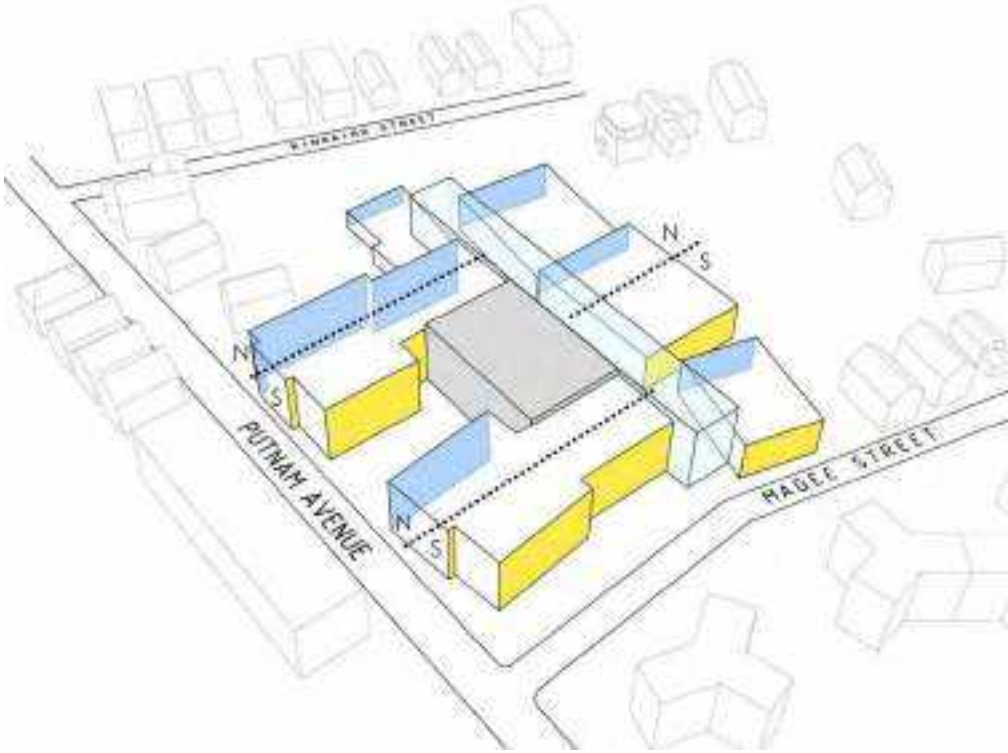
*thousands British thermal units

DLR Group
Architecture Engineering Planning Interiors

energy use intensity: EUI

Lower is Better

- reduce energy used
  - design first
  - systems second
- building area kept warm & dry

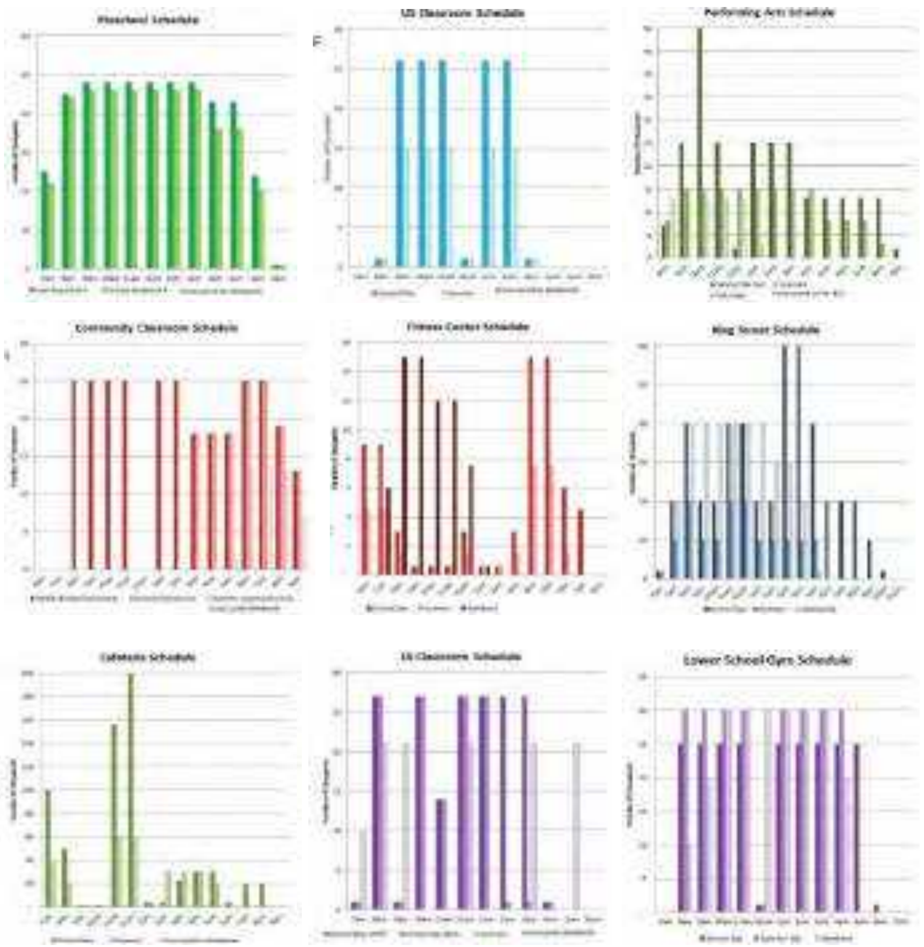


Graphics courtesy of Perkins Eastman

energy use intensity: EUI

Lower is Better

- reduce energy used
  - design first
  - systems second
- define building area kept warm & dry
- hours of operation

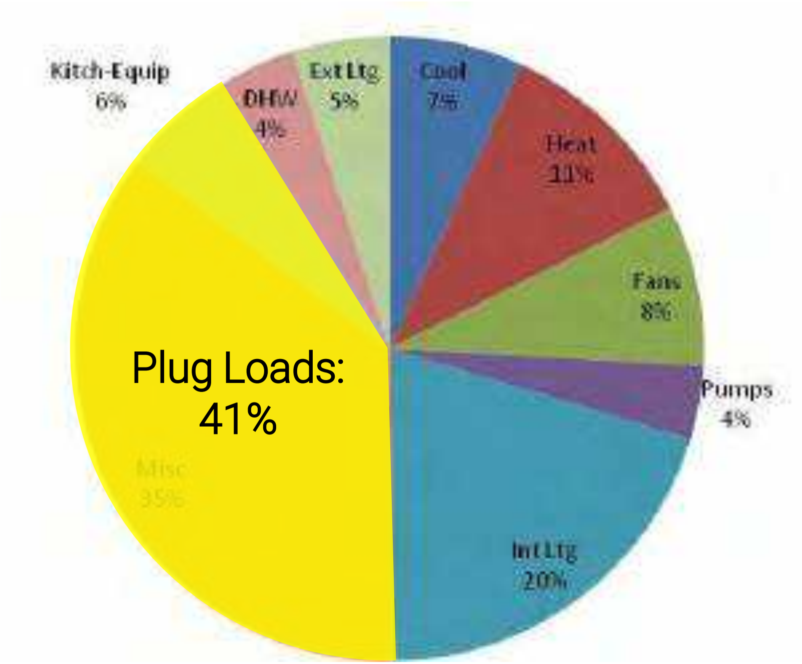


Graphics courtesy of AKF Engineers | In Posse

energy use intensity: EUI

Lower is Better

- reduce energy used
  - design first
  - systems second
- building area kept warm & dry
- hours of operation
- occupant behavior



Graphics courtesy of AKF Engineers | In Posse

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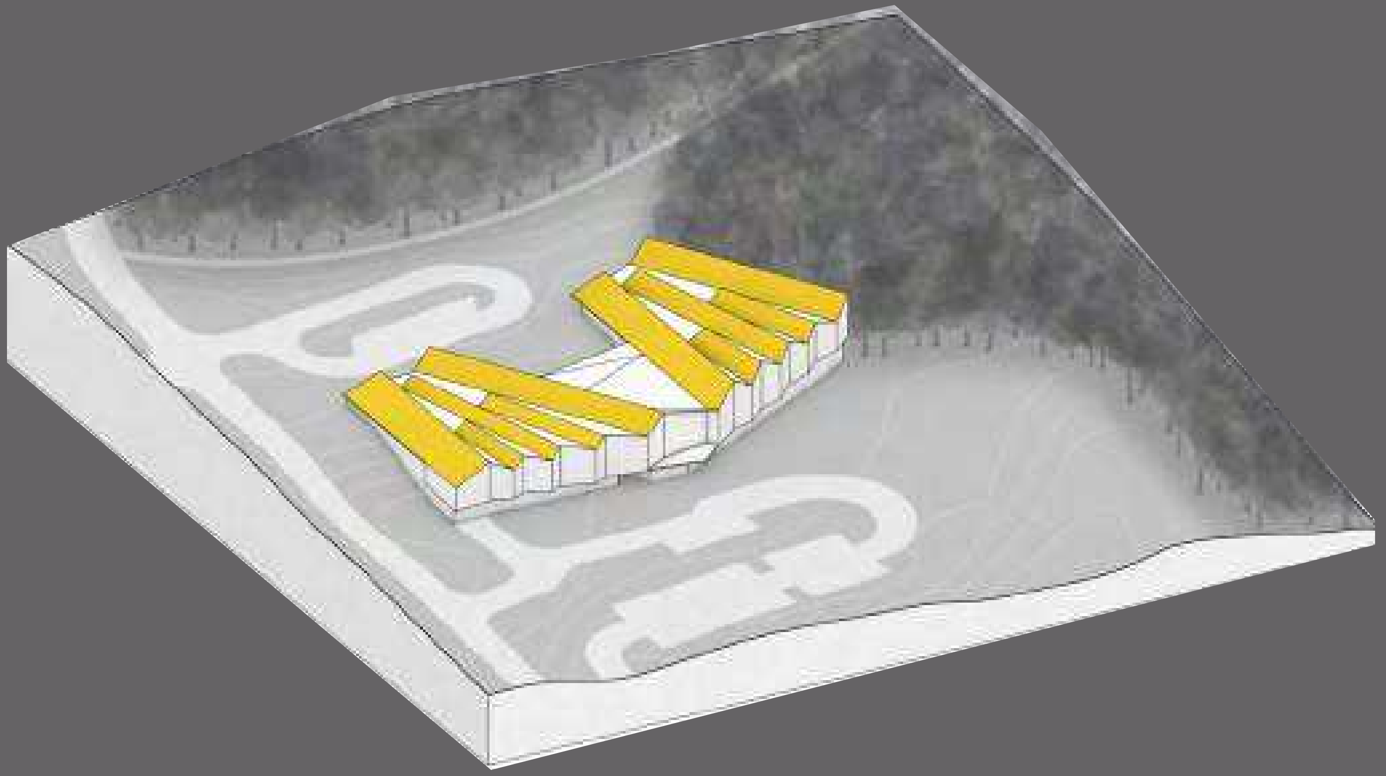
Demystifying Net Zero Energy

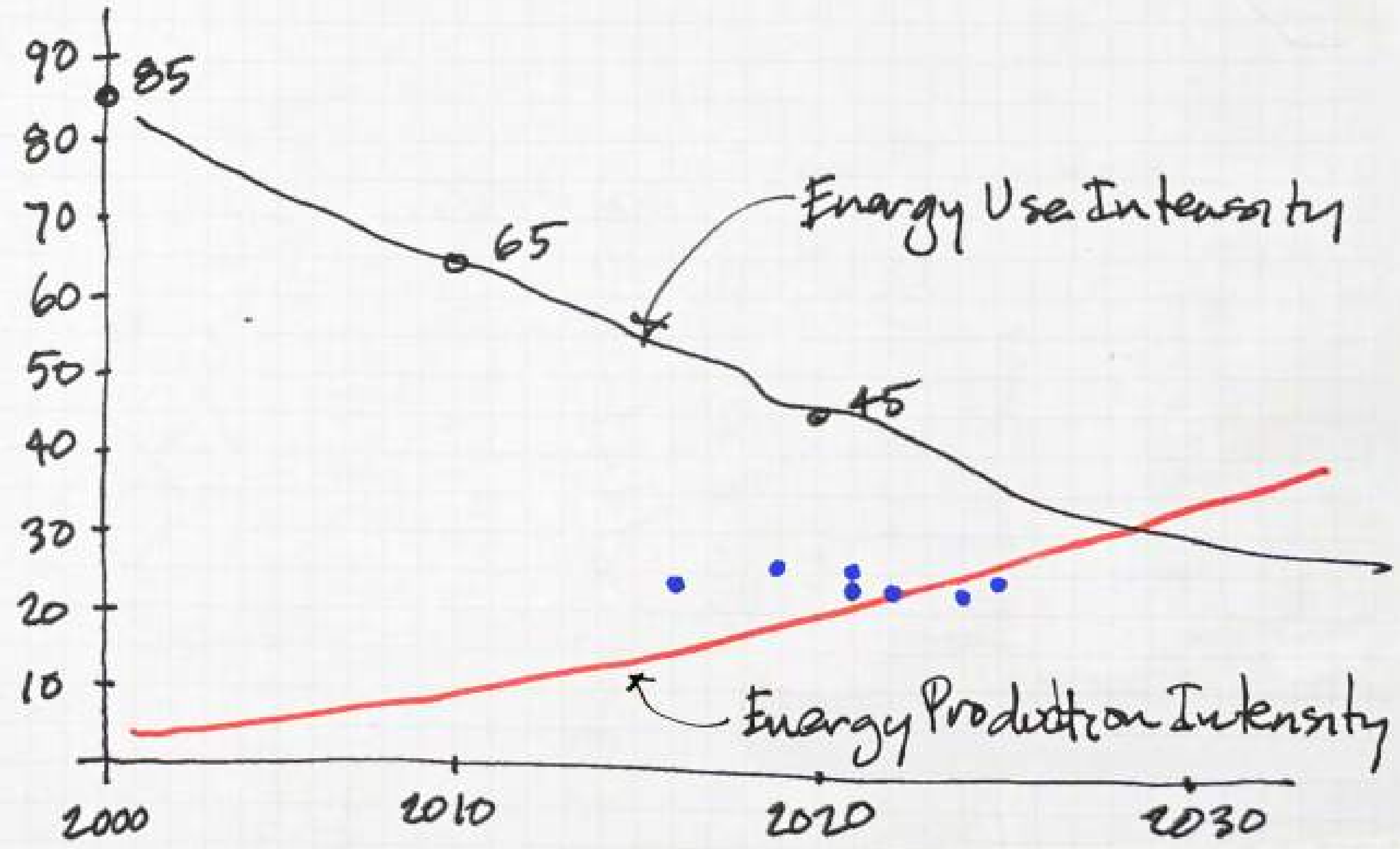
Annie E. Fales Elementary School

Westborough, MA
May 20, 2020



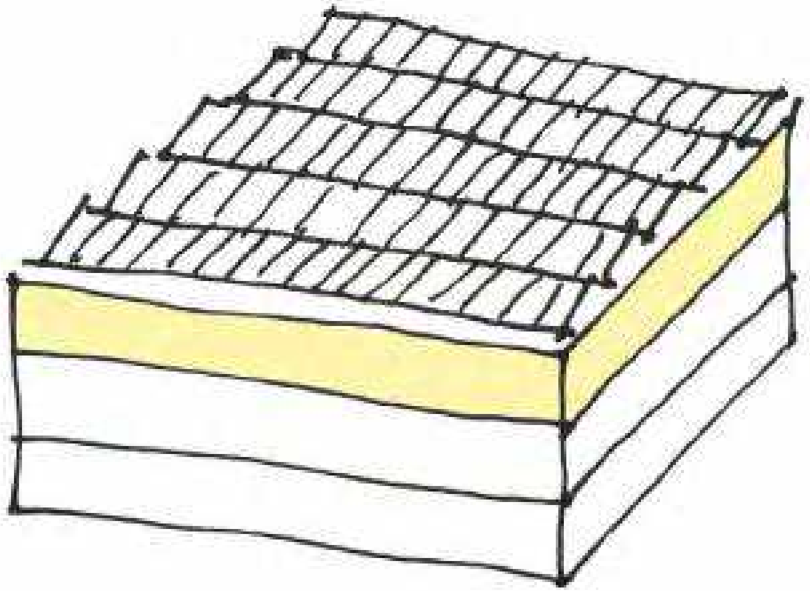
HMFH ARCHITECTS

Rapidly Changing Technology



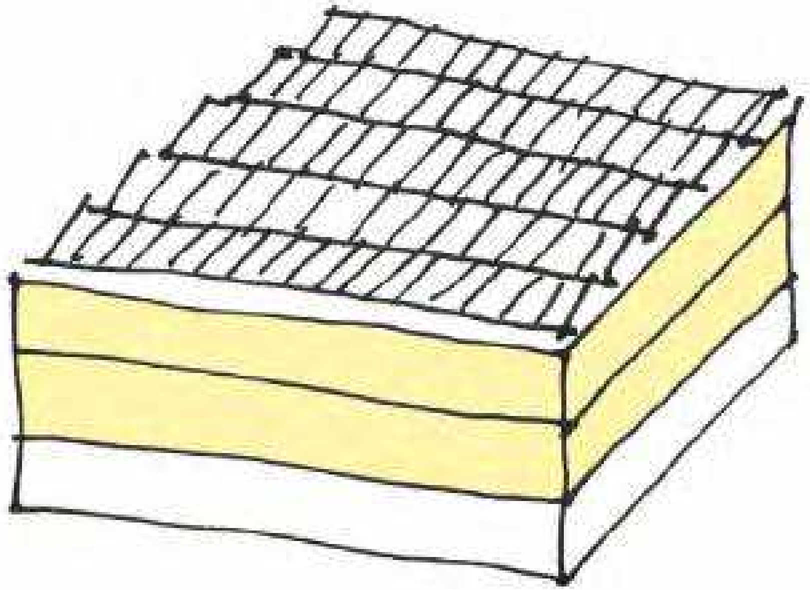
Changing Technology: Energy Production

2000



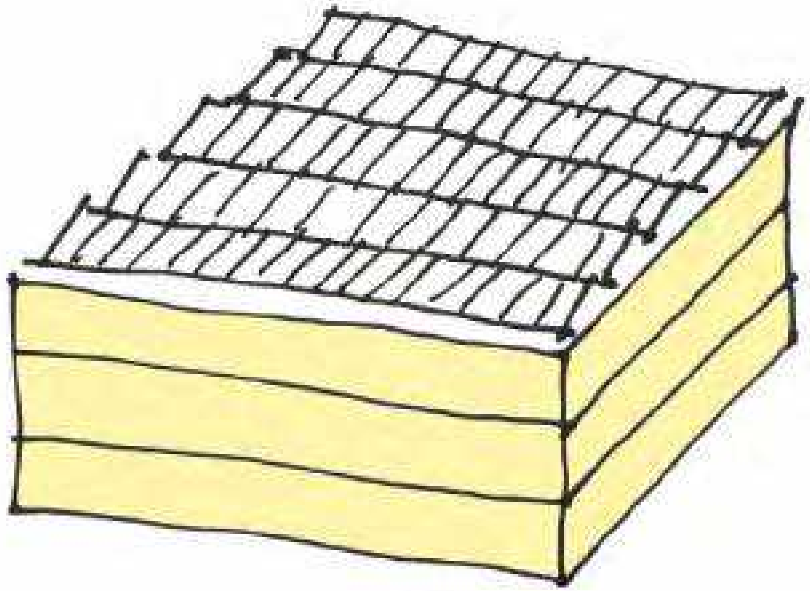
$12.50/watt
200 watts/panel

2010



$7.50/watt
300 watts/panel

2020



$2.50/watt
450 watts/panel

PV systems are more powerful and more affordable

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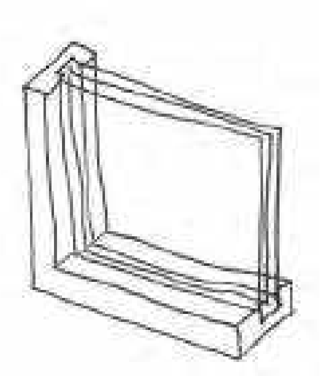
Changing Technology: Energy Reduction

	2000	2010	2020
	Commercial LED *not available*	$40.00/bulb 60 watt equivalent	$2.00/bulb 60 watt equivalent
	Triple glazed windows *not readily available*	**50% more $$** than double glazed windows	**20% more $$** than double glazed windows

Common practices now commonly used:

- lighting controls that adjust for occupancy and daylight
- heat recovery ventilation
- centralized energy monitoring and system controls

Energy reduction strategies are more available and more affordable

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GEOTHERMAL WATER-TO-WATER SOURCE SIMULTANEOUS HEATING/COOLING HEAT PUMP CHILLERS W/ HEAT RECOVERY PLANT

History of Chillers

50 + years: Water to Water Heat Pumps
30 years: Modular Chillers
About 20 years: Modular Chiller with Heat Recovery (Multistack)

Benefits

- High-efficiency
- Modular design provides level of redundancy & individual module control
- Heat recovery provides reheat during cooling season
- Durability & Reliability
- Service friendly w/ easy access to major components
- Fossil Fuel Free-Zero Combustion Design

Defining Variable Refrigerant Flow (VRF)

What is VRF?

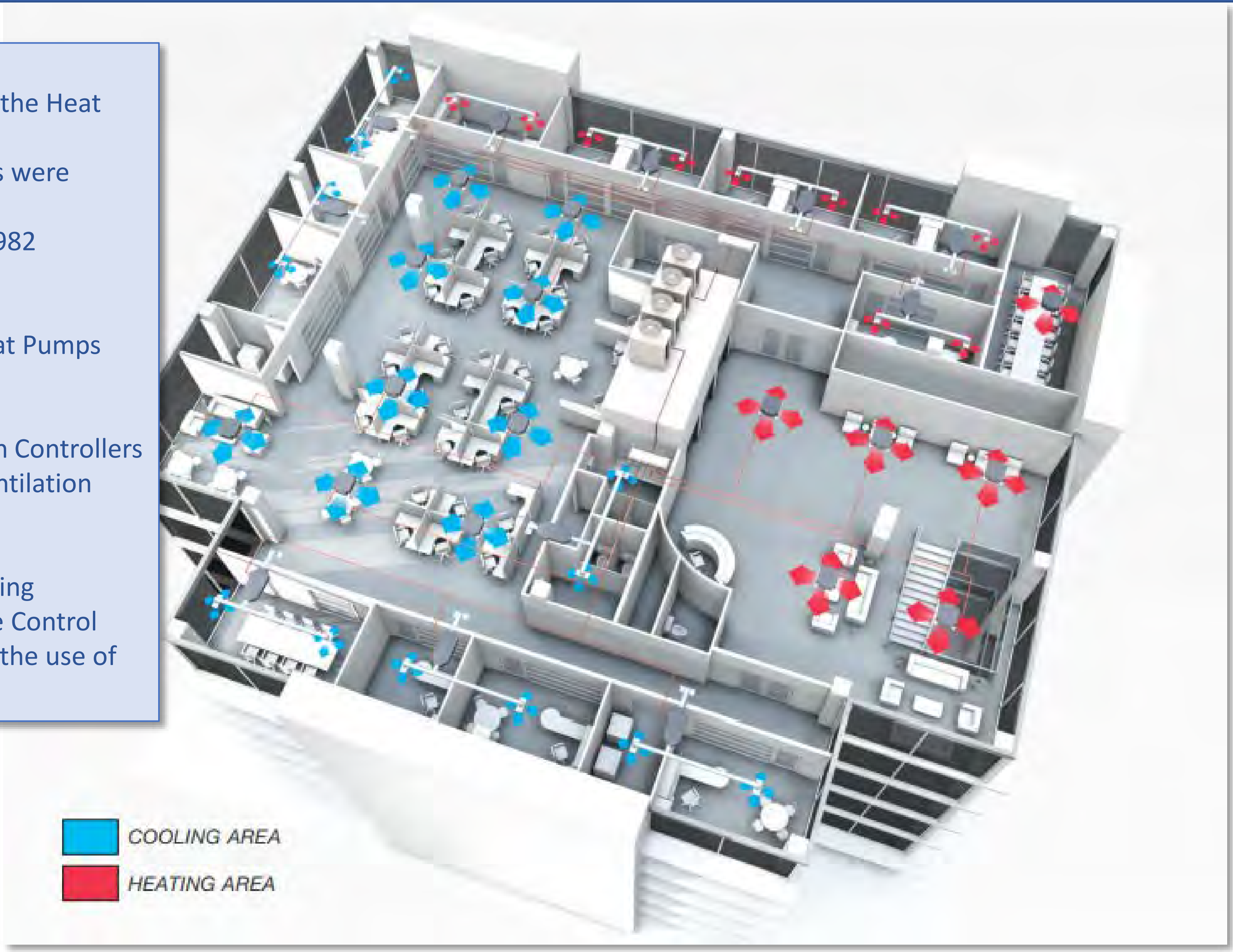
- VRF is a modern Evolution of the Heat Pump Cycle
- The first practical heat pumps were invented in 1948
- VRF has been around since 1982

System Consists of:

- Roof or Ground Mounted Heat Pumps
- Ceiling Cassettes
- Concealed Fancoil Units
- Refrigeration Piping w/Branch Controllers
- Energy Recovery Units for Ventilation

System Provides:

- Simultaneous Heating & Cooling
- Individual Space Temperature Control
- Built-in Redundancy through the use of multiple compressors



Defining Environmental Justice

Senate Bill S.9: *An Act creating a next-generation roadmap for Massachusetts climate policy*

- Environmental Justice Population
- Environmental Justice Principles
- Environmental Burden
- Environmental Benefit

Building Architecture as New Technology

Hosmer

Exterior Rendering

View from the corner of Concord Road and Chauncey Street

Hosmer

Interior Rendering

View from the second floor overlook of the Lower Learning Commons

Cunniff
Exterior Rendering

View from Warren Street

Cunniff

Interior Rendering

View of the interior educational environment with collaborative corridors

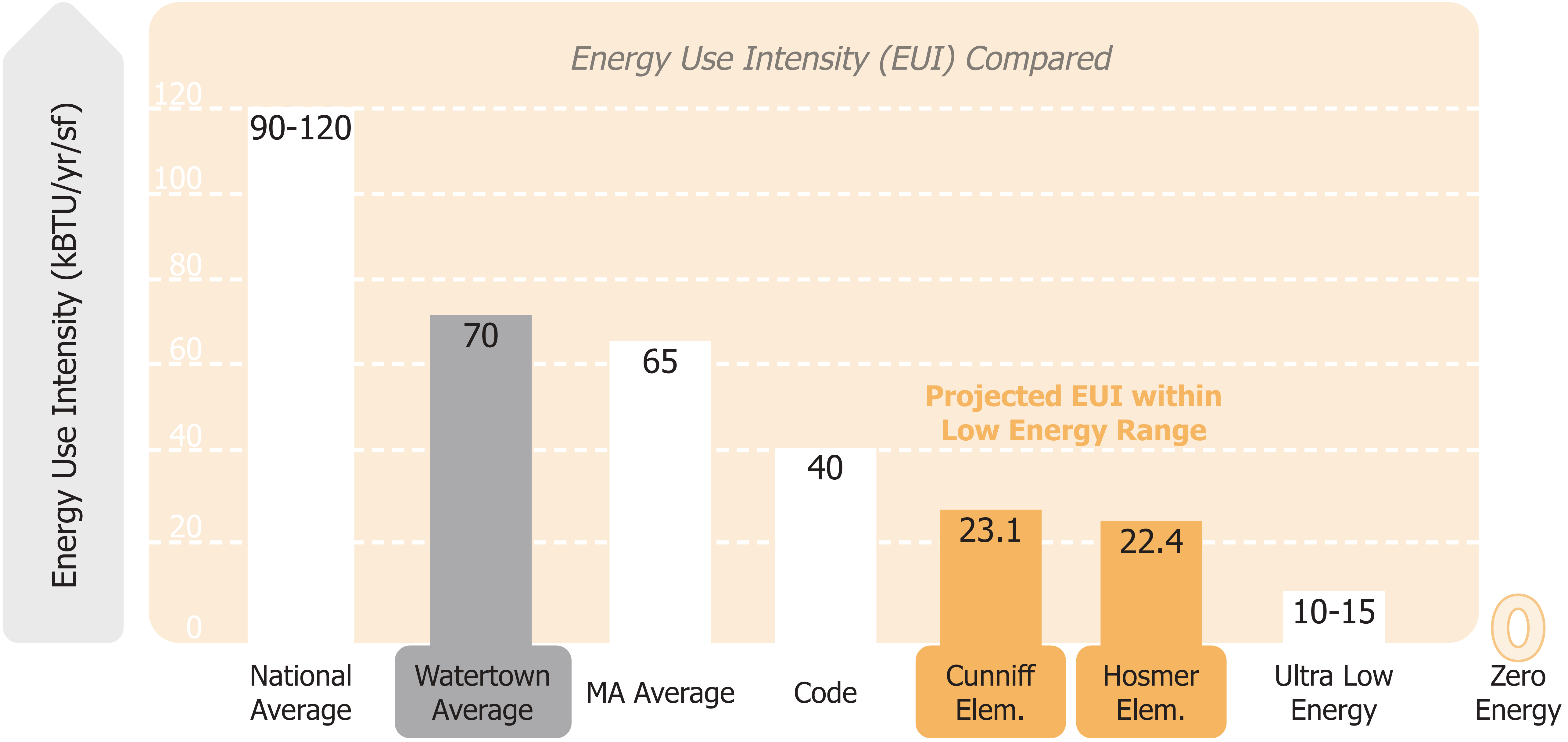
Hosmer

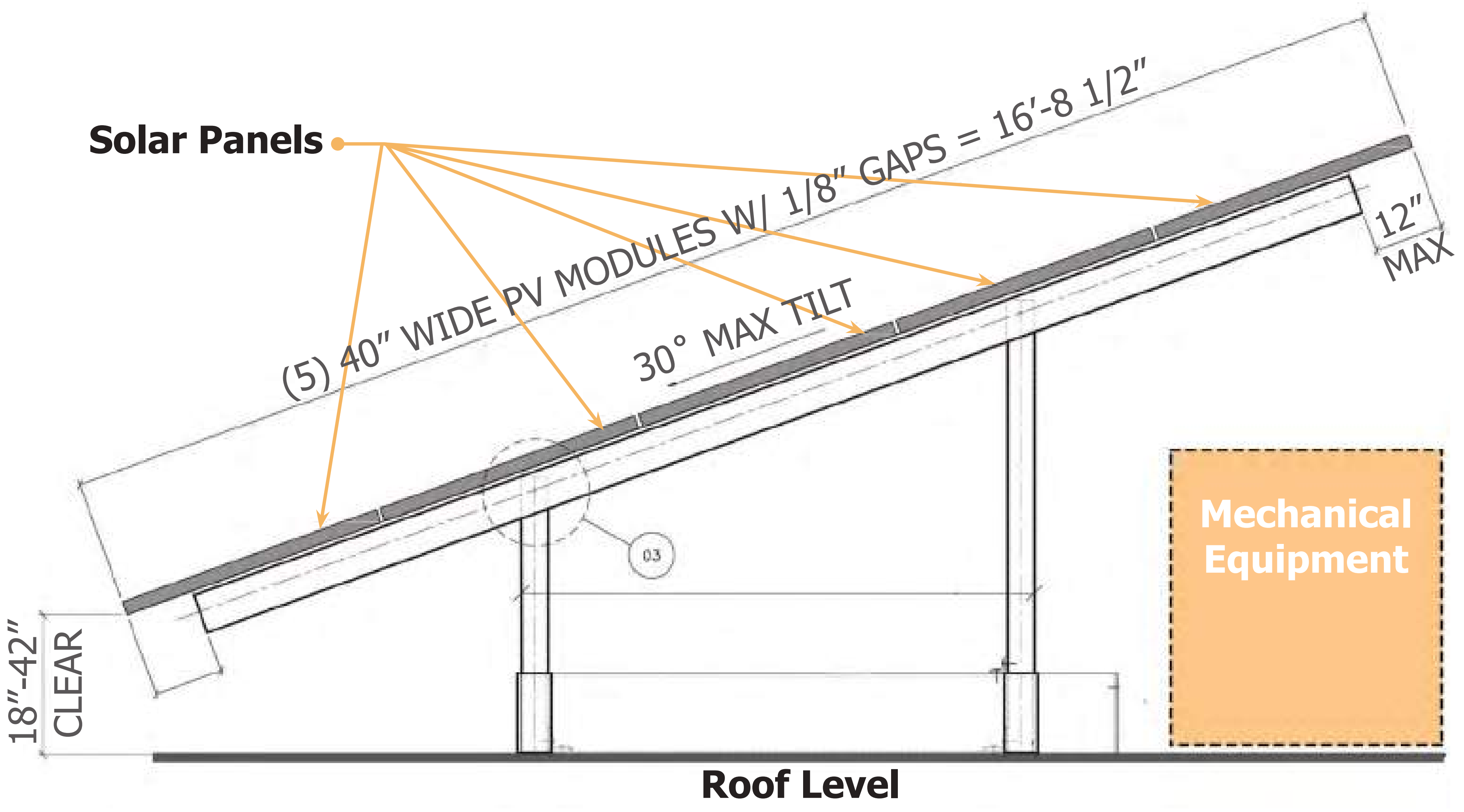
Interior Rendering

View of typical classroom in Hosmer, with cloud ceilings & exposed beams

Resultant Energy Use Intensity (EUI)

Cunniff & Hosmer Elementary Schools • Watertown, MA





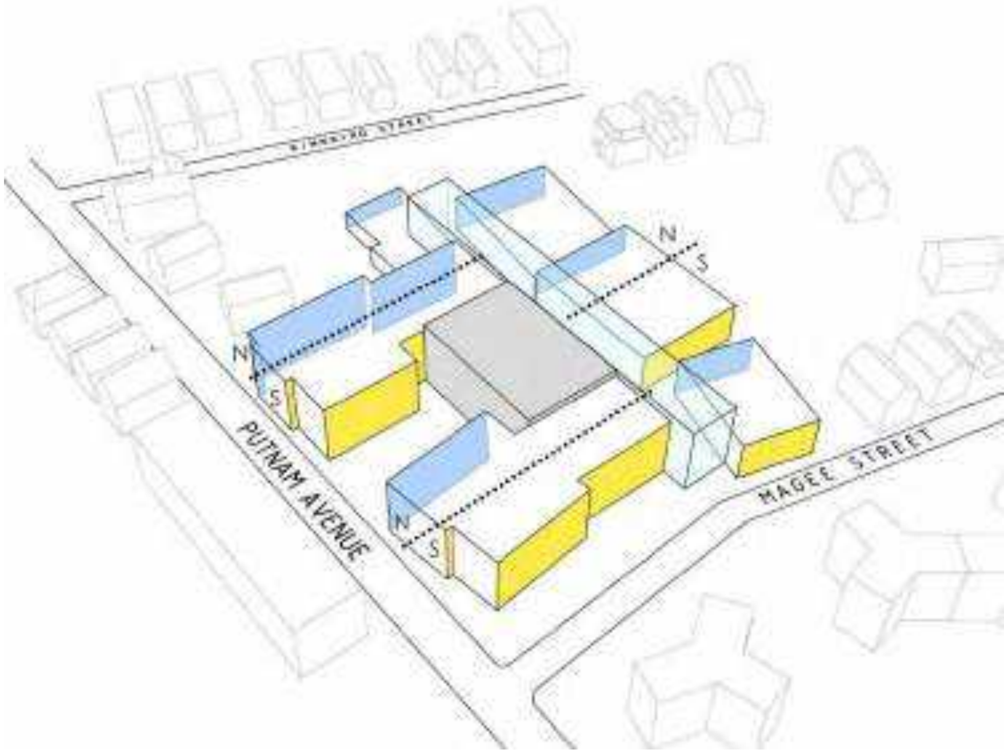
Elevated Solar Panel framing to reduce heat gain & clear equipment

VRF on Hosmer's roof

design **FIRST**

Optimize Building to Reduce Energy Use

- orientation
- window to wall ratio

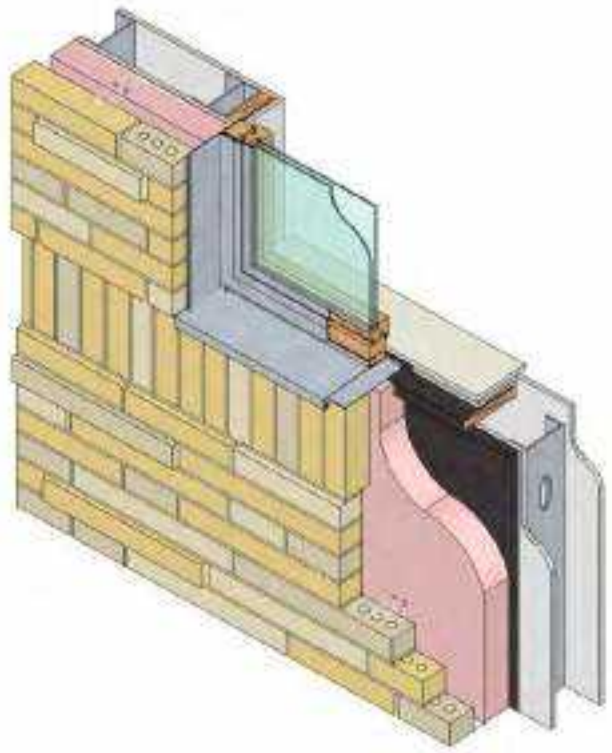


Graphics courtesy of Perkins Eastman

design FIRST

Optimize Building to Reduce Energy Use

- passive systems
  - insulation & weather barriers

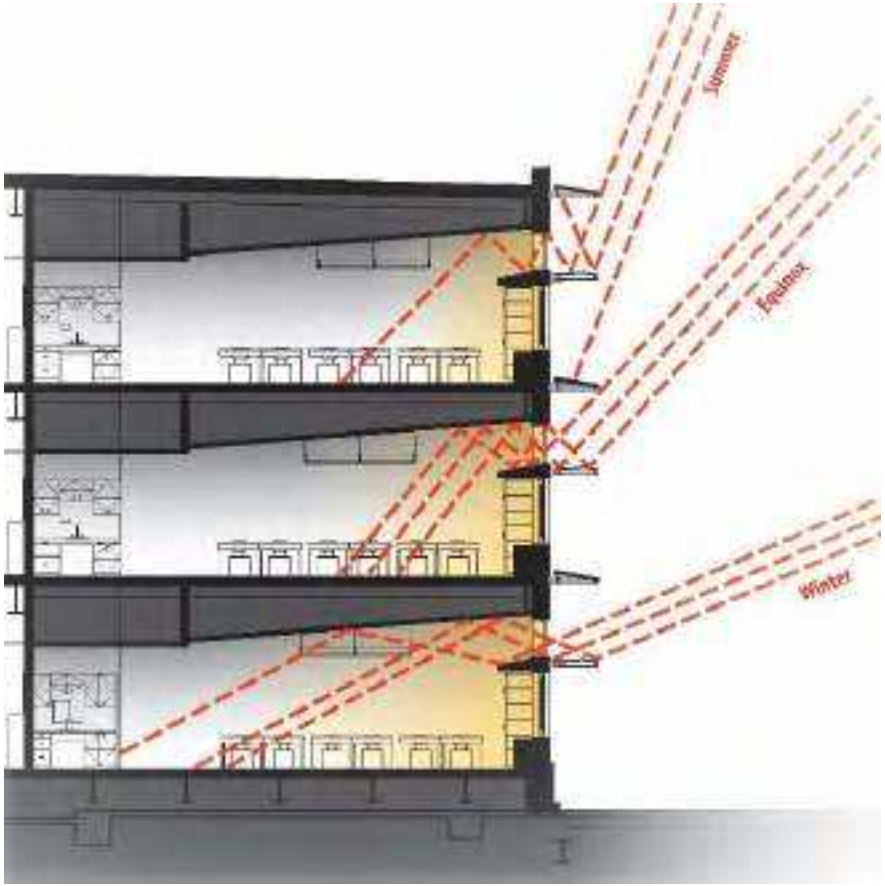


Graphics courtesy of Perkins Eastman

design FIRST

Optimize Building to Reduce Energy Use

- passive systems
  - insulation & weather barriers
  - sunshades & light shelves

