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

education | community | advocacy | research/tools
Why are we here?
Agenda

- **Overview** with Julie Janiski & Jacob Knowles
- **Panel Discussion**
  a. Local Governmental / Municipal Leadership
- **Breakout 1** - What’s Current?
- **Breakout 2** - What’s Next?
- **Next Steps & Resources** with Eversource | Mass Save & MassCEC
Desired Outcomes

1. Inform Massachusetts’s NZC efforts
2. Hear from this Community
3. Compile next steps
Presenters

Julie Janiski  
Partner | BuroHappold Engineering

Jacob Knowles  
Director of Sustainable Design | BR+A
CODES + ZONING REGULATIONS
NET ZERO CODES

Seattle
Energy Code is
Approaching Net Zero

California
Title 24-2019
(near residential NZE)
Zero Code
(commercial proposed)

National
IECC 2021
ZNE Appendix
IECC 2030 / ASHRAE
90.1-2031 = Approaching
ZNE

Massachusetts
Net Zero Stretch Code by 2022

Boston + Cambridge + Somerville
ZNE zoning regulations
in place or being developed

Washington, DC
Appendix Z
(voluntary compliance path)

Seattle
Energy Code is
Approaching Net Zero

California
Title 24-2019
(near residential NZE)
Zero Code
(commercial proposed)

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ZNE Appendix
IECC 2030 / ASHRAE
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ZNE

Massachusetts
Net Zero Stretch Code by 2022

Boston + Cambridge + Somerville
ZNE zoning regulations
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Washington, DC
Appendix Z
(voluntary compliance path)

https://www.energycodes.gov/status-state-energy-code-adoption
<table>
<thead>
<tr>
<th>Acton</th>
<th>Gill</th>
<th>Shutesbury</th>
<th>Gill</th>
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<td>Saugus</td>
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<td>Framingham</td>
<td>Sherborn</td>
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<td>Framingham</td>
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</table>

Represents 40% of the population of MA
MA CLIMATE BILL: NET ZERO STRETCH CODE

TODAY

CURRENT STRETCH CODE

Late 2021 / Early 2022

UPATED STRETCH CODE

MUNICIPAL OPT-IN NET ZERO STRETCH CODE
CARBON NEUTRAL ZONING + ORDINANCE

SOMERVILLE
ZONING ORDINANCE

BOSTON
CO$_2$ NEUTRAL ZONING

CAMBRIDGE
CLIMATE PLAN

WATERTOWN
SOLAR PV ORDINANCE

BROOKLINE
ELECTRIFICATION ORDINANCE

MANY OTHERS
SEEKING HOME RULE TO BAN GAS
WHAT IS NET ZERO?
CARBON NEUTRAL: OPERATION

\[
\text{ENERGY EFFICIENCY} + \text{ELECTRIC HEAT PUMPS} - \text{ON + OFF-SITE RENEWABLE ENERGY} = 0
\]
ENERGY EFFICIENCY: ENVELOPE

Thermally Broken
+ Highly Insulated Envelope

Triple Glazing
+ High Performance Frame
ENERGY EFFICIENCY: HVAC

Efficient Energy Recovery (80%)

Cold Outdoor Air

Minimal Extra Heat Needed

Warm Fresh Air
ELECTRIC HEAT PUMPS

GROUND-SOURCE

AIR-SOURCE
GAS vs. HEAT PUMP: CO2 EMISSIONS

Using Massachusetts (ISO-NE) Electric Grid

<table>
<thead>
<tr>
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<th>lbCO2e/MMBtu</th>
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<tr>
<td>Gas Heat (Boiler)</td>
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<tr>
<td>Electric Heat</td>
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<tr>
<td>(Heat Pump)</td>
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</tr>
<tr>
<td>Using Massachusetts</td>
<td></td>
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<tr>
<td>(ISO-NE) Electric</td>
<td></td>
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<tr>
<td>Grid</td>
<td>2021</td>
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<tr>
<td></td>
<td>2050</td>
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</table>
ON-SITE RENEWABLES
Prioritized as primary

OFF-SITE RENEWABLES
Supplement as necessary

\[ \text{100\% of the building's annual energy consumption} \]
LOW EMBODIED CARBON + LOW OPERATIONAL CARBON - CARBON CREDITS + RENEWABLE ENERGY = 0
CASE STUDY:
BRISTOL SBREGA BUILDING
Original Design: High Performance

