



Massachusetts School  
Building Authority



 The Green Engineer  
Sustainable Design Consulting



**We have created a unique virtual presentation best viewed in**

**“Side by Side: Speaker”**

**Please follow the directions in this video to ensure the optimal viewing experience. Thank you.**



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**“Side by Side: Speaker”**

**Please follow the directions in this video to ensure the optimal viewing experience. Thank you.**

**PRESENTERS**



**Kathryn Crockett**  
Principal Architect



**Chris Schaffner**  
The Green Engineer

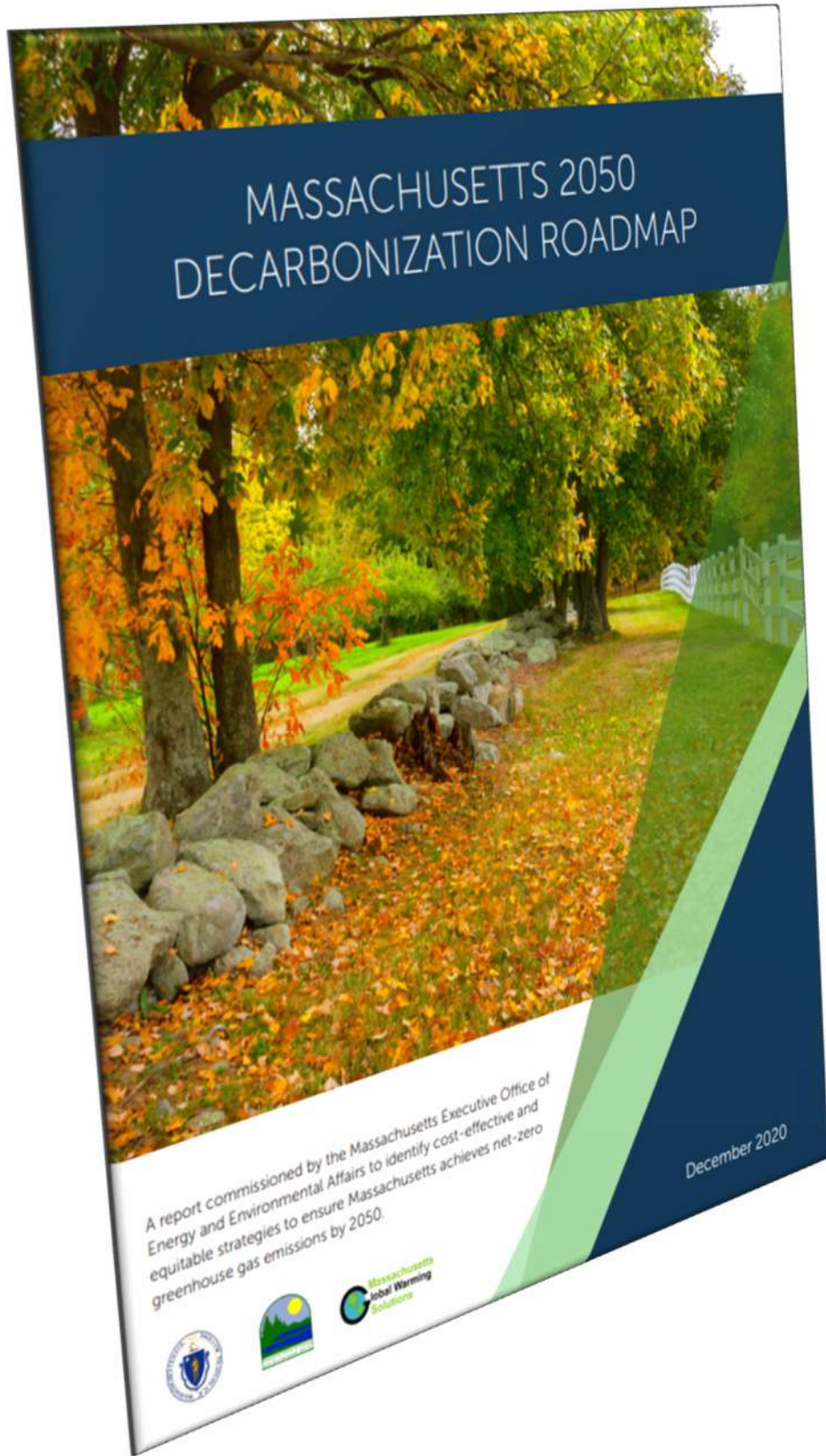


**Christina S. Bazelmans**  
Project Manager &  
Sustainability Lead

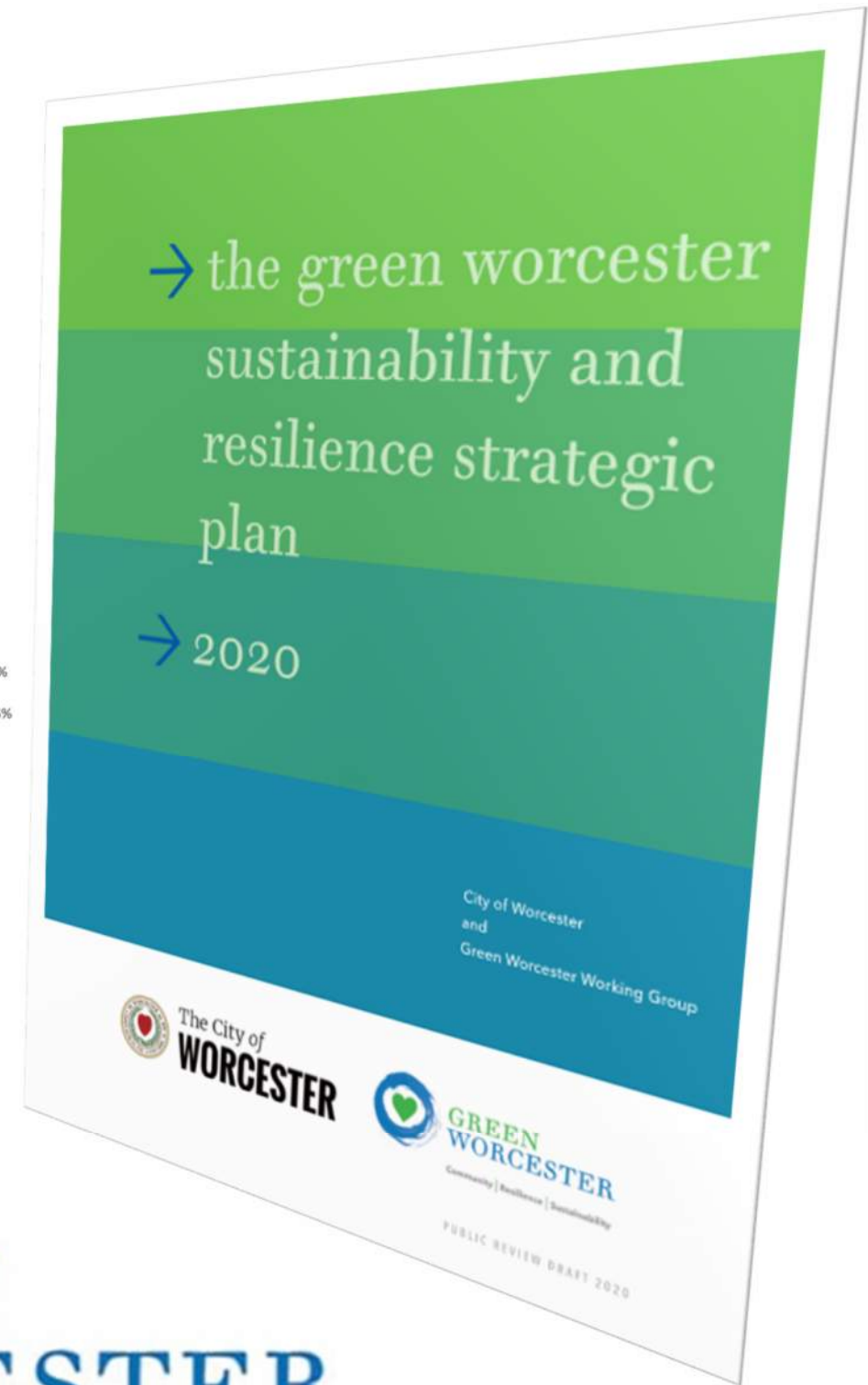
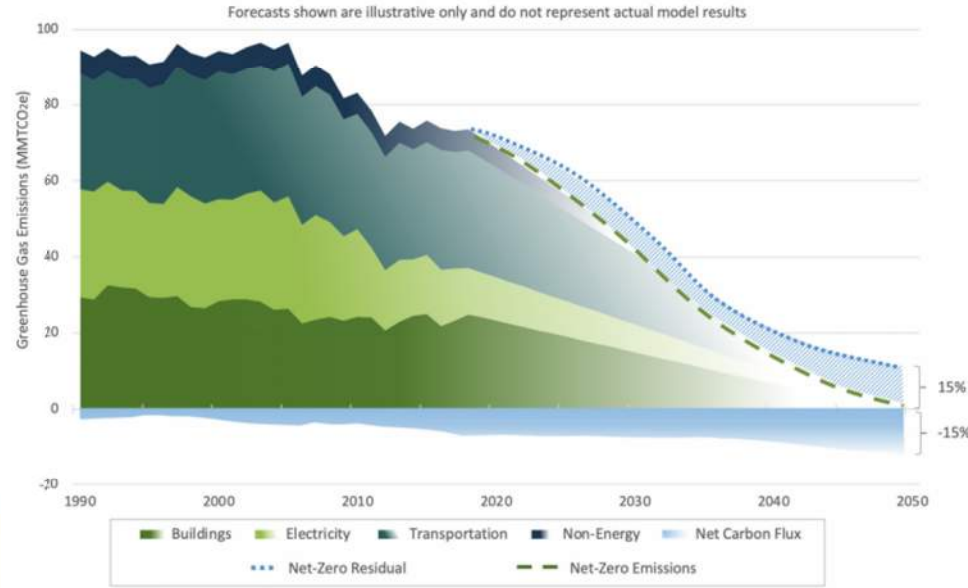