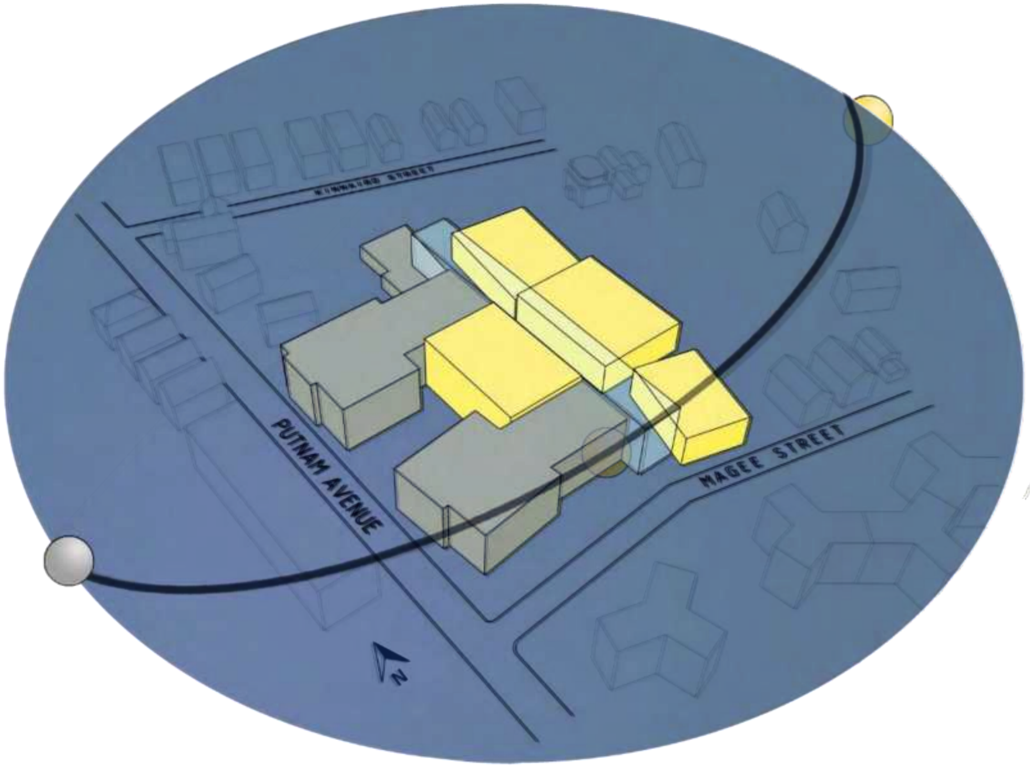


Graphics courtesy of Perkins Eastman

design FIRST

Optimize Building to Reduce Energy Use

- zone building by use

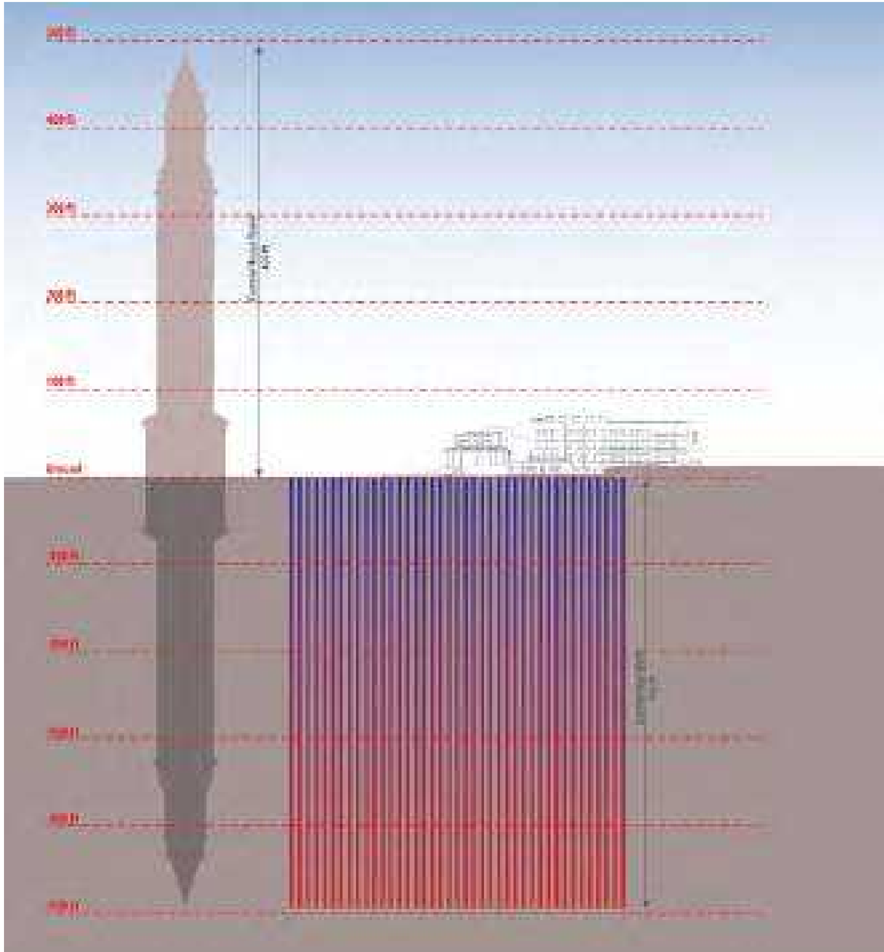


Graphics courtesy of Perkins Eastman

systems SECOND

Use Energy Efficiently

- “right-sized” efficient systems
- controls & sensors
- schedules & “off”
- commissioning & maintenance



Graphics courtesy of Perkins Eastman

user EXPERIENCE

Mayor Martin J. Walsh

BOSTON Public Schools

MSBA
Josiah Quincy Upper School

May 26, 2021

HMFH ARCHITECTS

JQUS Context Perspective

HM
FH

JQUS Section

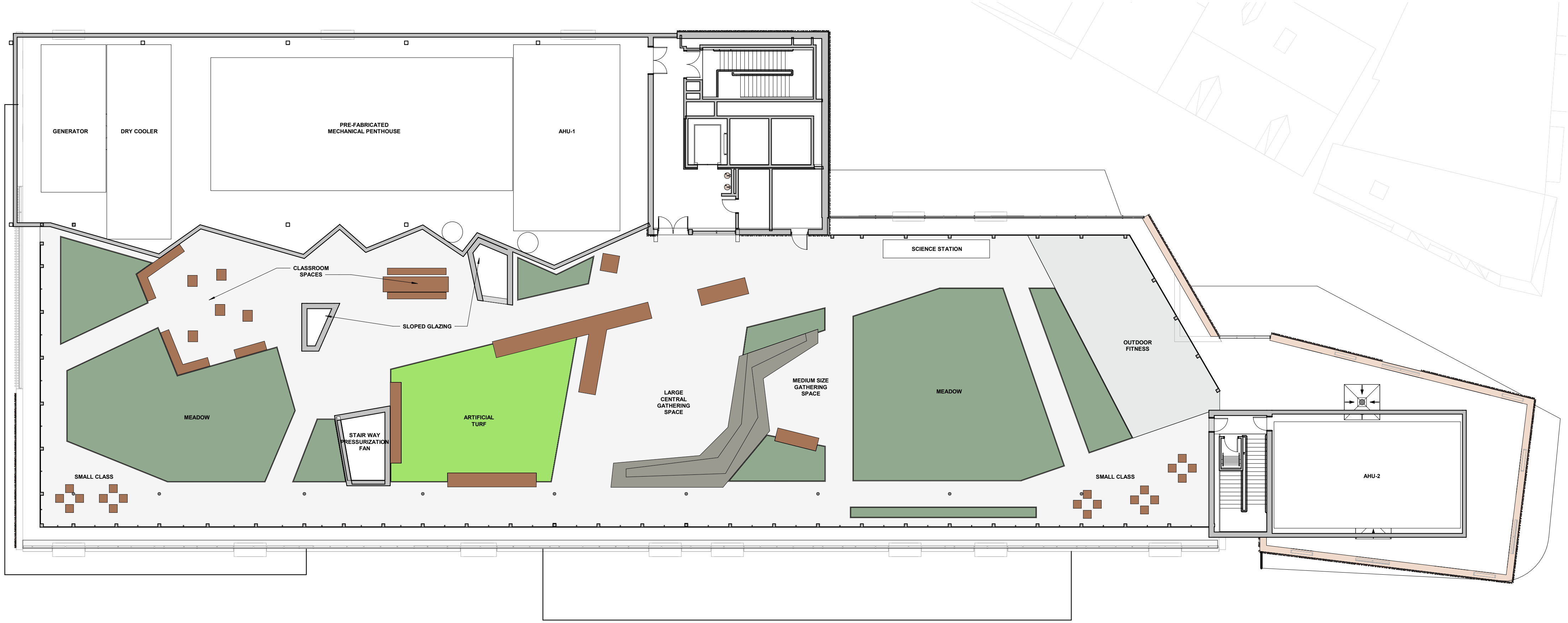
HMFH

View - Main Entrance at Washington Street

JQUS - Typical Academic Floor

HMFH

Roof Plan

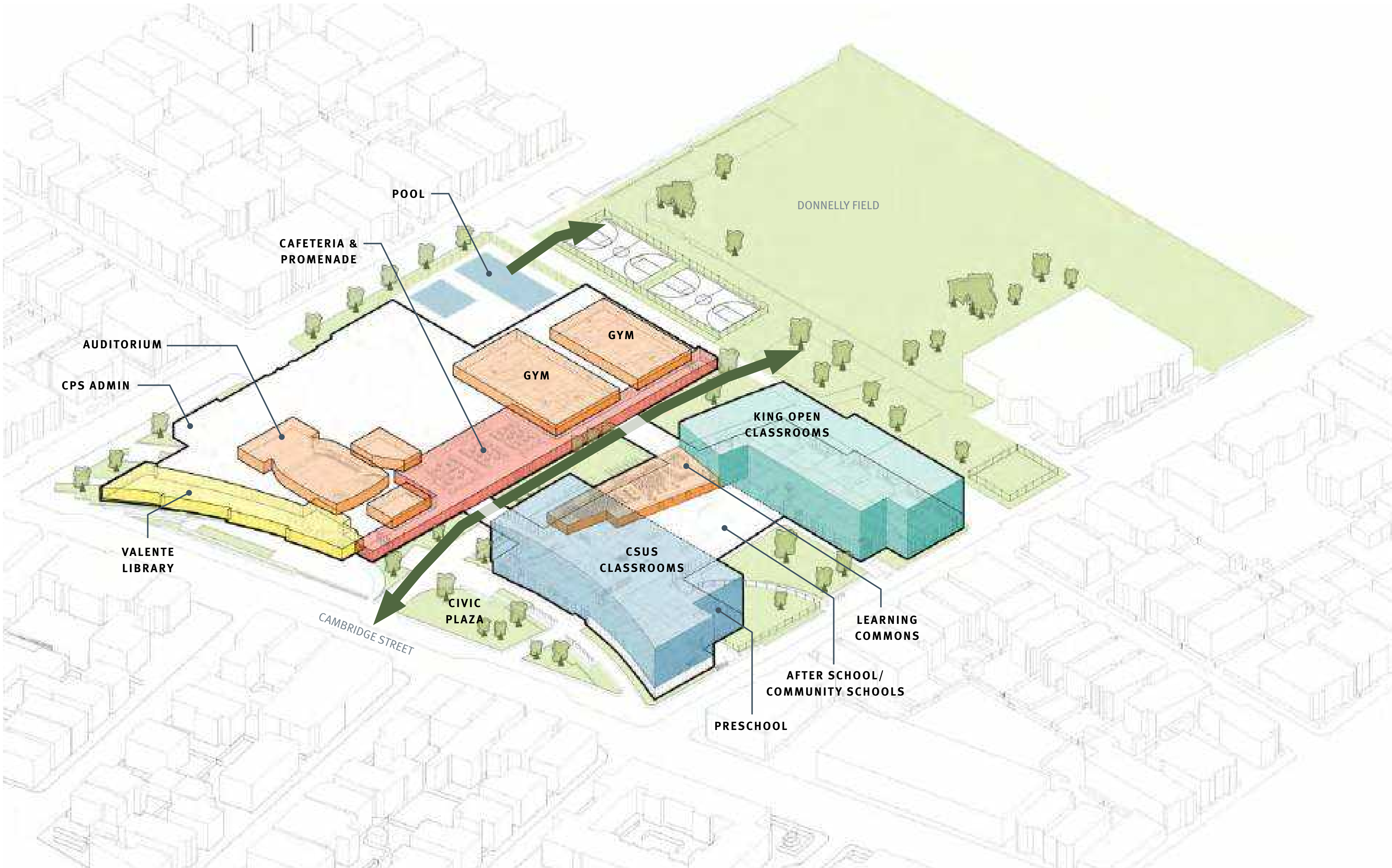

GENERATOR
DRY COOLER
PRE-FABRICATED MECHANICAL PENTHOUSE
AHU-1
CLASSROOM SPACES
SLOPED GLAZING
SCIENCE STATION
MEADOW
ARTIFICIAL TURF
STAIR WAY PRESSURIZATION FAN
LARGE CENTRAL GATHERING SPACE
MEDIUM SIZE GATHERING SPACE
MEADOW
OUTDOOR FITNESS
SMALL CLASS
SMALL CLASS
AHU-2

Roof Plan - Outdoor Educational Space

HMFH

CLOSER LOOK AT SOLAR

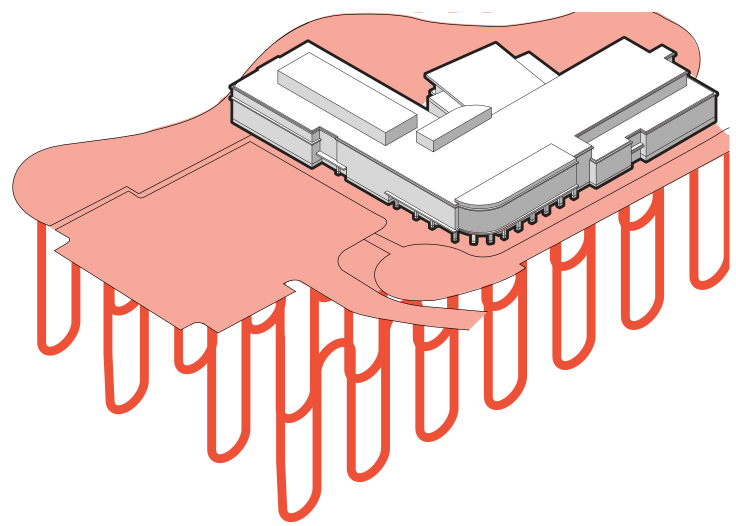
KING OPEN
PROGRAM



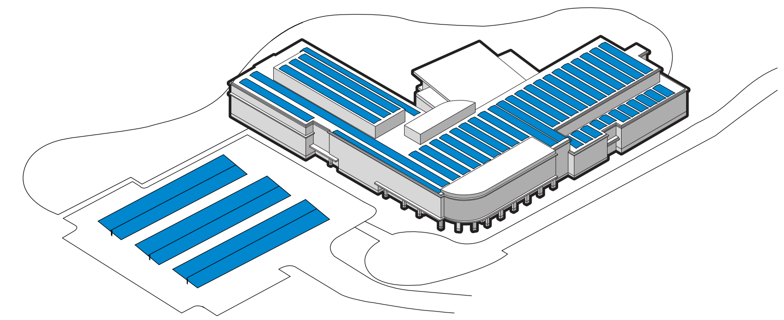
KING OPEN
PV

KING OPEN
FACADE MOUNTED PV

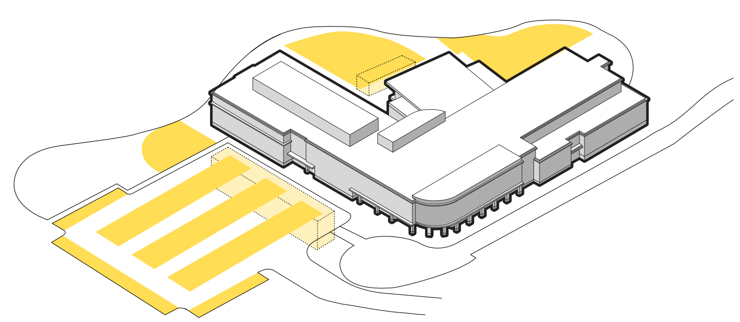
DOUGLAS & GATES SCHOOL
SITE SYSTEMS



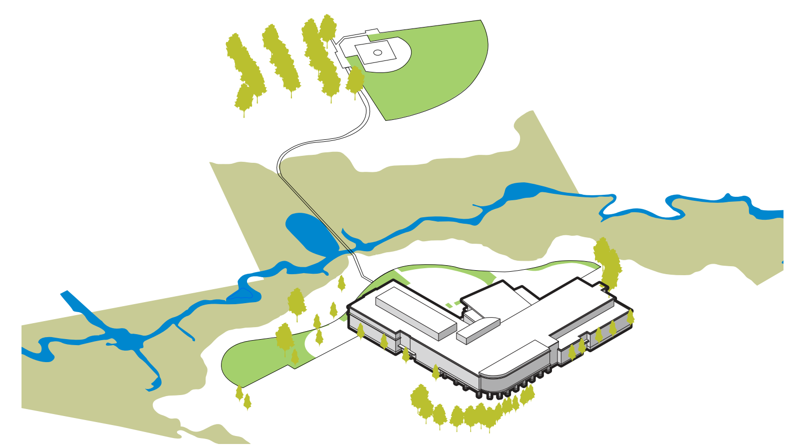
GEOTHERMAL HEATING & COOLING



PV & BATTERY STORAGE



STORMWATER RETENTION & INFILTRATION



RAINWATER HARVESTING

ARROWSTREET

DOUGLAS & GATES SCHOOL

PV & BATTERY STORAGE

PHOTOVOLTAIC SOLAR ARRAY SYSTEM (PV)

- Roof Mounted System
- Actual Size: 1,324 kWdc
- Estimated kWH generated: 1,318,000
- Complete Roof coverage
- Mechanical equipment located in roof wells with PV above

Closer Look at Solar

Hosmer Building & Site PV

N

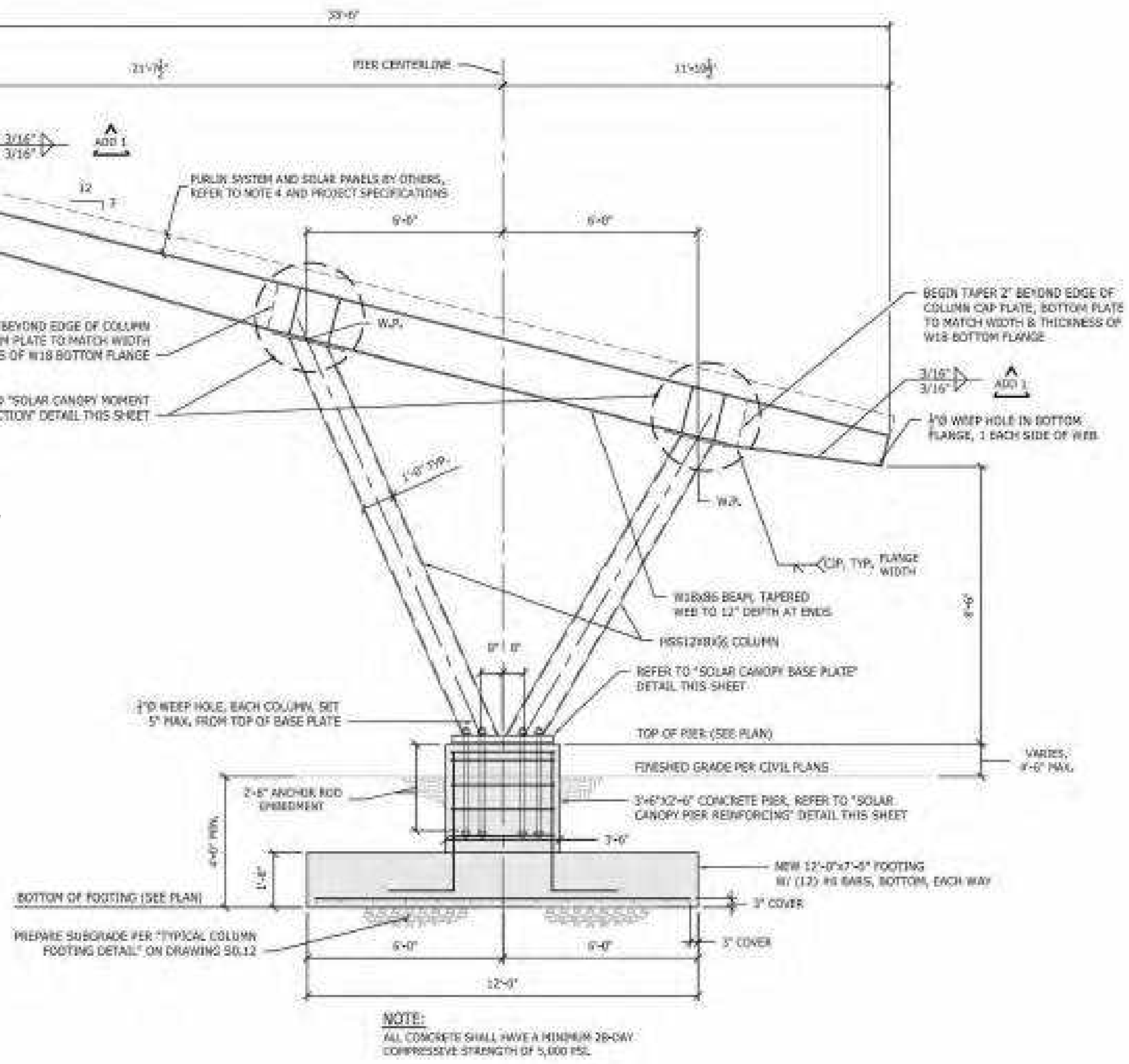
- Building Array = 42% of PV
- Site Array = 58% of PV
- Total # of PV panels = 1,920

Cunniff Building & Site PV

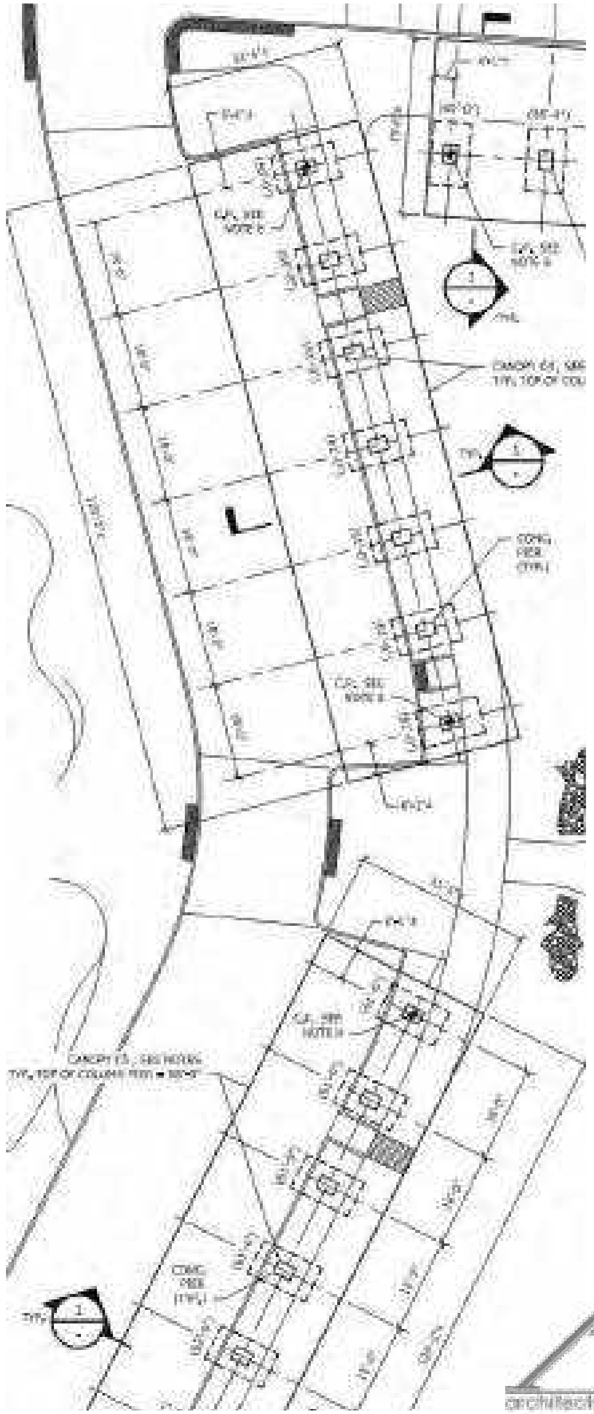
N

- Building Array = 44% of PV
- Site Array = 56% of PV
- Total # of PV panels = 1,169

Shelters cars, visitors, and reduces heat of pavement



Structural drawing of custom designed site solar canopy



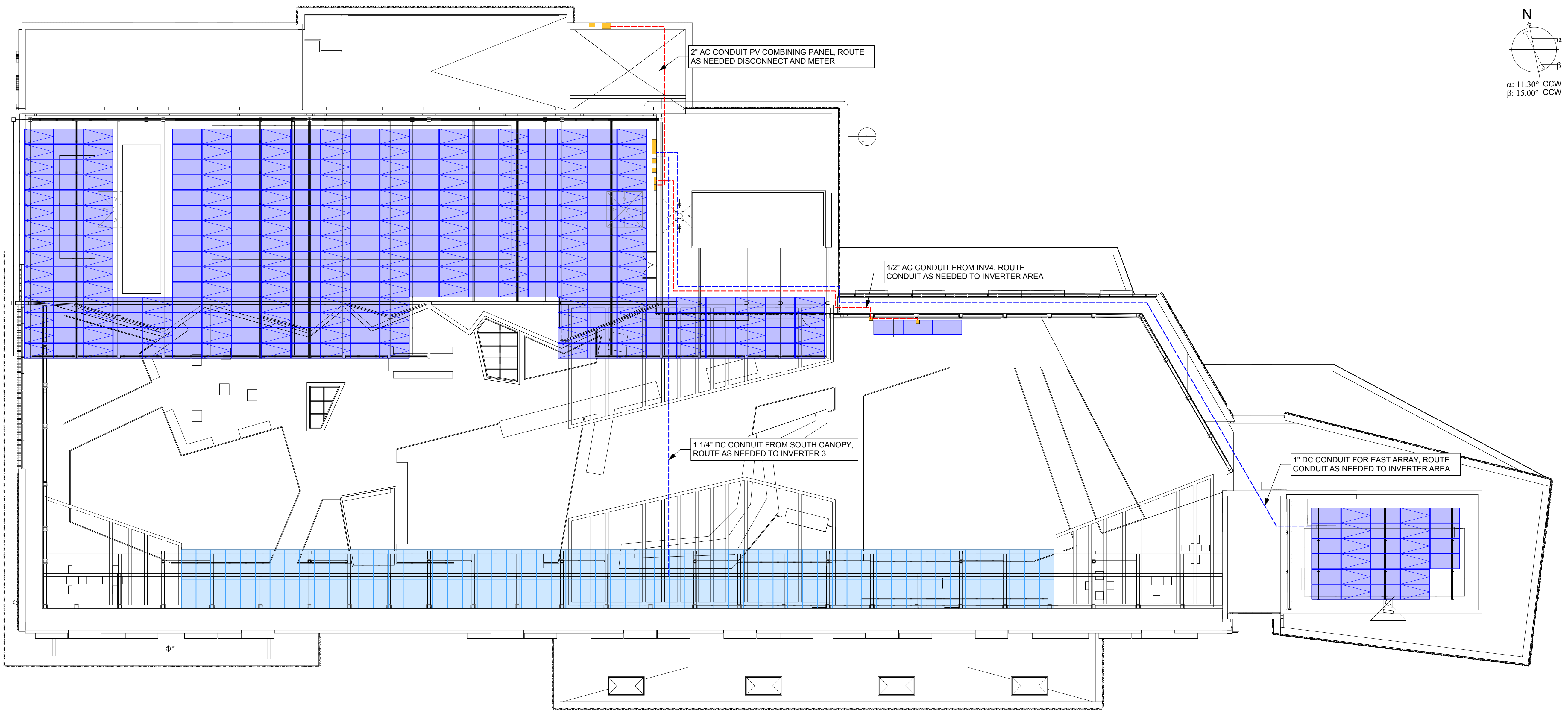
Solar canopies flanking parking

Installation of Cunniff solar canopy frames

Josiah Quincy Upper School

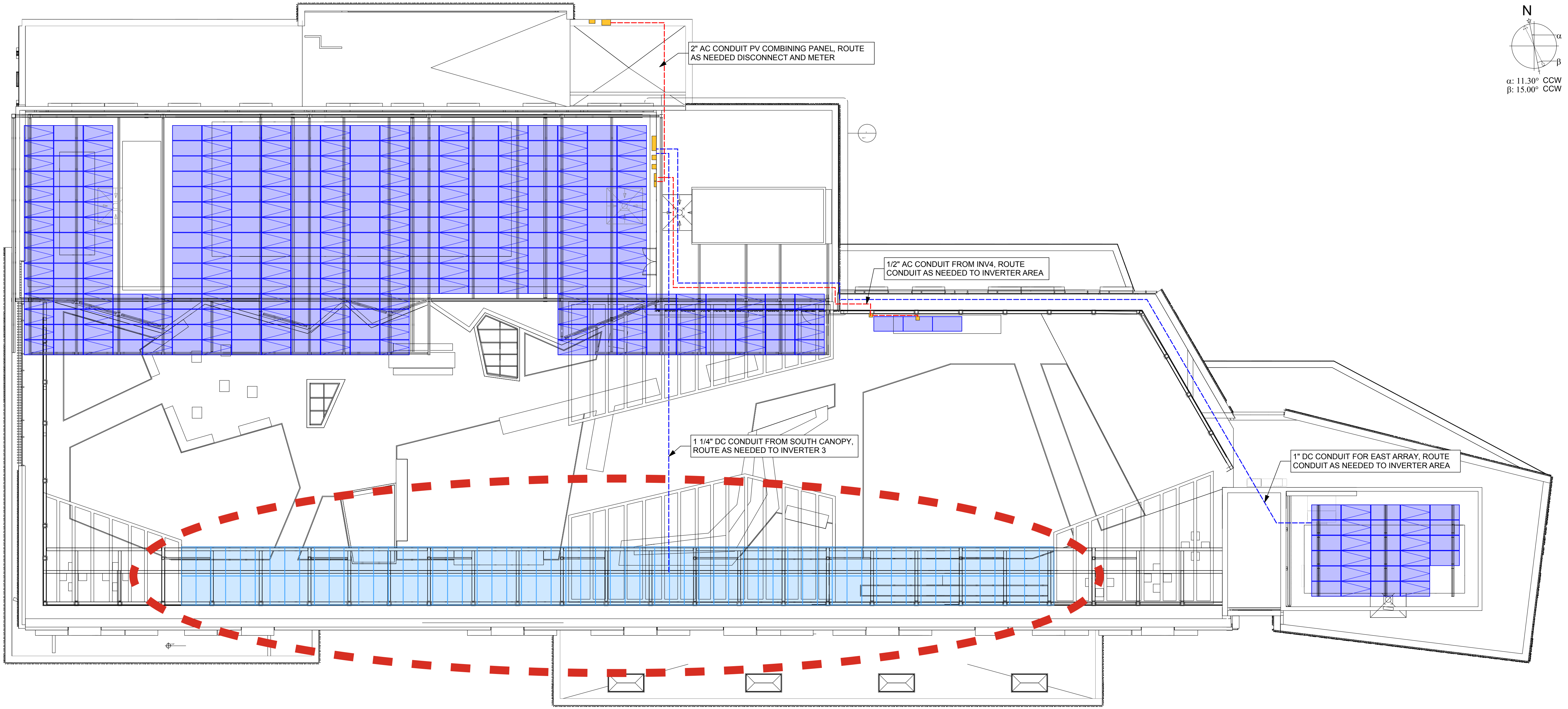
HMFH ARCHITECTS

PV Arrays at Roof



HM
FH

PV Arrays at Roof



PV Array removed due to cost

JQUS Educational Rooftop

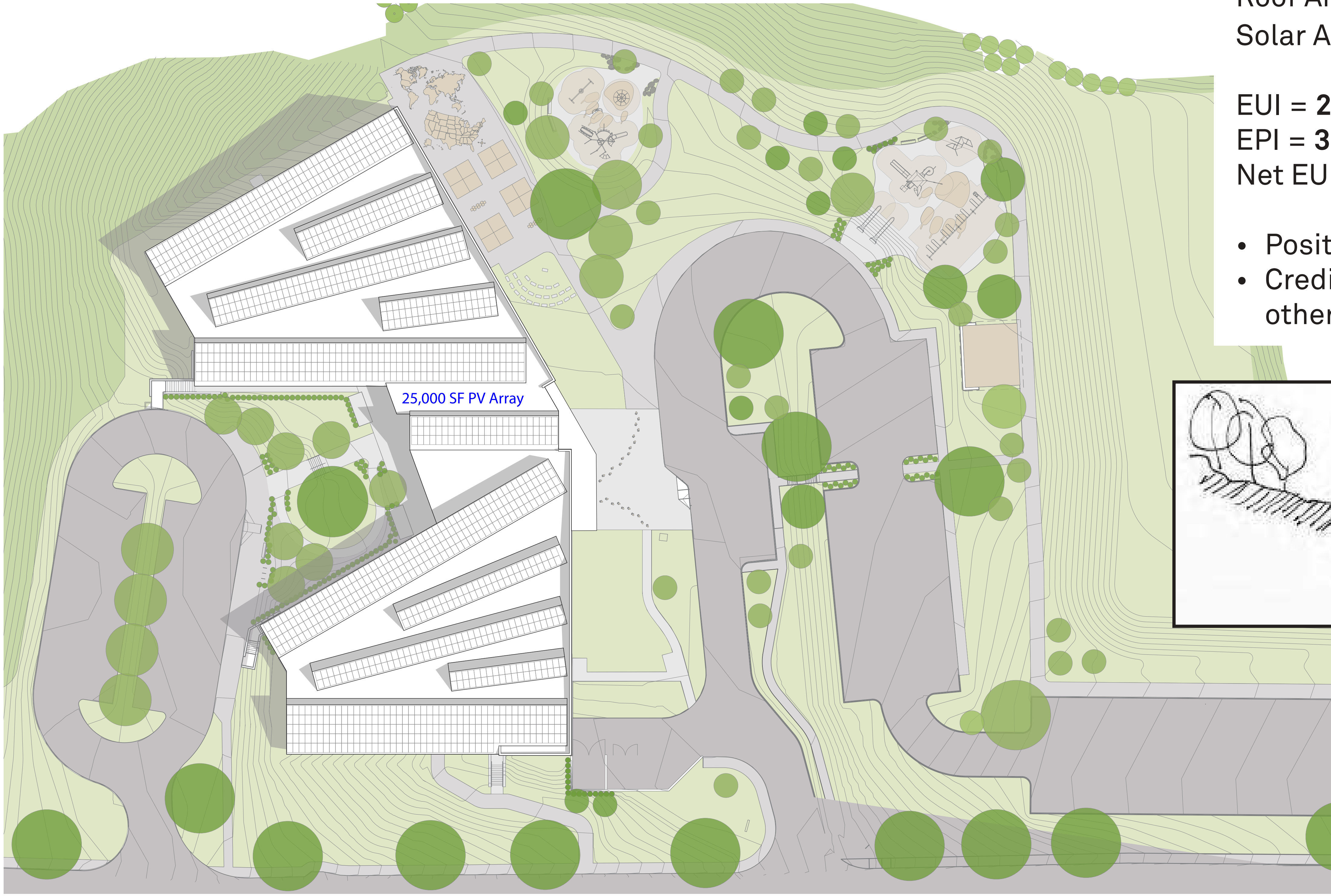
Outdoor Classroom

Outdoor Classroom

PV Arrays at Roof

HMFH

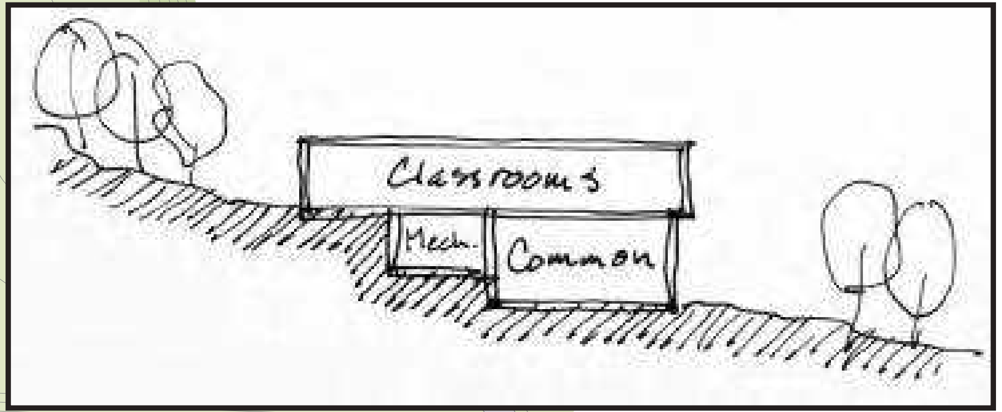
Fales Elementary School



Building Area: **70,000 GSF**
Roof Area: **40,000 SF**
Solar Array: **25,000 SF**

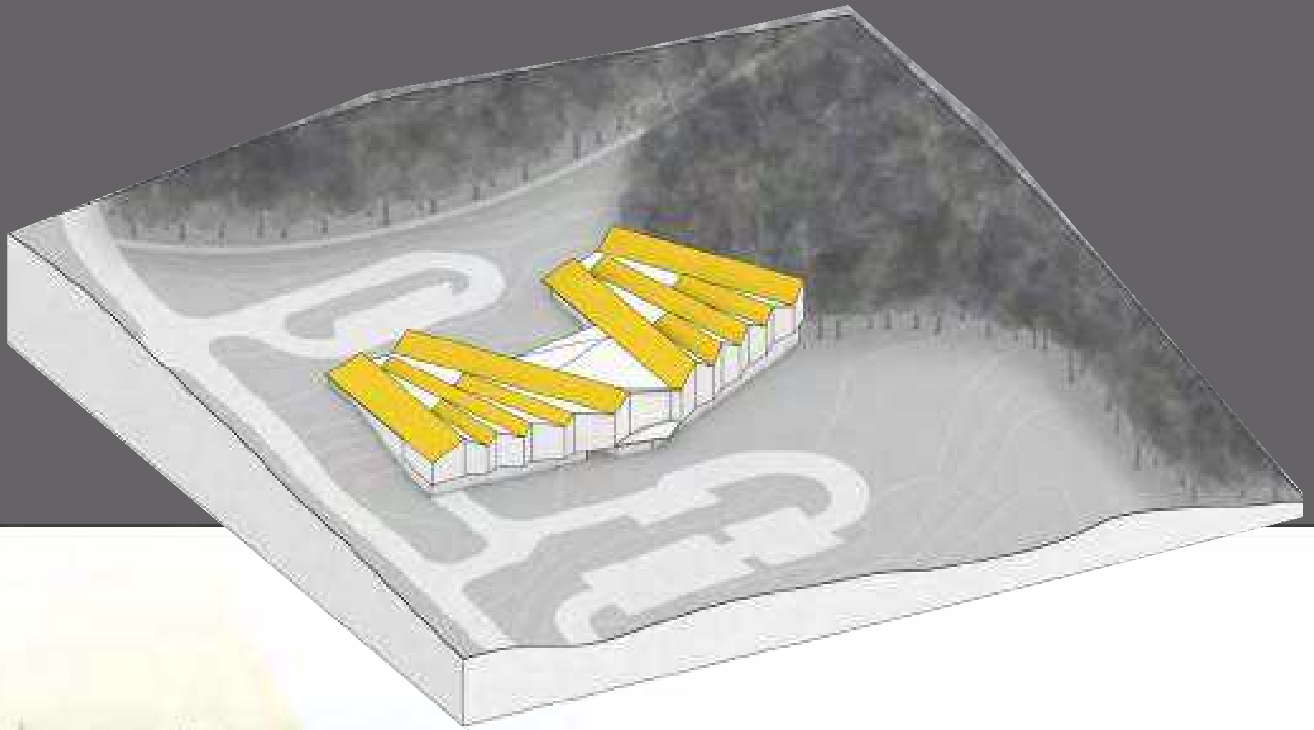
EUI = **24.9**
EPI = **31.1**
Net EUI = **6.2** Excess Energy

