ZNE Approach

Code Compliant

Target
Goal: 60% - 70%
Energy savings + avoid fossil fuels

Efficiency reduces purchased energy by 60% - 70%

Net Zero Energy Use

Renewable Energy supplies the remaining 30% - 40% of energy needs
ZNE: PROCESS

GOALS → DESIGN → VERIFY
EUI – kBtu/sf*yr
ZNE Metrics

- Generation Losses
- Distribution Losses
- Nuclear
- Renewable
- Nat. Gas
- (National Data)
- Coal
- ELECTRICAL
  - Cooling
  - Fans
  - Lighting
  - Receptacles
  - Heating
  - Losses
- NATURAL GAS
  - Site Lighting
  - Pumps
  - Hot Water
- CO2
- COST
- CARBON
- SOURCE ENERGY
- SITE ENERGY
ZNE Classification – NREL

Class A
Within Building Footprint
+ avoid fossil fuels

Class B
On Site

Class C
Combusted on Site

Class D
Off-Site
(Purchased/ Allocated)
## ZNE Classification – Verification / Certification Programs

<table>
<thead>
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**LEED Zero Energy**
- combustion is allowed

**LEED Zero Carbon**
- combustion is allowed
- carbon footprint of occupant transportation must be offset
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Building Size by ZNE Status

- ZE - Verified
  - 0 - 5k sf: 31%
  - 5k - 10k sf: 25%
  - 10k - 25k sf: 25%
  - 25k - 50k sf: 4%
  - 50k - 100k sf: 12%
  - Over 100k sf: 1%

- ZE - Emerging
  - 0 - 5k sf: 12%
  - 5k - 10k sf: 9%
  - 10k - 25k sf: 21%
  - 25k - 50k sf: 17%
  - 50k - 100k sf: 18%
ZNE Codes

**NATIONAL**
- **IECC 2021**
  - ZNE Appendix (residential)
- **IECC 2030 / ASHRAE 90.1-2031** = Approaching ZNE

**CALIFORNIA**
- Title 24-2019
  - (near residential ZNE)
  - Zero Code
  - (commercial proposed)

**MASSACHUSETTS**
- Net Zero Carbon Stretch Code
  - Start 2021??
  - Fully implemented 2024??
  - Boston + Cambridge
  - ZNE zoning regulations being developed

**WASHINGTON DC**
- Appendix Z
  - (voluntary compliance path)

Legend:
- No statewide code or home rule
- Less energy efficient than 90.1-2007
- IECC 90.1-2007 or equivalent
- Between IECC 90.1-2007 and 90.1-2010
- IECC 90.1-2010 or equivalent
- Between IECC 90.1-2010 and 90.1-2013
- IECC 90.1-2013 or equivalent
- IECC 90.1-2013 or better
Existing Buildings

**California**
Goal to achieve ZNE for 50% of existing buildings

**Massachusetts**
Boston + Cambridge ZNE zoning regulations being developed

**New York**
New York City Local Law 97 (2024/2030 CO₂ Limits)

**Washington DC**
Carbon Neutral by 2050

Legend:
- No statewide code or home rule
- Less energy efficient than 90.1-2007
- IECC 90.1-2007 or equivalent
- Between IECC 90.1-2007 and 90.1-2010
- IECC 90.1-2010 or equivalent
- Between IECC 90.1-2010 and 90.1-2013
- IECC 90.1-2013 or equivalent
- IECC 90.1-2013 or better
ZNE Off-Ramp

HIGH PERFORMANCE

NET ZERO READY

$
ZNE: S, M, L, XL
HARVARD HOUSE ZERO
Quad Zero

Solar Vent
A solar vent uses sunlight to create thermal updraft to draw air from basement spaces offering robust ventilation at times of higher levels of occupation.

Rain Garden and Landscape
Replacing an existing parking lot, excavated soil will remain on site in berms with new plantings. Mass balance reduces landfill while the planting aids rainwater retention and creates spaces for people to enjoy.