**Kevin Seaman**  
Seaman Engineering



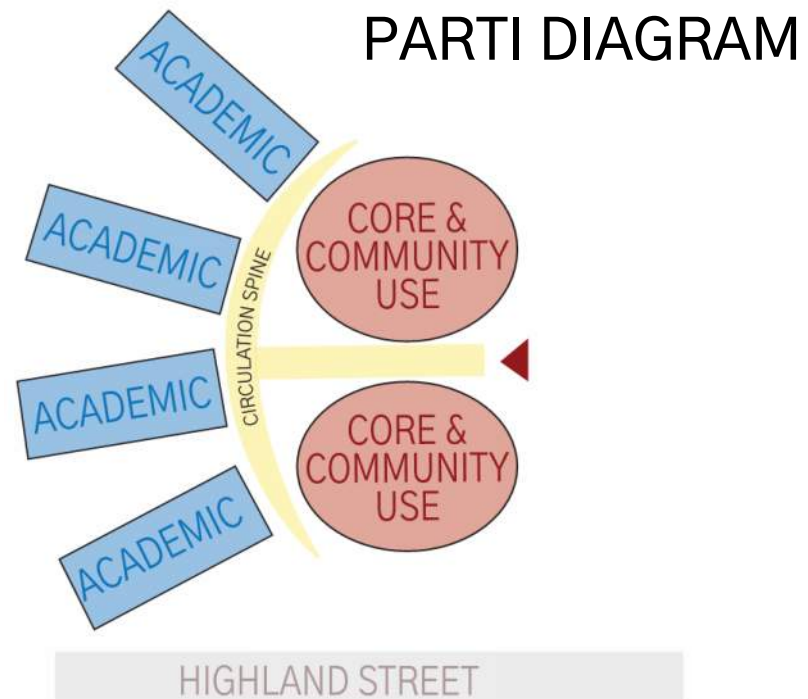


## GHG Emissions by 2050

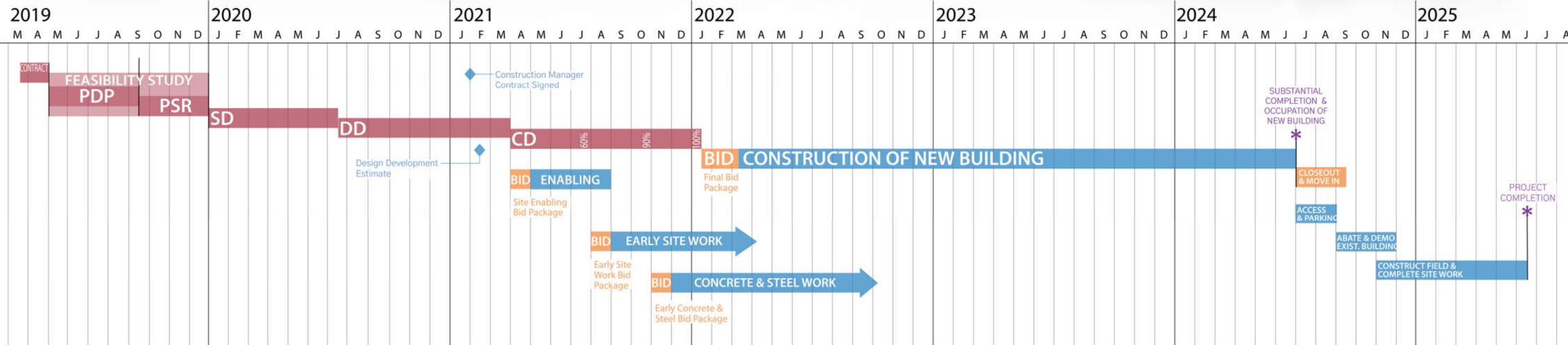


**GREEN  
WORCESTER**

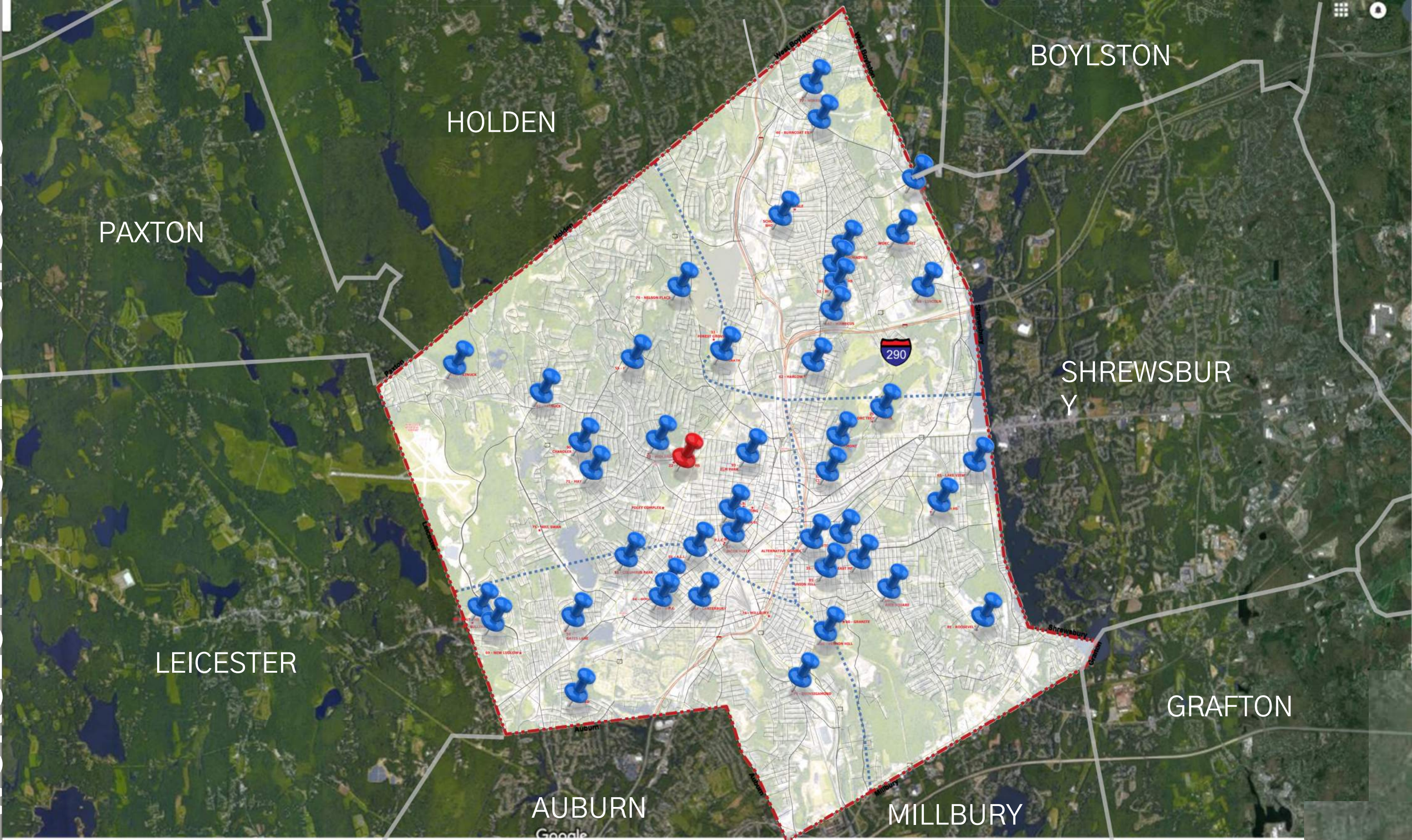
- **NEW CONSTRUCTION** ADJACENT TO THE EXISTING SCHOOL
- ENROLLMENT: **1670 STUDENTS**
- EXPANDED PROGRAM AND **COMMUNITY USE**
- AREA: +/- **422,000 SF**
- OCCUPANCY **FALL 2024**



# SCHEDULE



# WORCESTER PUBLIC SCHOOLS



PAXTON

HOLDEN

BOYLSTON

SHREWSBURY

LEICESTER

GRAFTON

AUBURN

MILLBURY

Google





**Rooftop Photo-Voltaic System**

Produces 800 kW; 50% of the school's electricity needs



**Super-Insulated Envelope**

25 R-value walls and 45 R-value roof allowed for a reduction in HVAC equipment sizes



**Passive Solar Shading**

Reduces glare and solar heat gain in summer and allows natural daylight in winter



**LED Lighting**

Equipped with occupancy and daylight sensors



**High Performance Glazing**

Double glazing with thermal coating resulting in less solar heat gain and a U-value of .21



**Displacement Air-Flow System**

Improved efficiency, indoor air quality and occupant comfort  
Chilled Beam system



**Perimeter Radiation**

Back-up heating for unoccupied hours and in case of emergency or power loss



**Flexible Use**

Flexible use of spaces and integrated technology increases utilization



**Enhanced Acoustic Performance**

Reduced background noise levels and reverberation, acoustic separation of STC 50 between classrooms



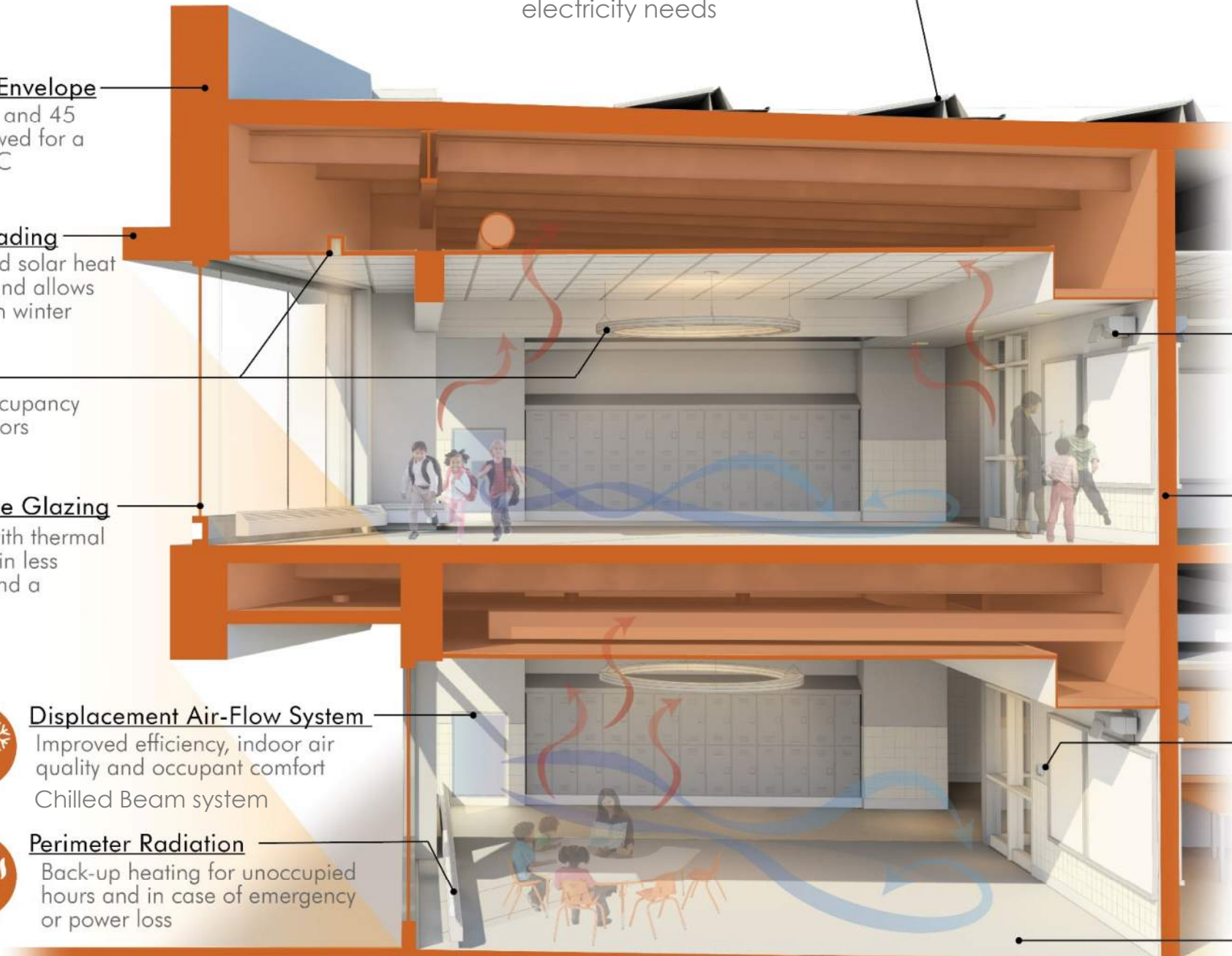
**Digital Energy Management System**

Controls building systems to optimize efficiency during occupied hours. Individual space temperature control is made possible by VAV terminals