- Positive Energy Production
- Credit for Excess Energy Applied to other District Schools



HMFH

Fales Elementary School



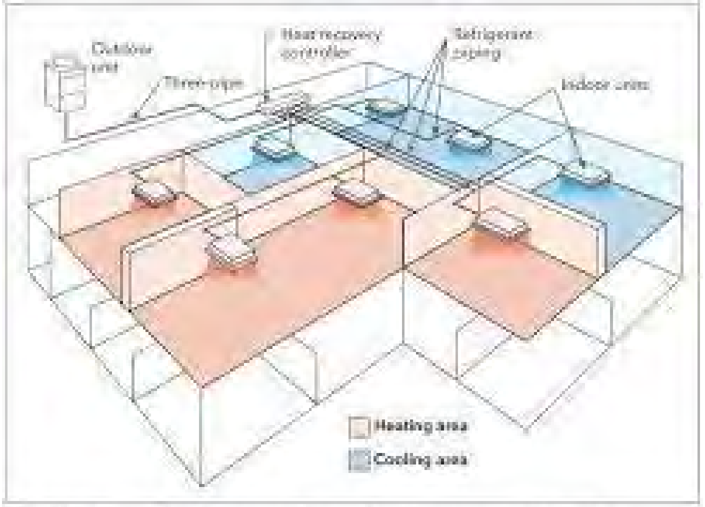
Fales Elementary School

HVAC SYSTEM OPTIONS

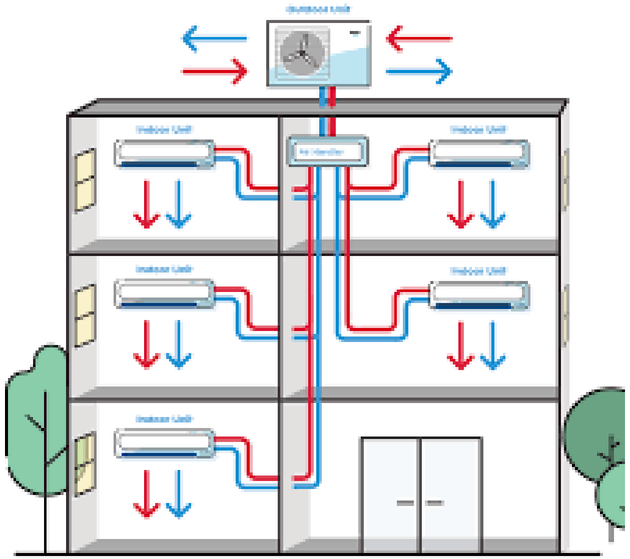
GAS	ALL-ELECTRIC	ALL-ELECTRIC NET ZERO	ALL-ELECTRIC NET ZERO
#1	#2	#3	#4
Air Cooled Heat Pump Chiller & Gas Boiler	Air Cooled Heat Pump Chiller & Electric Boiler	Ground Source Heat Pump	VRF
Displacement Ventilation	Displacement Ventilation	Displacement Ventilation	Overhead Ventilation

EFFICIENCY & SUSTAINABILITY ADVANTAGES with VRF

- No Fossil Fuels Consumed at School
- Designed for Net Zero Potential
- 40% - 50% efficiency improvement over standard rooftop units complying with ASHRAE 90.1
- Recent project has achieved an ***EUI of 22.4*** using VRF
- Simultaneous Heating & Cooling
- Multiple inverter driven compressors provide built in redundancy and match building loads more closely optimizing energy efficiency
- Excellent Flexibility
- Lower overall operation and maintenance cost w/smaller easier to maintain equipment
- No requirement for large mechanical rooms
- Smaller ductwork systems reduce ceiling, shaft and floor space requirements allowing more space for program needs
- No pumping systems to maintain
- No requirement for annual chemical treatment
- System aligned with the goals of the recently enacted Climate Bill
- Construction cost on par with conventional HVAC systems ***and lower*** than ground source/geothermal heat pump projects



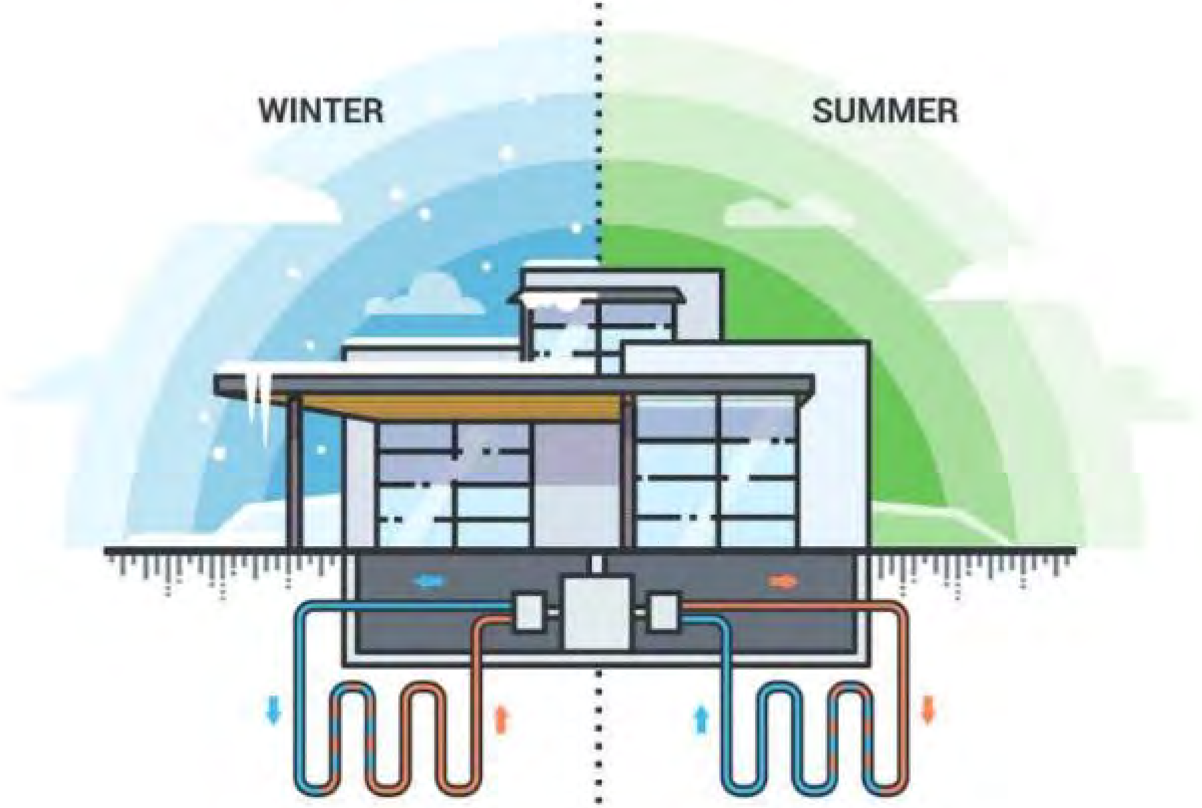
Variable refrigerant flow systems can deliver cooling to some zones and heating to others, with no reheat needed (an air-source system is shown here).



DEFINING GEOTHERMAL SYSTEM

Ground Source Closed-Loop Geothermal

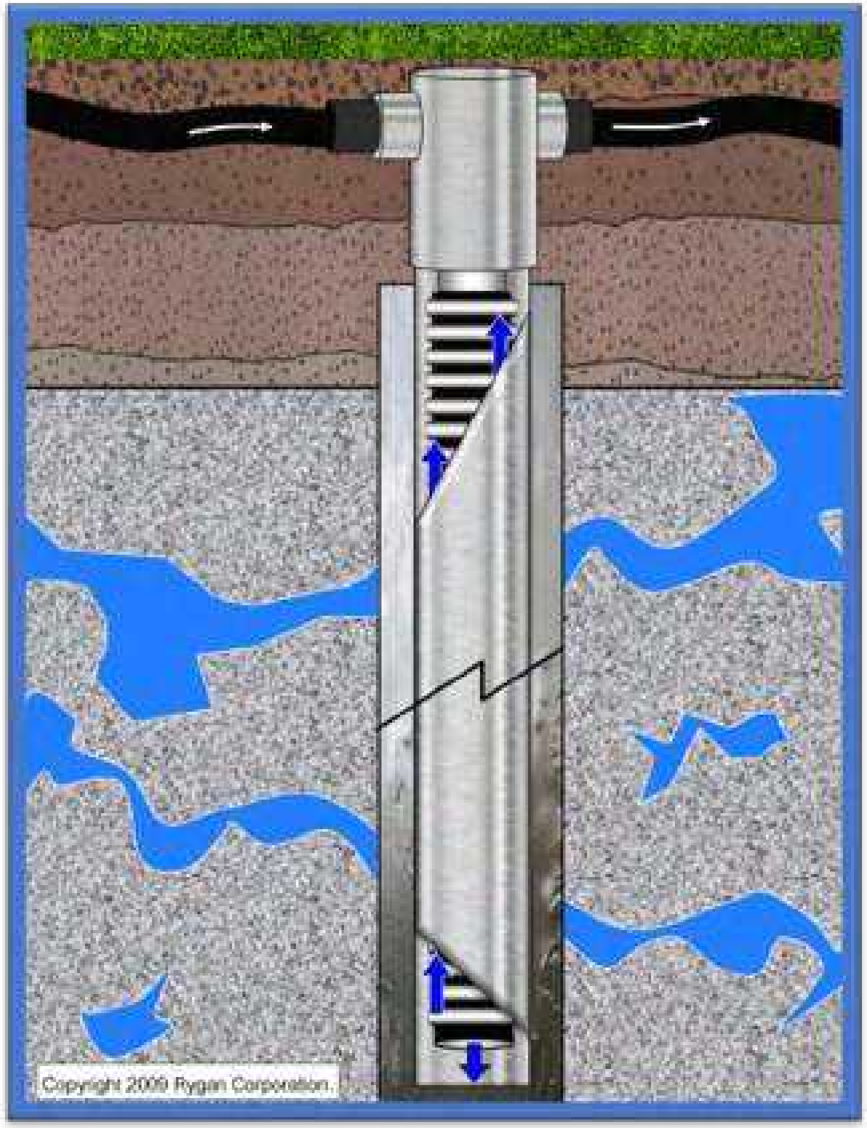
Pulls energy from below the earth's surface and provides hot water to air-handling equipment.



FOSSIL FUEL FREE

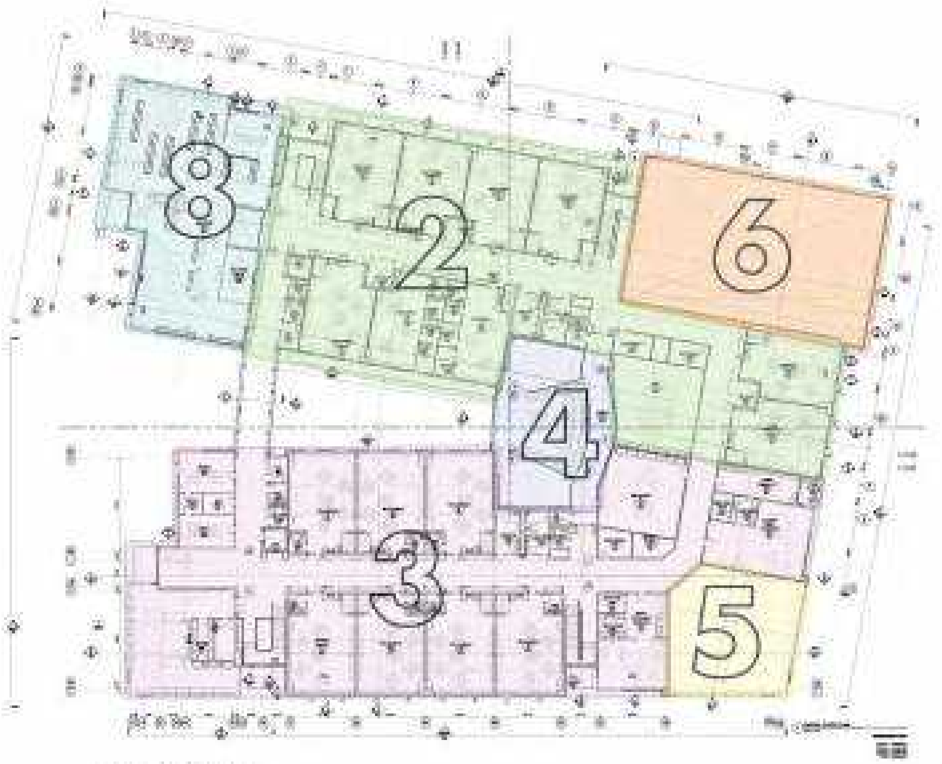
PROS	AND CONS (VS. VRF)
Quiet Operation, no exterior equipment	Higher capital cost due to closed loop wells
Provides simultaneous heating and cooling	Additional pumping required for source, heating and cooling loops
Longevity of equipment and ease of maintenance with indoor equipment	Compressor replacement every 15-20 years
High efficiency in both heating and cooling modes	
Built-in redundancy with modular Construction	
Provides 130 degree hot water for domestic	

Geothermal System - Quad Well U-bend

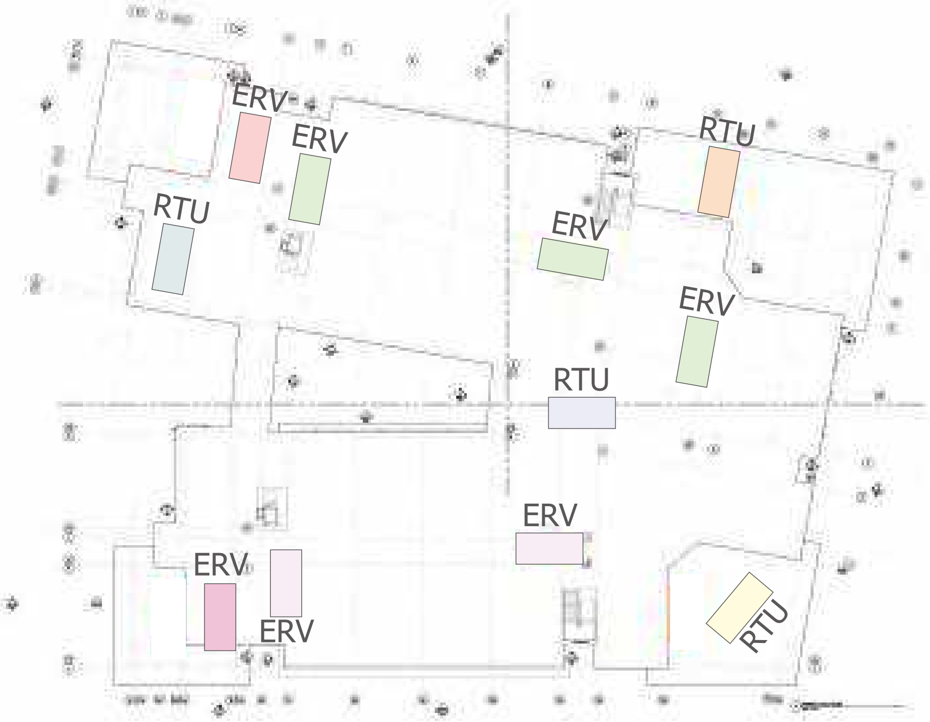


High Performance Geothermal Exchange (HPGX) - Rygan

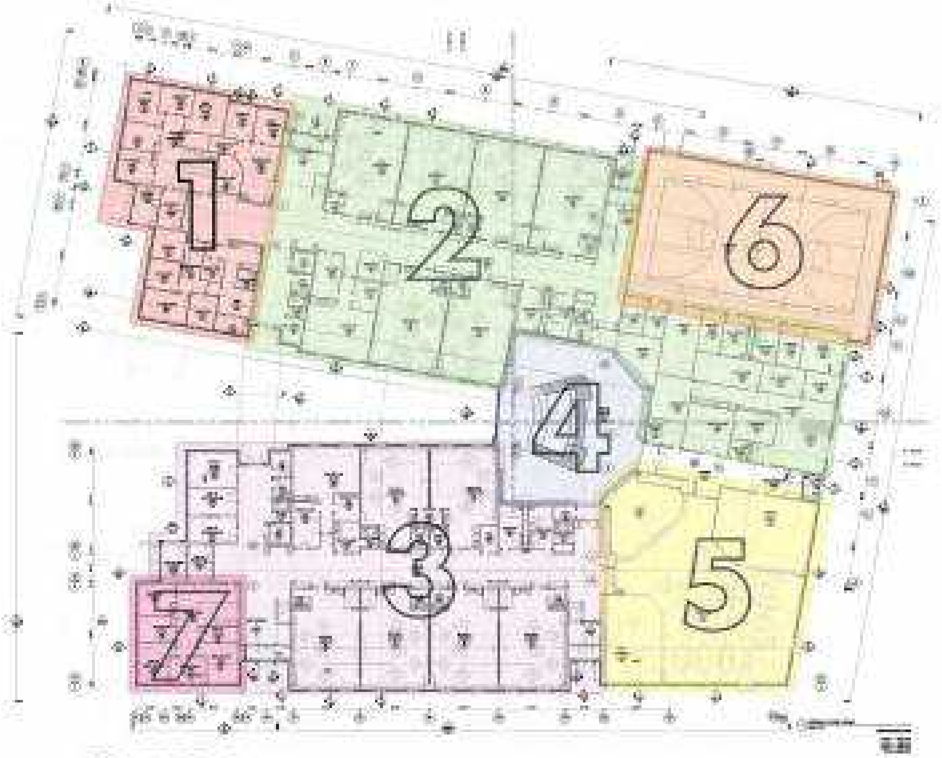
Air-Source vs Ground-Source Heat Pumps



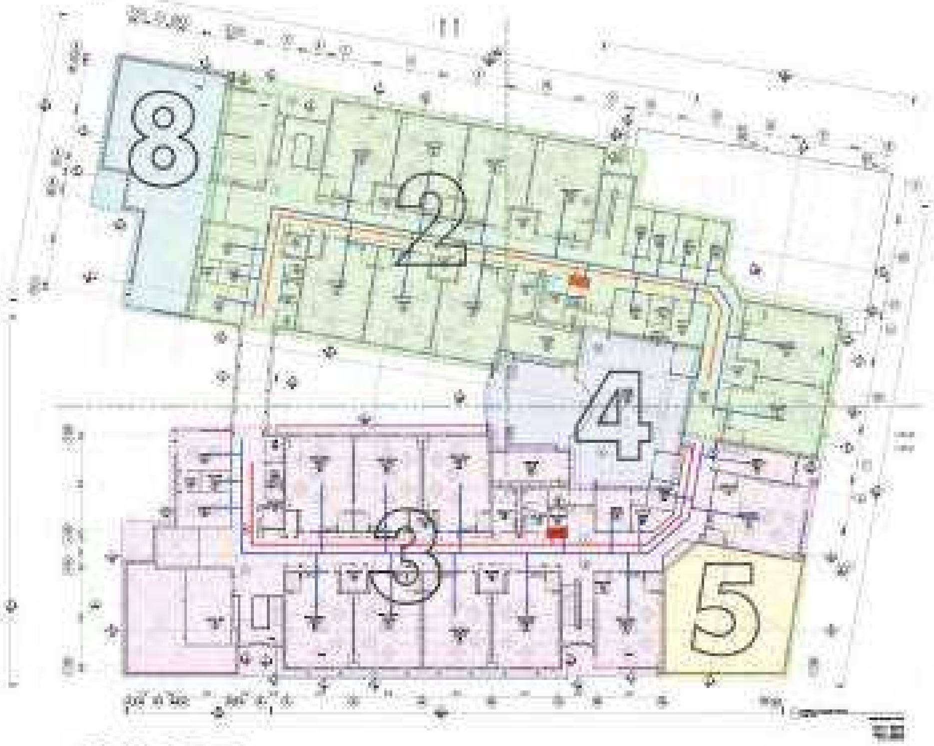
FLOOR 2



ROOF



FLOOR 1



FLOOR 3

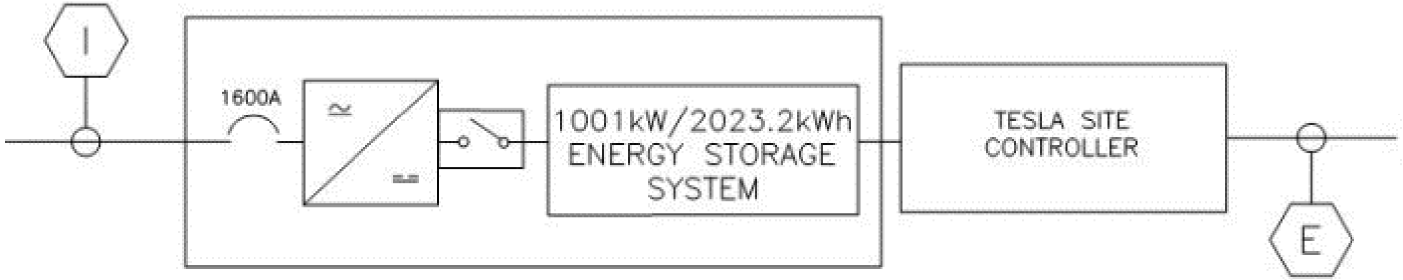
Hosmer HVAC Zoning:

Zones 1, 2, 3, & 7: VRF & ERV

Zones 4, 5, 6, & 8: RTUs

TESLA MEGAPACK LIGHT

(14) BIDIRECTIONAL INVERTER 71.5kVA
1001kW, 480VAC
(12) BATTERY MODULES 84.3kW
1001kW/2023.2kWh STORAGE SYSTEM



BATTERY ENERGY STORAGE SYSTEMS

- Energy produced is stored and used when required
- Does not emit any CO2 emissions
- Includes Lithium Ion
- Cost effective energy on demand
- Used for wind, solar, and electric vehicle charging infrastructure
- Generally sized for two-four hours at full load including building freeze protection

HVAC SYSTEM COMPARISONS

Code Compliant System:
- International Energy Conservation Code (2018 IECC)
- Classroom Unit Ventilators
- Gas Fired Boilers
- Packaged Rooftop Units
- Will not achieve LEED certification
- Cost: $37.00/sq.ft.

LEED Project:
- 2018 IECC
- ASHRAE 90.1 2013 (LEED v.4 requirement)
- Variable Air Volume System and/or Chilled Beams
- Rooftop Energy Recovery Units
- High Efficiency Gas Fired Condensing Boilers
- Large Ductwork Distribution System
- Cost: $38.00/sq.ft. (VAV) & $43.00 (Chilled Beam)

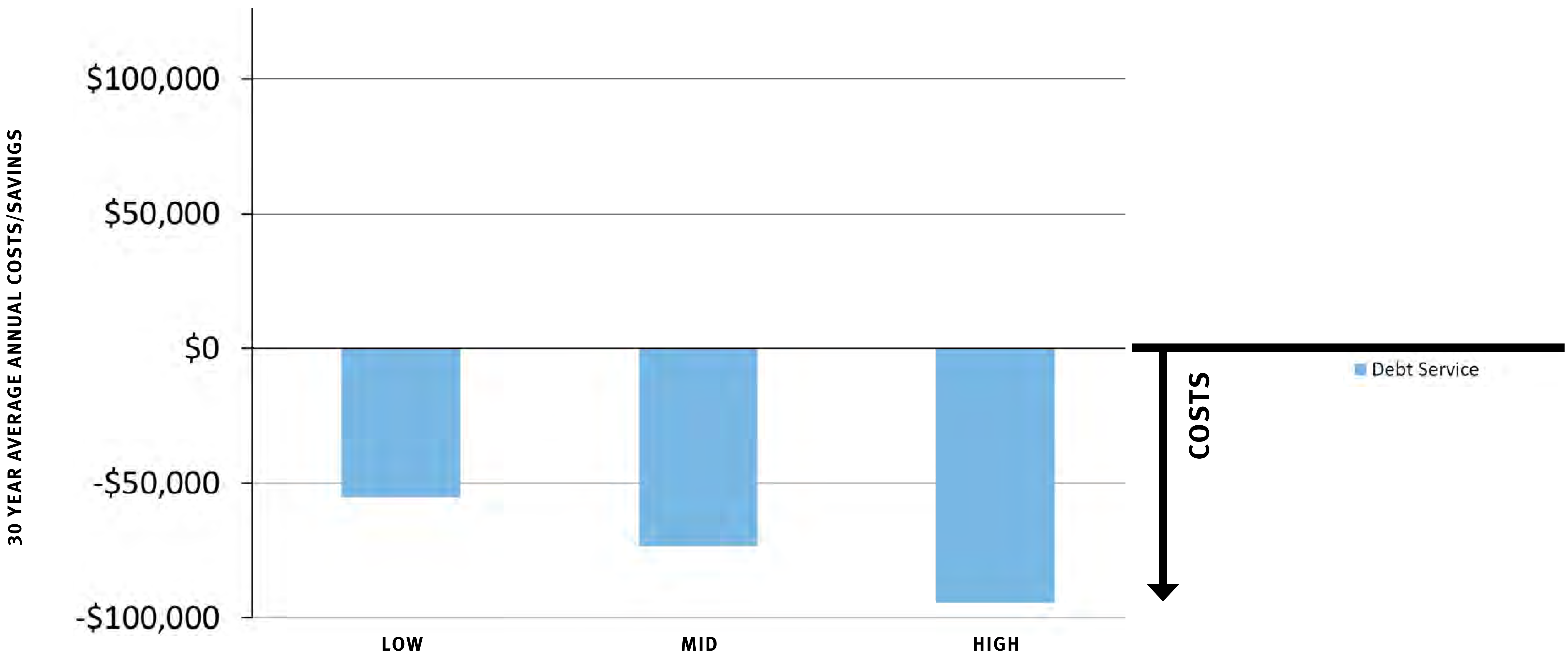
LEED Certified, Net Zero Project:
- Helps meet goal of exceeding 2018 IECC by 20%
- Variable Refrigerant Flow System (VRF)
- Energy Recovery Units for Ventilation
- Small ductwork distribution system for ventilation air
- Quiet, efficient, simple
- ***Can help schools achieve an EUI of 25 or below***
- Cost: $39.00/sq.ft.

PAYING OVER TIME

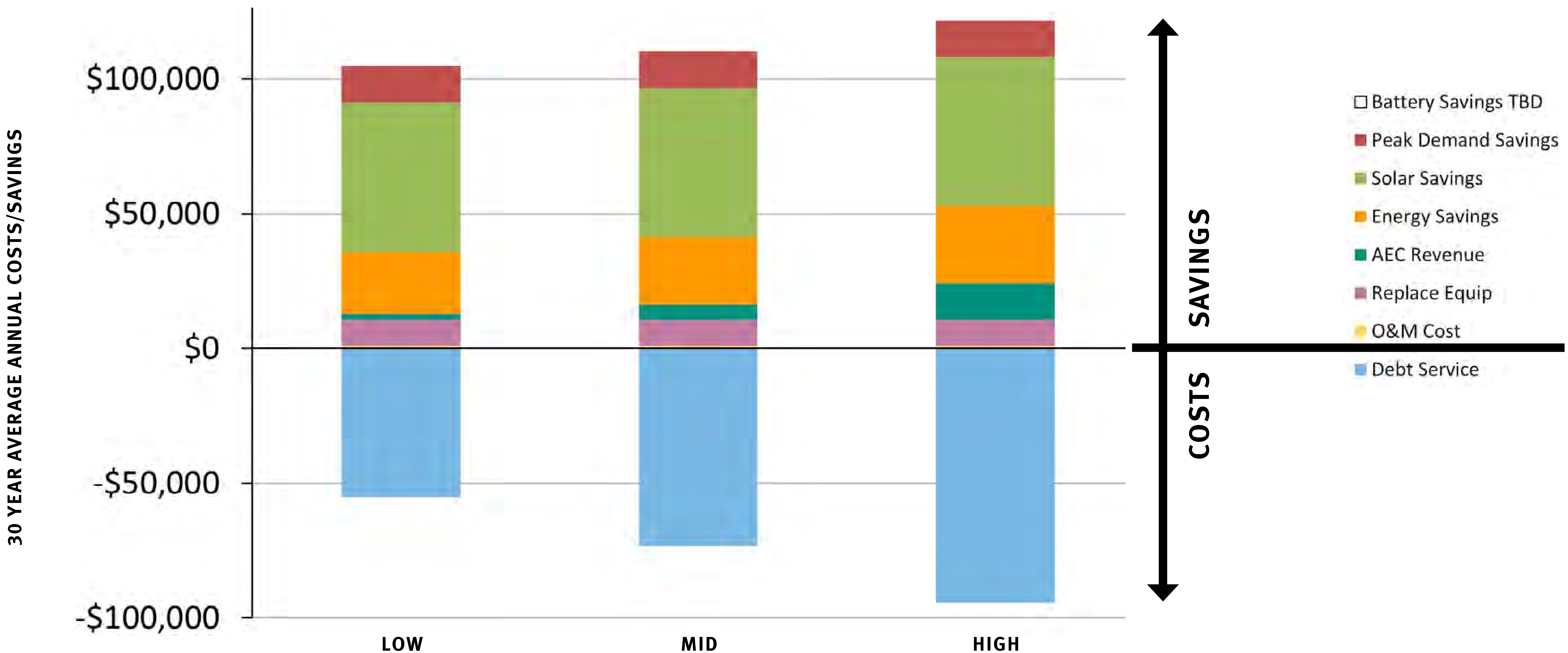
HVAC SYSTEM OPTIONS

GAS	ALL-ELECTRIC	ALL-ELECTRIC NET ZERO	ALL-ELECTRIC NET ZERO
#1	#2	#3	#4
Air Cooled Heat Pump Chiller & Gas Boiler	Air Cooled Heat Pump Chiller & Electric Boiler	Ground Source Heat Pump	VRF
Displacement Ventilation	Displacement Ventilation	Displacement Ventilation	Overhead Ventilation

ANNUAL SAVINGS vs. DEBT SERVICE
#3 GROUND SOURCE HEAT PUMP vs. #1 GAS BOILER

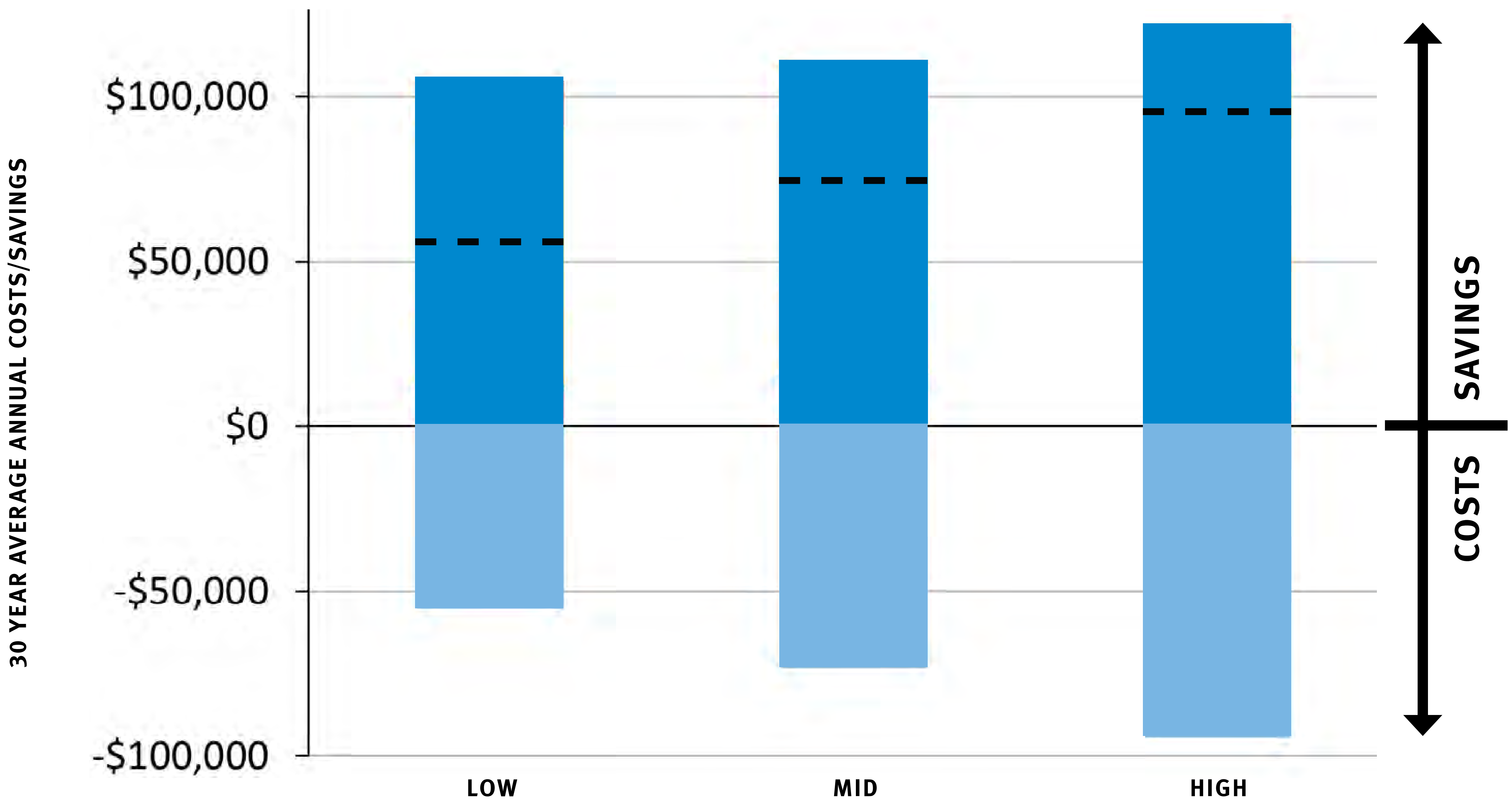


ANNUAL SAVINGS vs. DEBT SERVICE
#3 GROUND SOURCE HEAT PUMP vs. #1 GAS BOILER

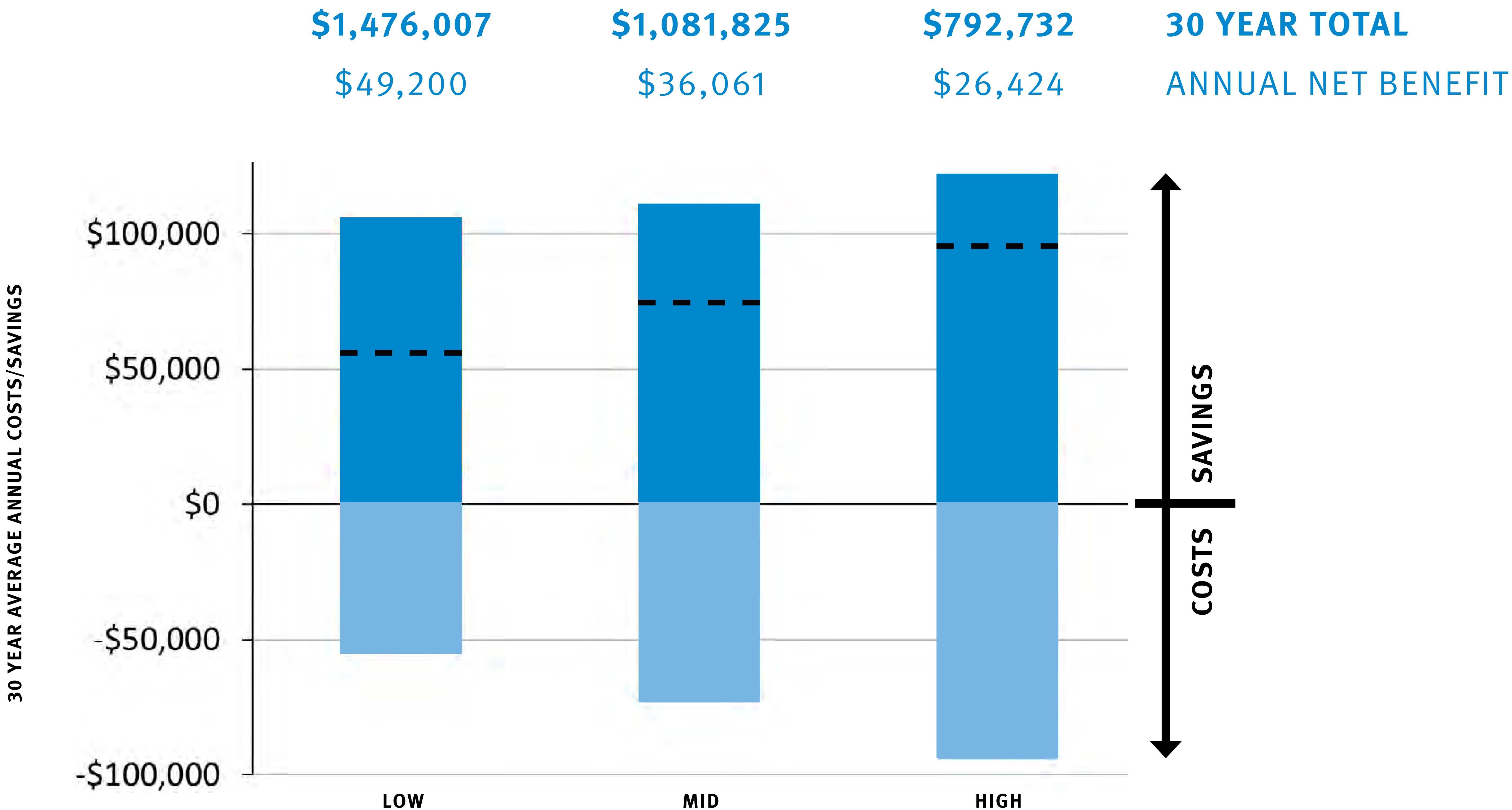


ANNUAL SAVINGS vs. DEBT SERVICE

#3 GROUND SOURCE HEAT PUMP vs. #1 GAS BOILER



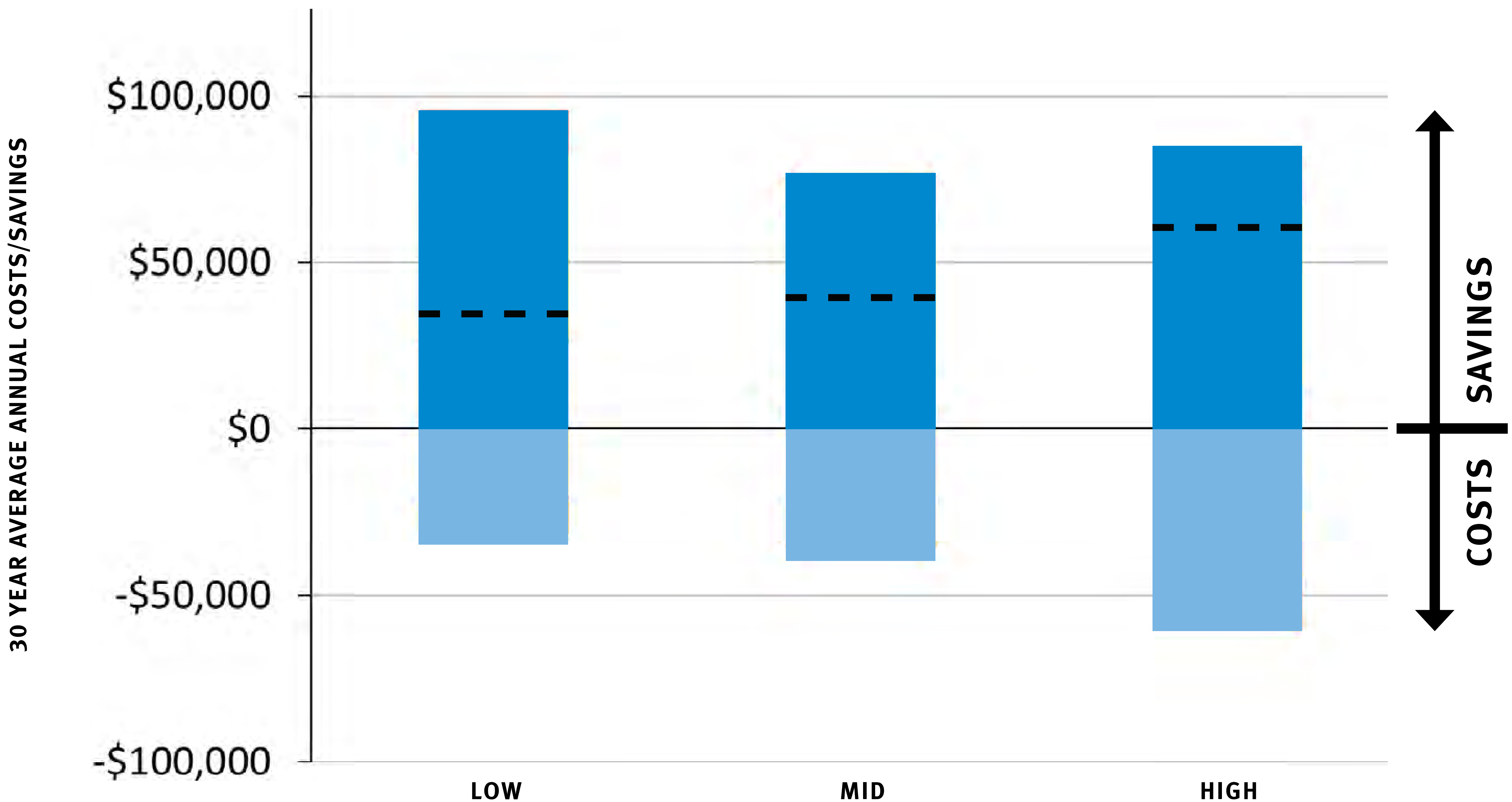
ANNUAL SAVINGS vs. DEBT SERVICE
#3 GROUND SOURCE HEAT PUMP vs. #1 GAS BOILER