- (2) AHU's with Run-Around Loop Heat Recovery and (1) AHU with Enthalpy Wheel Energy Recovery
- (3) Air Handling Units with 70,000 cfm total capacity
- Chillers: (2) at 150 tons each
- Boilers: (2) at 3,750 MBH each
- Electrical Transformer: 1,000 kVA
- Lighting: 1 W/sf
- Plug-Loads: 6-8 W/sf
- 1 cfm/sf minimum
- 72-74°F
- Air from AHU is used for cooling
- (22) Ducted Fume Hoods
through night and day and in and out of weeks and almost over a year
High Performance

Zero Net Energy

- Chillers: 2 at 150 tons each
- Boilers: 2 at 3,750 MBH each
- Electrical Transformer: 1,000 kVA
- Lighting: 1 W/sf
- Plug Loads: 6-8 W/sf
- 1 cfm/sf minimum
- 72-74°F
- Air from AHU is used for cooling
- (22) Ducted Fume Hoods
High Performance

- (1) 70 ton
- (1) 50 ton
- (1) 30 ton

Electrical Transformer: 1,000 kVA

- 70,000 cfm peak exhaust rate
- Chillers: (2) at 150 tons each
- Boilers: (2) at 3,750 MBH each
- (2) AHU's with Run-Around Loop Heat Recovery and (1) AHU with Enthalpy Wheel Energy Recovery
- (3) Air Handling Units with 70,000 cfm total capacity

- Lighting: 1 W/sf
- Plug Loads: 6 – 8 W/sf
- 1 cfm/sf minimum
- 72 – 74°F

Air from AHU is used for cooling
- (22) Ducted Fume Hoods

Zero Net Energy

- 24,000 cfm peak exhaust rate
- Ground Source Heat Pumps
  - (1) 70 ton
  - (1) 50 ton
  - (1) 30 ton
- Air Source Heat Pumps (2) at 80 tons each
- Enthalpy Wheel Energy Recovery
- Air Quality Monitoring
- Electrical Transformer: 1,000 kVA

- (2) Air Handling Units with 24,000 cfm total capacity
- Natural Ventilation in non-lab areas
- Fan-Coil Units provide Supplemental Cooling
- Lighting: 8.6 W/sf
- Plug Loads: 5 W/sf

- 0.87 cfm/sf occupied
- 0.33 cfm/sf unoccupied
- 70 – 76°F

- (17) Filtered Fume Hoods
- (4) Ducted Fume Hoods

- (30) 500' Deep Closed-Loop Wells
Energy Consumption

90.1 BASELINE

MODELED

- LIGHTING
- DHW
- EQUIP
- FANS
- PUMPS & AUX
- HEAT REJECT
- EXT LIGHTING
- HEATING
- COOLING
- ELECTRIC
- NATURAL GAS

73%
Measured Performance

EUI = 45

Excess solar energy

90.1 Baseline

Modeled

Actual

DHW

ENERGY POSITIVE

Legend:
- LIGHTING
- DHW
- EQUIP
- FANS
- PUMPS & AUX
- HEAT REJECT
- EXT LIGHTING
- HEATING
- COOLING
- ELECTRIC
- NATURAL GAS
Construction Cost

$275,000

<1% increase

+$275,000
$4,150,000
Net Present Savings

$230,000/yr
Operational Savings
(annual tuition for 50 students)
CASE STUDY:
BELMONT MIDDLE + HIGH SCHOOL
Geothermal

Rooftop Solar

RECs

Bond Payments
Solar Maintenance Premiums
REC Purchases

Utility Cost Savings
Geothermal Maintenance Savings
AEC Incentives

$0 (Cost Neutral)

$>5M Net Present Savings

AECs

Rooftop Solar
NET ZERO = READILY ACHIEVABLE BY ALL BUILDING TYPES
NET ZERO READY DATABASE SNAPSHOT

7.2 Million Sq Ft in Massachusetts Currently Documented. More Pending...

(select examples shown below)

Assembly

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Location</th>
<th>GSF</th>
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</thead>
<tbody>
<tr>
<td>Lexington Visitor Center</td>
<td>Lexington</td>
<td>76,899</td>
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<tr>
<td>Hadwen Rand Visitor Center</td>
<td>Worcester</td>
<td>5,575</td>
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<tr>
<td>Eastern Public Library</td>
<td>Boston</td>
<td>17,500</td>
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<tr>
<td>MA Education Building</td>
<td>Worcester</td>
<td>6,200</td>
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<tr>
<td>786 Belmont Public Library</td>
<td>Belmont</td>
<td>40,000</td>
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<tr>
<td>61 Oak Dr</td>
<td>Jamaica Plain</td>
<td>3,475</td>
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</table>

Office

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Location</th>
<th>GSF</th>
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</thead>
<tbody>
<tr>
<td>Woods Hole Research Center</td>
<td>Falmouth</td>
<td>505,200</td>
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<tr>
<td>SC of Fisheries &amp; Wildlife Field</td>
<td>Westborough</td>
<td>19,200</td>
</tr>
<tr>
<td>11-21 Greenfield</td>
<td>Boston</td>
<td>443,000</td>
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Education: K-12