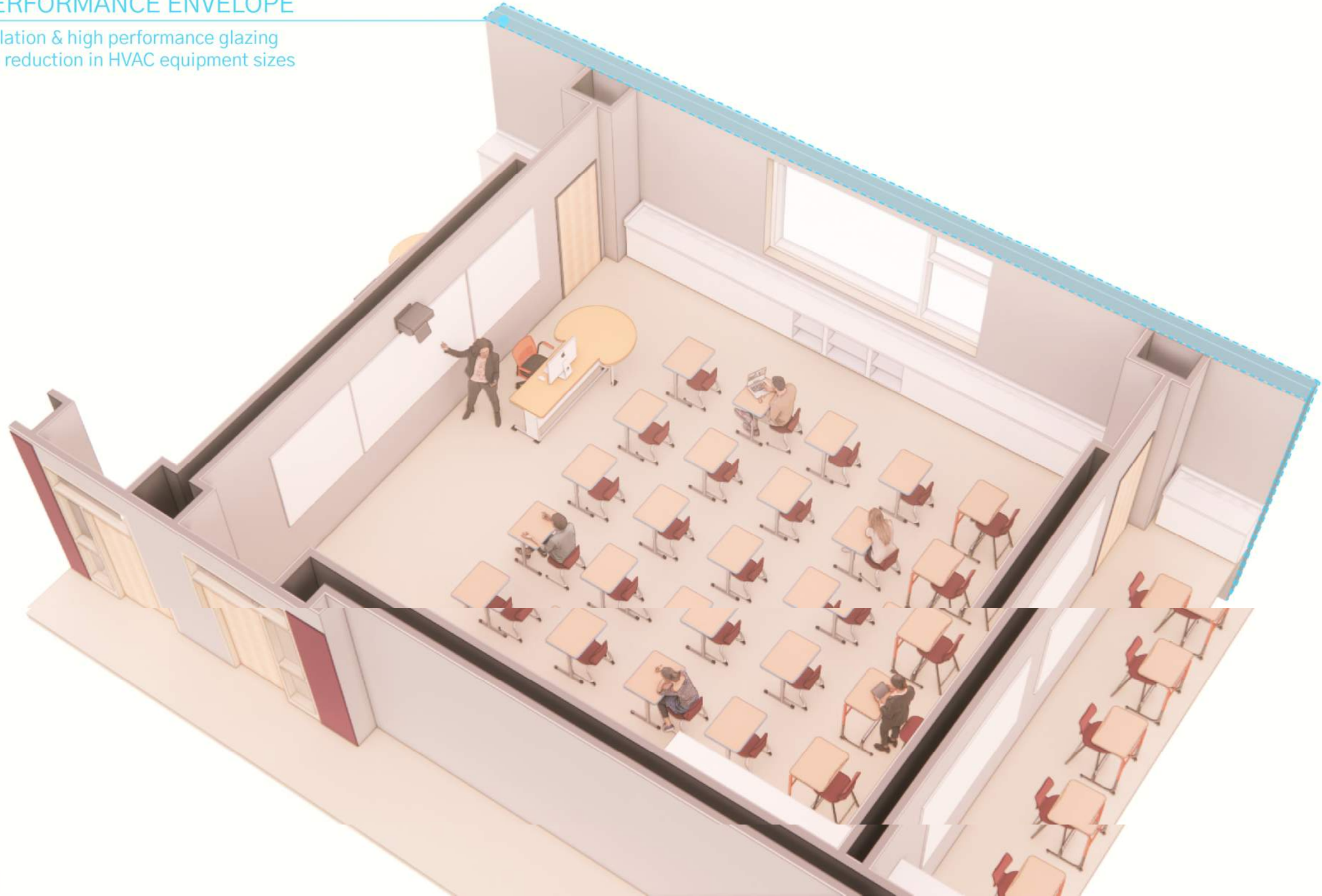
**Sustainable Materials**

Low-emitting, low-maintenance, durable finishes with high recycled content



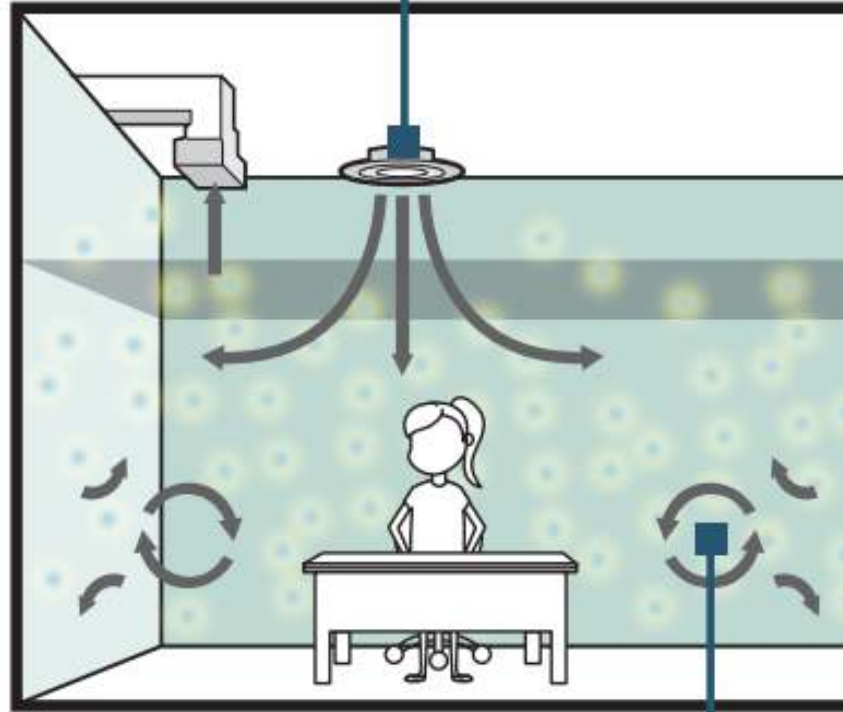
## HIGH PERFORMANCE ENVELOPE

Super-insulation & high performance glazing allows for a reduction in HVAC equipment sizes



## TRADITIONAL MIXING VENTILATION

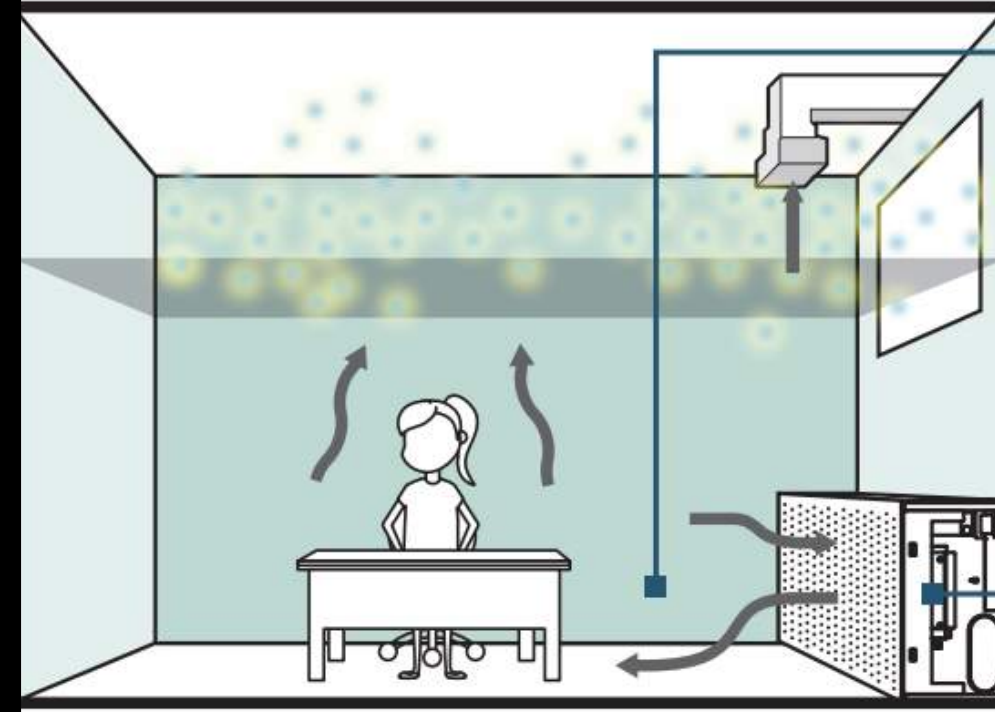
Ceiling diffusers push 55°F air at high speed



Temperature and pollutants are mixed uniformly throughout

## DISPLACEMENT CHILLED BEAM CABINETS

+ Supply at breathing level  
+ Conditions occupied area



Occupied Zone

+ Provides both heating and cooling  
+ Substantial airflow and ductwork reduction ( $\leq$  half)



- ✓ LOWER NOISE LEVELS
- ✓ LOWER MAINTENANCE
- ✓ HIGHER INDOOR AIR QUALITY
- ✓ IMPROVED THERMAL COMFORT
- ✓ MORE EFFICIENT
- ✓ LOWER OPERATING COSTS

800 kW

ELECTRICITY TARGET  
PROVIDED BY ROOFTOP  
SOLAR PV ARRAY

ENERGY USE  
REDUCTION BEYOND  
CODE BASELINE

±35%

38 Kbtu  
/SF  
/yr

TARGET SITE  
ENERGY USE  
INTENSITY (EUI)

R VALUES OF  
SUPER-INSULATED  
WALLS/ROOF

25 WALL / 45 ROOF



## Doherty Memorial High School Sustainability Workshop Survey

The purpose of this survey is to gather community input on the sustainable design features proposed for the Doherty Memorial High School Project.

The results of this survey will help to determine the discussion topics for the Virtual Sustainability Workshop scheduled for October 5th, 2020 from 4:30-6:30 PM.

Please provide all responses by September 28, 2020.

The building and site design will incorporate many of the features shown below. Which topics are most important to you?

Please rank each of the items in the list below on a scale from 1 (Most important) to 4 (Not important).