ANNUAL SAVINGS vs. DEBT SERVICE

#4 VRF vs. #1 GAS BOILER

$1,914,010	**$1,200,778**	**$607,194**	**30 YEAR TOTAL**
$63,800	$40,026	$20,240	ANNUAL NET BENEFIT



HVAC SYSTEM OPTIONS
COMPARISON

		Meets Eversource EUI	EUI	Carbon Emissions	Indoor Air Quality	Acoustics	PV Fits on Roof	Energy Cost	Maintenance Cost	Ease of Maintenance	Risk of Future Repair Cost
#3	Ground Source Heat Pump	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
#4	VRF										

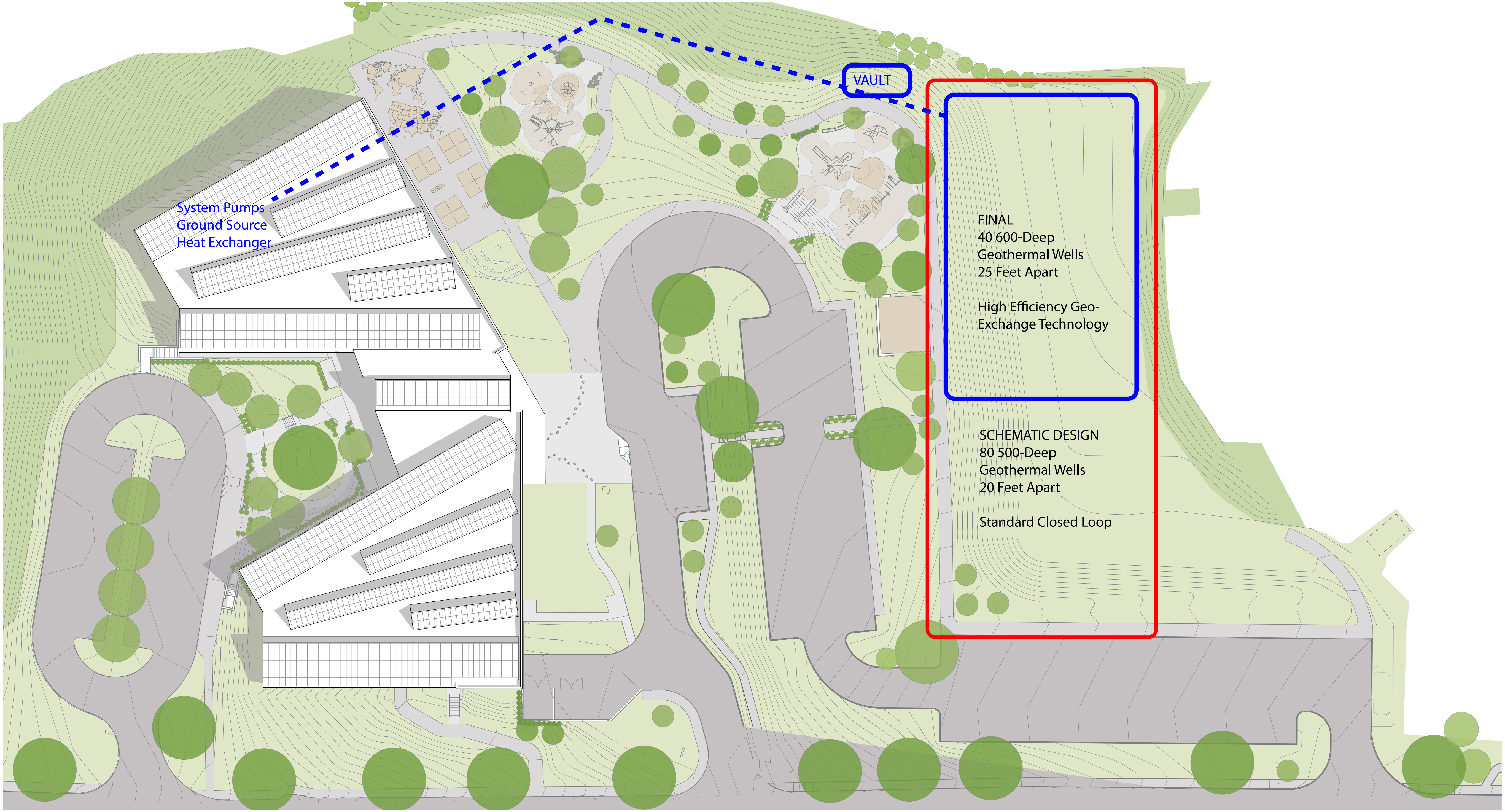
✓ = Performs better

HVAC SYSTEM OPTIONS
COMPARISON

		EUI	Carbon Emissions (mtons)	HVAC Capital Investment Cost			Annual Energy Cost			Annual Maintenance Cost			Combined Annual Cost Savings	Lifecycle Cost Savings	Discounted Payback (years)
					Delta	Total Construct Cost Delta		$/sf	Delta		$/sf	Delta			
#3	Ground Source Heat Pump	24	147	$7,219,665	11%	2.2%	$124,529	$1.27	-15%	$57,896	$0.59	-27%	$43,600	$767,218	19
#4	VRF	28.4	181	$6,507,218			$147,129	$1.50		$78,896	$0.80				

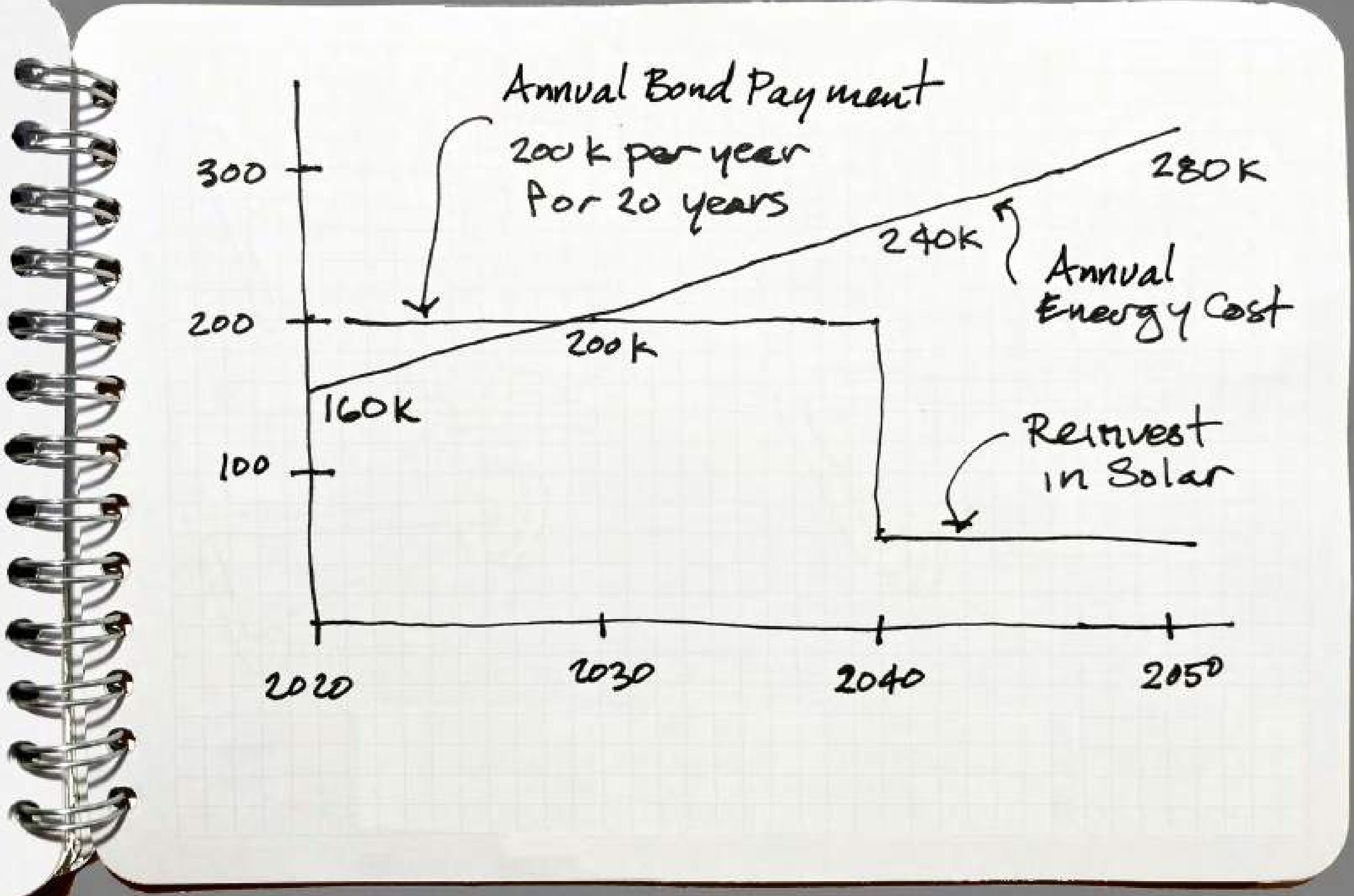
-Red values indicate there is additional cost, not savings, compared to Option 4
-Capital Cost does not include Eversource incentives
-Capital Cost includes additional electrical costs for option 4
-Energy Cost does not include peak demand charges

Fales Elementary School



H M
F H

Annual Cost for Net Zero Energy —can be Net Zero Dollars



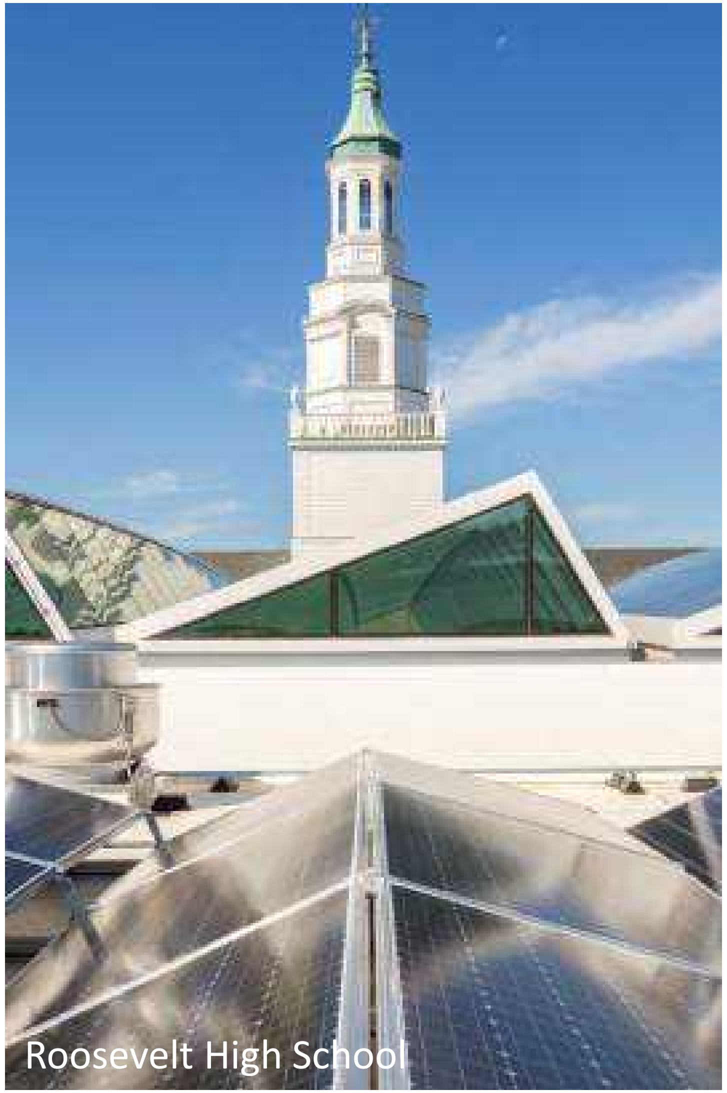
HM
FH

Cost Strategy

3 min.

COSTS

VIRGINIA SCHOOLS



Roosevelt High School

FIRST COST CONSTRUCTION ESTIMATES				
SCHOOL	CONSTRUCTION TYPE	FCPS 2019 BOND PACKAGE	NET ZERO READY	NET ZERO ENERGY
ELEMENTARY SCHOOL	RENOVATION & ADDITION	**RVA-BOND** $24.94M TOTAL $246/SF	**RVA-NZR** $27.44M TOTAL $271/SF	**RVA-NZE** $28.11M TOTAL $277/SF
	NEW CONSTRUCTION	**NC-BOND** $29.64M TOTAL $292/SF	**NC-NZR** $31.02M TOTAL $306/SF	**NC-NZE** $31.65M TOTAL $312/SF

Annual Operations and Maintenance Costs Per SF	
System Type	**Cost per Square Foot**
Bond - Air-cooled VRF	$0.59
NZR - Geothermal WSHP	$0.24

LIFE CYCLE COST CASE STUDY

VIRGINIA ELEMENTARY SCHOOLS

LIFE CYCLE COST SUMMARY				
Facility:	Fairfax County, VA			
SYSTEM	FIRST COST	ANNUAL EST. ENERGY COST	ANNUAL EST. HVAC MAINTENANCE COST	30 YEAR LIFE CYCLE COST*
RVA-BOND	$24,940,470	$119,502	$60,050	$39,678,044
RVA-NZR	$27,444,599	$44,866	$24,427	$32,260,007
NC-BOND	$29,639,477	$117,946	$60,050	$44,303,019
NC-NZR	$31,016,286	$40,454	$24,427	$35,621,763

- 6% increase in construction cost
- 60% savings in annual operations and maintenance costs
- **10% overall savings**

MECHANICAL SYSTEM PAYBACK SUMMARY

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	$10,643,800	2,020,046	2,865.0	$242,405	$36,051	$278,456	$1.57	55.1	$46,710	$175,000	960.0	$325,166	-	-	-

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. 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	$204,557	$120,609	$2,732,400	20
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	1,824.0	$148,704	$22,954	$171,658	$0.97	34.2	$37,460	$175,000	592.5	$209,118	$116,048	$4,635,005	Instant*****
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	681.8	$280,501	$44,665	-$1,363,213	Instant******
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	$12,238,150	1,426,031	0.0	$171,124	$0	$171,124	$0.97	27.5	$36,960	$0	570.4	$208,084	$117,082	$3,207,454	16

DCR Walden Pond Visitor's Center, Concord, MA (Direct Ownership)
105.84 kWdc (91.2 kWac)

POWER PURCHASE AGREEMENT (PPA)

Power Purchase Agreement (PPA)		Direct Ownership	
PROS	CONS	PROS	CONS
PPA is an alternative to affording solar equipment	Contract terms can range between 20-25 years	Purchase at fair market value (when you are ready to buy)	You are responsible for maintenance and repair which can be costly
Reduced electrical rate of 5-15% for energy produced	Roof area is part of PPA – Restricted Modifications	SMART Incentive Program Benefits – Reduce Paybacks	Initial capital cost
$0 upfront investment		Take advantage of electricity generated by your system and may pay nothing at all to power the facility, you may receive a credit.	
$0 maintenance cost			

Denise Rouleau, Lead Program Manager, National Grid
Kim Cullinane, Sr. Energy Efficiency Consultant, Eversource

mass save

ZNE/Deep Energy Savings Participation Pathway

06/08/2021

WE ARE MASS SAVE®:

BERKSHIRE GAS An AVANGRID Company · Cape Light Compact · EVERSOURCE · Liberty · nationalgrid · Unitil

Together, we make good happen for Massachusetts.

Your local electric and natural gas utilities and energy efficiency service providers taking strides in energy efficiency: Berkshire Gas, Cape Light Compact, Eversource, Liberty Utilities, National Grid and Unitil.

As one, we form Mass Save®, with the common goal of helping residents and businesses across Massachusetts save money and energy, leading our state to a clean and energy efficient future.

WE ARE MASS SAVE®:

Path 1: Zero Net Energy/Deep Energy Savings

INTENT

Drive projects toward ZNE, low carbon and low EUI in operation - focus on outcomes

KEY PROGRAM DRIVER: 25 SITE EUI

Exceptions to 25 EUI can be negotiated | Early analysis and focus on EUI target

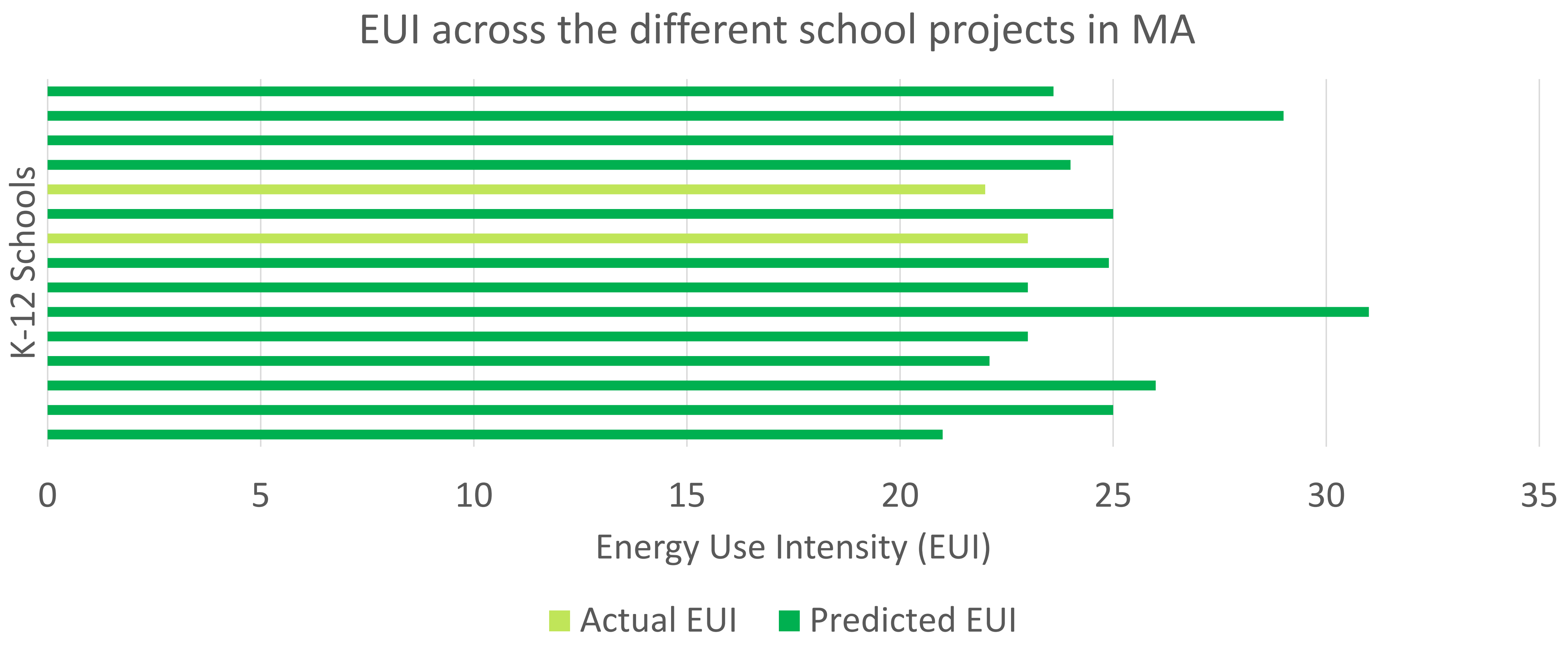
ZNE TECHNICAL SUPPORT

General ZNE/low EUI consulting | Load reduction analysis | HVAC system selection support | Life cycle cost analysis

ACTON-BOXBOROUGH DOUGLAS-GATES ELEMENTARY SCHOOL

Opening Fall 2022 | All electric | Triple net zero

ZNE or ZNE Ready School Projects in MA



Incentives ($) Offered

Customer Incentives		
Construction Incentive	Paid if project design achieves 25 EUI or negotiated EUI target	$1.25/sf
Post Occupancy Incentive	Available after 1-year post-occupancy period if project achieves target EUI	$1.00/sf
ZNE or PH Certification Incentive	Paid for project ZNE or PH certification	$3,000
Verification Incentive	Optional scope to conduct data review to identify and correct issues	50% of fee up to $10,000
Design Team Incentives		
Calculated at $0.20/sf and capped at $15,000, but not less than $8,000 per project		

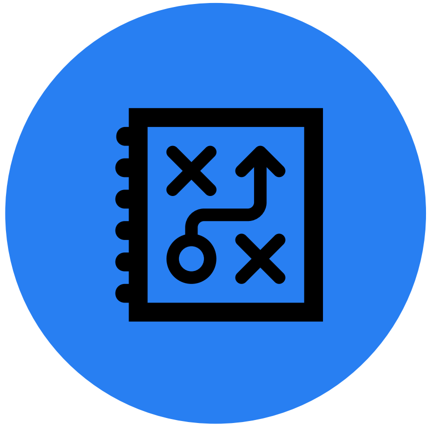
Verification Incentive

(Optional)

Mass Save offers 50% cost share up to $10,000

WE ARE MASS SAVE®:

Scope to include:



Review control strategies at end of design

Multiple trend data reviews at post occupancy

Multiple EUI data pulls at post occupancy

Path 1: Project Incentive Example

Building Sf	200,000	
Incentive	Sf Incentive	Total Incentive
Construction	$ 1.25	$ 250,000
Post Occupancy	$ 1.00	$ 200,000
ZNE or Passive House Certification		$ 3,000
Optional Verification Incentive *		$ 10,000
ZNE Consultant Constribution *		$ 10,000
		$ 473,000
* 50% of the fee up to $10,000		

Value of Setting Early EUI Target

- Centers team on a clear goal
- Serves as a touchstone for decision making throughout design
- Encourages thought about building operations considerations
- Prevents value engineering of energy saving equipment and systems
- Allows school district to check performance against the target over time (and relative to other schools)

When Should You be Reaching Out?

- Feasibility/Conceptual
- Schematic Design (SD)
- Design Development (DD)
- Construction Document (CD)
- Construction Bid
- Construction

Early in Design Process

New Program Resources

MassSave.com

Program summary and individual pathway overviews | Program Memorandums of Understanding (MOUs)

Kim Cullinane
Eversource
kim.cullinane@eversource.com
(508) 353-5806

Margaret Song
Cape Light Compact
msong@capelightcompact.org
(508) 375-6843

Denise Rouleau
National Grid

Jodi Beebe
(on behalf of National Grid)
jordana.c.beebe@leidos.com
(617) 631-6039

Brad Hunter
Unitil
hunterb@unitil.com
(603) 294-5231

Thanks for listening.

WE ARE MASS SAVE®:

Value Engineering

4 min.

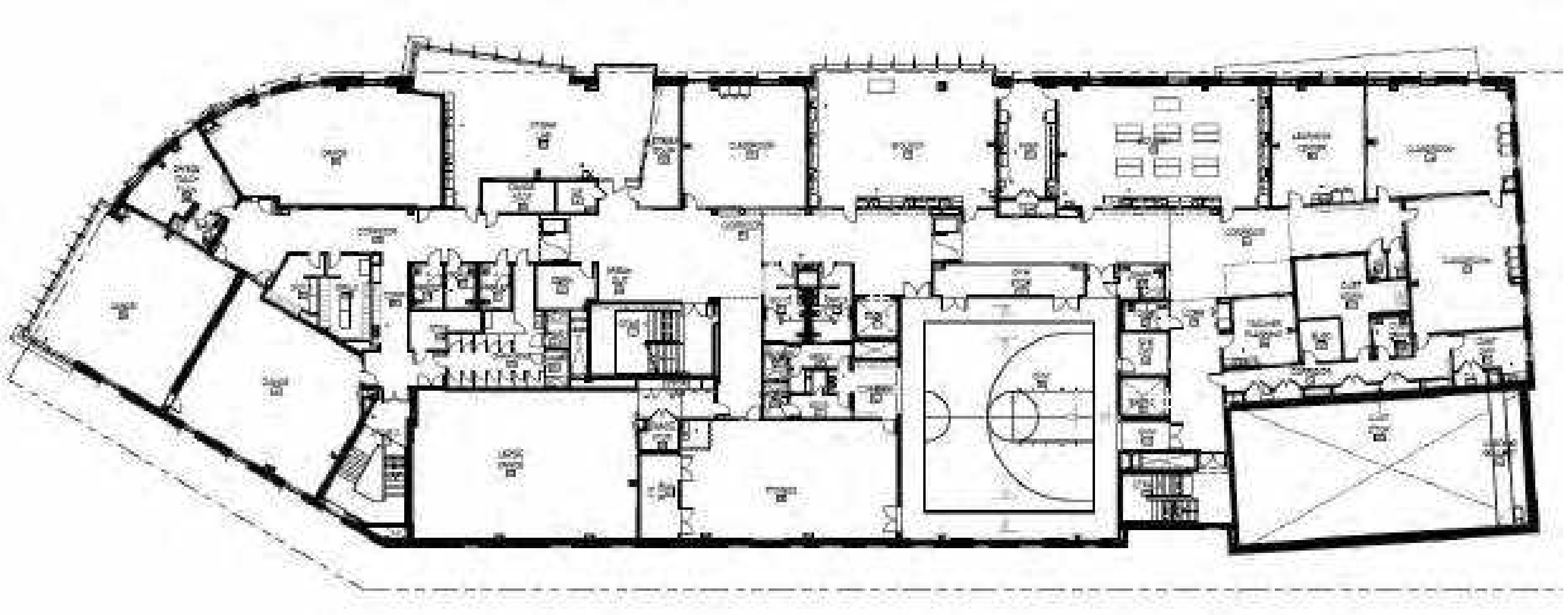

TOBIN MONTESSORI VASSAL LANE SCHOOL
PERKINS EASTMAN

BOSTON ARTS ACADEMY (BAA)

Location: Boston, MA
Use: High School – Arts
Number of Students: 500
Square Footage: 153,000 sf
Floors: 5

EXTERIOR ENVELOPE AND MECHANICAL DESIGN

BOSTON ARTS ACADEMY



- Engineer proposed perimeter heat
- Architect proposed triple-glazed windows
  - More annual hours of comfort
  - Reduces # of Air-Source Heat Pumps
- What is the cost?

EXTERIOR ENVELOPE AND MECHANICAL COST

BOSTON ARTS ACADEMY

Cost of Systems and Envelope

- Double Glazing $1,586,391
- Triple Glazing $1,078,105

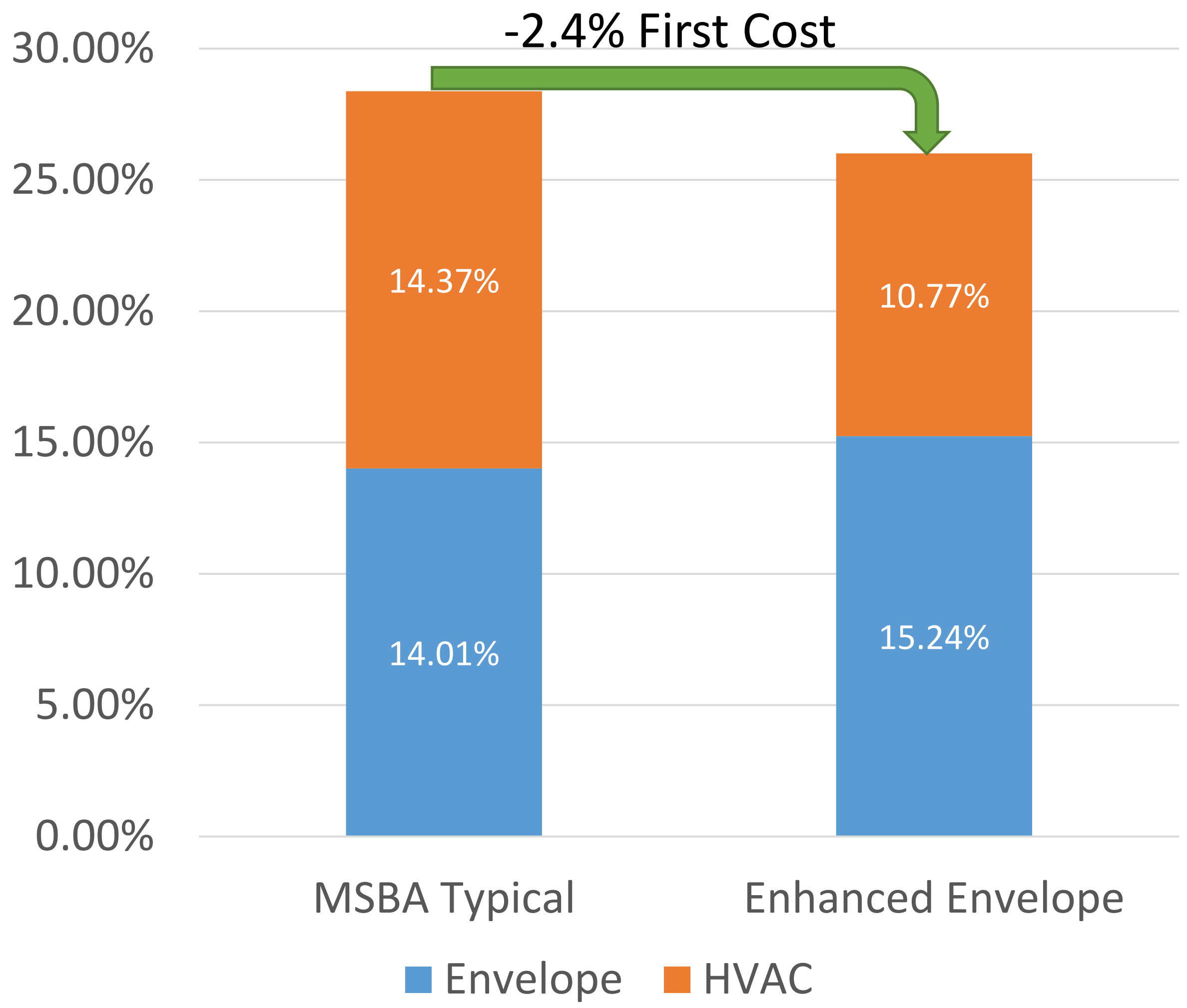
Triple Gazed design = $508,242 first cost savings

With Double Glazing			With Triple Glazing		
Boiler Size		1300	Boiler Size		600
Boiler Cost		$84,000	Boiler Cost (Estimate)		$71,400
Boiler Misc		$12,000	Boiler Misc (Estimate)		$10,200
Pump Size (GPM)		87	Pump Size (GPM)		40
Pump Cost		$31,000	Pump Cost (Estimate)		$26,350
Piping Cost		$791,826	Piping Cost (Estimate)		$593,870
Piping Insulation Cost		$330,000	Piping Insulation Cost (Estimate)		$231,000
Level 1 FTR Length		228	Level 1 FTR Length		41
Level 1 FTR Cost		$19,380	Level 1 FTR Cost		$3,485
Level 2 FTR Length		316	Level 2 FTR Length		92
Level 2 FTR Cost		$26,860	Level 2 FTR Cost		$7,820
Level 3 FTR Length		368	Level 3 FTR Length		240
Level 3 FTR Cost		$31,280	Level 3 FTR Cost		$20,400
Level 4 FTR Length		377	Level 4 FTR Length		189
Level 4 FTR Cost		$32,045	Level 4 FTR Cost		$16,065
Level 5 FTR Length		342	Level 5 FTR Length		180
Level 5 FTR Cost		$29,070	Level 5 FTR Cost		$15,300
Control zones perim heat		100	Control zones perim heat		40
Controls cost	$	150,000	Controls cost	$	60,000
FTR Cost with Double Glazing		$138,635	FTR Cost with Triple Glazing		$63,070
Boiler and Piping Cost		$1,248,826	Boiler and Piping Cost		$932,820
Total Cost of FTR and Boilers		$1,537,461	Total with Triple Glazing FTR		$1,055,890
Architectural Treatment of Perimeter Heat	$	48,930	Architectural Treatment of Perimeter Heat	$	22,260
TOTAL COST		$1,586,391	TOTAL COST		$1,078,150

Savings with Triple Glazing Versus Double Glazing **$508,242**

VALUE ENGINEERING CONSTRAINTS

- Savings in HVAC balances cost in exterior envelope
- Reduced HVAC Equipment = Reduced Maintenance
- Passive Survivability
- **You cannot take the cost savings for one system without increasing the cost of another**

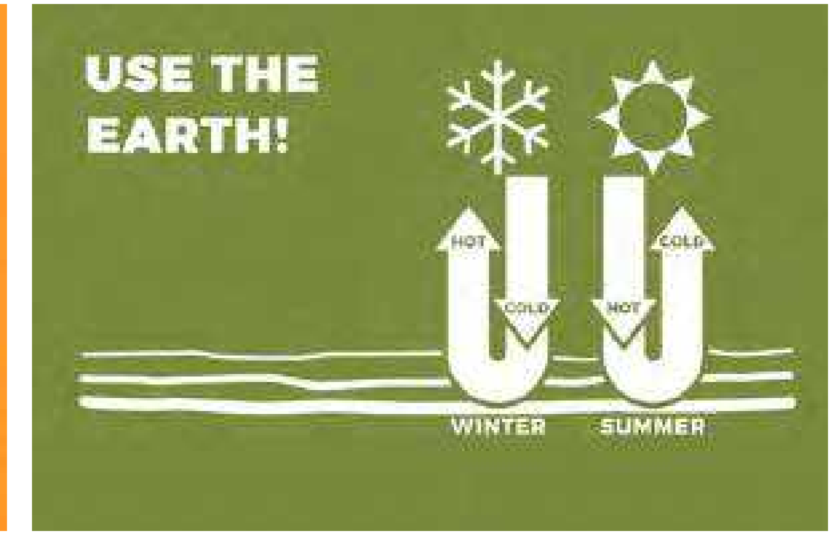


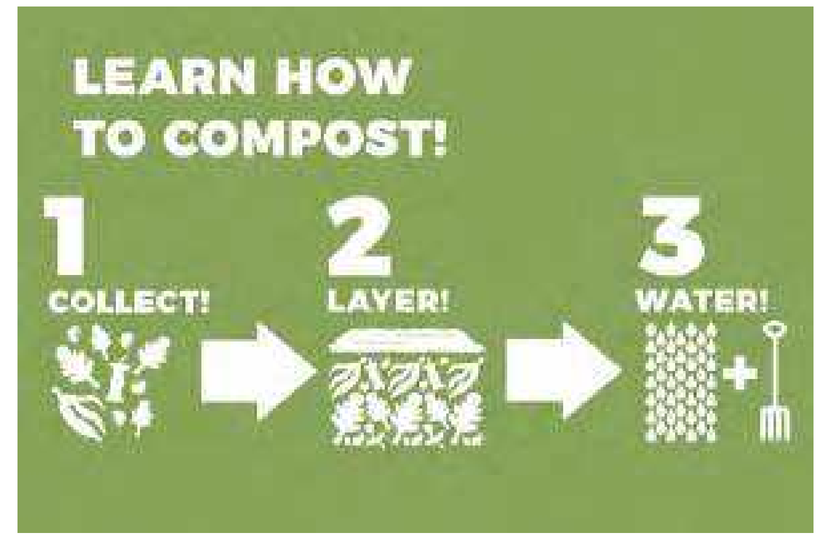
ENGAGEMENT OF STUDENTS & COMMUNITY


TURN OFF
THE LIGHTS!
UNPLUG
DEVICE!

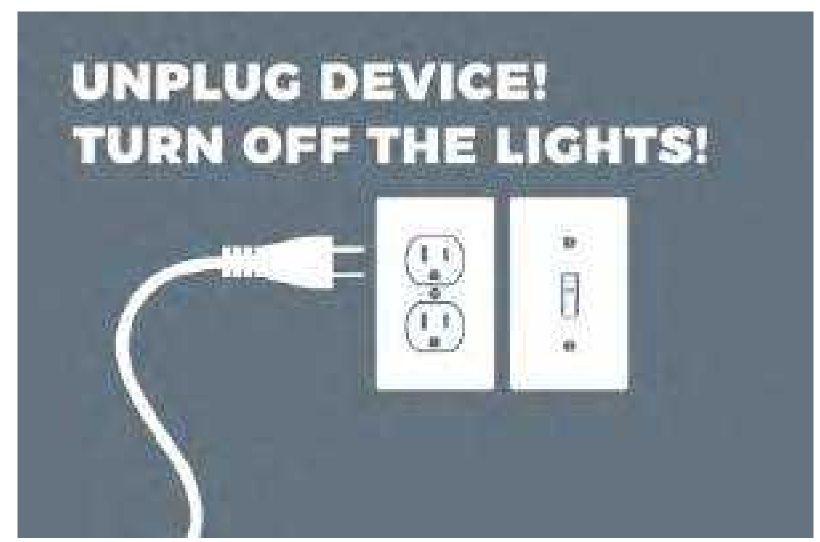

ENJOY
THE QUIET.
LOCKERS!
VOICES!
MUSIC!
FOOTSTEPS.


LET THE SUN
SHINE IN!


USE THE
EARTH!
HOT
COLD
COLD
HOT
WINTER
SUMMER


LEARN HOW
TO COMPOST!
1
COLLECT!
2
LAYER!
3
WATER!

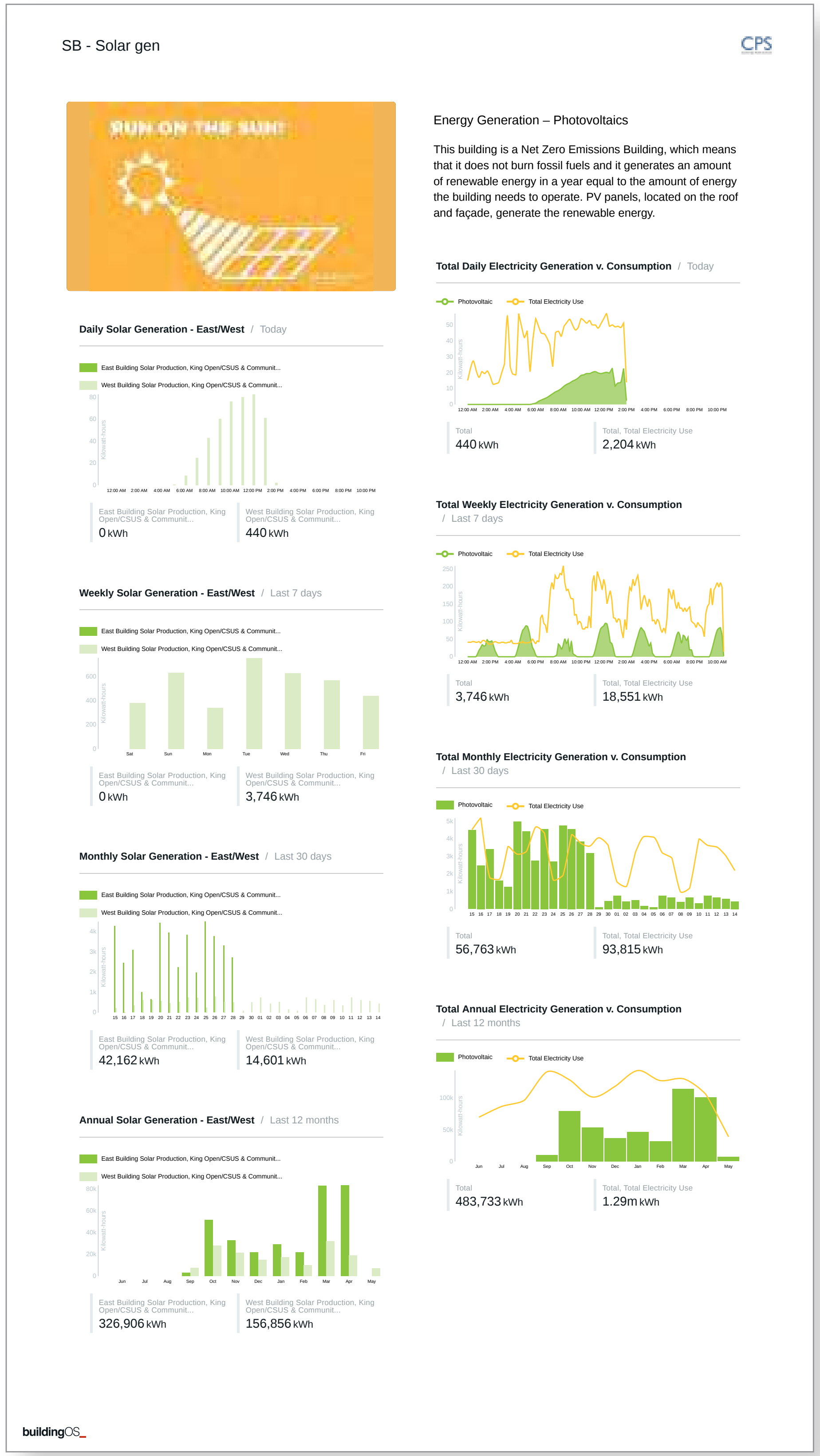

CONSERVE
WATER!