Green Roof
A green roof is integrated with the landscape to help mitigate stormwater runoff and diminish solar gain to the space below.

100% Daylight Autonomy
No artificial light is required during daylight hours on non-cloudy days. Roof and window treatments are custom shaped to allow maximum light admission during the winter, and limit direct sunlight during summer.

Improved Envelope
Insulation, air tightness and waterproofing are substantially increased through improvements to the existing walls and roof.

Power Production
Minimal on site power needs are met by photovoltaic shingles on roof, and stored via batteries in the house, additional energy is returned to the grid.

100% Natural Ventilation
Ventilation is maintained through smart window technology which uses internal and external monitoring to automatically open and close windows as needed for a healthier interior environment.

Thermal Energy Storage
Mass is increased in the house by adding dense materials to the floors and stairs, thereby slowing thermal inertia to buffer both daily and seasonal changes in thermal conditions.

Almost Zero energy for Heating/Cooling
Geothermal wells provide all heating and cooling energy and via a minimal heat pump is circulated through radiant slabs in the house. A solar thermal panel on the roof provides all domestic hot water and can switch over to heat certain areas of the house.
Natural Ventilation
Pressure Coefficients Programmed Into Controls

Wind direction north west

Wind direction south west

<table>
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<tr>
<th>Zone</th>
<th>N</th>
<th>NE</th>
<th>E</th>
<th>SE</th>
<th>S</th>
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<td>335</td>
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<th>Cp 0</th>
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<td>-0.13</td>
<td>-0.19</td>
<td>-0.32</td>
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</table>
Radiant Slab
Heating Mode

\[ T_m = 24.5 - 0.14 \cdot (T_E + 15) \]

Local valve ON/OFF control

\[ T_{SUP} = 30 - 0.36 \cdot (T_E + 11) \]

\[ \Delta T = 2.8C \]

\[ \Delta T = 3C \]
Cooling Mode

Valve 100% open.

\( T_r \approx 23^\circ C \)

\( CO_2 \approx 850 ppm \)

Control by WM
Control Strategy

- **Valves open/close to maintain slab temp (dewpoint control)**

  - Slab valves 100% open
  - Slab valves closed
  - Slab valves open/close to maintain slab temp

- **Control Strategy**
  - High humidity cooling
  - Cooling
  - Passive
  - Heating
  - Slab valves 100% open
  - Valves open/close to maintain slab temp (dewpoint control)
  - Cooling from geo-exchange
  - Heating from geo heat pump

- **Ventilation Options**
  - Comfort ventilation:
    - 1,250 ppm
  - Pulse ventilation:
    - 1,050 ppm
    - 850 ppm

- **Temperature and Humidity**
  - 64°F (dewpoint)
  - 59°F
  - 46°F
Extech Sabic

Schuco FW 50+ SI

TYPICAL CW TO POLYCARBONATE TRANSITION
0540C4: PROVIDE ADDITIONAL FRAMING AT EACH ITEM 0843C1 LOCATION.

0512S: SEE STRUCTURAL DRAWINGS.
BRISTOL COMMUNITY COLLEGE
1st Floor
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
- (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 peak exhaust rate
- 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

- Chillers: (2) at 150 tons each
- Boilers: (2) at 3,750 MBH each
- Electrical Transformer: 1,000 kVA

(1) AHU: with Run-Around Loop Heat Recovery and (1) AHU with Enthalpy Wheel Energy Recovery

(2) AHUs with Run-Around Loop Heat Recovery and (1) AHU with Enthalpy Wheel Energy Recovery

24,000 cfm peak exhaust rate

Zero Net Energy

- Ground Source Heat Pumps:
  - (1) 70 ton
  - (1) 50 ton
  - (1) 30 ton
- Air Source Heat Pumps: (2) at 60 tons each
- Electrical Transformer: 1,000 kVA