	1 (Most Important)	2 (Important)	3 (Slightly Important)	4 (Not as Important)
Heat Island Reduction	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Healthy Materials	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Embodied Carbon	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

100+



RESPONDENTS INCLUDING STAFF, STUDENTS, PARENTS, NEIGHBORS & CITY AND COMMUNITY REPRESENTATIVES

66%



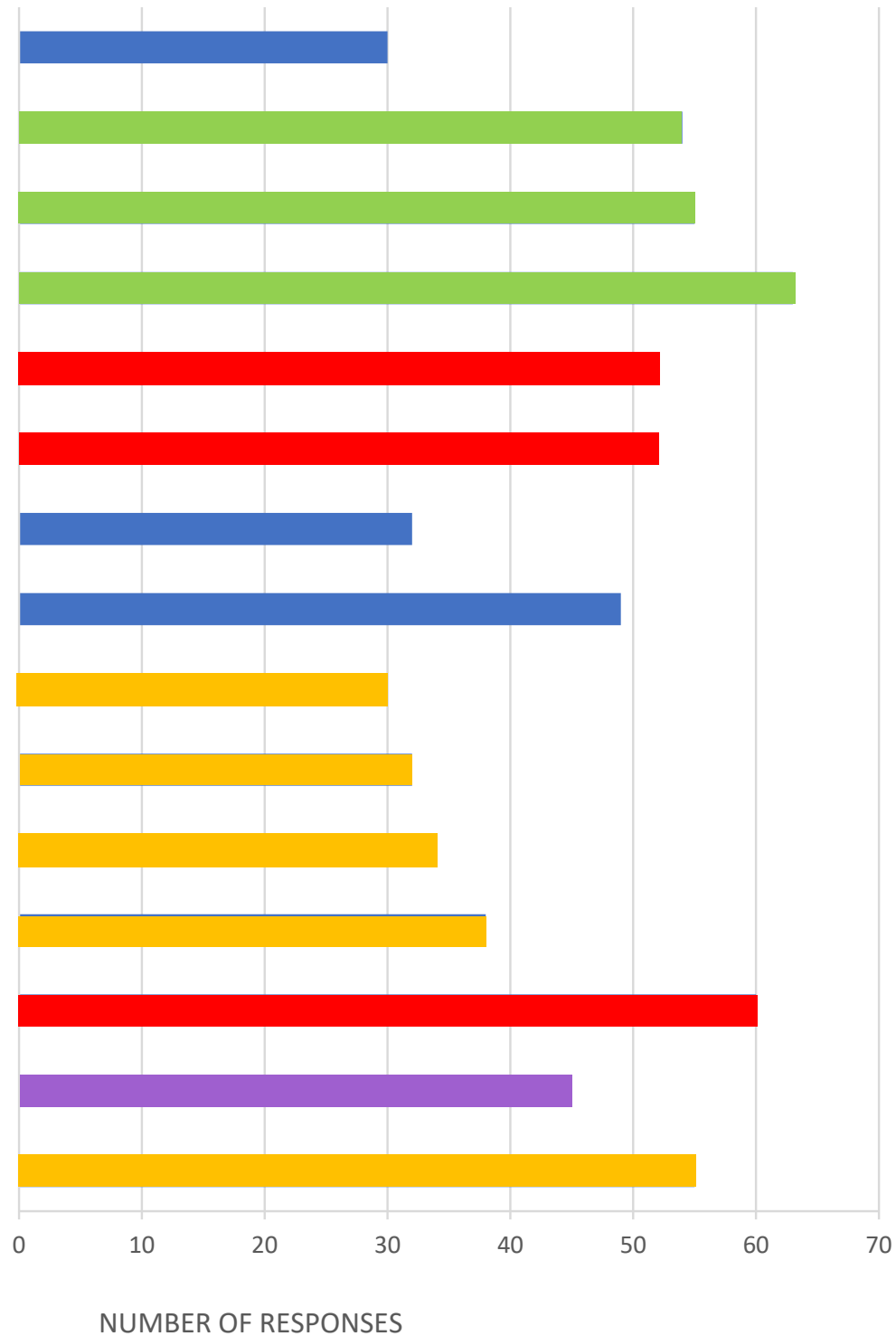
OF RESPONDENTS BELIEVE RENEWABLE ENERGY IS A TOP PRIORITY

72



RESPONDENTS PRIORITIZE A HEALTHY LEARNING ENVIRONMENT FOR STUDENTS AND STAFF

OPERATIONS AND MAINTENANCE  
NET ZERO ENERGY / NET ZERO READY  
EMBODIED CARBON REDUCTION  
RENEWABLE ENERGY  
HEALTHY MATERIALS  
COVID-19 / INDOOR AIR QUALITY  
EMERGENCY RESILIENCE  
EFFICIENT WATER USE  
RAINWATER MANAGEMENT  
BIODIVERSITY  
HEAT ISLAND REDUCTION  
PEDESTRIAN AND CYCLIST FRIENDLY  
HEALTHY LEARNING ENVIRONMENT  
BUILDING AS A TEACHING TOOL  
EQUITABLE AND UNIVERSAL ACCESS



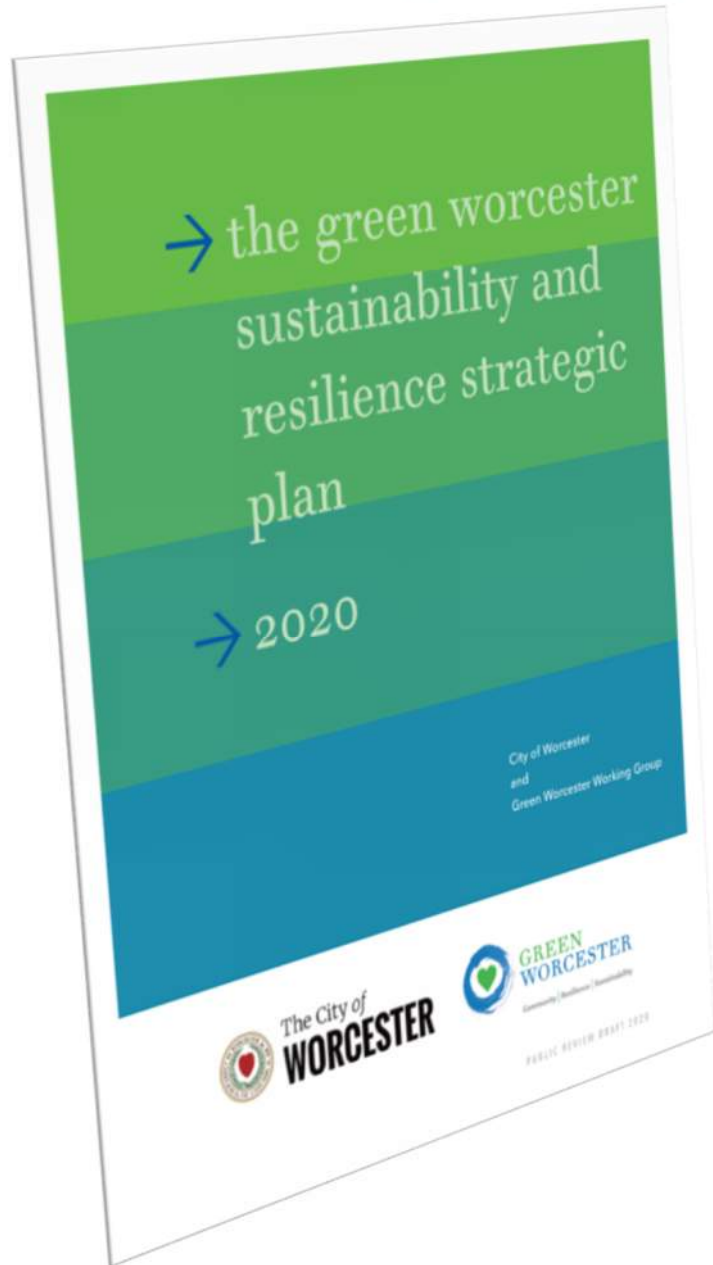
DISCUSSION TOPIC CATEGORIES:

- 1 ENERGY**
- 2 HEALTHY LEARNING ENVIRONMENT**
- 3 SITE ACCESS & SUSTAINABILITY**
- 4 BUILDING AS A TEACHING TOOL**



# GREEN WORCESTER

Community | Resilience | Sustainability



I. A Green Heart for Worcester: Our Values and Vision		15
II. The Green Worcester Approach: Stewardship, Transparency, and Accountability		31
III. 100% Clean and Affordable Energy		43
IV. Connected Green and Blue Spaces with Healthy Natural Systems		53
V. Net Zero and Climate Resilient Buildings		65
VI. Sustainable Transportation Choices		75
VII. One Water – Integrated Water Management		91
VIII. Towards Zero Waste		103
IX. Sustainable Food Systems		113
X. Pollution Prevention		121
XI. Climate Change Resilience		127
XII. Sustainability, Resilience, and Green Education in All Policies		137



City of Worcester, Massachusetts

# Climate Action Plan



December 2006



## ENERGY & ASSET MANAGEMENT

John W. Odell, Director



Green Worcester Worcester Energy

# 1. SUSTAINABILITY OF MAINTENANCE

(MINIMIZE STAFFING / FUNDING RESOURCES REQUIRED)

# 2. INITIAL & LONG-TERM COSTS

(CONSTRUCTION / UTILITY COSTS)

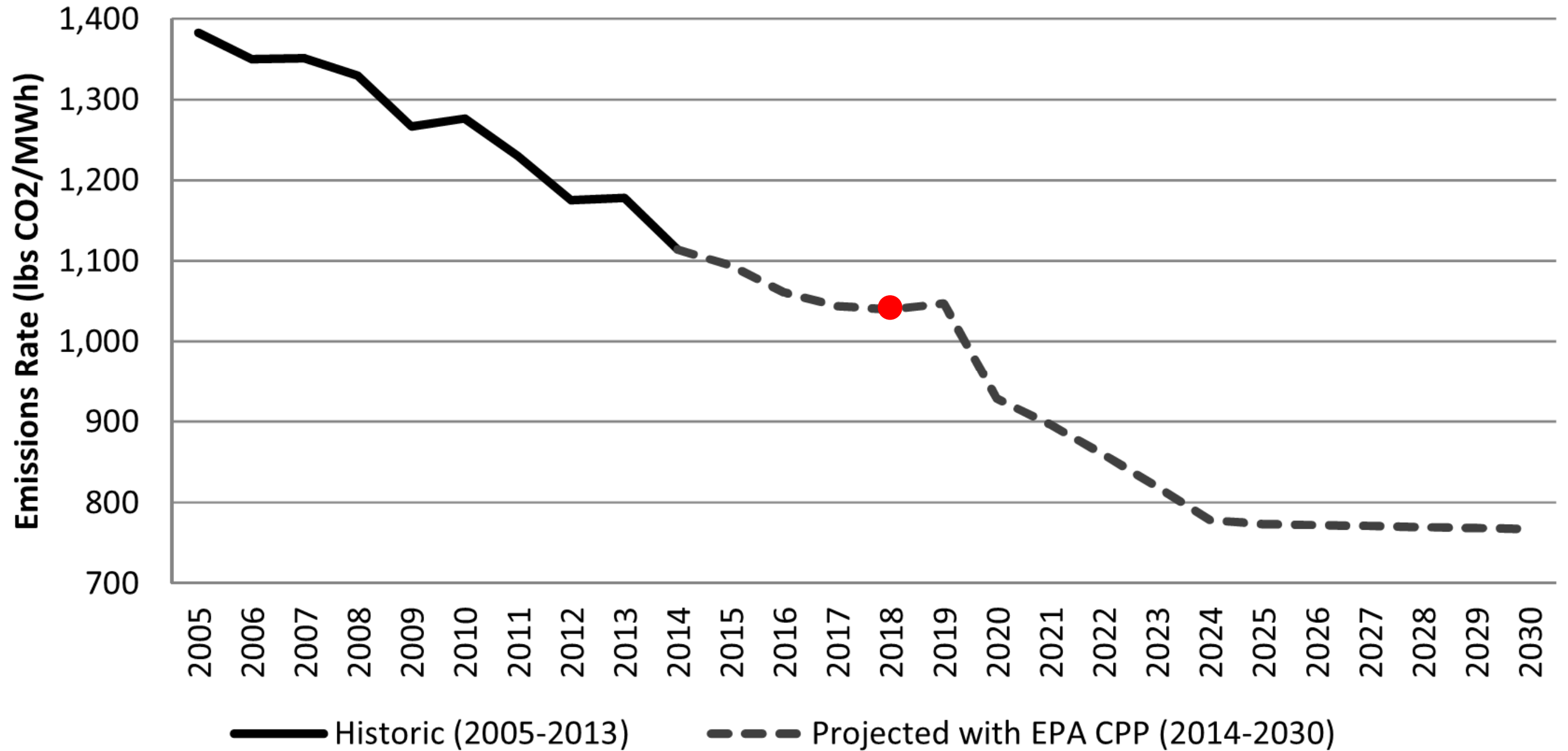
# 3. APPROPRIATE SYSTEM FOR A LEARNING ENVIRONMENT