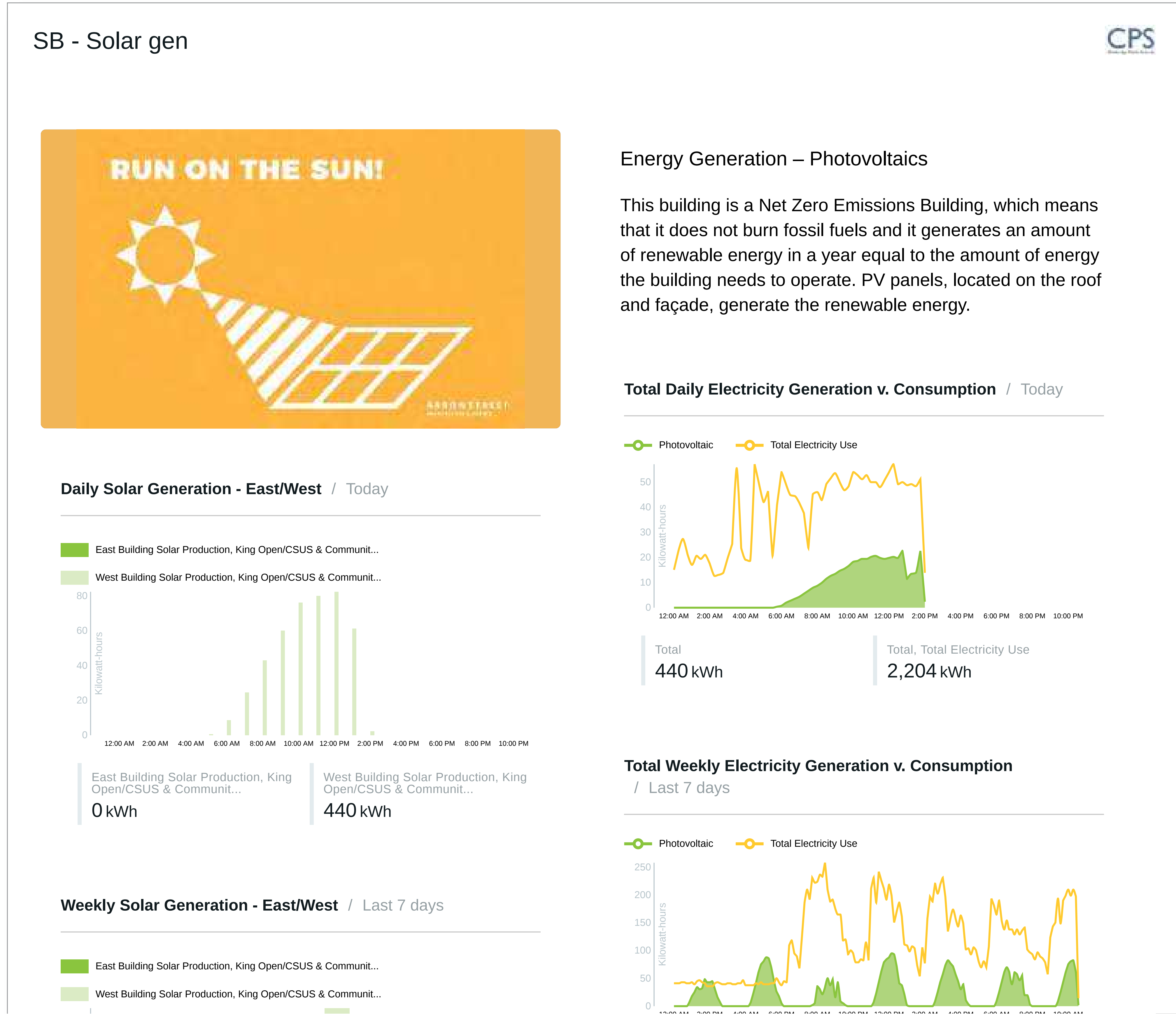

UNPLUG DEVICE!
TURN OFF THE LIGHTS!


RUN ON THE SUN!

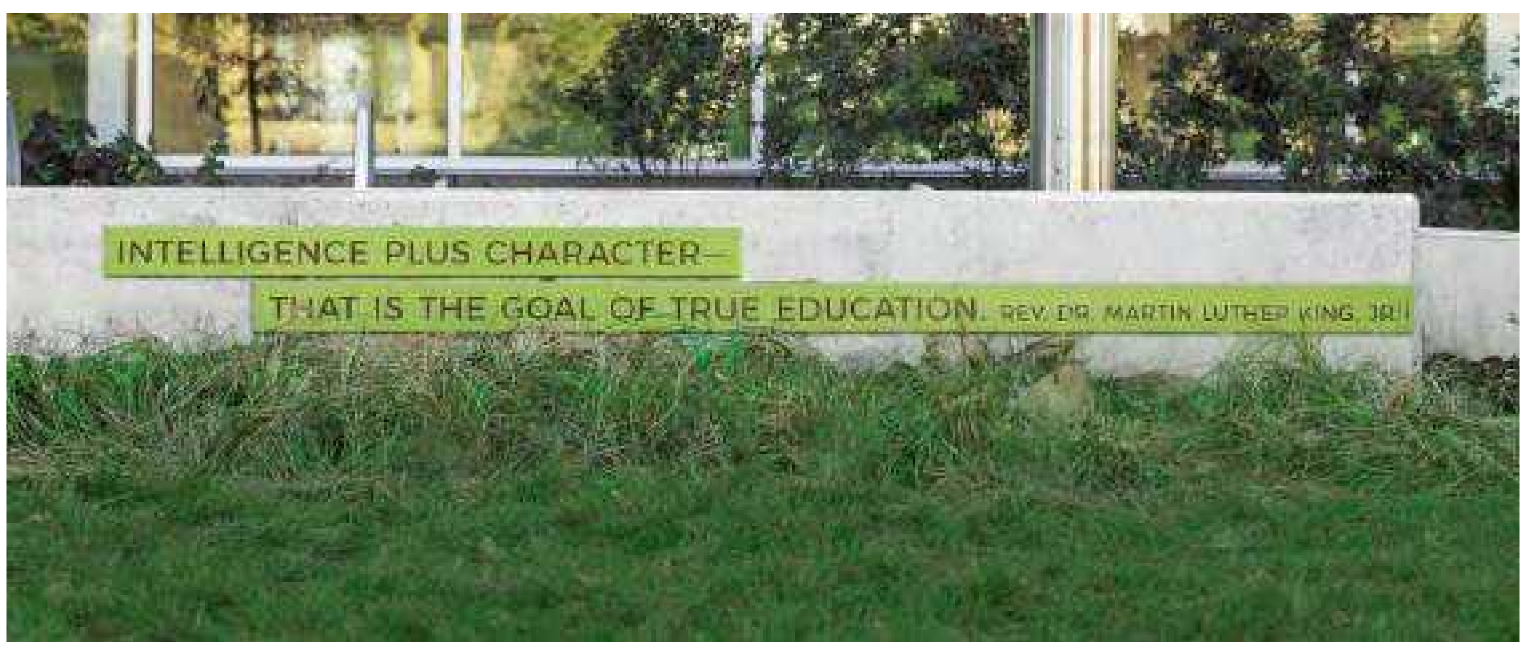

LEARN HOW
TO COMPOST!
1
COLLECT!
2
LAYER!
3
WATER!

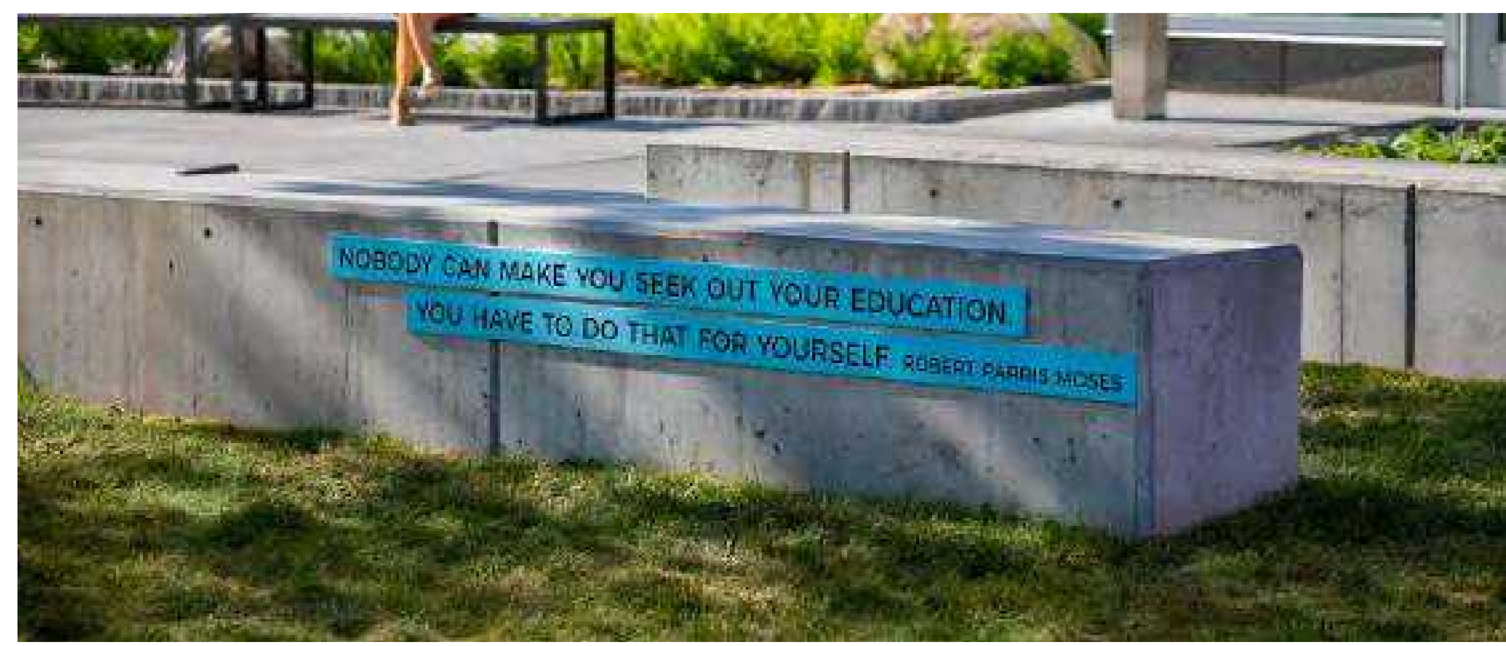

2
LAYER!
3

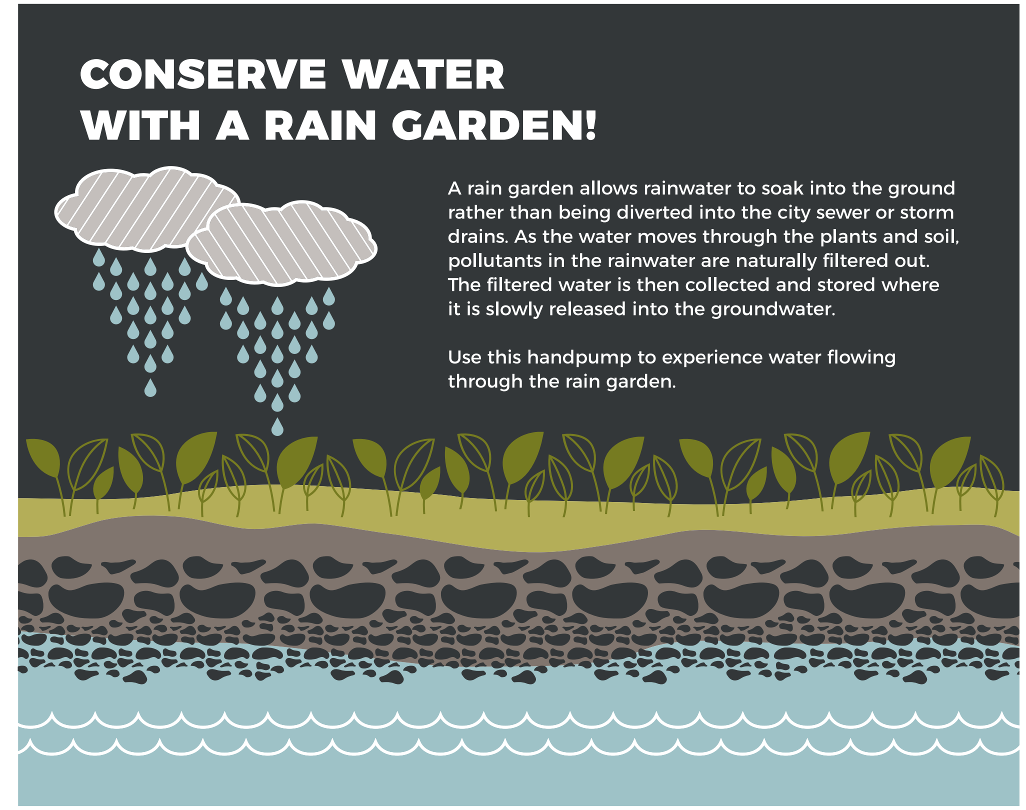




ARROWSTREET


INTELLIGENCE PLUS CHARACTER—
THAT IS THE GOAL OF TRUE EDUCATION. REV. DR. MARTIN LUTHER KING, JR.


NOBODY CAN MAKE YOU SEEK OUT YOUR EDUCATION
YOU HAVE TO DO THAT FOR YOURSELF. ROBERT PARRIS MOSES


CONSERVE WATER
WITH A RAIN GARDEN!
A rain garden allows rainwater to soak into the ground rather than being diverted into the city sewer or storm drains. As the water moves through the plants and soil, pollutants in the rainwater are naturally filtered out. The filtered water is then collected and stored where it is slowly released into the groundwater.
Use this handpump to experience water flowing through the rain garden.


EAT LOCAL!
LOCAL FOOD PRODUCTION
WHAT IS IT:
When food is grown locally, either in your town, state, or region, it is more sustainable. Food grown far away creates pollution from the trucks that drive it to your area and the refrigeration needed to keep it fresh on the journey takes a lot of energy. In addition, local food tastes great and is often the freshest.
WHAT DOES THE BUILDING DO:
This garden grows fruits and vegetables that you can eat! It is an example of the types of things that you can grow in your own home or yard in Cambridge. It is important to understand how plants grow and no better way to understand than to grow them yourself.
WHAT CAN YOU DO:
Shop at neighborhood grocers, farm stands, or farmer's markets. Wherever you buy produce, select items that are grown in your state or region.

Engagement of Students and Community

Hosmer

Interior Rendering

View of main stair in Hosmer

Instructional guides for classroom occupants

..ılıl 12 STEPS TO NET-ZERO lılı..

Ai3's CLASSROOM USER GUIDE

The purpose of the following User Guide is to explain the features of the school that contribute to its energy savings and efficiency. Implementing these strategies will ensure the maintainance of a Net-Zero Energy Building.

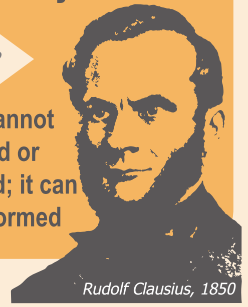
WHAT IS A NET-ZERO SCHOOL?

The Department of Energy reports that K-12 schools expend $6 Billion on energy consumption each year; more than the costs of textbooks and computers combined, and second only to the cost of teacher salaries. A **Net-Zero school** is designed and constructed to produce as much energy on site as it consumes from the electric grid. The Net-Zero school also reinforces teaching and learning as an extended classroom. The incorporation of efficient building materials and cutting-edge renewable energy technology makes the building a three-dimensional learning space. Students learn through practical, hands-on experiences and observations of the building's components, systems, and operation.

But what is energy?

1st law of thermodynamics

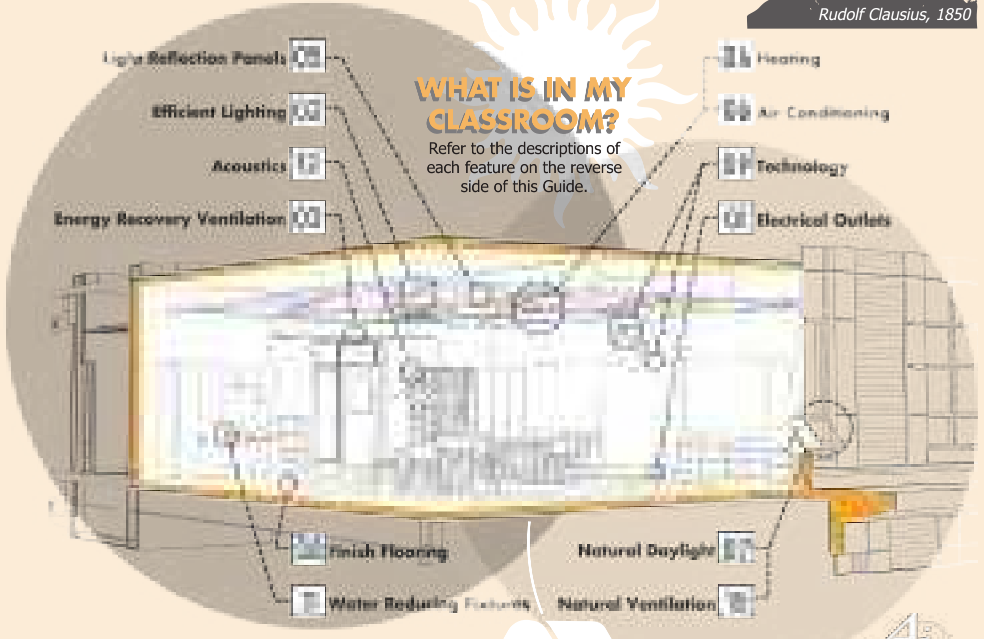
Energy cannot be created or destroyed; it can be transformed



Rudolf Clausius, 1850

WHAT IS IN MY CLASSROOM?

Refer to the descriptions of each feature on the reverse side of this Guide.



WHAT IS MY ROLE AS A USER?

Net-Zero Energy Buildings are the pinnacle of what sustainable design and construction are trying to accomplish. We have incorporated numerous energy-efficient technologies and building strategies to allow this new school to achieve Net-Zero status. However, **occupant behavior** accounts for approximately 50% of the building's energy usage, and your activities as an occupant will be critical in achieving Watertown's goal of Net-Zero Energy. This means always engaging in **energy conscious practices**; such as unplugging electronics not in use, closing windows when the heating or air-conditioning systems are used, turning lights off when leaving the room, and using the appropriate flush settings.

WHAT ELSE CAN I DO?

Being conscious of energy usage to ensure that your building produces as much energy, if not more, than is used helps the environment because it **reduces emissions**. Outside of energy conservation sustainability should also be practiced. To be **sustainable** is to avoid depleting natural resources so that an ecological balance is maintained. **Recycling** is a sustainable practice because it converts waste into recycled material, which can then be reused rather than using new resources. **Composting** natural waste is another sustainable practice becuase it reduces the amount of waste that would ultimately end up in a landfill. Landfills emit compounds that, over time, are harmful to the ozone layer.

..ılıl 12 STEPS TO NET-ZERO lılı..

Ai3's CLASSROOM USER GUIDE

01 Electrical Outlets

One of the biggest challenges in lowering energy consumption is eliminating inefficient appliances and equipment plugged into electrical outlets. These items become particularly concerning if they utilize electricity outside typical occupancy hours. For this reason, most of the outlets in your classroom automatically shut off at the end of the school day. If you absolutely must have items which utilize electricity when the building is not occupied, these can be plugged into specially designated 24/7 outlets, but please use these sparingly as they have a huge impact on building energy use.

02 Efficient Lighting

Lighting throughout the building is designed to dim automatically when there is enough natural lighting entering the building through exterior windows. This dimming of electrical lighting is particularly important in the classroom, because classrooms are one of the largest areas of energy consumption. There are provisions for overriding the daylight dimming functions in your classroom; however, we discourage overriding the dimming systems unless it is necessary to achieve appropriate lighting for the current activity in the classroom.

03 Energy Recovery Ventilation

A heat recovery ventilation system removes old air from the classroom and supplies new fresh air. This is called "Energy Recovery" because the system can extract energy from the cold or hot air (depending on the season) removed from one classroom and use it to cool or heat the new fresh air supplied to another classroom. The fresh air system for your classroom should be left on "auto" but you can press the boost button during occupancy if something within your classroom requires additional ventilation. Note that when the boost button is used, much more electricity is too, so use it sparingly.

04 Heating

The heating of your room is provided by the two square ceiling cassettes located in the ceiling. These units are tied to your room thermostat and work independently of all other systems in the building to heat your classroom to the desired temperature. You may sometimes notice a short delay in the startup of these cassettes. This is because they receive their heating/cooling freon from a common source shared by other cassettes in the building and it is most efficient to supply this freon when multiple spaces are calling for its production and use.

05 Light Reflection Panels

Light reflection panels in your classroom are designed to amplify the daylight coming into the classroom and reduce the amount of artificial lighting (electricity) required. Please do not cover or block them.

06 Air Conditioning

The cooling of your room is provided by two ceiling cassettes. These units are tied to your room thermostat and work independently of all other systems in the building to cool your classroom to the desired temperature. You may sometimes notice a short delay in the startup of these cassettes. This is because they receive their heating/cooling refrigerant from a common source shared by other cassettes in the building and it is most efficient to supply this freon when multiple spaces are calling for its production and use. The system may be pausing until another classroom also needs refrigerant.

07 Natural Daylight

The windows in your classroom form a major role in reducing the amount of artificial light required in the classroom. They include exterior sunshades to block solar gain during the appropriate seasons and allow it when beneficial in colder months. We request that you do not block your windows or utilize the interior shades unless it is necessary, and that you return the interior shades to an open position as soon as possible. If you keep your interior shades in a closed position or cover your windows, it defeats many natural lighting and heating attributes of the building's exterior envelope.

08 Finish Flooring

Your classroom floor finishes are made from linoleum. Linoleum is a sustainable, natural, and durable product that played a role in making sure the school achieved LEED Gold status. Although linoleum is quite durable, it requires some care. If you do have a spill, simple soap and water should be utilized to clean the floor finish. Additionally, you may notice that light colors have been selected for floor, wall, and ceiling products. We recognize that this may require more cleaning but has significant benefits in light reflectance and reducing the overall artificial lighting required in the classroom.

09 Technology

Technology equipment within your classroom is plugged into specially designated outlets that turn off automatically based on the schedule of occupancy. However, we highly encourage you to turn off equipment manually if it is not in use. We also request that you do not plug technology equipment into the outlets which are powered 24/7, as this defeats our goal of reducing energy use.

10 Natural Ventilation

Your classroom contains operable windows to allow for natural fresh air when the weather is appropriate. Note that your classroom is always receiving fresh air even when the windows are closed. The energy recovery ventilation provides 15 ft^3 of fresh air per minute. This is more than an open window provides and this system can detect the number of occupants in your classroom to adjust the amount of fresh air accordingly. If the windows are open, turn off the thermostat. The ceiling cassettes should never be operating with windows open, as this results in a significant waste of energy.

11 Water Reducing Fixtures

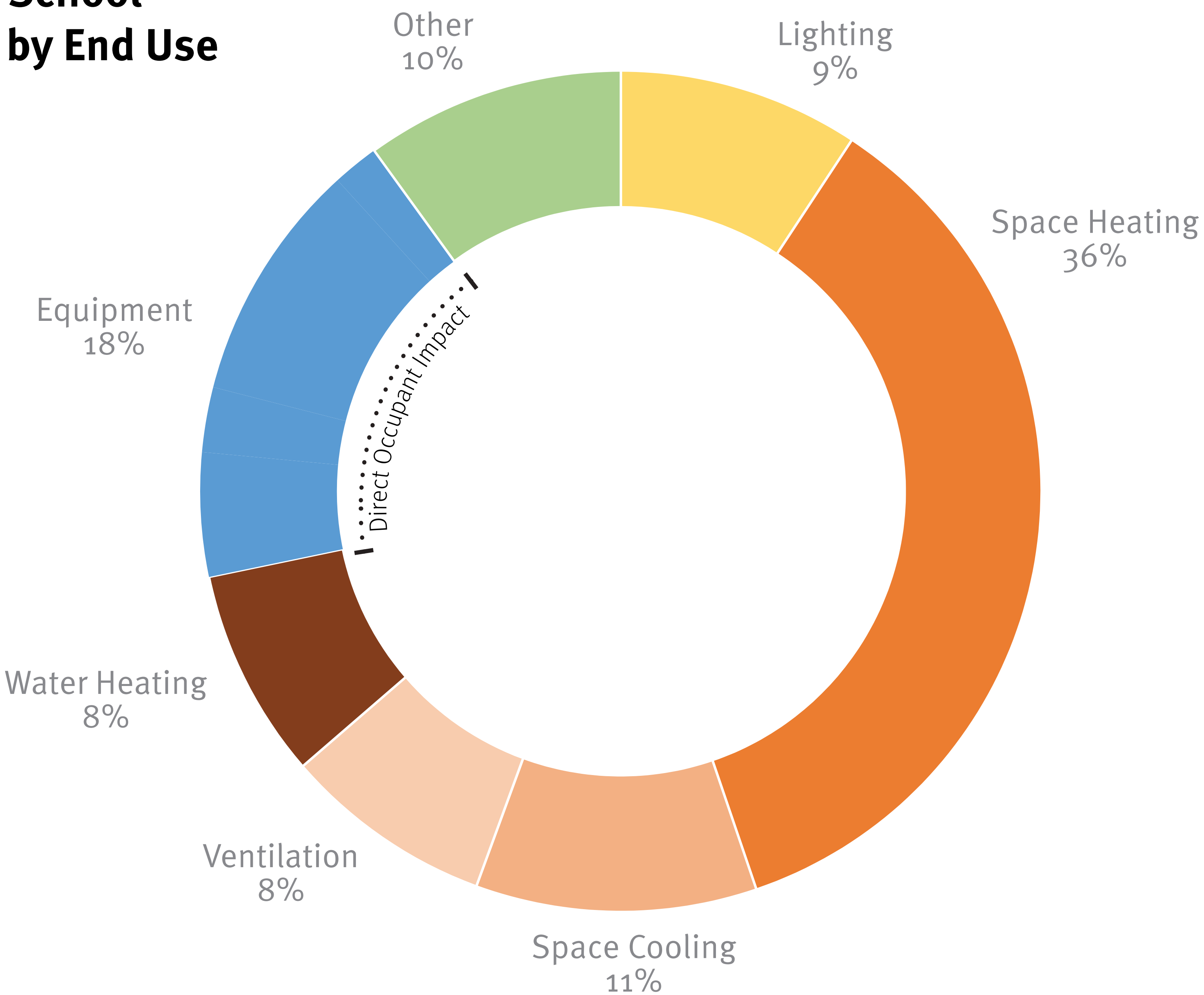
Toilets and faucets inside and throughout the building are water-reducing fixtures that are intended to minimize overall building water usage. The toilets have two flush options and we encourage the minimum amount of water usage (Flush Option 1) unless it is necessary to utilize the maximum water use flush (Option 2).

12 Acoustics

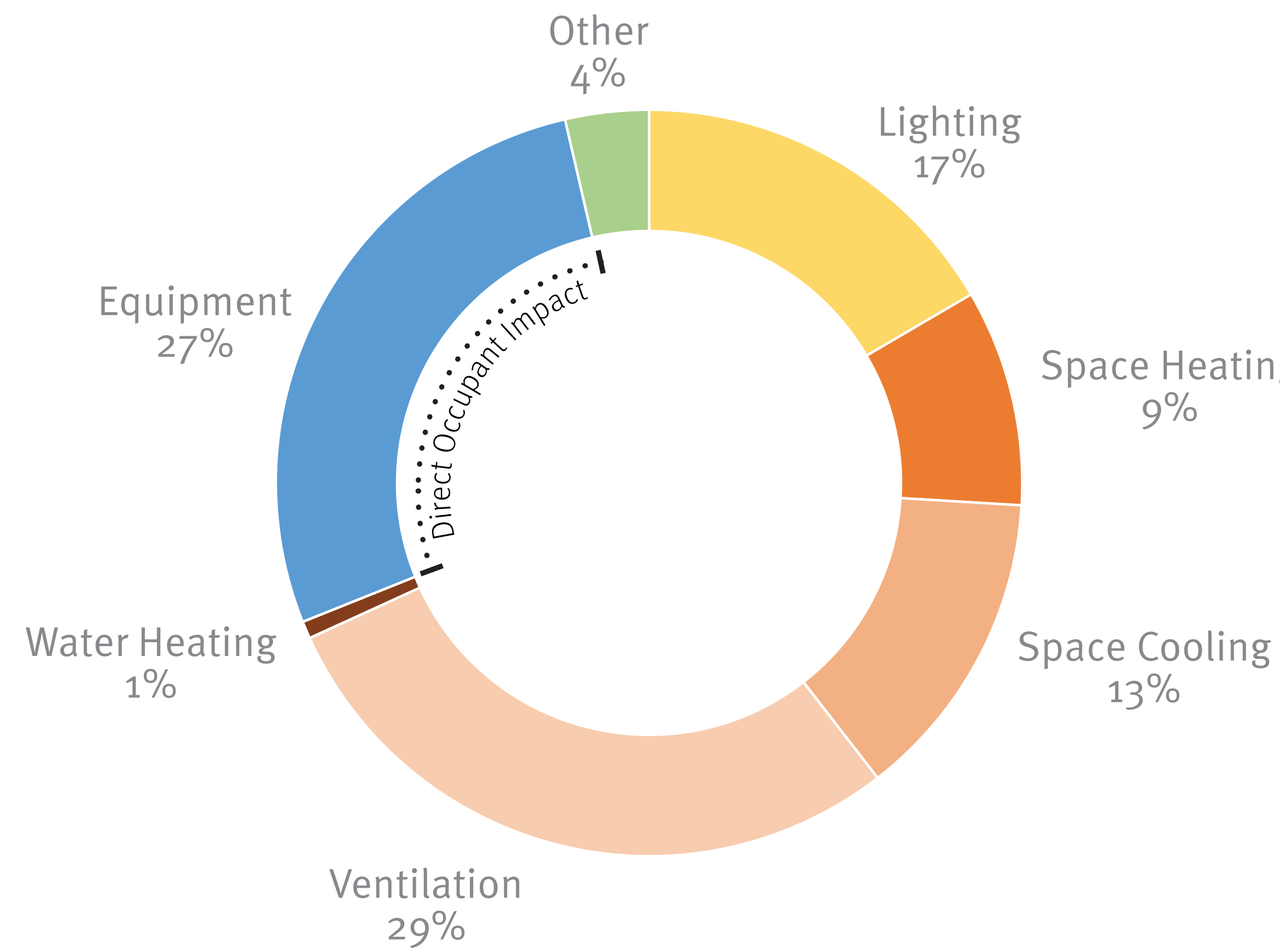
Although your classroom is designed with a sound reinforcement system to provide voice amplification when necessary, the classroom acoustics are designed to minimize the need for this system. We encourage you to utilize the sound reinforcement system, but ask that you evaluate the natural acoustics in your classroom and only use voice amplification when required.

ENGAGEMENT OF OCCUPANTS & STAFF

Typical School Energy by End Use



King Open/ Cambridge Street Upper Schools Energy by End Use



ARROWSTREET

ENGAGEMENT PROCESS

ENGAGEMENT PROCESS
KING OPEN

Feasibility Phase

-Define goals
-User meetings with all groups
-Collect usage data (schedules, equipment, etc)

Schematic Design

-Build consensus on goals
-Establish NZE Champions Group
-NZE Champions Workshop

Design Development & CDs

-Meet with NZE Champions group in each phase to discuss design as it develops

Construction

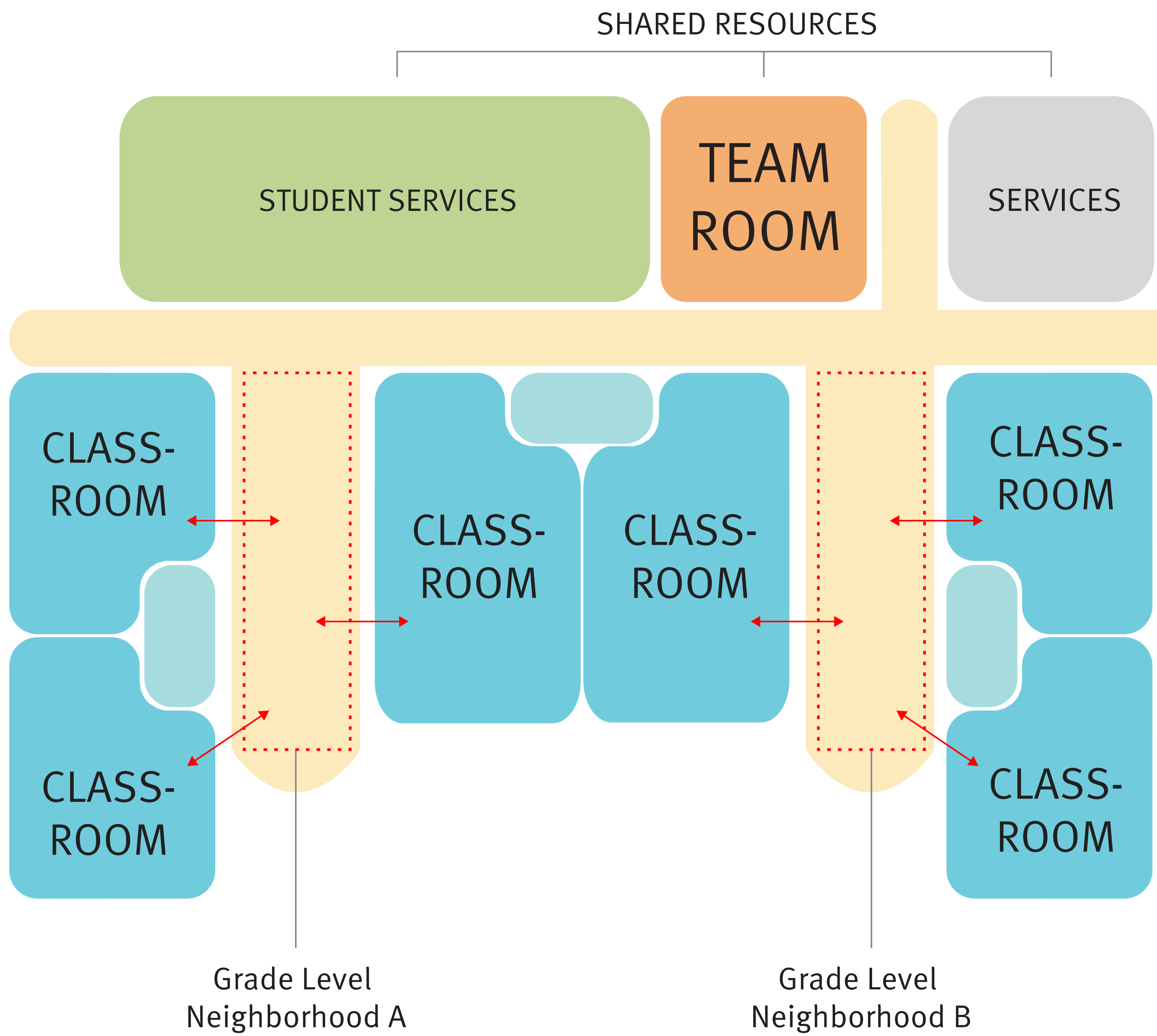
-Workshop with all staff and students start to get used to what to expect
-Training before move-in

Post Occupancy

-Operations Manual: user cards, phone app
-Curriculum incorporation
-Yearly training

ENGAGEMENT LEADS TO ENERGY REDUCTION - 13.6%

ENGAGEMENT LEADS TO ENERGY REDUCTION - 7%



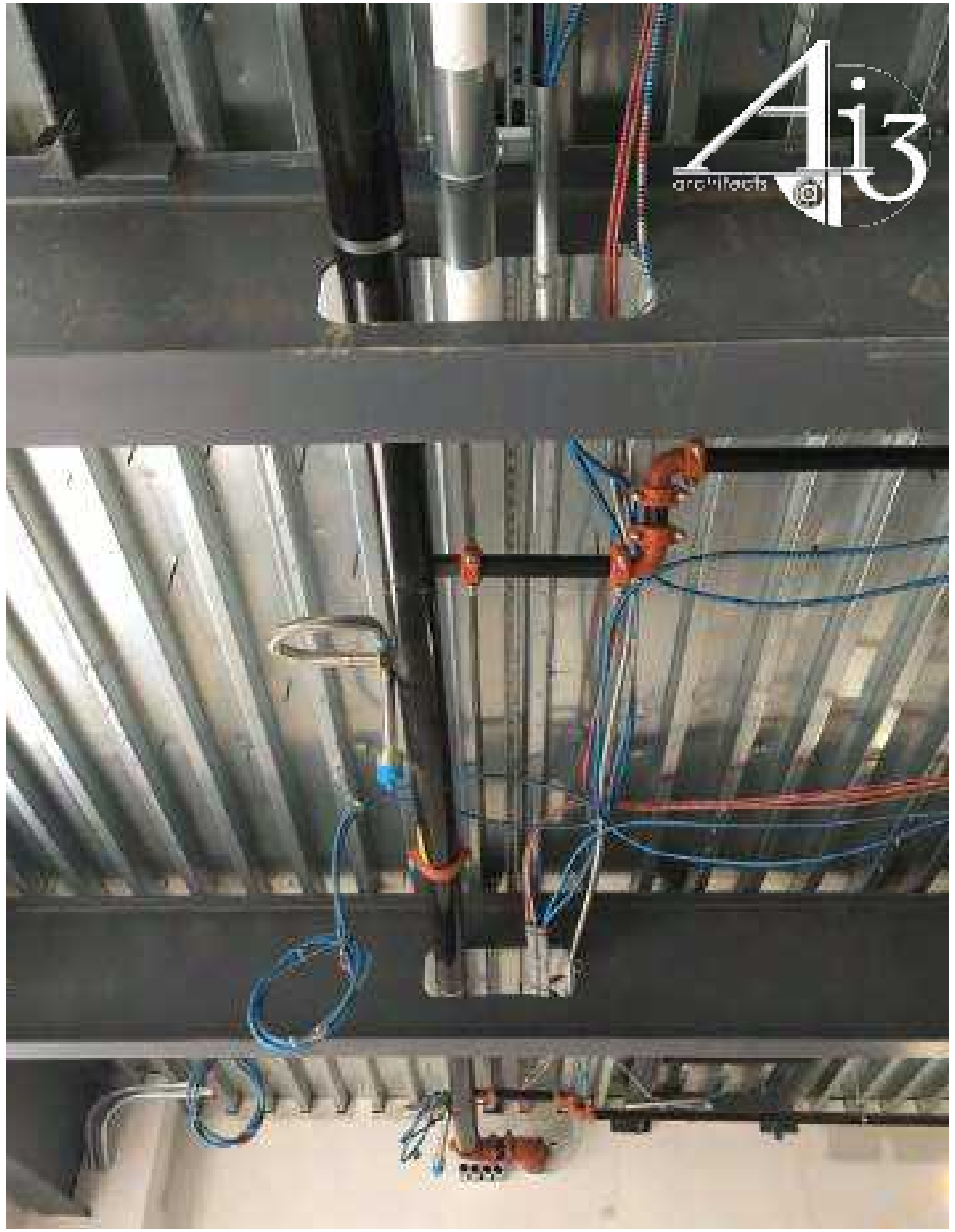
ARROWSTREET

Engaging Occupants and Staff

Designing for Efficient Systems

Ductwork and refrigerant lines were coordinated tight to steel

1 of 2 VRF ceiling cassettes installed in every typical classroom



Coordinated beam penetrations to maintain ceilings heights

COMMUNITIES ARE UNIQUE

Educational Benefits:

- Create living laboratories that adapt students to a knowledge-based technologically advanced society
- Occupant engagement can serve as a teaching tool for students, STEM programs, and the larger community
- Give students the confidence to take leadership roles in their schools as advocates for environmental sustainability and their own learning needs

Health Benefits:

- Better indoor air quality, acoustics, and daylight
- Improved occupant performance
- Lower absenteeism
- Attract and retain students and faculty

Cost Benefits:

- Lower operating costs for maintenance
- Lower energy bills
- Reduced exposure to the volatility of shifting energy prices

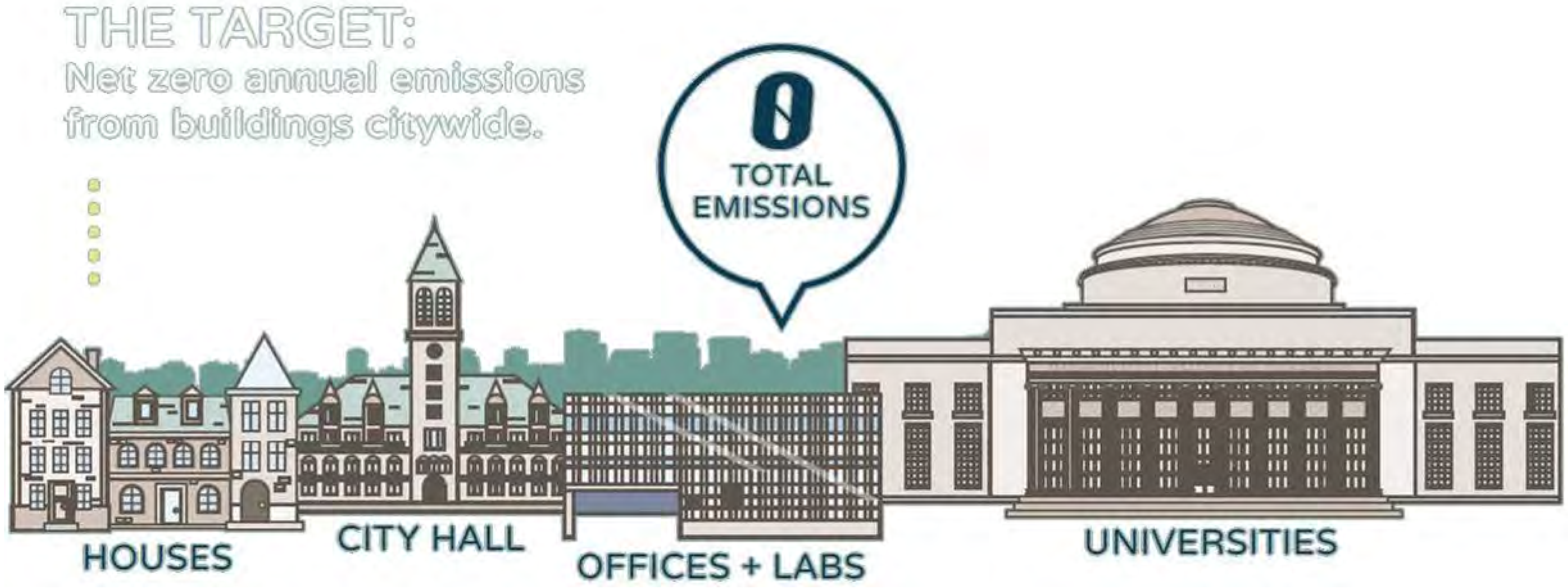
ARROWSTREET

KING OPEN/CAMBRIDGE STREET UPPER SCHOOL AND COMMUNITY COMPLEX

with Arrowstreet

2015


THE PATH TO A
NET ZERO
CAMBRIDGE


THE TARGET:
Net zero annual emissions from buildings citywide.
0
TOTAL EMISSIONS
HOUSES
CITY HALL
OFFICES + LABS
UNIVERSITIES

CITY OF CAMBRIDGE

5 ACTION PLAN

Energy Efficiency in Existing Buildings

Reduce energy use in buildings through retrofits and improved operations.