- Enthalpy Wheel Energy Recovery
- Air Quality Monitoring
- Natural Ventilation in non-lab areas

- Lighting: 0.6 W/sf Plug Loads: 5 W/sf
- Lighting: 1 W/sf Plug Loads: 6–8 W/sf

- Fan-Coil Units provide Supplemental Cooling
- (30) 500' Deep Closed-Loop Wells

- 0.87 cfm/sf occupied
- 0.33 cfm/sf unoccupied

70 – 76°F
24,000 cfm peak exhaust rate

72 – 74°F
The chart illustrates the maximum measured simultaneous average for 1st + 2nd floor lab spaces, with different categories such as processing, chemistry, microbiology, biology, chemistry prep, bio stock, and others. The lines represent different scenarios, with ZNE, original, and subsequent projects. The values range from 0 to 10, with specific W/SF plug loads for each category.
High Performance

Zero Net Energy
$4,150,000
Net Present Savings

$230,000/yr
Operational Savings
(annual tuition for 50 students)
EUI = 45
The diagram shows the comparison between PV generation and building consumption over a year. The green line represents PV generation, peaking in summer months, while the blue line represents building consumption, which is more consistent throughout the year. The bar chart on the right indicates a significantly higher PV generation compared to building consumption.
Triple Glaze

Solar Array

Dual Wheel DOAS
Ground Source Heat Pump AHUs

Ground Source VRF

Ground Source DHW

Boilers (Back-Up)

Geothermal
Triple Glaze

Solar Array

Geothermal

DHW

Ground Source DHW

Ground Source VRF

Boilers (Back-Up)

Dual Wheel DOAS

Ground Source Heat Pump AHUs

Solar Array
$0.2M (increase)
Solar Shading Strategy
There are two shading strategies that are oriented to maximize shading.

Vertical Sawtooth
A vertical sawtooth with 60% glazing is used on the shallow single bay floor plate zone where daylight does not need to penetrate as deep into the floorplate.

Diagonal Louvers
A diagonal louver in front of 60% glazing is used in the deep floor plate zones to cut out the solar gain and drive daylight deep into the plan.
Chilled beams for space conditioning and ventilation
Supply air chase connected to air distribution ductwork
Return air chase
Fan powered box pulling air from plenum and providing cooling
Patented high strength, light weight fiberglass casing presents the lowest thermal resistance and pressure drop of any system commercially available. It is the proven leader of performance.

Nylon reinforced EDPM center flow channel provides thermal separation between the two fluid streams minimizing thermal crosstalk. Outer ridges provide convective heat transfer.
GEOTHERMAL REDUCE HEATING DEMAND

- Proprietary run-around heat recovery
- Roof PV (PPA)
- Condensing boiler
- Heat pump chillers
- Water cooled chiller plant
- Closed loop geothermal
- Radiant slab
- Triple glazing
- High performance facade
PRECEDENTS? (only in California and only government / university)
LIFE CYCLE COST

RELATIVE 20-YEAR NET PRESENT COST

Net Construction Cost
20-Year Natural Gas Cost
20-Year Electricity Cost
20-Year Evap Cooling Water Cost

Net Present Savings $16M
Simple Payback 1 Year

$16M NET PRESENT SAVINGS

Ultra-Low Fossil Fuel
SUMMARY
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<th>Office</th>
<th>Art + Media Studio</th>
<th>Teaching Lab</th>
<th>Research Lab</th>
<th>Inpatient Tower</th>
<th>Higher Ed</th>
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<td>Zone System</td>
<td>Radiant Slab</td>
<td>VRF Cassette</td>
<td>Fan Coil</td>
<td>Fan Powered Box + Chilled Beam</td>
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<td>Fan Powered Box + Chilled Beam</td>
<td>Fan Coil Unit (or Fan Powered Box + Chilled Beam)</td>
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<td>Enthalpy Wheel</td>
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<td>Proprietary Run-Around Heat Recovery</td>
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THANK YOU