(INDOOR AIR QUALITY AND NOISE REDUCTION CONSIDERATIONS)

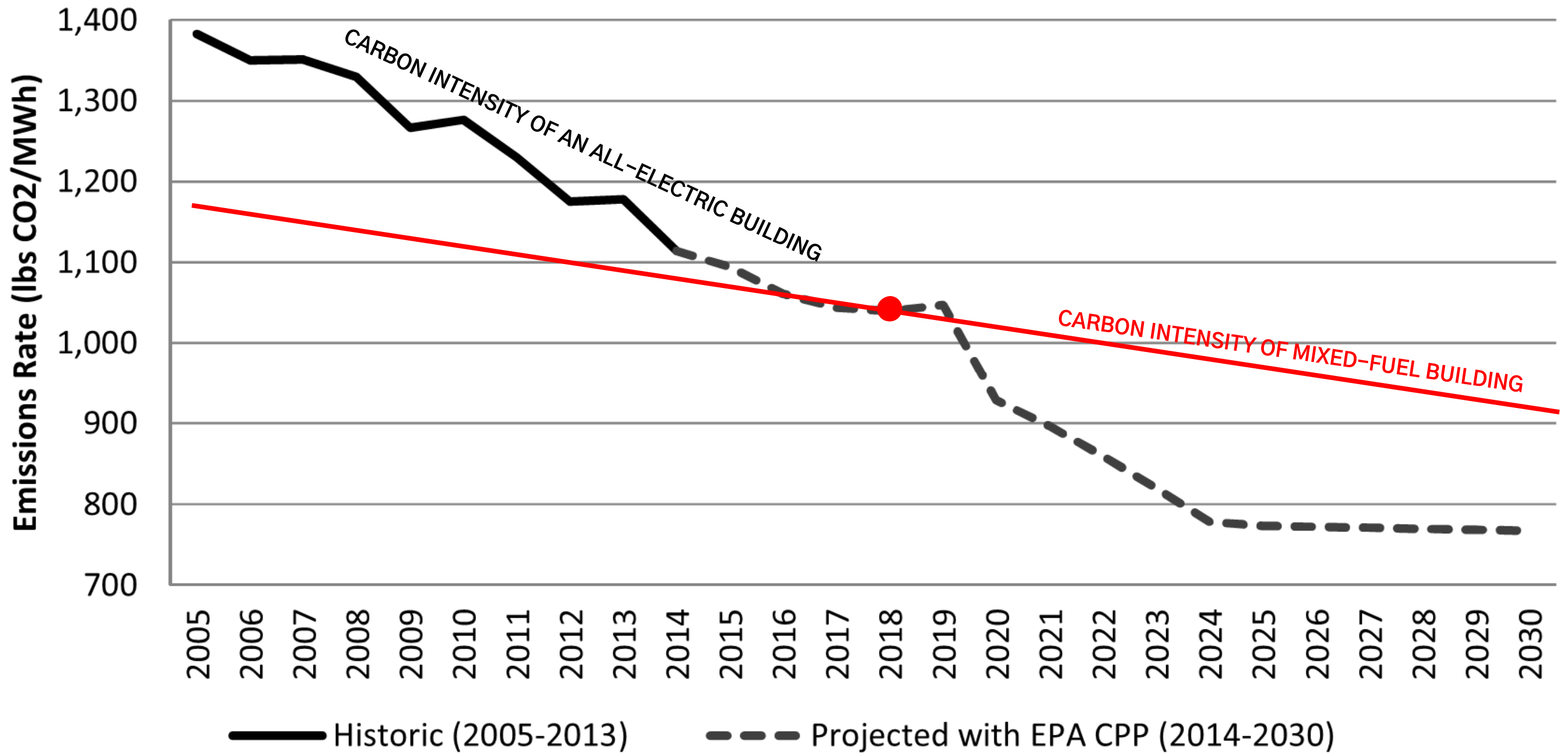
# 4. EMERGENCY RESILIENCE

(REDUNDANT FUEL SOURCES / FUNCTION AS A WARMING SHELTER)

# CARBON INTENSITY OF US ELECTRICAL GENERATION

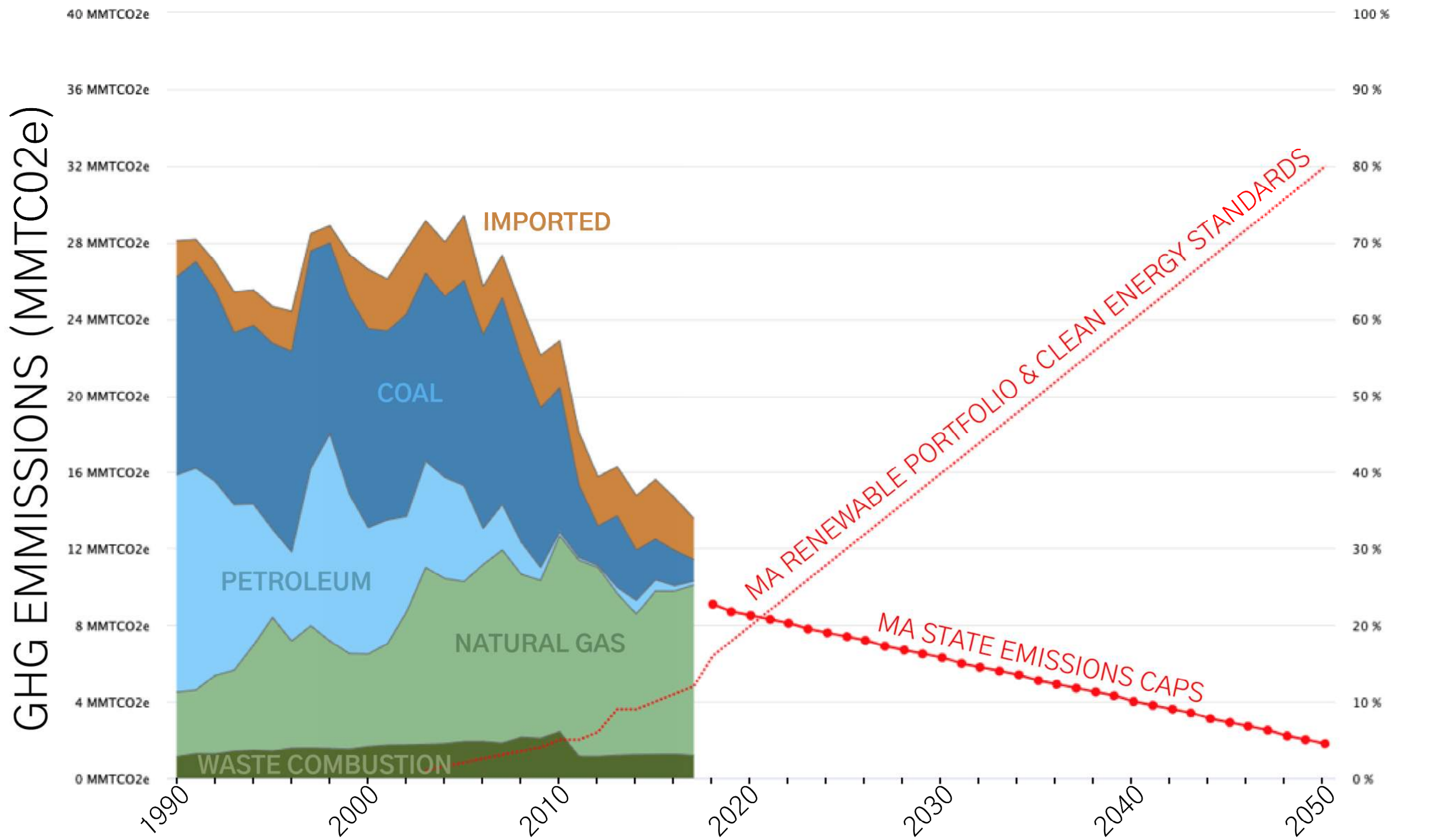


# ALL ELECTRIC BUILDINGS REDUCE CO<sub>2</sub> OVER TIME



# MA ELECTRICITY GHG EMISSIONS BY SOURCE

MA GRID DECARBONIZATION



		"As Designed"	Hybrid	Redesign to Reduce Gas Load	Full Electric-No Fossil Fuels	Full Electric-No Fossil Fuels
		DESIGN DEVELOPMENT	FUTURE CONVERSION	REDESIGN	ELECTRIC BOILERS	ALL VRF
Expected Service Life (n) - HVAC		20.0	20.0	20	20	15
Initial Costs	Install Cost HVAC (\$) 3	\$ 21,012,747	\$ 21,223,676	\$ 21,645,534	\$ 21,434,605	\$ 20,590,889
	Additional Costs Electrical (\$)	\$ 0	\$ 0	\$ 1,500,000	\$ 2,500,000	\$ 2,500,000
	<b>Total Initial Costs (\$)</b>	<b>\$ 21,012,747</b>	<b>\$ 21,223,676</b>	<b>\$ 23,145,534</b>	<b>\$ 23,934,605</b>	<b>\$ 23,090,889</b>
Operating Costs	Annual Maintenance Costs (\$)	\$97,027	\$ 97,027	\$ 118,120	\$ 97,027	\$ 139,213
	Natural Gas Cost (\$)	\$49,054	\$ 46,110	\$ 12,263	\$ 0	\$ 0
	Electricity Cost (\$)	\$513,451	\$ 519,408	\$ 602,811	\$ 662,925	\$ 619,253
	<b>Total Annual Operating Cost (\$)</b>	<b>\$659,532</b>	<b>\$ 662,546</b>	<b>\$ 733,194</b>	<b>\$ 759,953</b>	<b>\$ 758,466</b>
TEAC Calcs	Annual Operating Cost (\$)	\$ 659,532	\$ 662,546	\$ 733,194	\$ 759,953	\$ 758,466
	Amortized Cost - HVAC + Electrical	\$ 1,347,907	\$ 1,361,438	\$ 1,469,913	\$ 1,510,658	\$ 1,798,743
<b>Total Equivalent Annual Cost (\$)</b>		<b>\$ 2,007,439</b>	<b>\$ 2,023,984</b>	<b>\$ 2,203,107</b>	<b>\$ 2,270,611</b>	<b>\$ 2,557,209</b>
TEAC (Incremental Cost/SF)		\$ 4.76	\$ 4.80	\$ 5.22	\$ 5.38	\$ 6.06
Electricity Consumption (kWh)		3,111,823	3,147,928	3,653,398	4,017,729	3,753,047
Gas Consumption (therms)		54,504	51,234	13,626	0	0
<b>GHG Emissions (MTCO2e) - Energy Star Carbon Factors</b>		<b>1031</b>	<b>1023</b>	<b>943</b>	<b>958</b>	<b>895</b>
<b>Site EUI (kBTU/SF)</b>		<b>38.0</b>	<b>37.5</b>	<b>32.7</b>	<b>32.4</b>	<b>30.2</b>