Net Zero New Construction

Require low carbon new construction.

Renewable Energy Supply

Replace fossil fuels with low carbon energy.

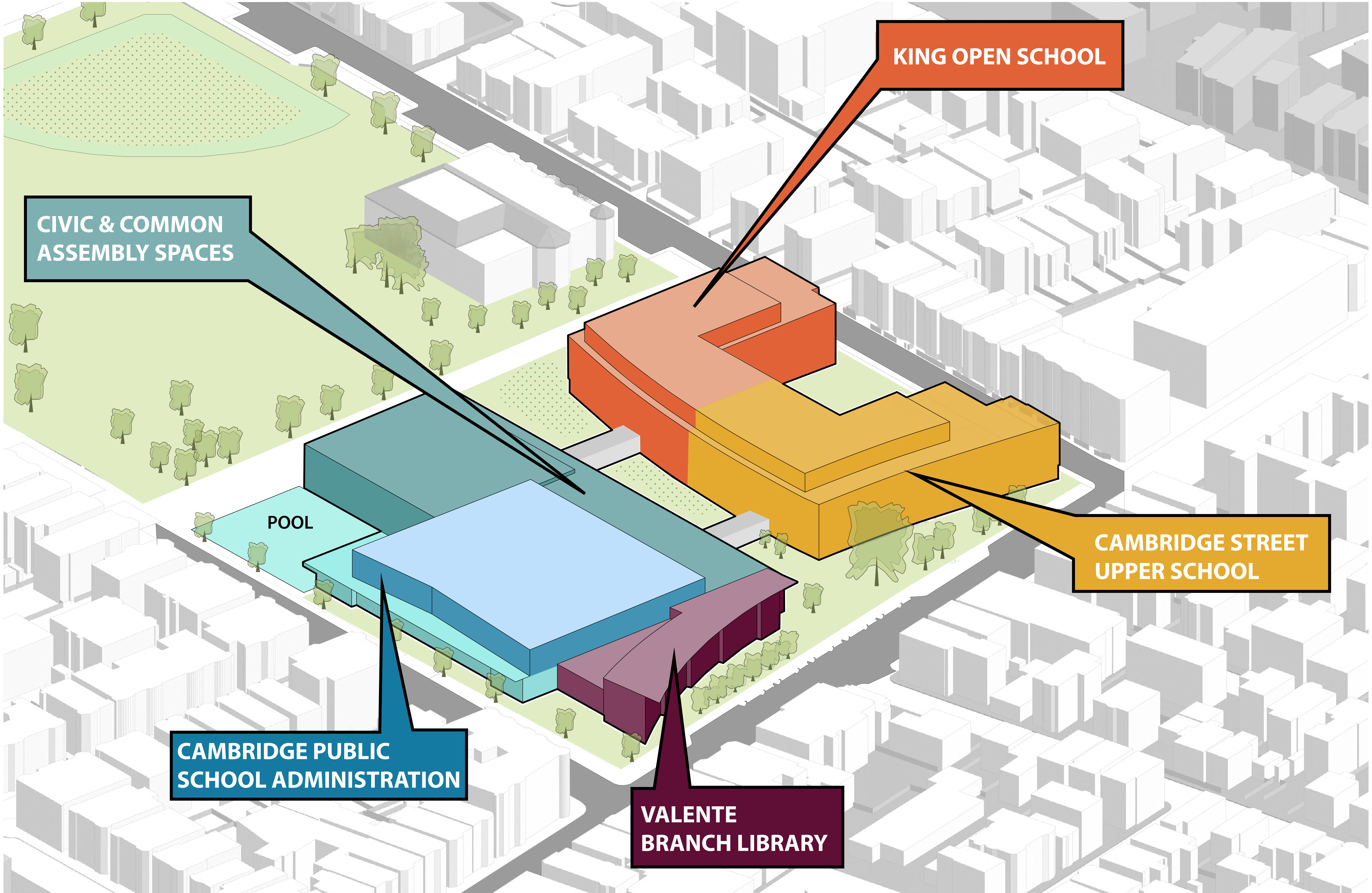
Local Carbon Fund

Option to invest in a net zero community.

Engagement and Capacity Building

Industry training and community involvement.

MULTIPLE USERS



NET ZERO CHALLENGES

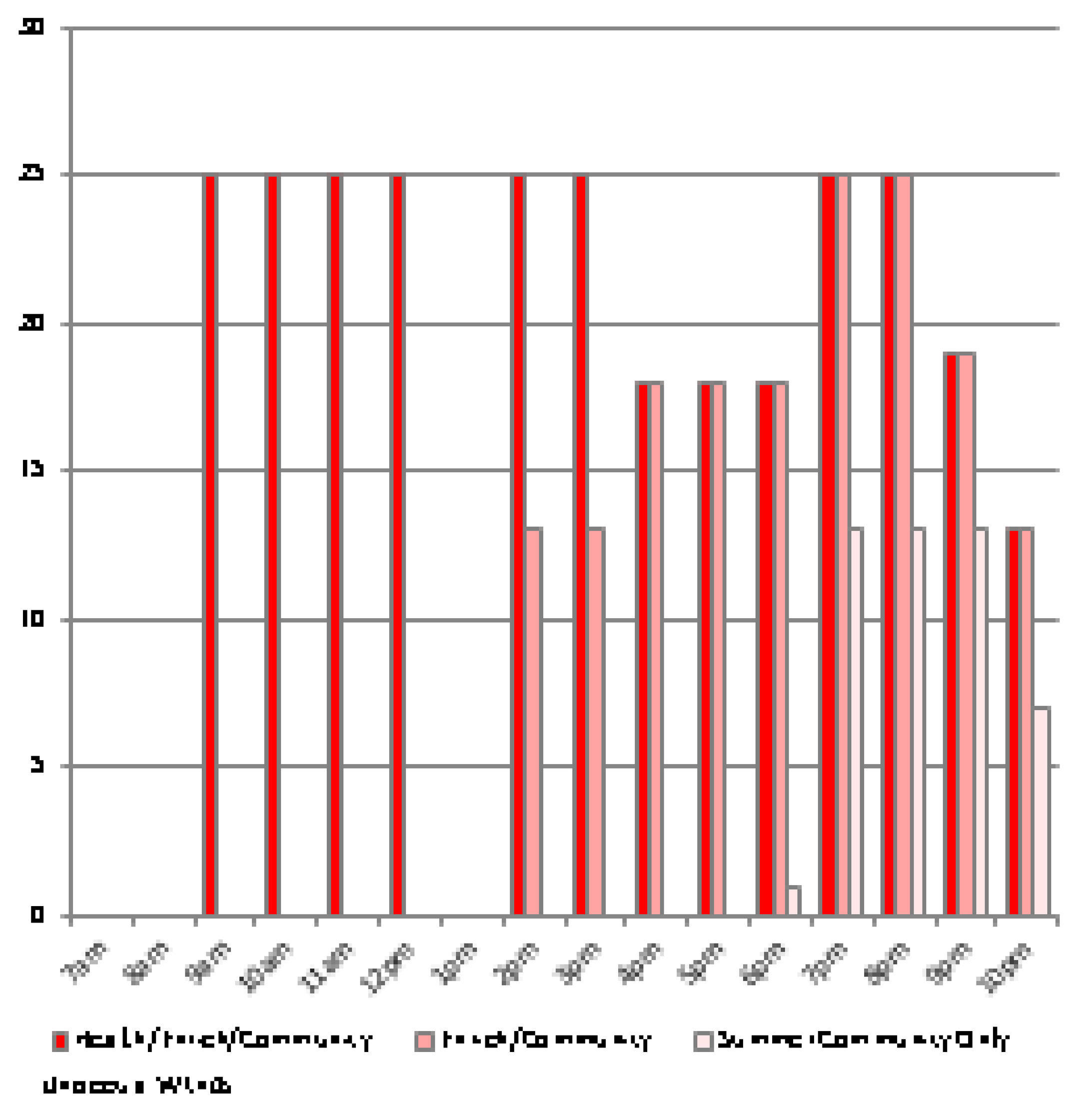
Multiple Programs with Extended Hours

After School Programs

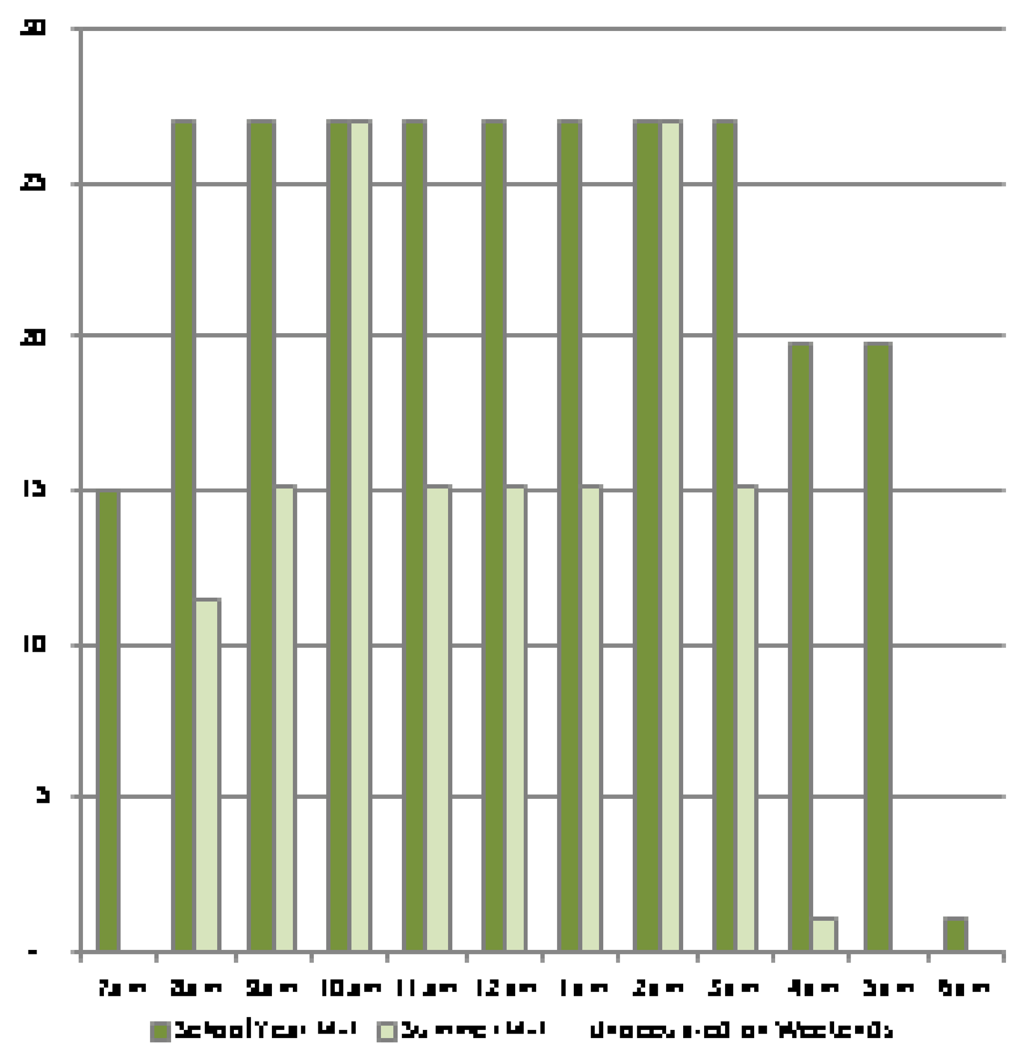
Community Classrooms

Weeknight & Weekend Gymnasium Use

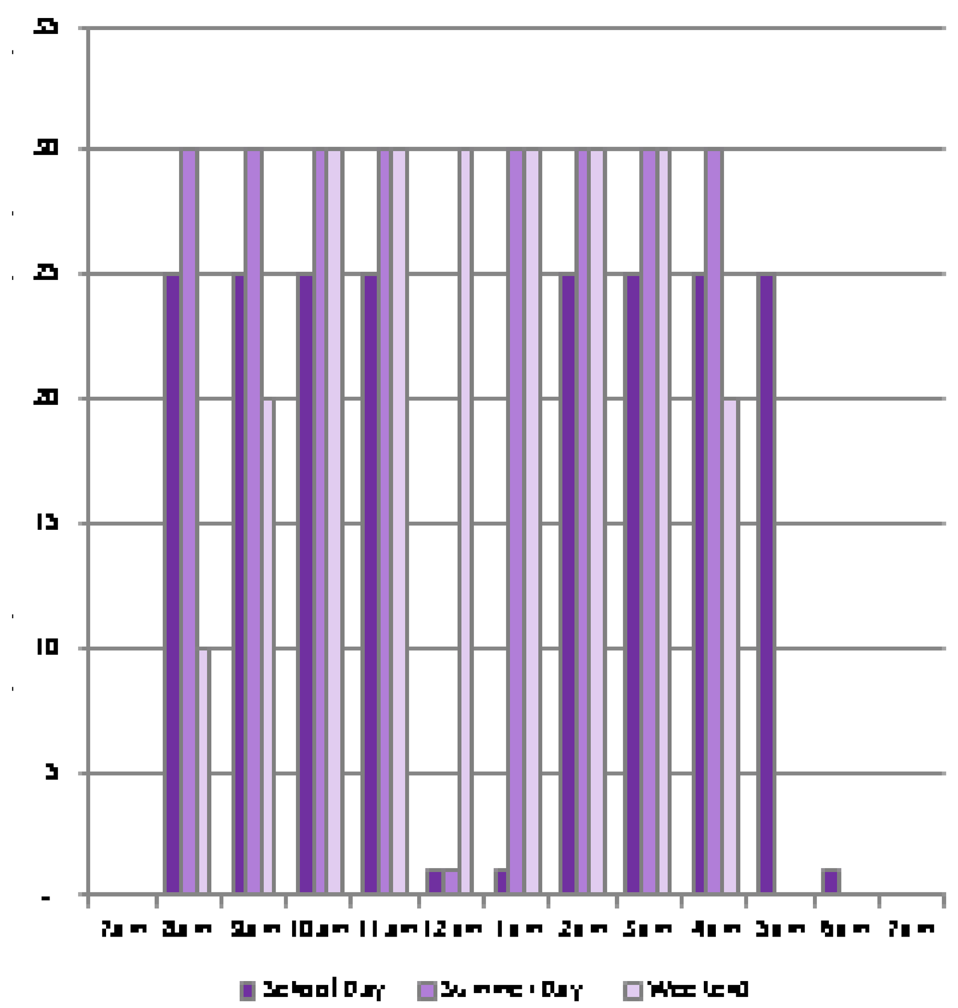
Public Branch Library

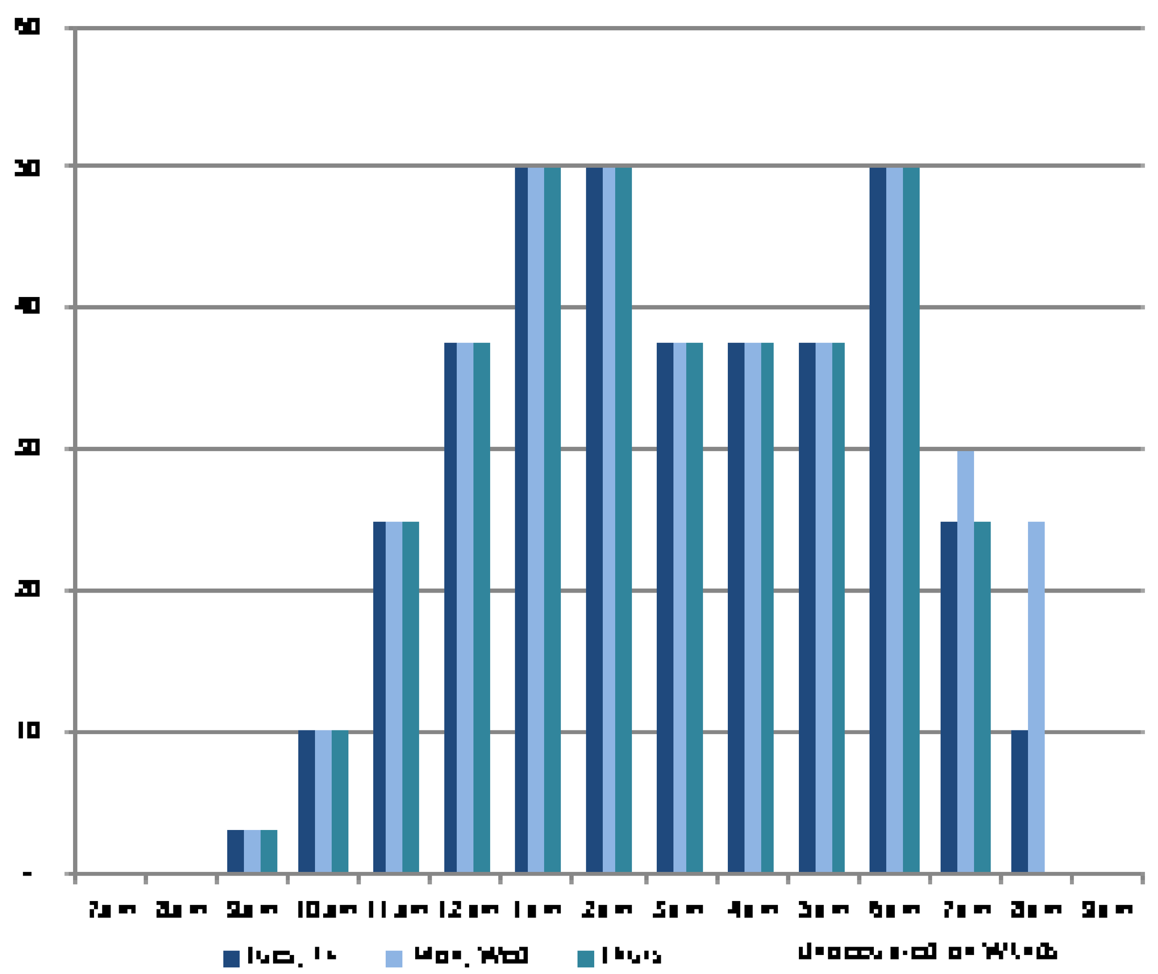


Community Classroom



Learning Commons



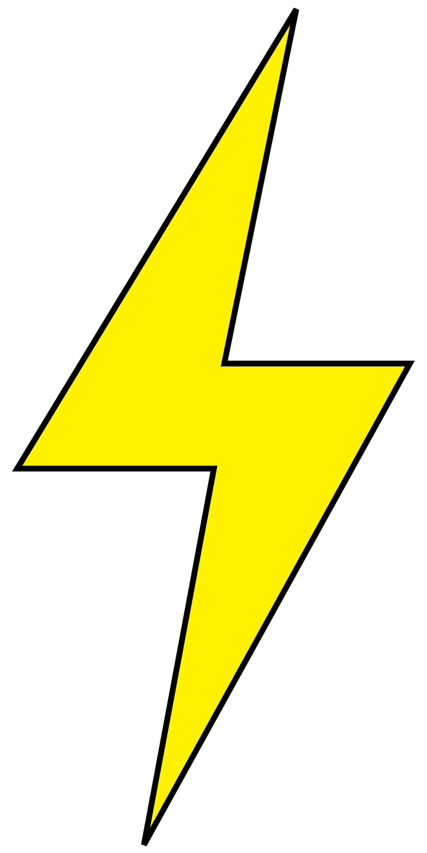


PATHWAY TO NET ZERO EMISSIONS

Eliminate On-site Combustion of Fossil Fuels

Reduce Demand

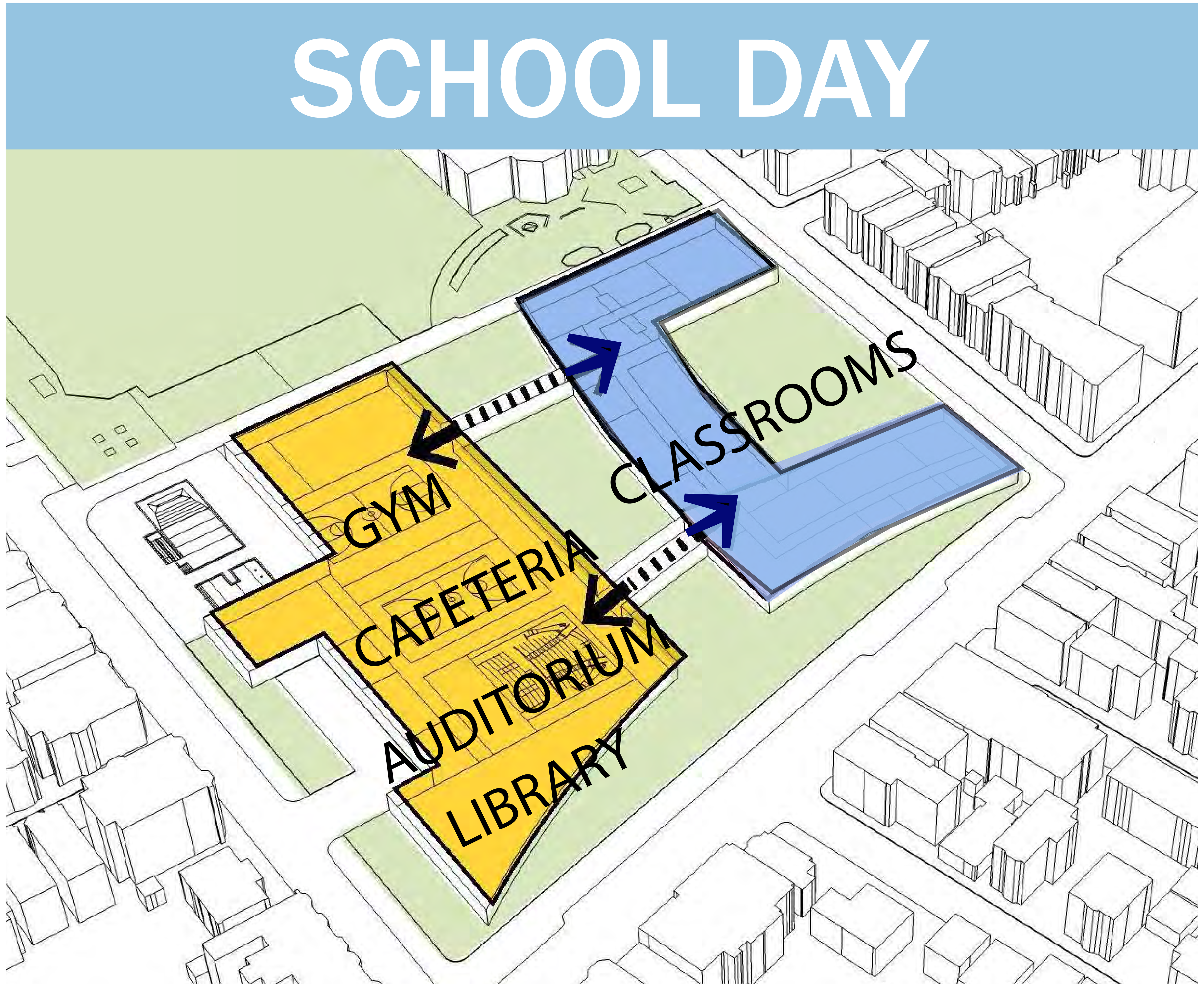
Maximize On-site Production of Electricity

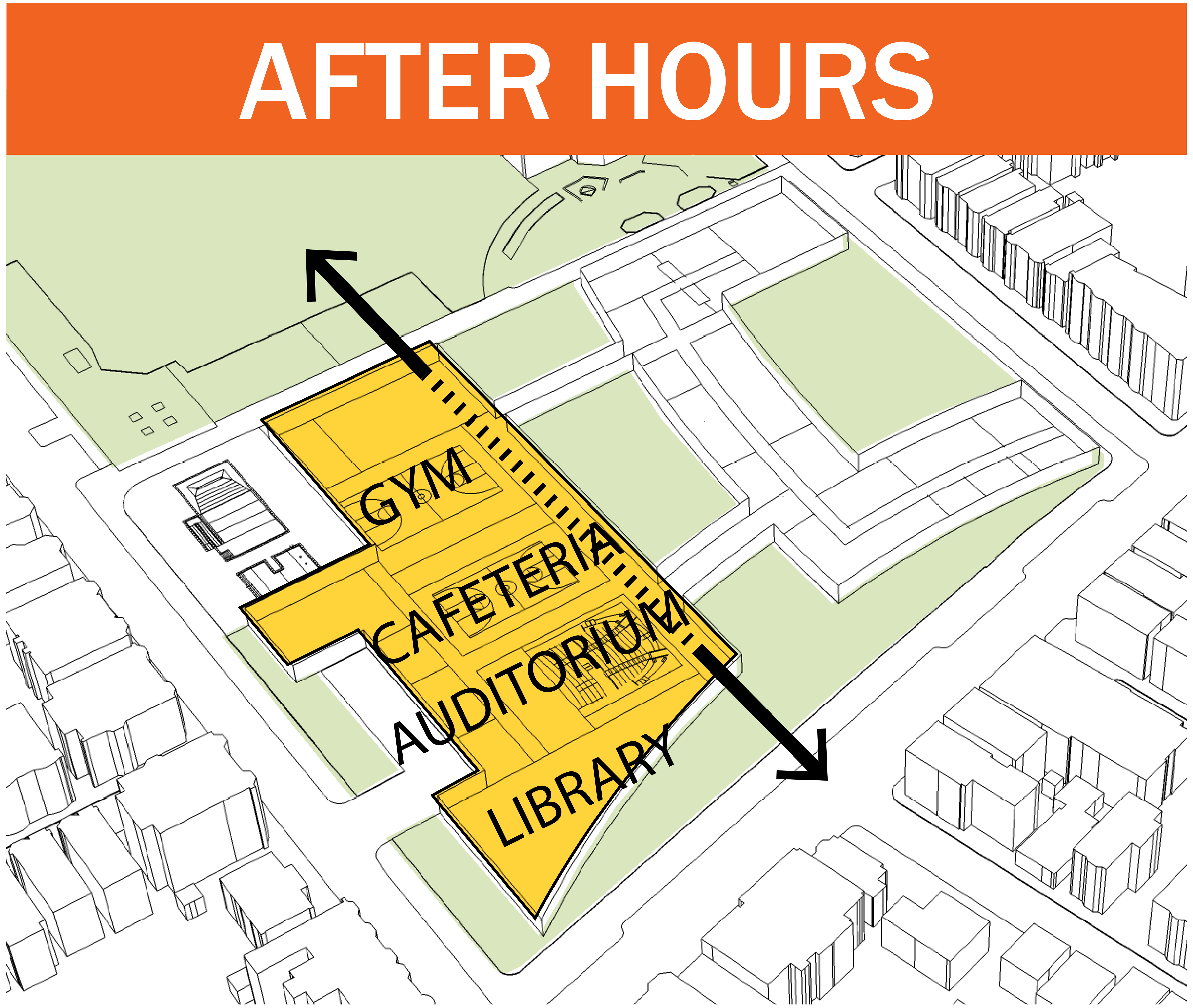


RESPONSE TO CHALLENGES

Step 1: Eliminate On-Site Fossil Fuel Combustion

REDUCE DEMAND





Organization allows ready shut down of systems in unused areas to reduce energy use.

ELIMINATE ON-SITE FOSSIL FUEL COMBUSTION

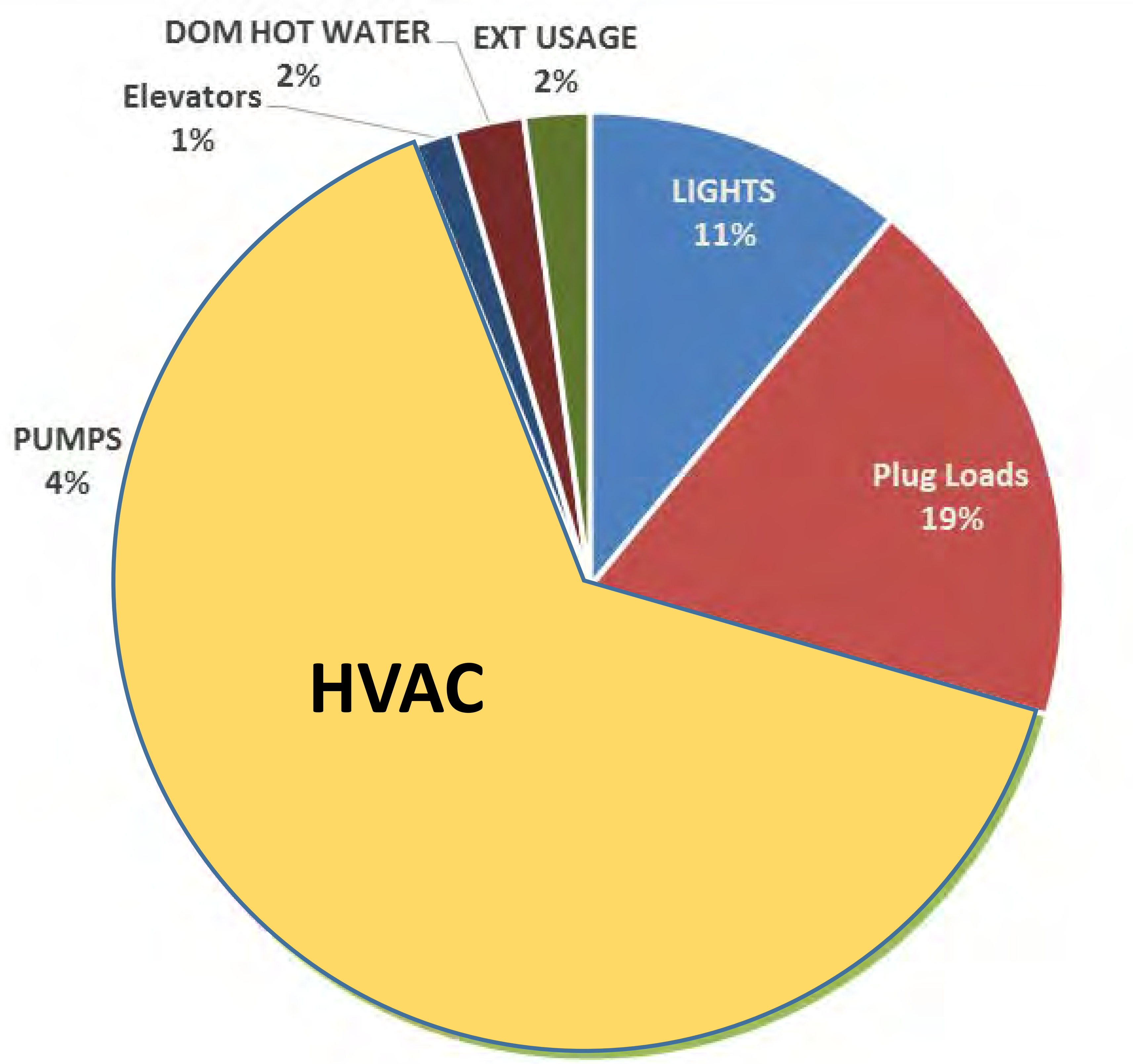
Strategy 1: Geothermal Wells & Heat Exchange

190 Geothermal Wells

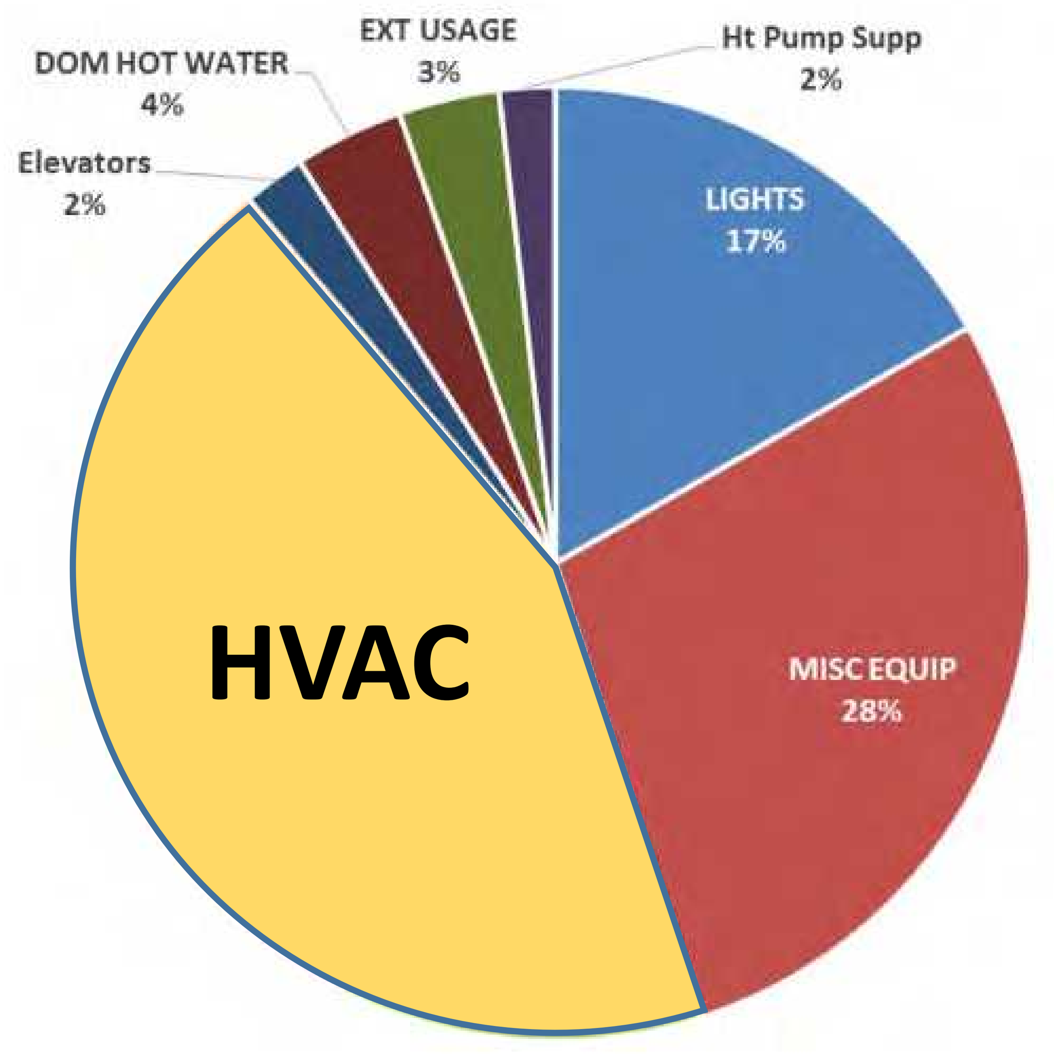
- **Tight Site**
- **Article 97 Limitations**
- **Soil capacity**