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<thead>
<tr>
<th>Building Name</th>
<th>Location</th>
<th>GSF</th>
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</thead>
<tbody>
<tr>
<td>Douglass &amp; Gilm Schools</td>
<td>Acton</td>
<td>1,927,400</td>
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<tr>
<td>King Open/ Cambridge in Upper</td>
<td>Cambridge</td>
<td>243,000</td>
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<tr>
<td>Schools Campus</td>
<td>Westborough</td>
<td>70,000</td>
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<tr>
<td>Anke E. F. Plate Elementary School</td>
<td>Lexington</td>
<td>16,875</td>
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<tr>
<td>Lexington Children's Place</td>
<td>Cambridge</td>
<td>270,000</td>
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<tr>
<td>Table Mountain Upper School</td>
<td>Leominster</td>
<td>110,000</td>
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<tr>
<td>Upper School Project</td>
<td>Leominster</td>
<td>60,905</td>
</tr>
<tr>
<td>Belmont Middle &amp; High School</td>
<td>Belmont</td>
<td>144,000</td>
</tr>
<tr>
<td>Corotif Elementary School</td>
<td>Cambridge</td>
<td>100,000</td>
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<tr>
<td>Dr. Martin Luther King, Jr. School</td>
<td>Cambridge</td>
<td>142,500</td>
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<tr>
<td>Homer Elementary School</td>
<td>New Bedford</td>
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Residential: Affordable

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<th>Building Name</th>
<th>Location</th>
<th>GSF</th>
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<tbody>
<tr>
<td>402 Wiggles Ave / Widge Commons (B-Residential Portfolio)</td>
<td>Cambridge</td>
<td>3,760</td>
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<tr>
<td>402 Wiggles Ave / Widge Commons (Building B)</td>
<td>Cambridge</td>
<td>1,426</td>
</tr>
<tr>
<td>Rock Cambridge</td>
<td>Cambridge</td>
<td>100,000</td>
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<tr>
<td>1006 Broadway</td>
<td>Chelsea</td>
<td>31,550</td>
</tr>
<tr>
<td>Harbor Village</td>
<td>Gloucester</td>
<td>1,900</td>
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<tr>
<td>11 Tafts</td>
<td>Somerville</td>
<td>14,195</td>
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Lab / Tech / Science

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<th>Building Name</th>
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<th>GSF</th>
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<tbody>
<tr>
<td>Cape Cod Community College Science and Engineering Center</td>
<td>Barnstable</td>
<td>1,070,400</td>
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<tr>
<td>Bridgewater Community College STEM Lab &amp; Science Building</td>
<td>Fall River</td>
<td>50,000</td>
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</tbody>
</table>

(continued on next page)
HOW MUCH DOES IT COST TO BUILD NET ZERO READY?

*47% of GSF reported on % cost difference

85% OF RESPONSES: <1% PREMIUM

Percent Change in Construction Cost due to Net Zero Ready in MA
WHOLE-BUILDING CARBON EMISSIONS
LOW EMBODIED CARBON + LOW OPERATIONAL CARBON - CARBON CREDITS + RENEWABLE ENERGY = 0
OPERATIONAL + EMBODIED CARBON

MATERIAL SELECTION & PROCUREMENT
- Regional extraction/manufacture
- Less resources used to manufacture
- Industrial best practice for reuse and recycle
- High quality offsets

BUILDING PERFORMANCE
- High-Performance Envelope
- Efficient, Electric Systems
- Renewable Energy, incl. high quality offsets
Total Carbon Emissions of Global New Construction from 2020-2050
Business as Usual Projection

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Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017
EMBODIED CARBON / EXAMPLE - STRUCTURE
EMBODIED CARBON / EXAMPLE - INSULATION

kgCO₂ represents R-20 at 234 m²

- 6,735 kgCO₂ emitted

EXTRUDED POLYSTYRENE (XPS)
CLOSED CELL SPRAYFOAM (HFC)
CLOSED CELL SPRAYFOAM (HFO)
EXPANDED POLYSTYRENE (EPS)
MINERAL WOOL BATT
FIBERGLASS BATT
DENIM BATT
WOOL
DENSE PACK CELLULOSE
CORK
HEMPCRETE
STRAW BALE

- 7,437 kgCO₂ embodied

INGREDIENTS VARY

EMISSIONS INFLUENCED LARGELY BY SOURCE ENERGY TYPE

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EMBODIED CARBON / EXAMPLE - REFRIGERANTS