	"As Designed"	Hybrid	Redesign to Reduce Gas	Full Electric-No	Full Electric-No
Expected Service Life (n) - HVAC	20.0				
Initial Costs	Install Cost HVAC (\$) 3	\$ 1,012,74			
	Additional Costs Electrical (\$)	\$ 0			
	<b>Total Initial Costs (\$)</b>	<b>\$ 2,012,74</b>			
Operating Costs	Annual Maintenance Costs (\$)	\$97,027			
	Natural Gas Cost (\$)	\$49,054			
	Electricity Cost (\$)	\$513,451			
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TEAC Calcs	Annual Operating Cost (\$)	659,532			
	Amortized Cost - HVAC + Electrical	\$1,347,90			
<b>Total Equivalent Annual Cost (\$)</b>	<b>\$ 2,017,4</b>				
TEAC (Incremental Cost/SF)	\$ 476				
Electricity Consumption (kWh)	3,111,823	3,147,928	3,653,398	4,017,729	3,753,047
Gas Consumption (therms)	54,504				
<b>GHG Emissions (MTCO2e) - Energy Star Carbon Factors</b>	<b>195</b>				
<b>Site EUI (kBtu/SF)</b>	<b>38.0</b>				

## TEAC = Total Equivalent Annual Cost

Amortizes the upfront cost over the life span of the systems being studied and adds that to the operating cost

**Annual Operating Cost**

**+ Bond Payment on the Capital Cost**

**TEAC**

## GHG Emissions = Greenhouse Gas Emissions

Metric tons of carbon dioxide equivalent; a gas which contributes to the greenhouse effect

## EUI = Energy Use Intensity

The amount of energy used per square-foot of building area

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<b>GHG Emissions (MTCO2e) - Energy Star Carbon Factors</b>		<b>1031</b>	<b>1023</b>	<b>943</b>	<b>958</b>	<b>895</b>
<b>Site EUI (kBTU/SF)</b>		<b>38.0</b>	<b>37.5</b>	<b>32.7</b>	<b>32.4</b>	<b>30.2</b>

		"As Designed"	Hybrid	Redesign to Reduce Gas Load	Full Electric-No Fossil Fuels	Full Electric-No Fossil Fuels
		DESIGN DEVELOPMENT	FUTURE CONVERSION	REDESIGN	ELECTRIC BOILERS	ALL VRF
Expected Service Life (n) - HVAC		20.0	20.0	20	20	15
Initial Costs	Install Cost HVAC (\$) 3	\$ 21,012,747	\$ 21,223,676	\$ 21,645,534	\$ 21,434,605	\$ 20,590,889
	Additional Costs Electrical (\$)	\$ 0	\$ 0	\$ 1,500,000	\$ 2,500,000	\$ 2,500,000
	<b>Total Initial Costs (\$)</b>	<b>\$ 21,012,747</b>	<b>\$ 21,223,676</b>	<b>\$ 23,145,534</b>	<b>\$ 23,934,605</b>	<b>\$ 23,090,889</b>
Operating Costs	Annual Maintenance Costs (\$)	\$97,027	\$ 97,027	\$ 118,120	\$ 97,027	\$ 139,213
	Natural Gas Cost (\$)	\$49,054	\$ 46,110	\$ 12,263	\$ 0	\$ 0
	Electricity Cost (\$)	\$513,451	\$ 519,408	\$ 602,811	\$ 662,925	\$ 619,253
	<b>Total Annual Operating Cost (\$)</b>	<b>\$659,532</b>	<b>\$ 662,546</b>	<b>\$ 733,194</b>	<b>\$ 759,953</b>	<b>\$ 758,466</b>
TEAC Calcs	Annual Operating Cost (\$)	\$ 659,532	\$ 662,546	\$ 733,194	\$ 759,953	\$ 758,466
	Amortized Cost - HVAC + Electrical	\$ 1,347,907	\$ 1,361,438	\$ 1,469,913	\$ 1,510,658	\$ 1,798,743
<b>Total Equivalent Annual Cost (\$)</b>		<b>\$ 2,007,439</b>	<b>\$ 2,023,984</b>	<b>\$ 2,203,107</b>	<b>\$ 2,270,611</b>	<b>\$ 2,557,209</b>
TEAC (Incremental Cost/SF)		\$ 4.76	\$ 4.80	\$ 5.22	\$ 5.38	\$ 6.06
Electricity Consumption (kWh)		3,111,823	3,147,928	3,653,398	4,017,729	3,753,047
Gas Consumption (therms)		54,504	51,234	13,626	0	0
<b>GHG Emissions (MTCO2e) - Energy Star Carbon Factors</b>		<b>1031</b>	<b>1023</b>	<b>943</b>	<b>958</b>	<b>895</b>
<b>Site EUI (kBTU/SF)</b>		<b>38.0</b>	<b>37.5</b>	<b>32.7</b>	<b>32.4</b>	<b>30.2</b>

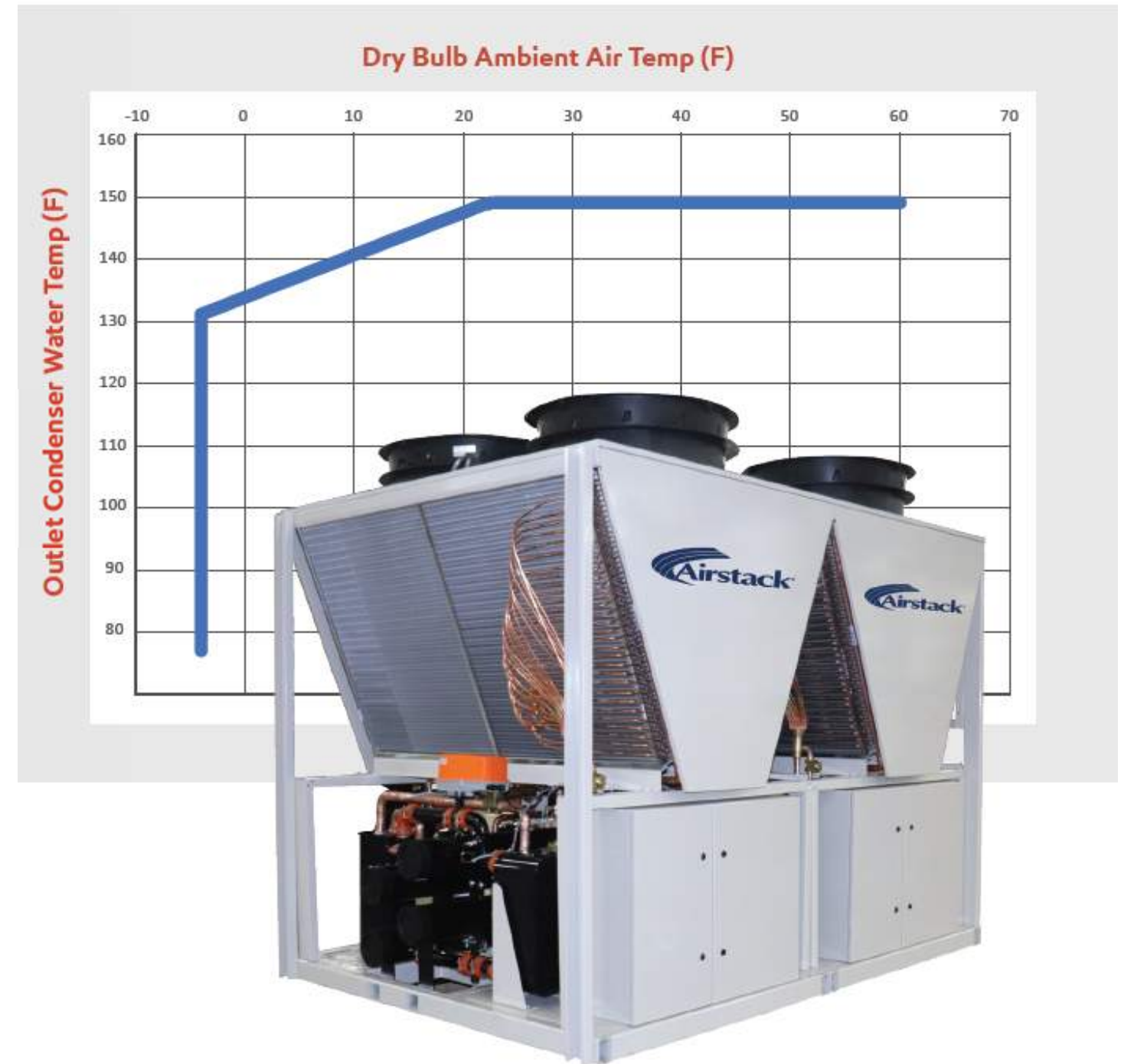
		"As Designed"	Hybrid	Redesign to Reduce Gas Load	Full Electric-No Fossil Fuels	Full Electric-No Fossil Fuels
		DESIGN DEVELOPMENT	FUTURE CONVERSION	REDESIGN	ELECTRIC BOILERS	ALL VRF
Expected Service Life (n) - HVAC		20.0	20.0	20	20	15
Initial Costs	Install Cost HVAC (\$) 3	\$ 21,012,747	\$ 21,223,676	\$ 21,645,534	\$ 21,434,605	\$ 20,590,889
	Additional Costs Electrical (\$)	\$ 0	\$ 0	\$ 1,500,000	\$ 2,500,000	\$ 2,500,000
	<b>Total Initial Costs (\$)</b>	<b>\$ 21,012,747</b>	<b>\$ 21,223,676</b>	<b>\$ 23,145,534</b>	<b>\$ 23,934,605</b>	<b>\$ 23,090,889</b>
Operating Costs	Annual Maintenance Costs (\$)	\$97,027	\$ 97,027	\$ 118,120	\$ 97,027	\$ 139,213
	Natural Gas Cost (\$)	\$49,054	\$ 46,110	\$ 12,263	\$ 0	\$ 0
	Electricity Cost (\$)	\$513,451	\$ 519,408	\$ 602,811	\$ 662,925	\$ 619,253
	<b>Total Annual Operating Cost (\$)</b>	<b>\$659,532</b>	<b>\$ 662,546</b>	<b>\$ 733,194</b>	<b>\$ 759,953</b>	<b>\$ 758,466</b>
TEAC Calcs	Annual Operating Cost (\$)	\$ 659,532	\$ 662,546	\$ 733,194	\$ 759,953	\$ 758,466
	Amortized Cost - HVAC + Electrical	\$ 1,347,907	\$ 1,361,438	\$ 1,469,913	\$ 1,510,658	\$ 1,798,743
<b>Total Equivalent Annual Cost (\$)</b>		<b>\$ 2,007,439</b>	<b>\$ 2,023,984</b>	<b>\$ 2,203,107</b>	<b>\$ 2,270,611</b>	<b>\$ 2,557,209</b>
TEAC (Incremental Cost/SF)		\$ 4.76	\$ 4.80	\$ 5.22	\$ 5.38	\$ 6.06
Electricity Consumption (kWh)		3,111,823	3,147,928	3,653,398	4,017,729	3,753,047
Gas Consumption (therms)		54,504	51,234	13,626	0	0
<b>GHG Emissions (MTCO2e) - Energy Star Carbon Factors</b>		<b>1031</b>	<b>1023</b>	<b>943</b>	<b>958</b>	<b>895</b>
<b>Site EUI (kBtu/SF)</b>		<b>38.0</b>	<b>37.5</b>	<b>32.7</b>	<b>32.4</b>	<b>30.2</b>