ELIMINATE ON-SITE FOSSIL FUEL COMBUSTION

The Payoff



Without Geothermal



With Geothermal

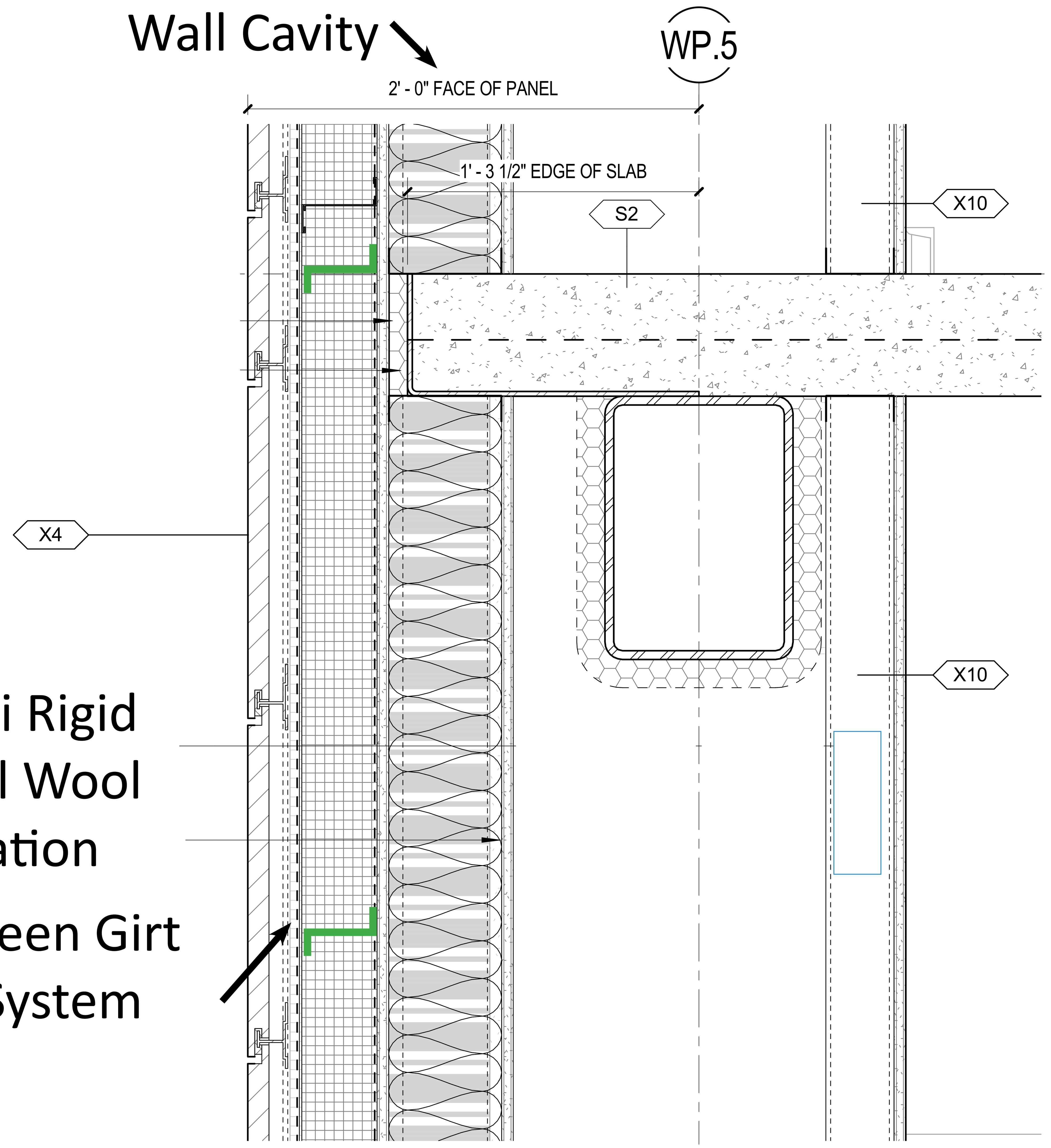
Geothermal System Reduces Energy Demand by 54%

REDUCE DEMAND

Strategy 2: High Efficiency Envelope

ROOF: R-40
Window to Wall Ratio: 40%

Insulated Interior Wall Cavity



4” Semi Rigid Mineral Wool Insulation

Green Girt System

WALL: R-28

REDUCE DEMAND

Strategy 3: Reduce Fan Energy

Displacement Ventilation

Demand Control Ventilation

Using CO_2 Sensors

Forced Air for Ventilation Needs

Trim Heating or Cooling by Radiant Panels/ Chilled Beams

Occupancy Sensors for Standby Mode

Throttle VAVs and AHUs

REDUCE DEMAND

Strategy 4: Solar Hot Water

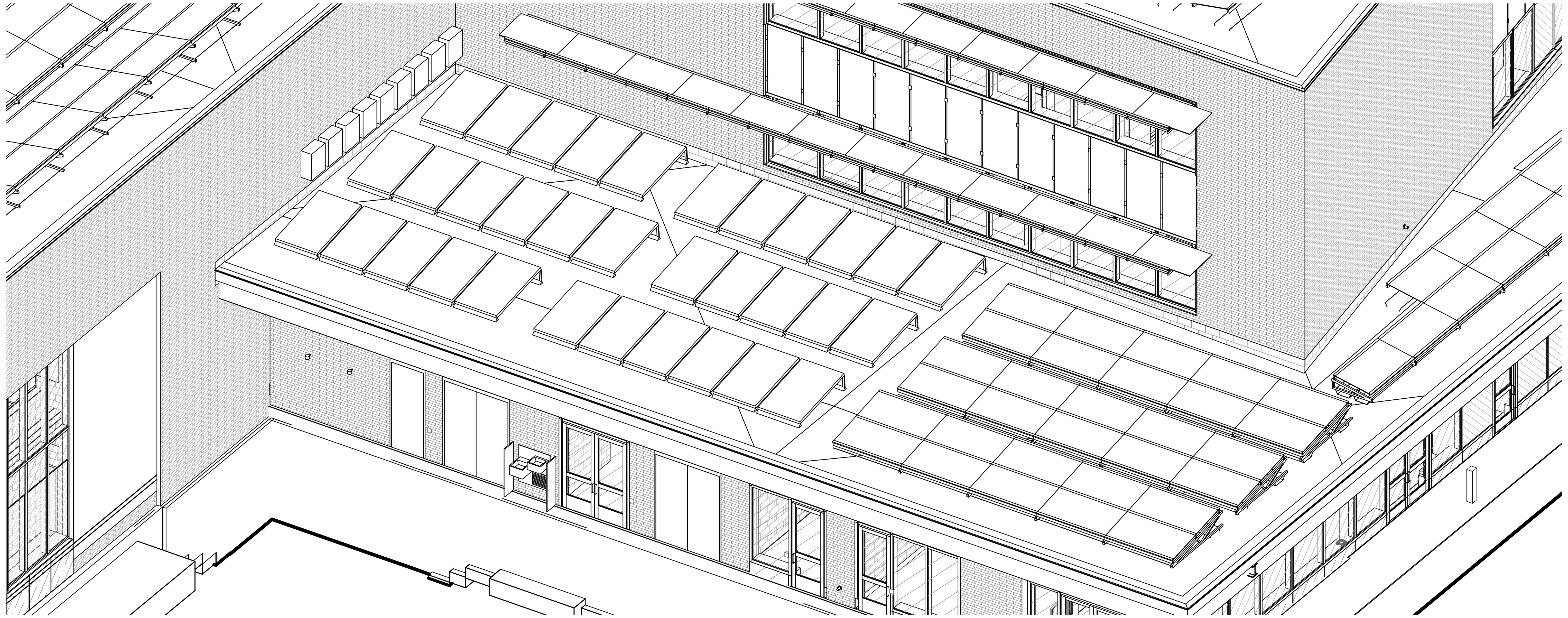
Panels with Peak Capacity of 1,000,000 BTU/hr

Hot Water Generated Will Serve the Cafeteria Kitchen

(and Pool Locker Rooms in Summer)

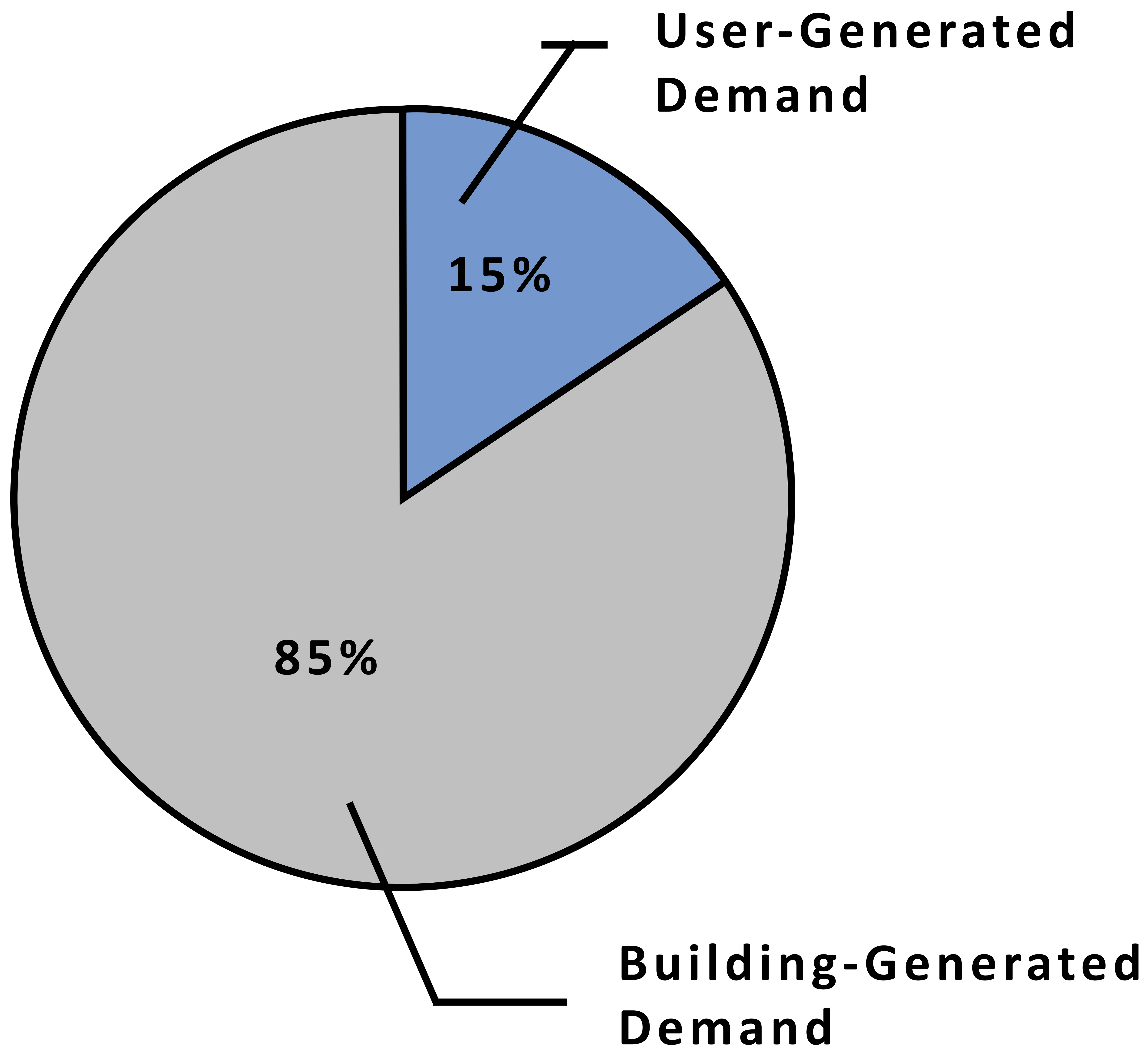
Any Hot Water not Needed by Kitchen will Serve Radiant Loop

(or Be Used to Temper Pool in Summer)

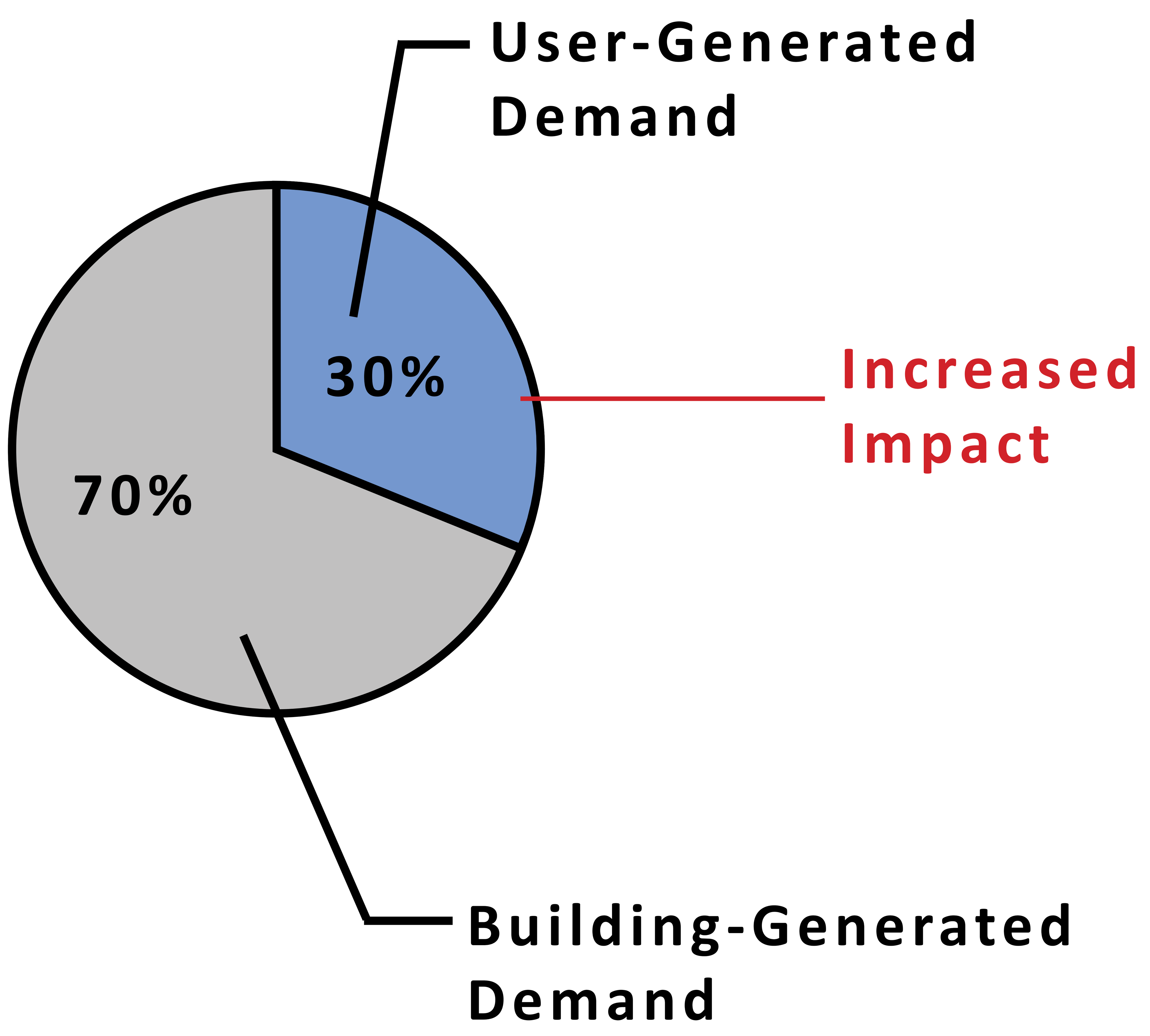


REDUCE DEMAND

Strategy 5: Engage Users



Baseline EUI



Improved EUI

REDUCE DEMAND

Strategy 1: BUILDING ORGANIZATION

RESULTS

How Did We Do?

ON-SITE ENERGY GENERATION

PHOTOVOLTAIC PANELS

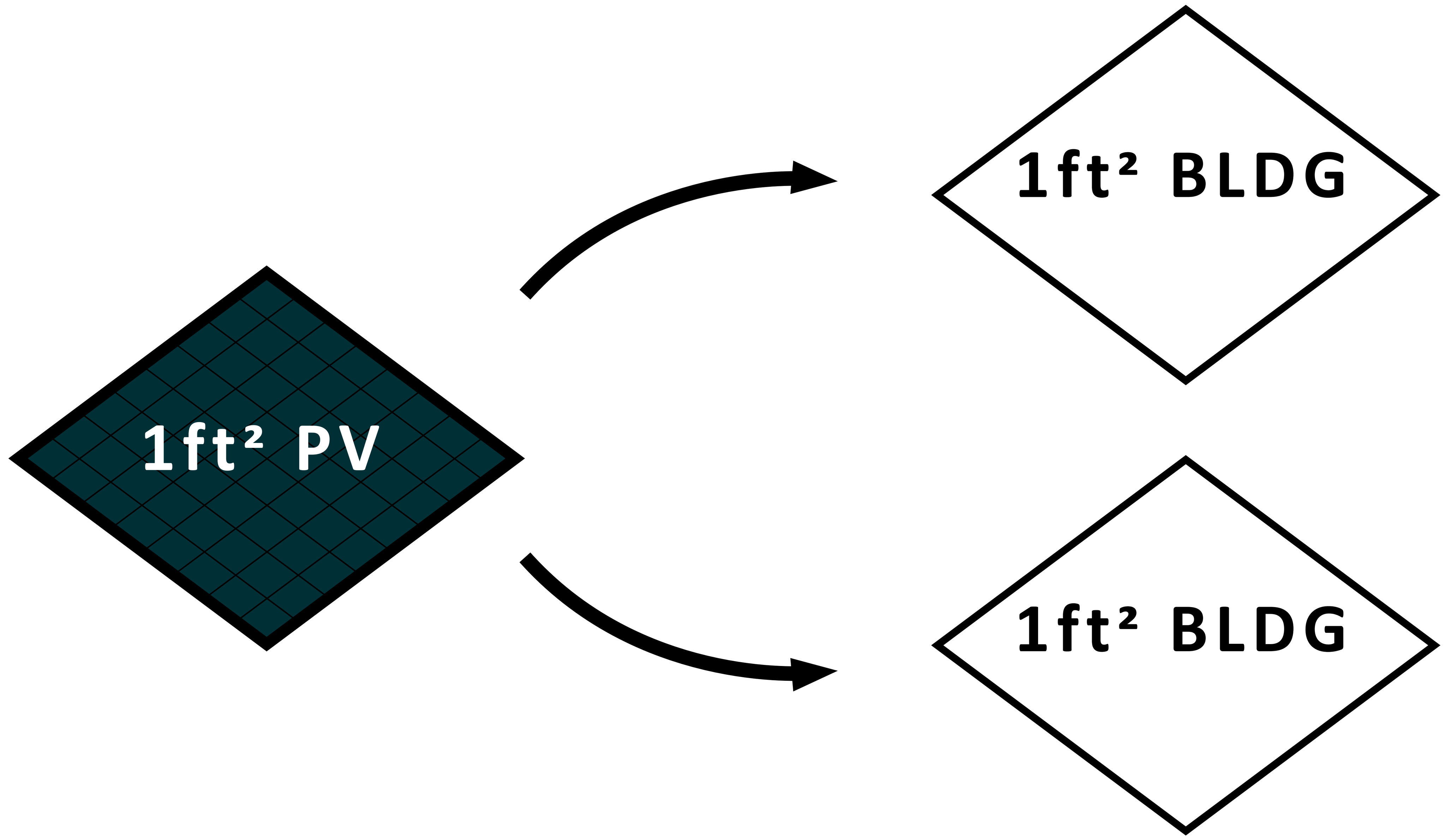
ON-SITE ENERGY GENERATION

PHOTOVOLTAIC PANELS

NET ZERO CHALLENGES

The Efficiency of PV is Relatively Low Today

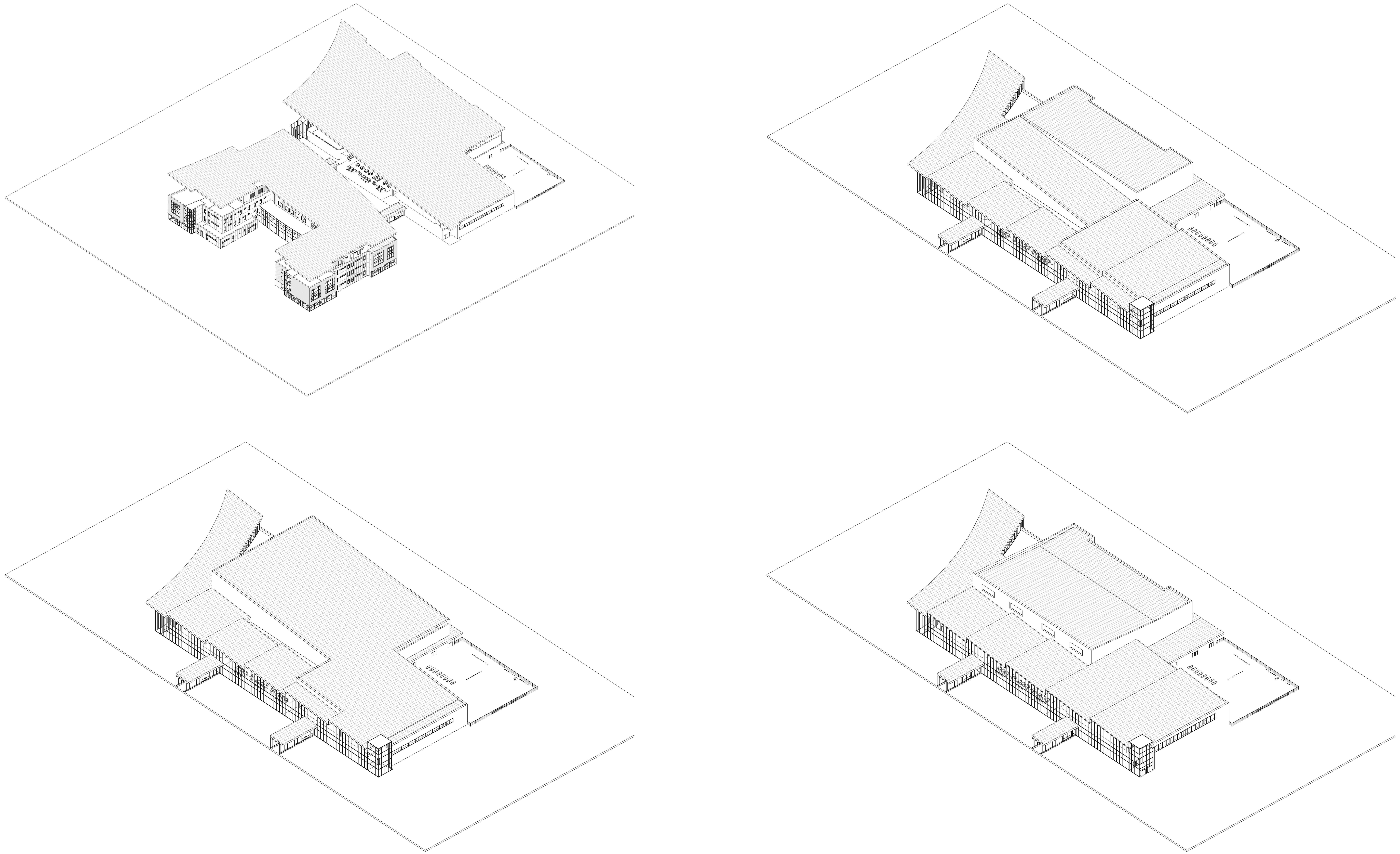
1ft² of PV Supplies Energy to 2ft² of Building



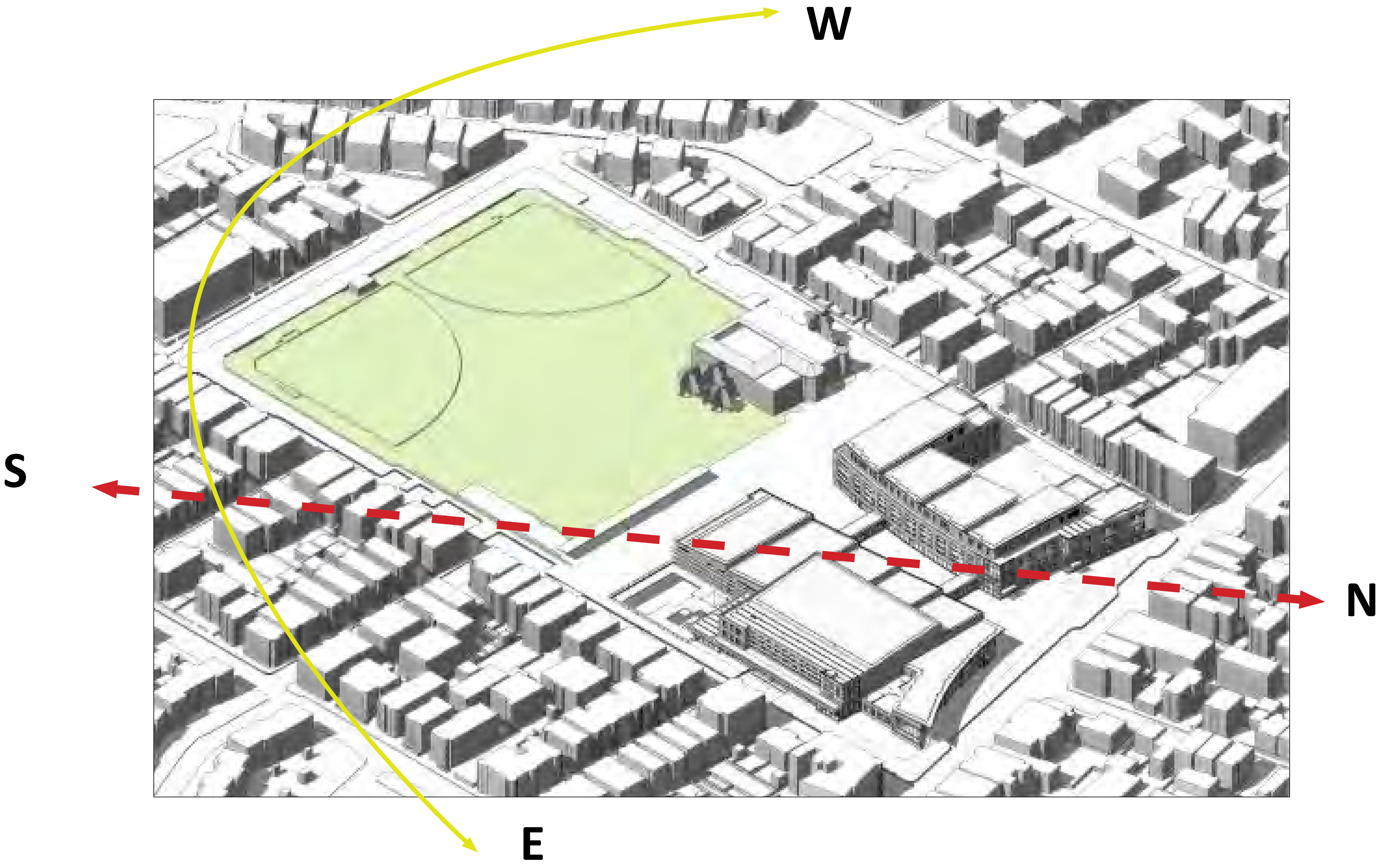
Anything Over 2 Stories Becomes A Challenge

ON-SITE ENERGY GENERATION

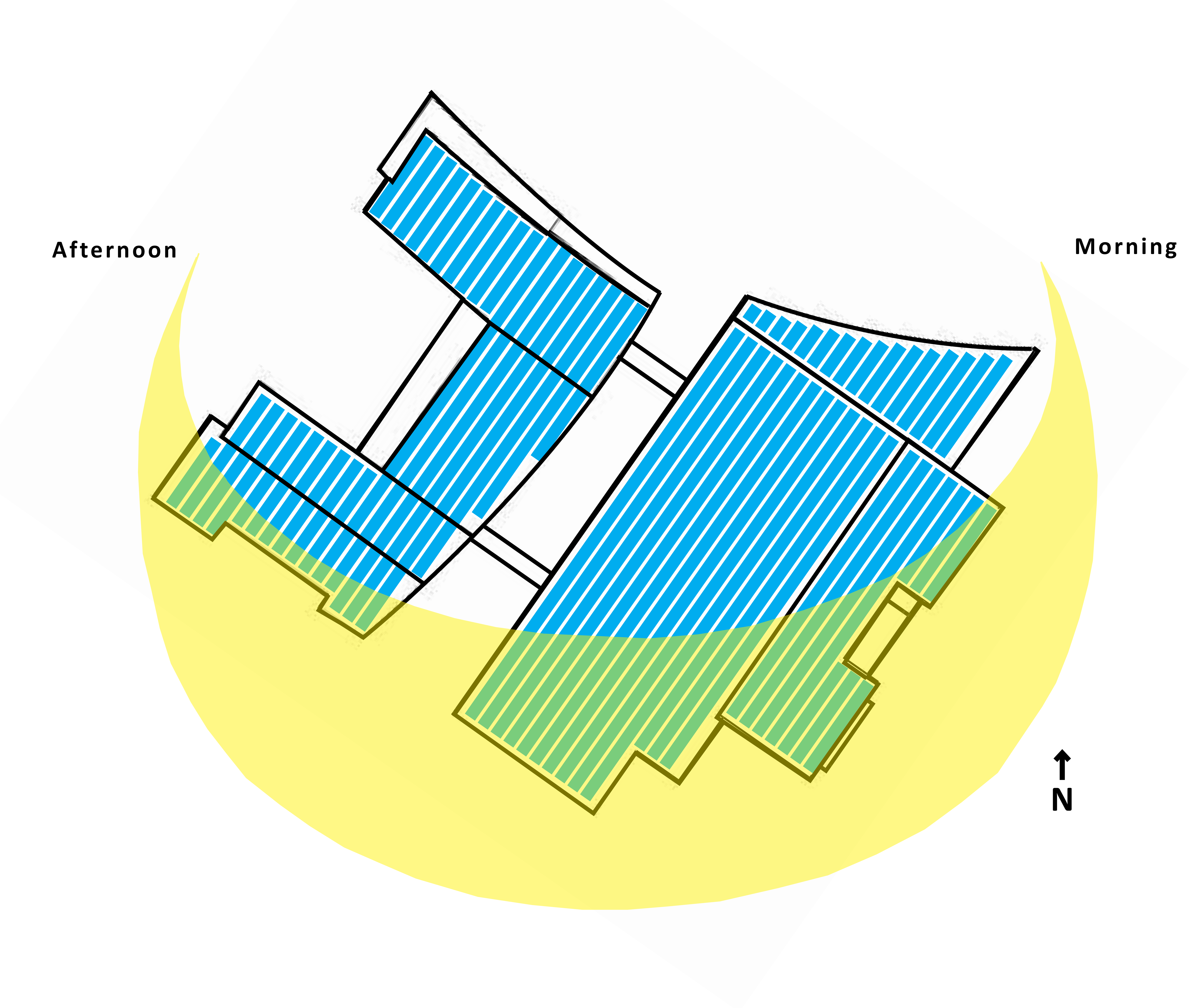
PHOTOVOLTAIC PANELS



The Site is Approximately 45º Off the N/S Grid



This Leads to the Fundamental Question:
How Do We Orient the PV Panels?

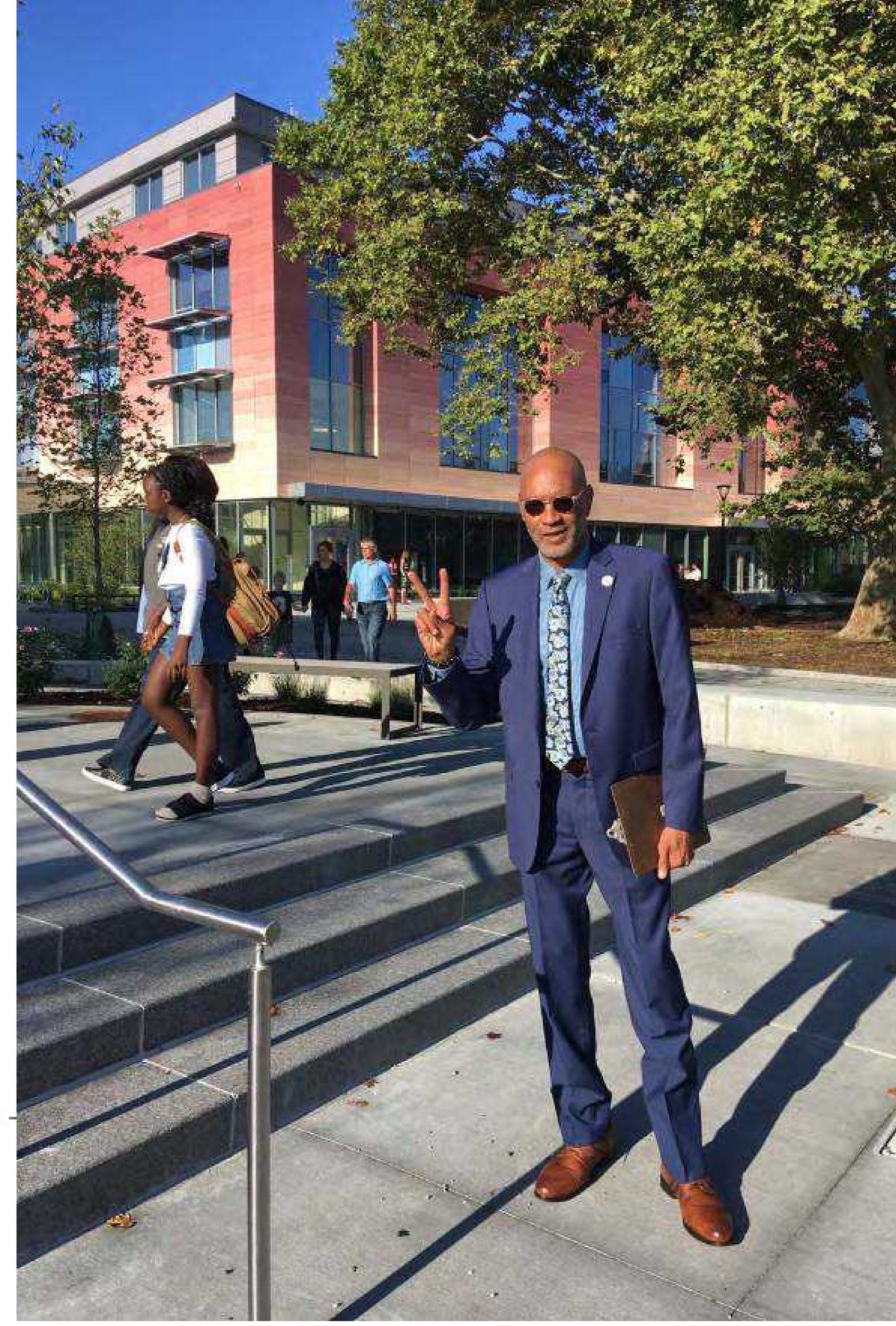


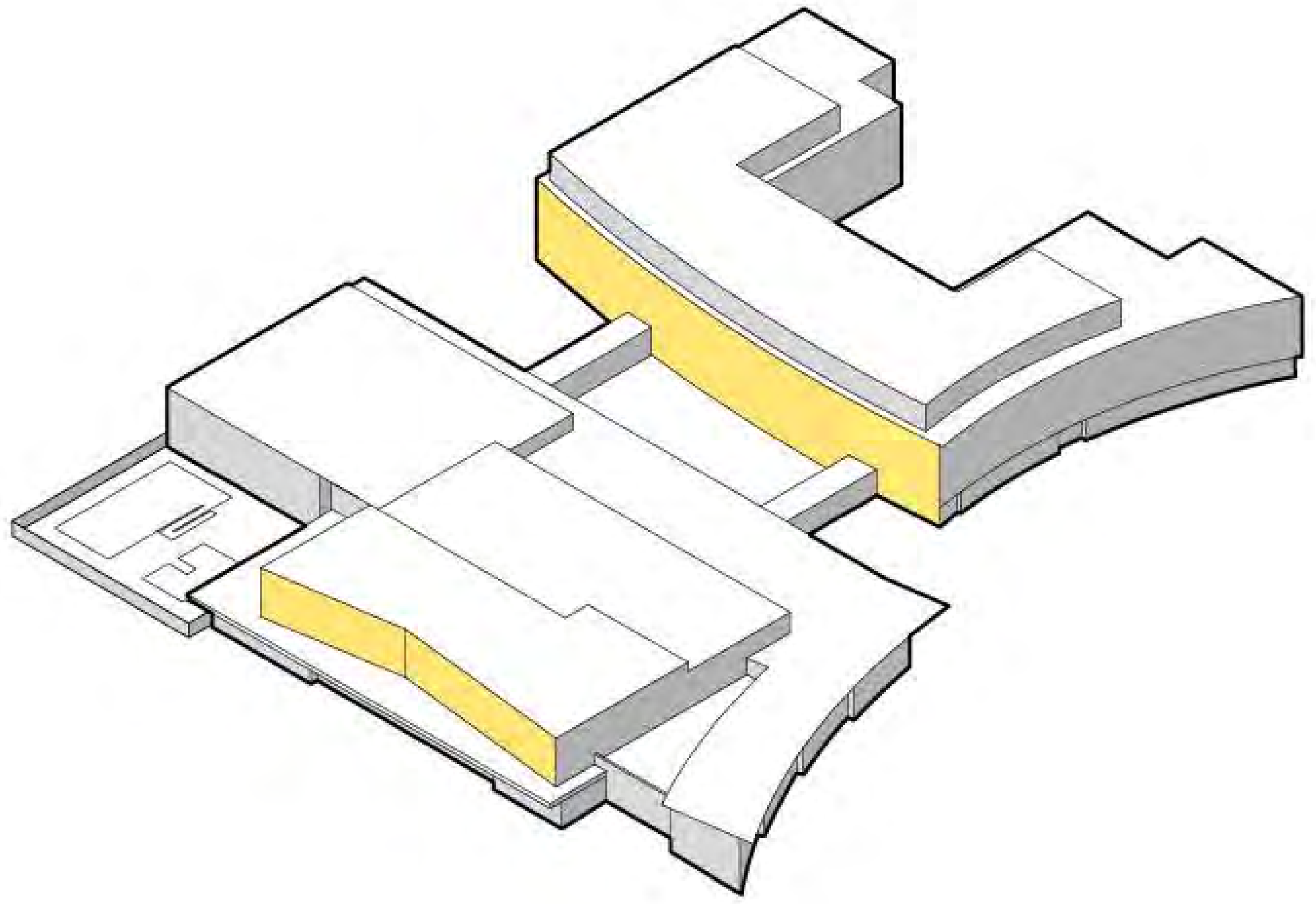
Option 3 - E/W Orientation, Building Layout: More Efficient PV Spacing. Captures Sun All Day.

Photovoltaics Integrated Into Light Shelves

NET ZERO EMISSION - RESULTS

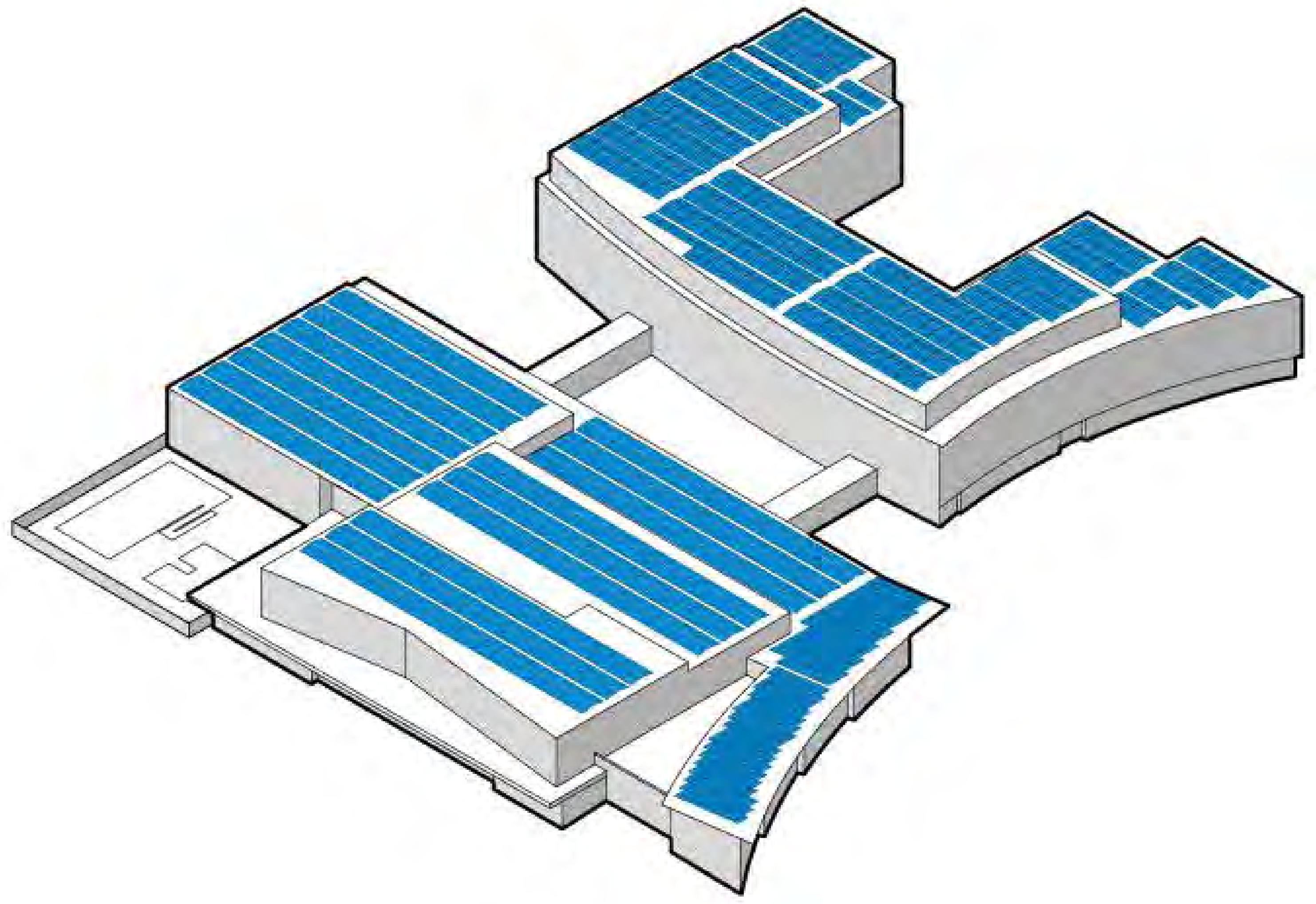
How Did We Do?