CFCs, now banned
- R-11, R-12, R-113 & others

HCFCs & HFCs
- R-22, R-123, R-134a, R-245fa, R-404A, R-407C, R-410A & others

HFOs & HFO Blends
- R-452B, R-454B, R-513A, R-514A, R-1233zd, R-1234yf, R-1234ze & others

Global Warming Potential (kg CO₂e)

- R-12
- R-404A
- R-410A
- R-22
- R-407C
- R-1234ze
- R-1234yf

HFO, next-gen
- R-404A
- R-410A
- R-22
- R-407C

Image: Buro Happold
Policy Options

1. Prescriptive
2. Adopt other green building certification requirements
3. Performance targets or limits

https://carbonleadershipforum.org/clf-policy-toolkit/
MA Municipalities - Examples

→ Somerville, Zoning Ordinance; Density increase

→ Newton, Zoning Ordinance; 20,000sf+ special permit

In development:

→ Cambridge: Reporting, Re-use, Thresholds

→ Boston: Zero Net Carbon Zoning, Exploratory

https://carbonleadershipforum.org/clf-policy-toolkit/
WHOLE BUILDING CARBON EMISSIONS: OPERATIONAL + EMBODIED

Image: Buro Happold
11 LENOX STREET, BOSTON, MA

- 7 Stories
- 37,500 sf
- Multi-family
- 34 units
- $14m Cost

STRATEGIES

Operational Carbon
- Passive House (PHIUS), Triple-Pane Windows, Robust Insulation
- Ventilation: Energy Recovery
- Heating/Cooling: Daiken VRF (heat pumps)
- Hot Water: Heat Pump Hot Water Heater
- All-Electric
- Rooftop Solar PV (40kW)
- EV Charging

Embodied Carbon
- FSC Timber (Nordic); glulam post and beam, CLT floors
- Lightweight recycled insulated fill
- Prefab modular concrete cores
OFFICE/LAB, SOMERVILLE, MA

- 4 Stories
- Speculative

**STRATEGIES**

**Operational Carbon**
- High-performance envelope: triple-pane windows, external sun shading
- Ventilation: Heat recovery
- Heating/Cooling: Heat pump chiller to maximize heat recovery for heating
- All-Electric Ready
- 100% LED lighting design
- LEED Platinum

**Embodied Carbon**
- Structural concrete mix
- Low-carbon steel, rebar, decking
- Mineral wool insulation
- LEED Platinum

Image: Buro Happold
SMALL EDUCATION CENTER, MA

- 2 Stories
- 2,600 sf

STRATEGIES

Operational Carbon

➢ High-performance envelope: robust insulation, external sun shading
➢ Natural ventilation strategies
➢ All-Electric: Heat pumps
➢ Energy Star appliances
➢ Rooftop Solar PV
➢ ILFI Zero Carbon

Embodied Carbon

➢ Timber structure, FSC
➢ Mineral wool insulation
➢ Design for disassembly
➢ Less aluminum extrusion profiles
➢ Concrete: CarbonCure, Maximum SCMs
➢ ILFI Zero Carbon
WHOLE BUILDING CARBON EMISSIONS: OPERATIONAL + EMBODIED

Image: Buro Happold
CARBON NEUTRAL

LOW EMBODIED CARBON + LOW OPERATIONAL CARBON - CARBON CREDITS + RENEWABLE ENERGY = 0
HIGH QUALITY OFFSETS

Offset units cancel out emissions

Businesses and organisations purchase offset units
# BUILDING DESIGN & HEALTH / WELLBEING

## THEN

![The Problem of 'Sick-Building Syndrome'](

## NOW

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<tr>
<th>Product Description</th>
<th>Value</th>
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<td>Owens Coming EcoTouch Batt-FSK Faced</td>
<td>0.153</td>
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<tr>
<td>Owens Coming EcoTouch Batt-Unfaced</td>
<td>0.0559</td>
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<tr>
<td>CertainTeed Blowing Wool Fiberglass</td>
<td>0.155 (Red List Free)</td>
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<tr>
<td>CertainTeed Sustainable Wool Fiberglass</td>
<td>0.0236</td>
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<tr>
<td>Knauf Jet Stream ULTRA</td>
<td>0.0878 (Declare Label)</td>
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<tr>
<td>Knauf KN Utility</td>
<td>0.947</td>
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<tr>
<td>Knauf JetSpray Thermal</td>
<td>0.232</td>
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*CA Average = 0.175*

Image: Buro Happold
Joseph Curtatone
Mayor of Somerville

Stephanie Ciccarello
Town of Amherst

Andrea Love
Cambridge Net Zero Task Force
Kimberly Cullinane