**SUMMARY**

	"As Designed"	Hybrid	Redesign to Reduce Gas Load	Full Electric-No Fossil Fuels	Full Electric-No Fossil Fuels
	DESIGN DEVELOPMENT	FUTURE CONVERSION	REDESIGN	ELECTRIC BOILERS	ALL VRF
<b>Total Initial Costs (\$)</b>	<b>\$21 M</b>	<b>\$ 21.2 M</b>	<b>\$ 23.1 M</b>	<b>\$ 23.9 M</b>	<b>\$ 23.1 M</b>
<b>Total Annual Operating Cost (\$)</b>	<b>\$660,000</b>	<b>\$ 663,000</b>	<b>\$ 733,000</b>	<b>\$ 760,000</b>	<b>\$ 758,000</b>
<b>Total Equivalent Annual Cost (\$)</b>	<b>\$ 2,007,439</b>	<b>\$ 2,023,984</b>	<b>\$ 2,203,107</b>	<b>\$ 2,270,611</b>	<b>\$ 2,557,209</b>
<b>GHG Emissions (MTCO2e) - Energy Star Carbon Factors</b>	<b>1031</b>	<b>1023</b>	<b>943</b>	<b>958</b>	<b>895</b>
<b>Site EUI (kBTU/SF)</b>	<b>38.0</b>	<b>37.5</b>	<b>32.7</b>	<b>32.4</b>	<b>30.2</b>

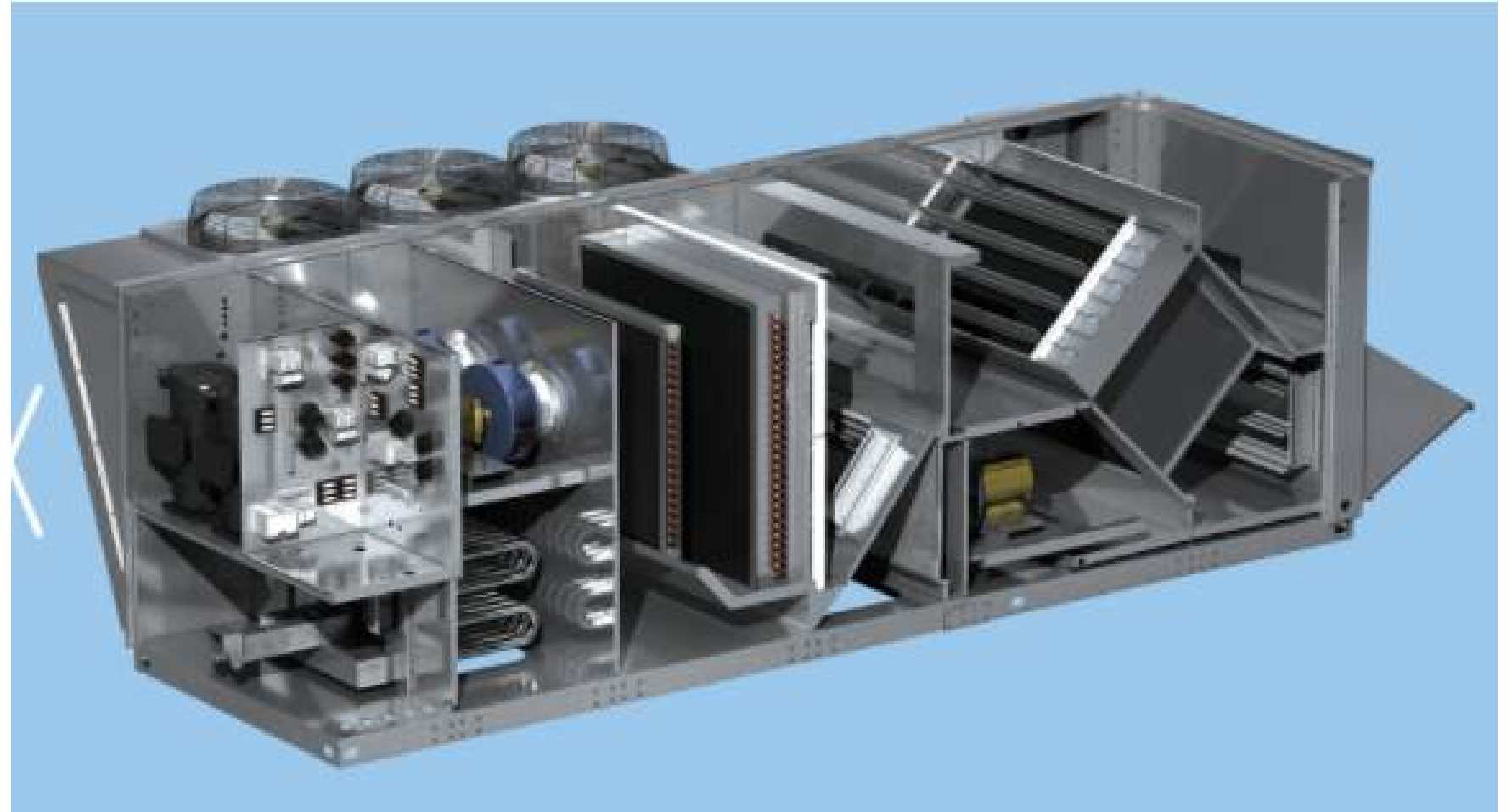
# ELECTRIC HEAT RECOVERY CHILLER/HEATER

- Generates both chilled water and hot water simultaneously
- Operation down to 0F outdoor with 130F hot water as air to water heat pump and -20F as heat recovery chiller/heater
- Multiple 30-ton modules (est. 150-ton+)

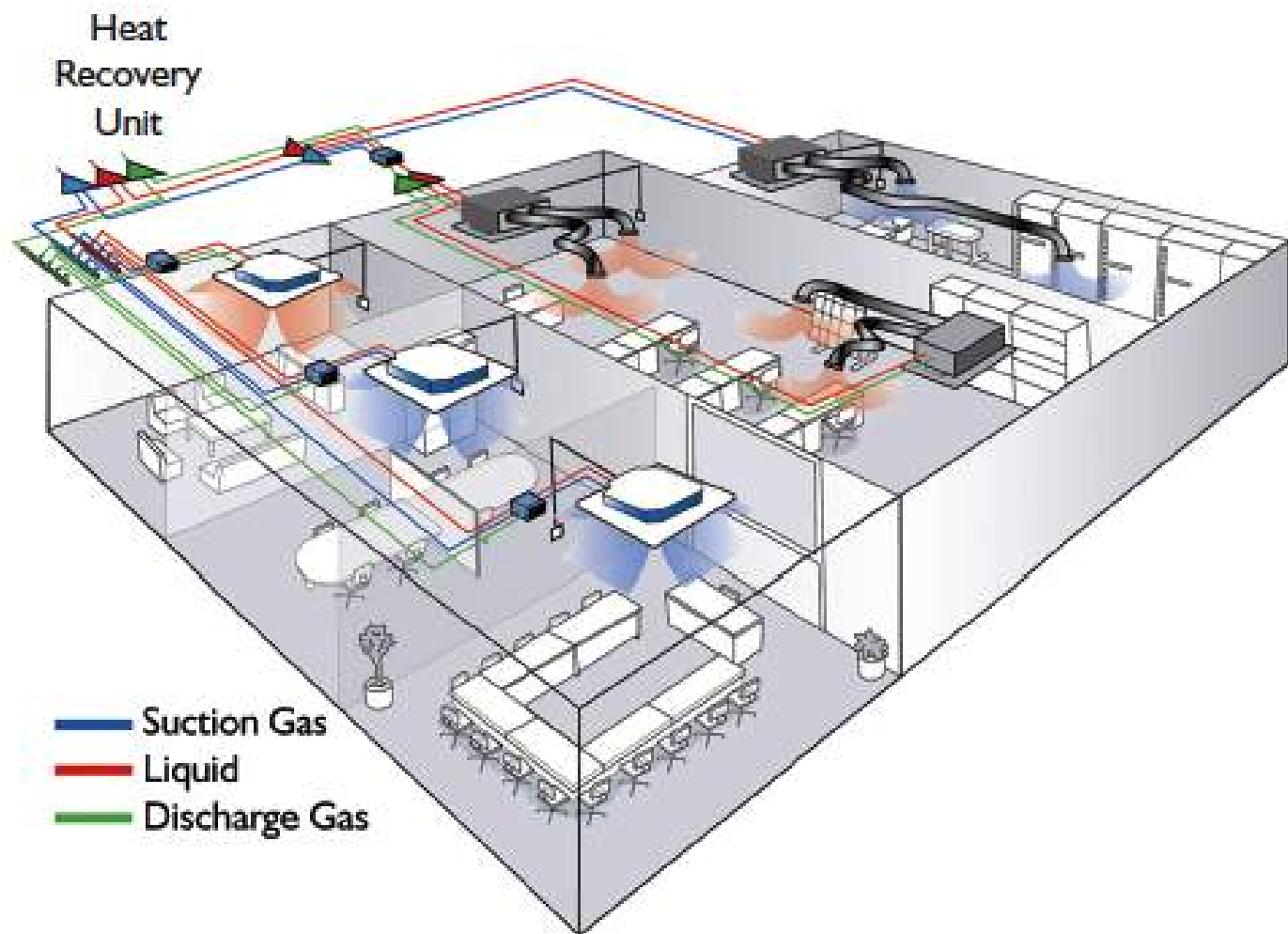


# ELECTRIC AIR SOURCE HEAT PUMP RTU'S

- Inverter Compressors
- ERV Wheel or Core
- Hot Water Back-up heat Option
- Uses electricity for heat instead of gas

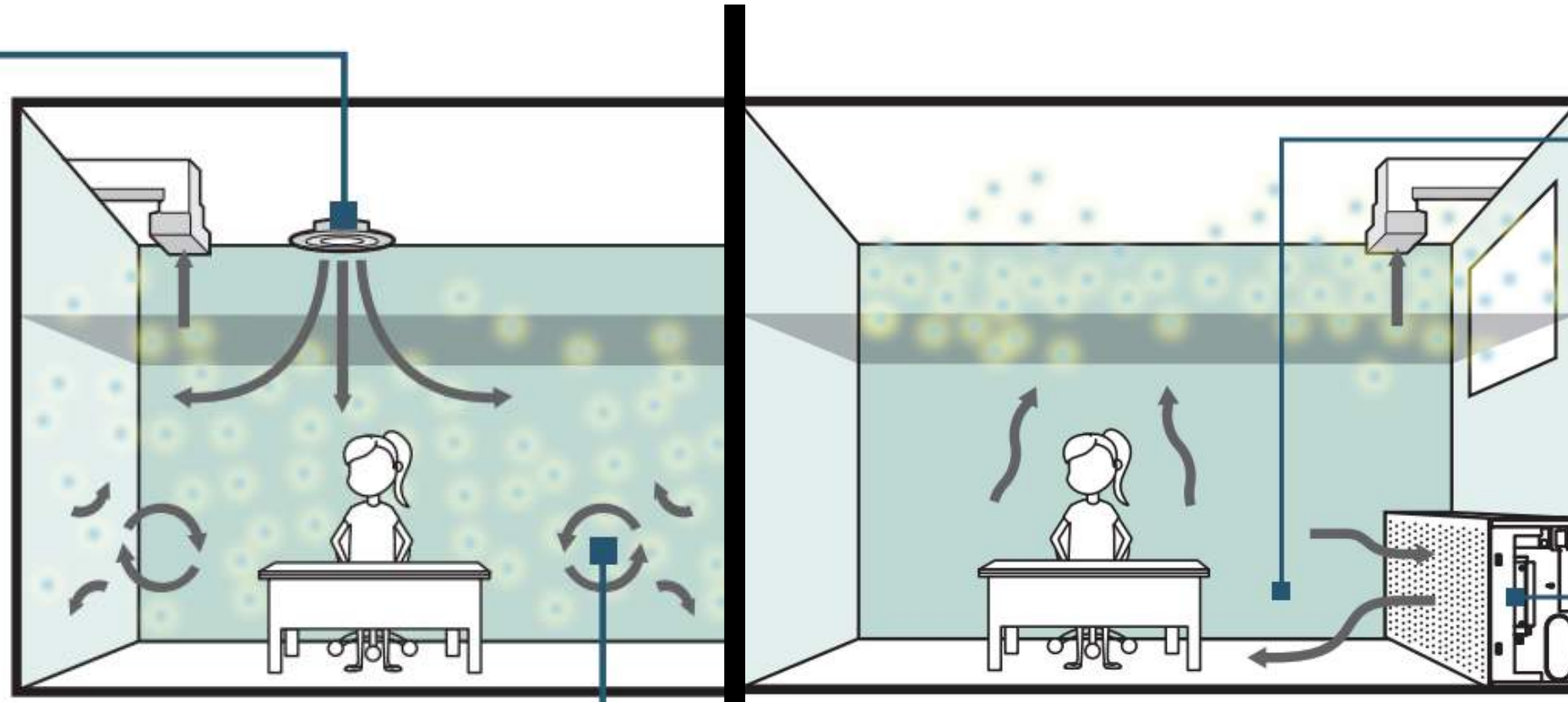


# ELECTRIC VRF HEAT RECOVERY HEAT PUMP SYSTEM



# DISPLACEMENT CHILLED BEAM CABINETS

Ceiling diffusers push 55°F air at high speed



+ Supply at breathing level  
+ Conditions occupied area

Occupied Zone

+ Provides both heating and cooling  
+ Substantial airflow and ductwork reduction ( $\leq$  half)