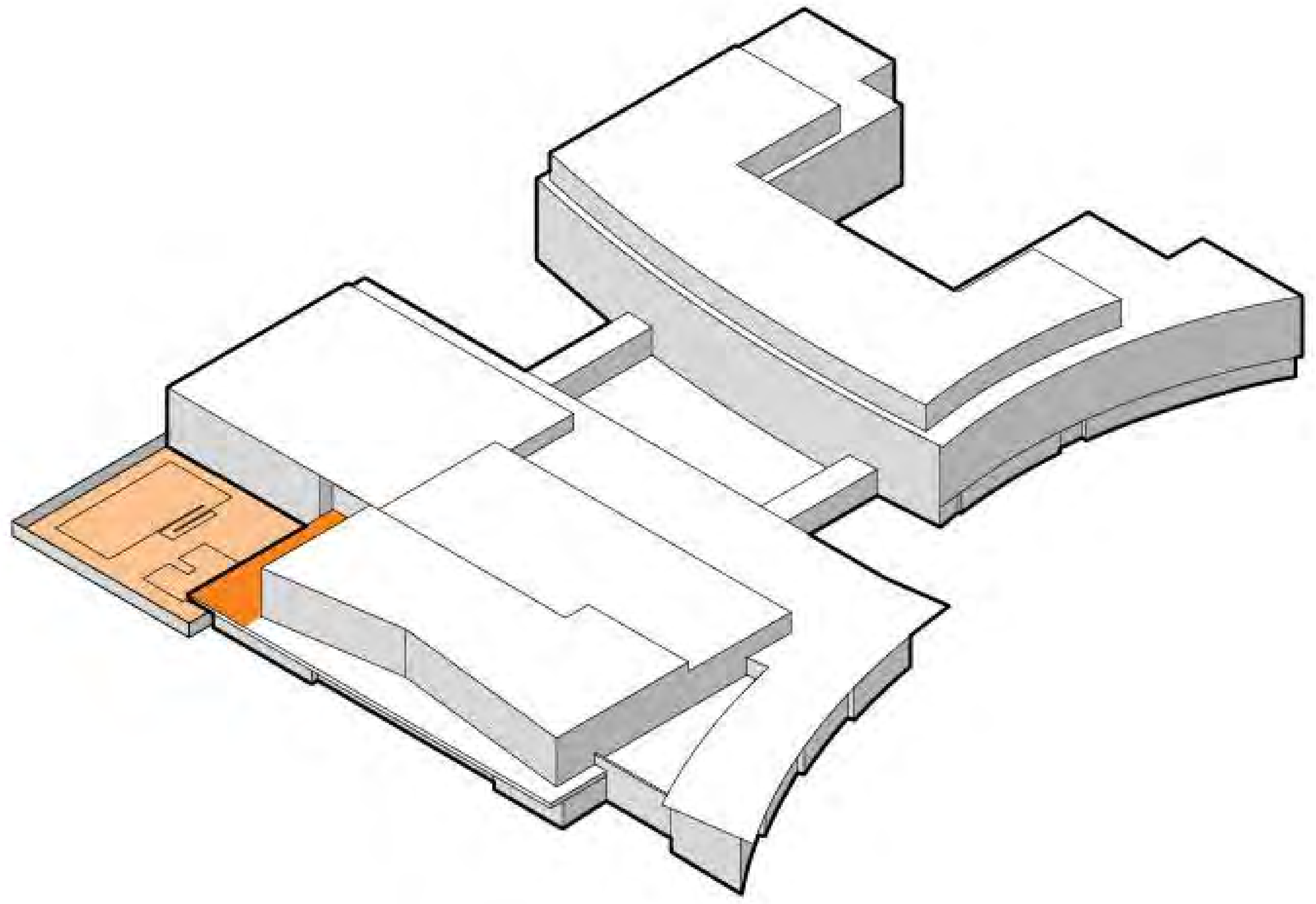
FACADE MOUNTED PV

72% energy reduction over Architecture 2030 baseline



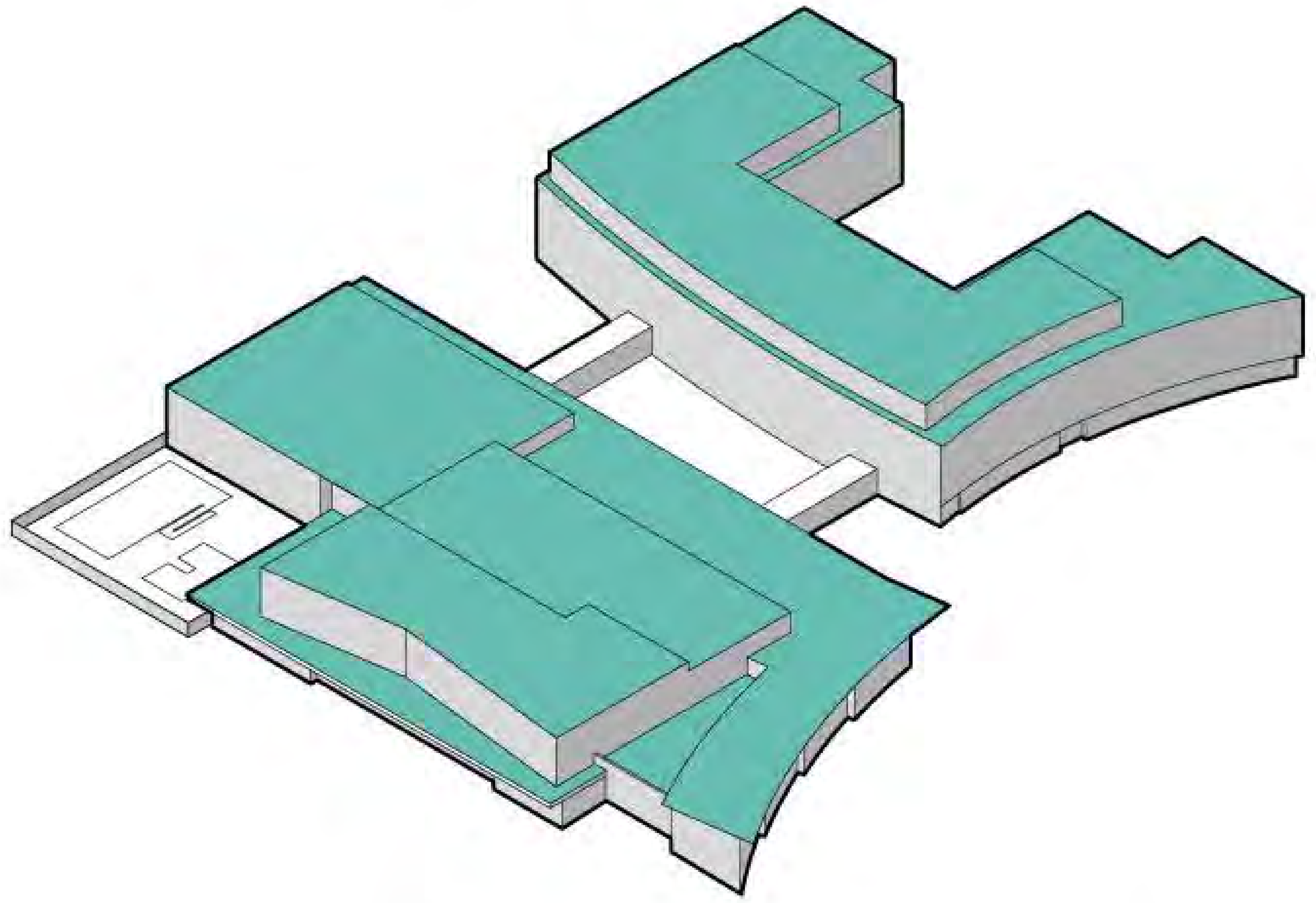
ROOF MOUNTED PV

1,300 MWh PV



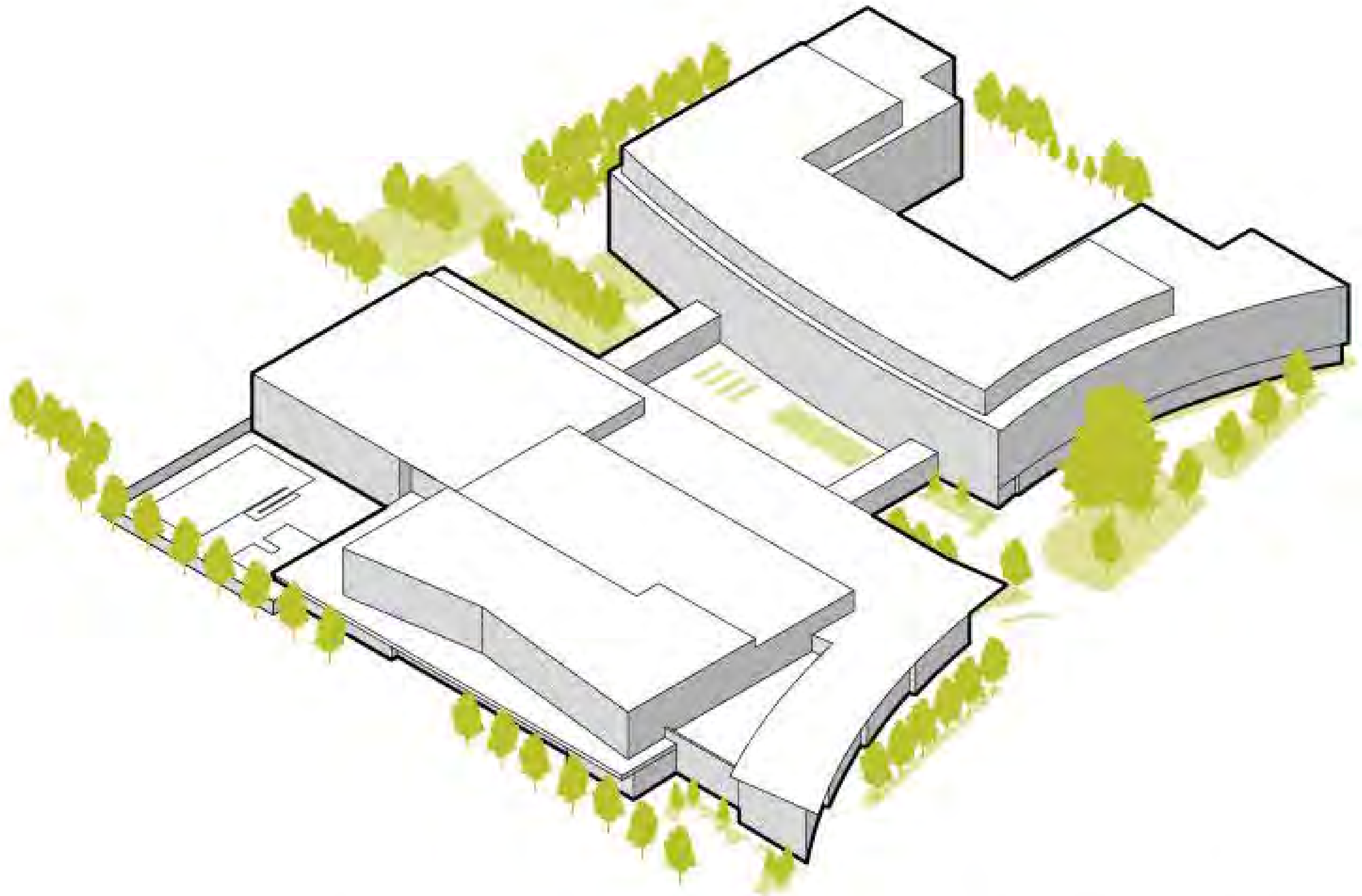
SOLAR THERMAL

25 pEUI



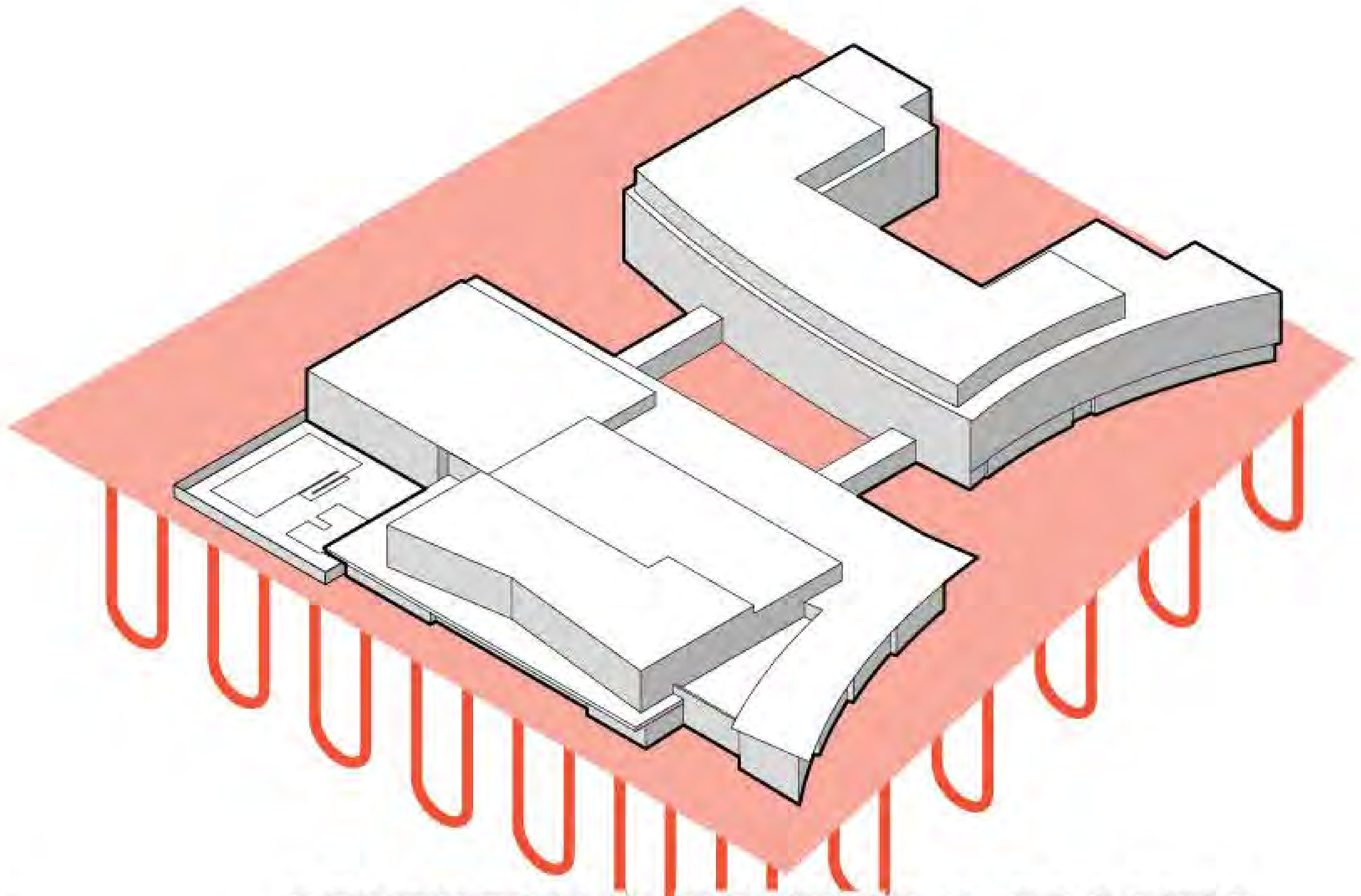
RAINWATER HARVESTING

100% water retention



INCREASED VEGETATION & NATIVE PLANTS

1 additional acre of green Space

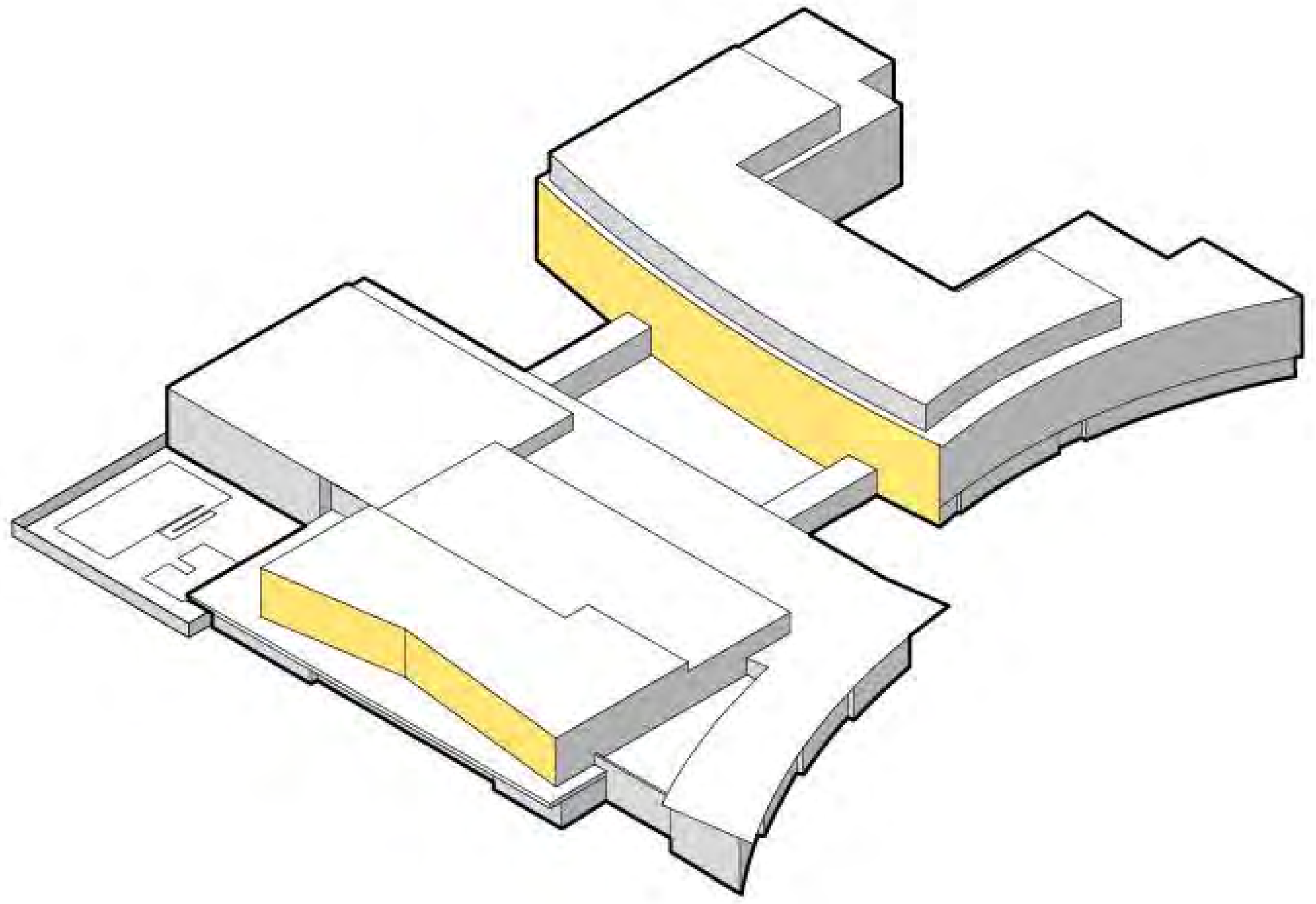


GEOTHERMAL HEATING & COOLING

190 geothermal wells


SCHOOL BUS
TOW ZONE
NO STOPPING
TOW ZONE
NO PARKING
SCHOOL
BUS ONLY
7AM-4PM
COMMUNITY COMPLEX


Cambridge
Willow
NO
TURN
ON RED



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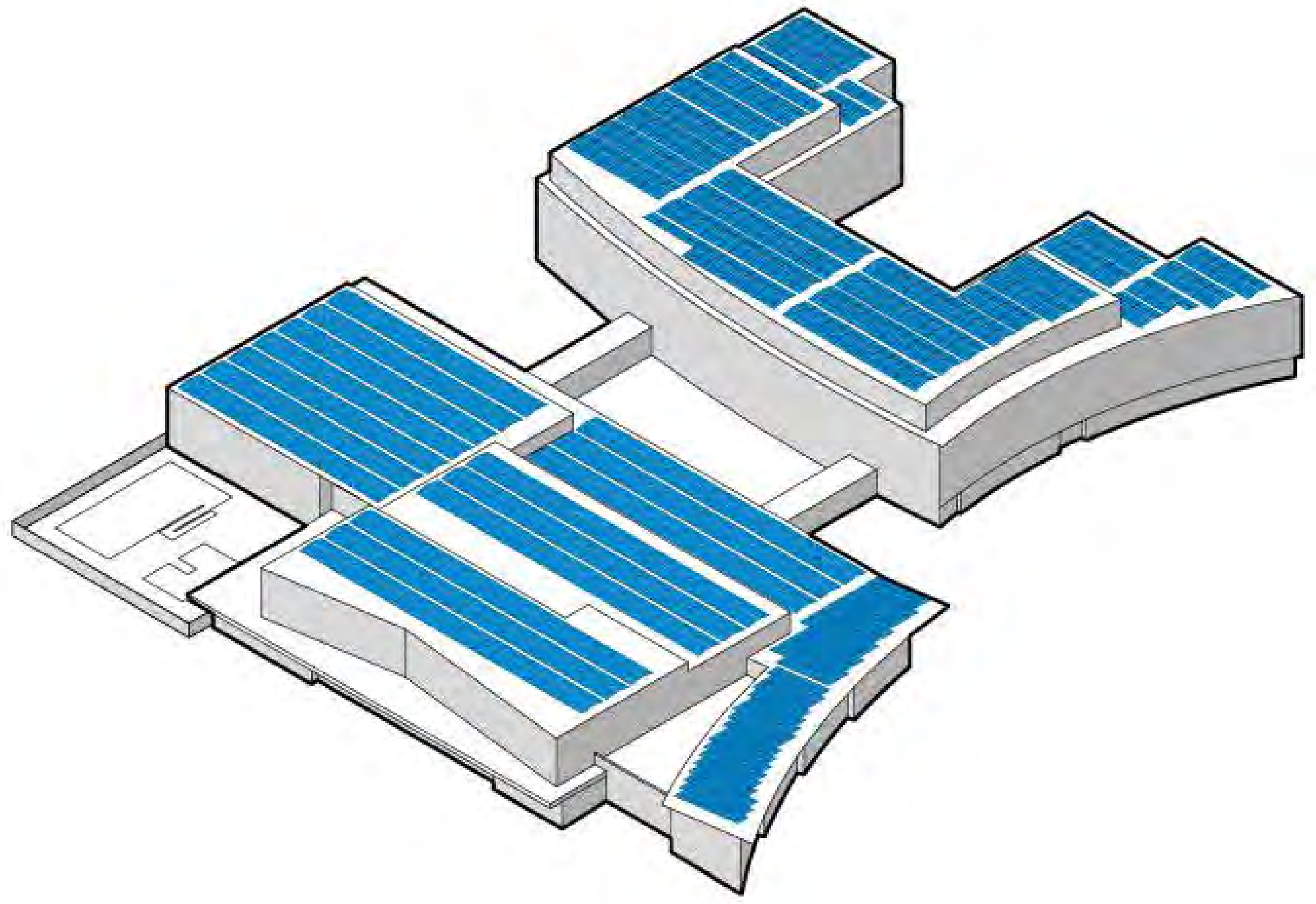

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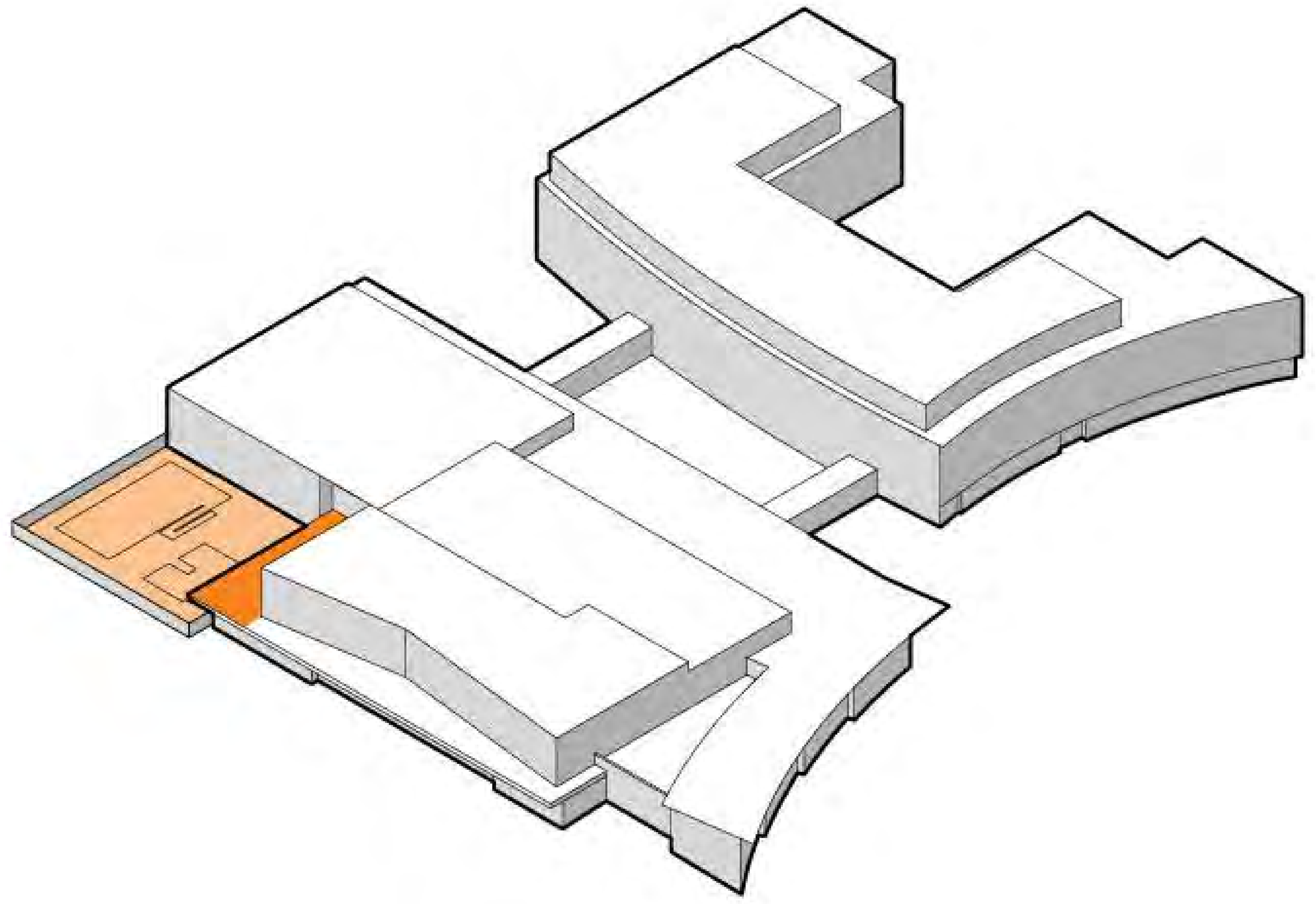

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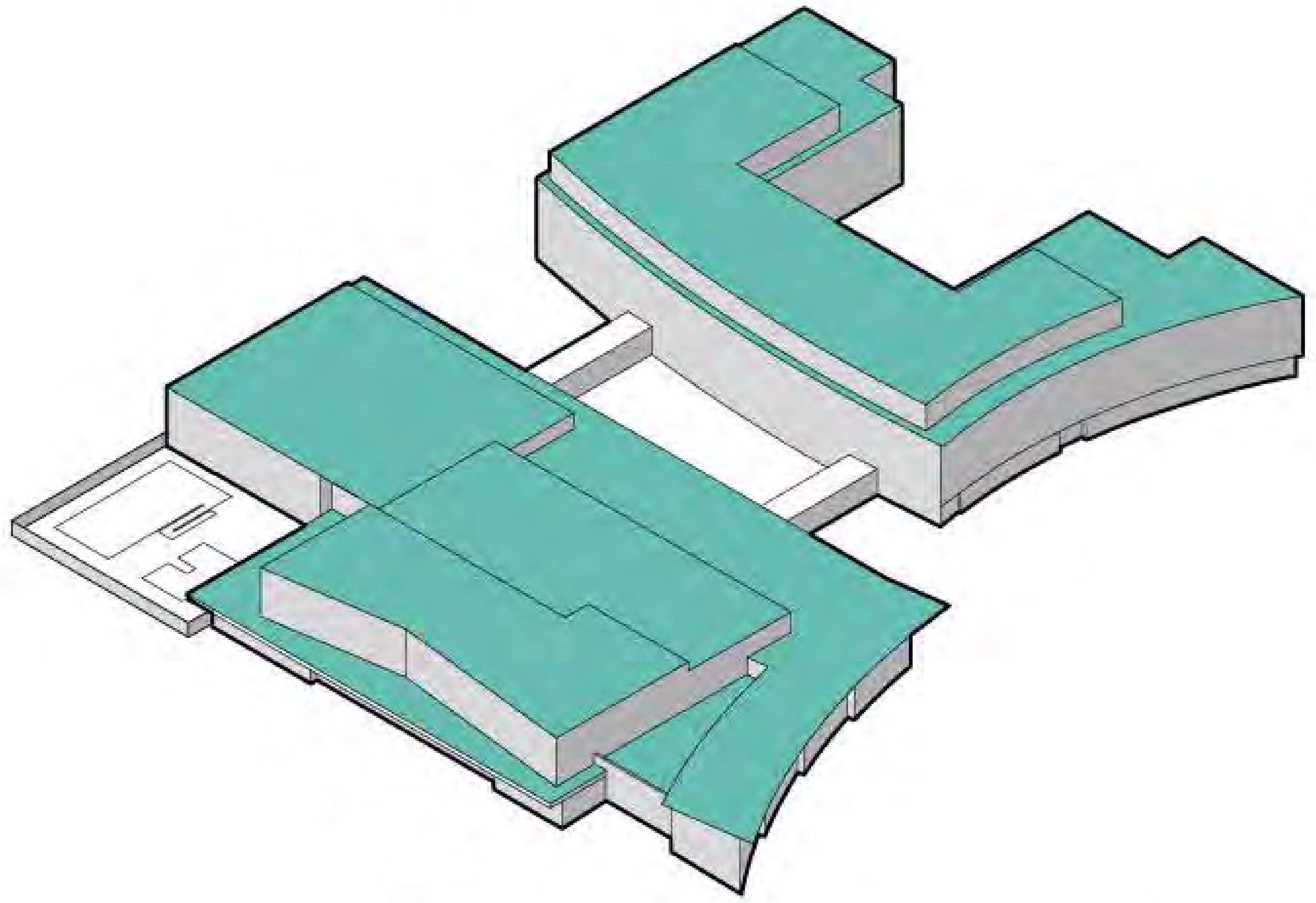

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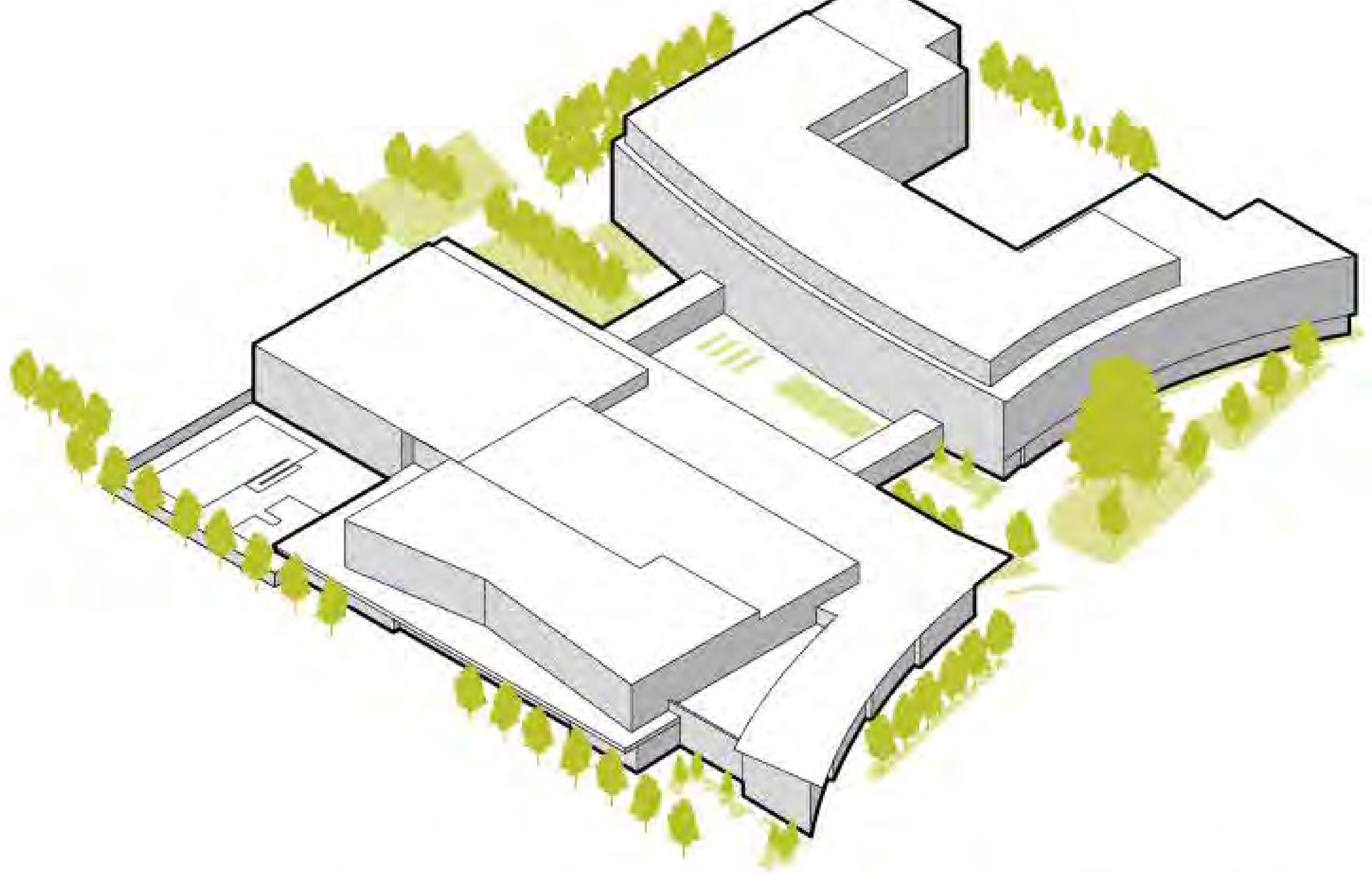
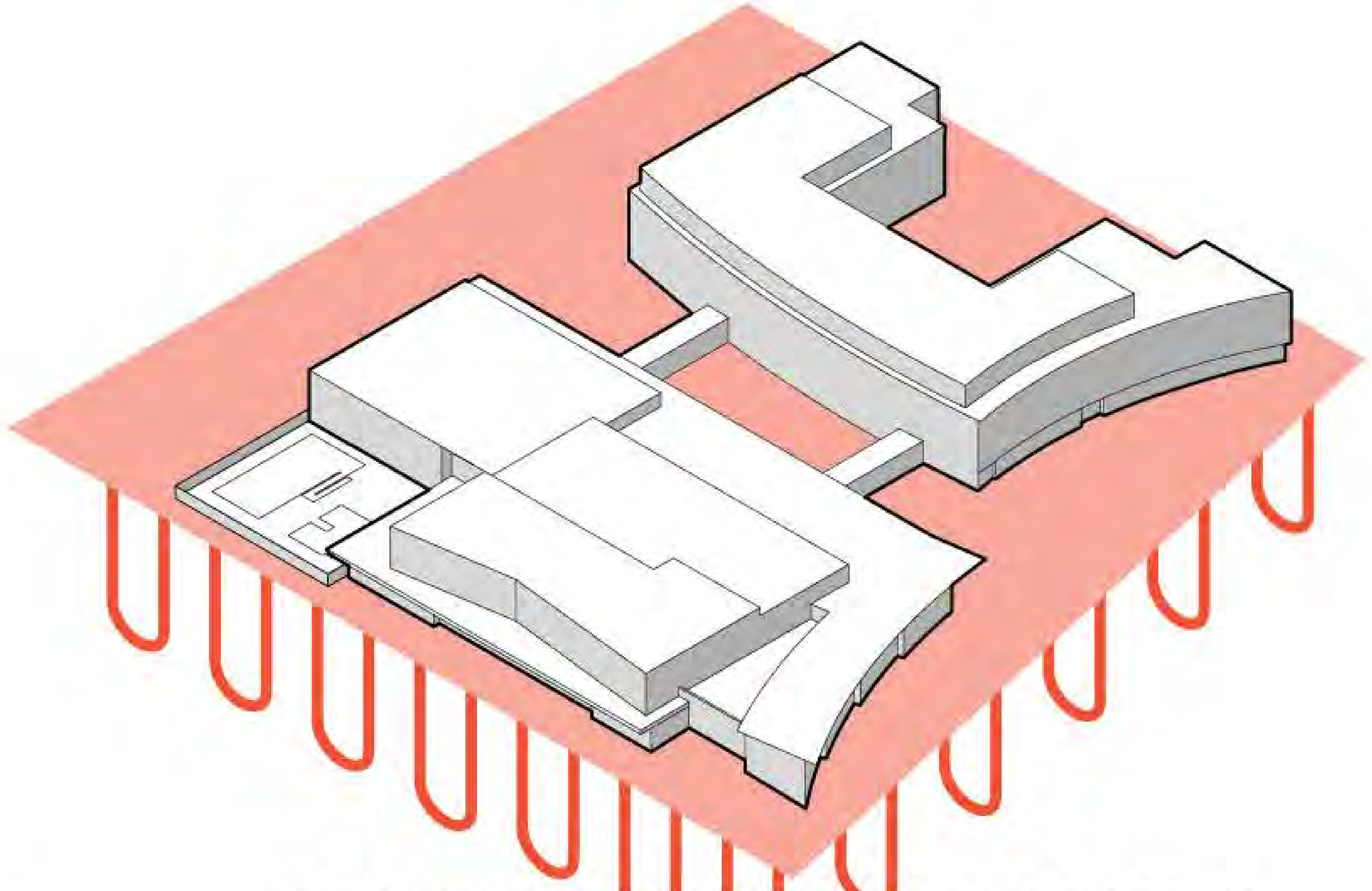


INCREASED VEGETATION & NATIVE PLANTS

1 additional acre of green Space



GEOTHERMAL HEATING & COOLING

190 geothermal wells