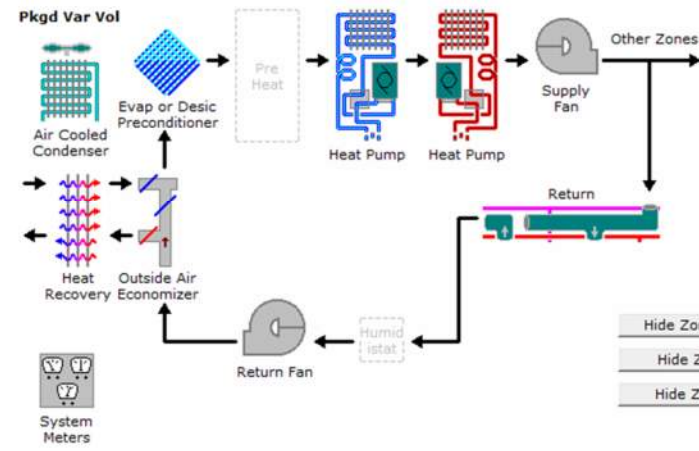
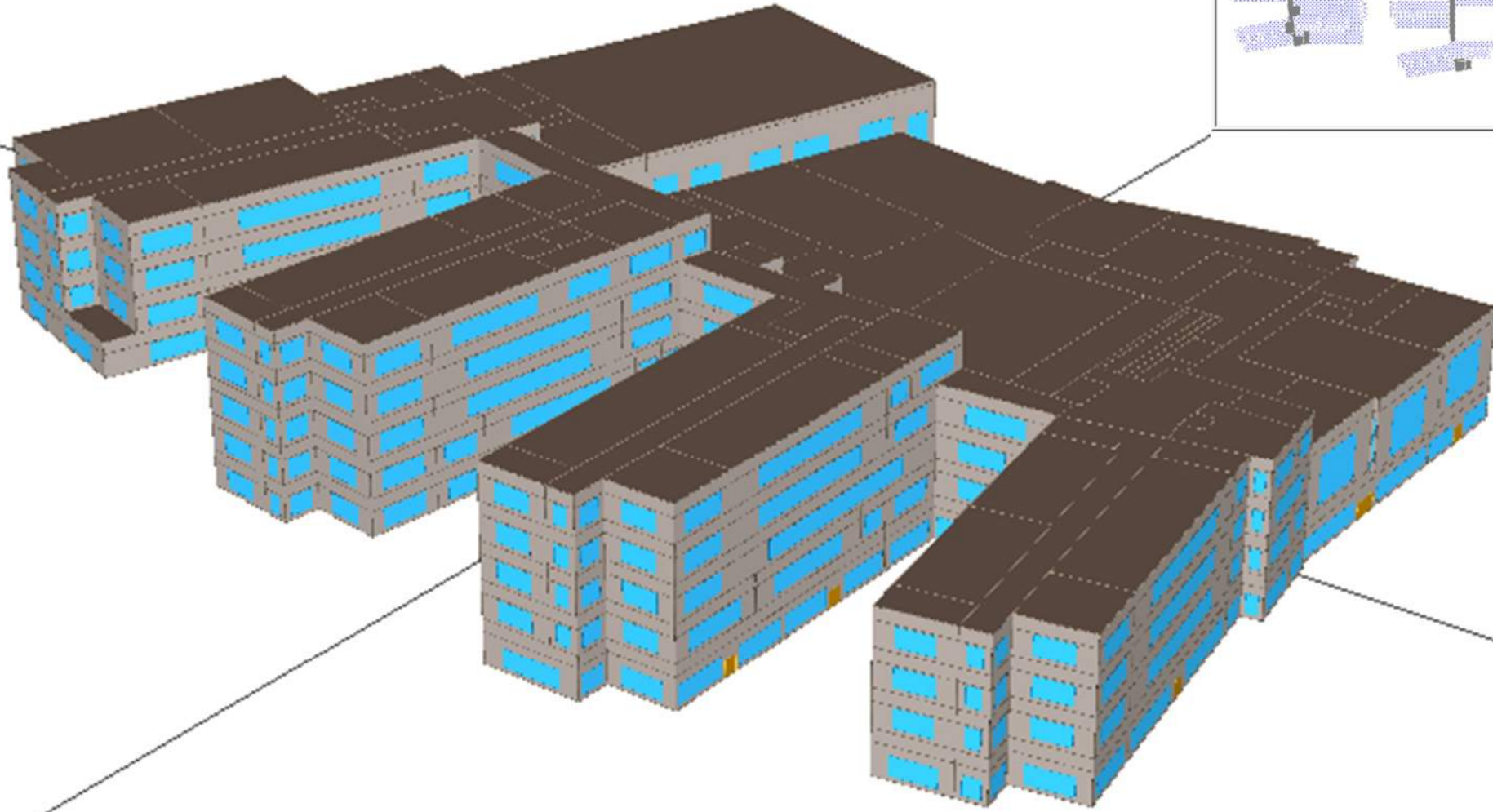
Temperature and pollutants are mixed uniformly throughout



ACBC with fin tube heater

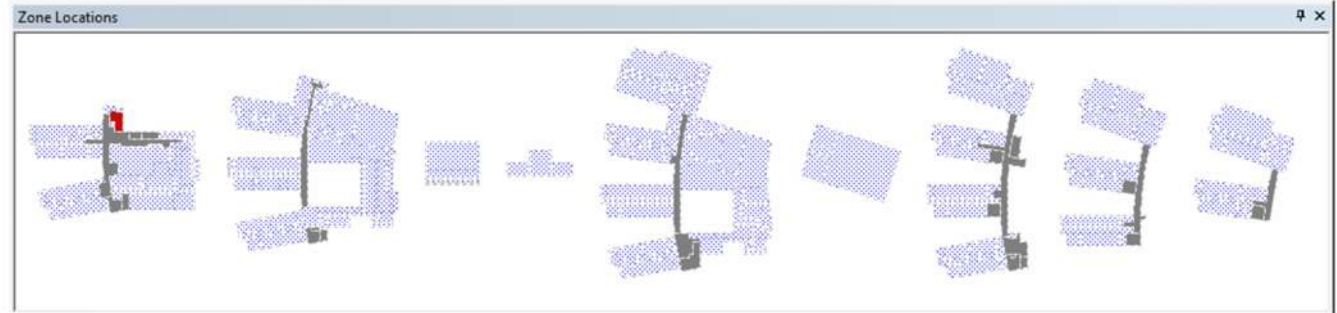
- ✓ EASE OF MAINTENANCE
- ✓ FRESH AIR IN BREATHING ZONE
- ✓ SUPERIOR ACOUSTICS
- ✓ LESS DUCTWORK REQUIRED FOR LOW VELOCITY AIR

# DETAILED eQUEST ENERGY MODEL



Hide Zone Assignments  
Hide Zone Features  
Hide Zone Locations

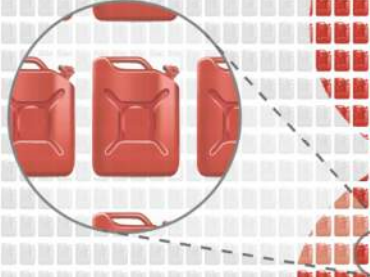
- ### Zone Assignments
- EL1 North Perim Zn (G.I
  - EL1 East Perim Zn (G.E
  - EL1 South Perim Zn (G
  - EL1 WNW Perim Zn (G.I
  - EL1 North Perim Pl Zn (
  - EL1 East Perim Pl Zn (G
  - EL1 South Perim Pl Zn (
  - EL1 WNW Perim Pl Zn (
  - EL2 WNW Perim Zn (G.I
  - EL2 East Perim Zn (G.E
  - EL2 East Perim Zn (G.E



	<b>CODE BASELINE</b>	<b>100% CONSTRUCTION DOCUMENTS</b>
<b>Natural Gas Cost (\$)</b>	\$136,669	\$ 39,127
<b>Electricity Cost (\$)</b>	\$600,455	\$ 447,876
<b>Total Annual Energy Cost (\$)</b>	<b>\$737,124</b>	<b>\$ 487,003</b>
<b>Electricity Consumption (kWh)</b>	3,639,123	2,714,401
<b>Gas Consumption (therms)</b>	112,300	32,150
<b>GHG Emissions (MTCO2e) Energy Star Carbon Factors</b>	<b>1,467</b>	<b>820</b>
<b>Site EUI (kBTU/SF)</b>	<b>53.9</b>	<b>28.8</b>

647 MTCO<sub>2</sub> IS THE EQUIVALENT OF

727,803



GALLONS OF GASOLINE CONSUMED

# BASELINE SUSTAINABLE ENVELOPE / SYSTEMS

**+** HEAT RECOVERY CHILLER

**+** VRF HEAT PUMPS

**+** AIR SOURCE HEAT PUMP RTU'S

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**70% REDUCTION  
IN PROJECTED FOSSIL FUEL USE**

- **EARLY DECISION MAKING IS CRITICAL**

- **EARLY DECISION MAKING IS CRITICAL**
- **NATURAL GAS /ELECTRICITY IN ENERGY MODELS**

- **EARLY DECISION MAKING IS CRITICAL**
- **NATURAL GAS /ELECTRICITY IN ENERGY MODELS**
- **IMPACT OF CLIMATE ACT LEGISLATION**

- **EARLY DECISION MAKING IS CRITICAL**
- **NATURAL GAS /ELECTRICITY IN ENERGY MODELS**
- **IMPACT OF CLIMATE ACT LEGISLATION**
- **EXTENDED COMMISSIONING SERVICES**

- **EARLY DECISION MAKING IS CRITICAL**
- **NATURAL GAS /ELECTRICITY IN ENERGY MODELS**
- **IMPACT OF CLIMATE ACT LEGISLATION**
- **EXTENDED COMMISSIONING SERVICES**
- **CAREER OPPORTUNITIES**



Massachusetts School  
Building Authority



 The Green Engineer  
Sustainable Design Consulting

