Affordable Housing: Saving Energy & Money While Addressing Climate & Equity Goals

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Curated by Danny Veerkamp (Thoughtforms Corporation)

Northeast Sustainable Energy Association (NESEA)
February 28, 2022
Massachusetts Buildings: Energy and Carbon

- 27% MA emissions from buildings’ onsite fuels
- 2.0 million Number of existing buildings in MA that will exist in 2050
- 500,000 Number of new buildings expected in MA by 2050
PASSIVE HOUSE:
WHAT A TERRIBLE NAME!
Performance: Bristol Commons, Taunton 2014

16 Affordable 2-8 unit “stealth passive all electric”

Heating Energy/sq. ft. **78% less** than LEED Gold Townhouses

New Ecology Study excerpt. 5 Years of performance monitoring reports available.
Passive House Skepticism

PASSIVE HOUSE?

SOUNDS EXPENSIVE
Passive House Design Challenge

• Up to $4,000 per unit incentive
• 8 Affordable Projects: 540 Units
• 5 Occupied; 3 Under Construction
Incremental Cost of Passive House Standard: 2.4% average

Does not include final change orders for Kenzi and Mattapan Station; incentives not included
What are the biggest incremental costs?

- Much better ventilation
- Windows and Doors
- Efforts to reduce thermal bridging
- Higher level of construction verification

Heating and Cooling Equipment Cost Decrease:
- 6 out of 8 projects have **significantly lower size and cost for heating and cooling** equipment

- Window premium is coming way down. In some cases, cost neutral
LESSONS

- Architects with more PH training and experience had lower cost; better outcomes
- Decide early if you are seeking PH certification; if whole team on board coming out of charrette, more will go more easily
- There is a large learning curve on first PH project – expect it
- Give yourself plenty of room in PH model for things to go wrong
- All 7 of 8 projects likely to get PH certification successfully, MassSave fallback incentives still reward trying and above code outcome
- More complex roofline = more expensive
Passive House Multifamily Incentives

- 100% of feasibility study cost up to $5,000
- 75% of PH modeling cost up to $20,000
- $3,000 per unit for PH certification
Current PH Enrollment Stats

- 116 buildings enrolled for PH incentives
- Represents 6,500+ units
- 70 buildings have completed PH feasibility studies

Passive House Education

- PH Lunch & Learns/Workshops: 59
- Total Attendees: 2,497
- PHIUS/ PHI Accreditation Reimbursements: 107

- See phmass.org video library for free recordings
PH Performance: Distillery, Boston 2020

Uses 63% less energy per sq. ft. than median new multifamily in Boston.

Data from Boston Energy Disclosure 2020 sorted for new construction multifamily built since 2010; Cross checked for LEED certification; Credit to Jayne Lino, MassCEC
PH Performance: Philadelphia 2019 Affordable

57% less energy per sq. ft. than Median Code Built

Data from Philadelphia Energy Disclosure 2019 cross checked for LIHTC multifamily; Credit to Green Building United, Katie Bartolotta
PH Performance 2019: Gilford Village Knowles III, NH

PH uses 49% less energy per sq. ft. than Gilford Village Knowles II LEED built 2008 (same building, different standard)

Graphic representation of study by Resilient Building Group (2020 Report of average 3 year energy usage data ending in 2019)
New Hampshire Affordable Multifamily

42% less energy per sq. ft than Median LEED

Graphic representation of study by Resilient Building Group (2021), New Construction 2006+, LIHTC
• Two paths now for energy performance: New Construction and Rehab (Preservation)
• 5 points more for new construction Passive proposal
• Rehab now must meet Enterprise Green Communities mandatory requirements
• 3 points for reduced embodied carbon
TRIPLE DECKER DESIGN CHALLENGE GOALS

• Identify scalable and replicable system designs for triple decker energy fossil fuel free retrofits

• Assess opportunity to add additional unit during the energy retrofit process

• Consider the full carbon impact of retrofit options including embodied carbon
<table>
<thead>
<tr>
<th>Poster</th>
<th>Project Name and Summary</th>
<th>Description</th>
</tr>
</thead>
</table>
| ![Poster](image1.png) | **Winner: Triple Decker Retrofit Design**  
**TDC Retrofit Toolkit:** by Zephyr Architects  
**Design Drawing**  
**Narrative**  
**Video** | - This Triple Decker Retrofit Design provides a series of tools to help home owners decide the most effective ways to renovate their buildings, balancing immediate benefits with long-term savings.  
- Estimated construction cost: $152,149 (and $16,700 Solar PV)  
- 94% decrease in annual energy use; HERS rating change: 174 to 11  
- 3,500 kgCO2e embodied carbon emissions in proposed building material  
- Solar PV: 5.6kW  
- Heating & Cooling: Air-source heat pumps (ducted), Hot Water: Hybrid heating |
| ![Poster](image2.png) | **Winner: 3+ Retrofit Design**  
**The Back Stack:** by MERGE Architects Inc.  
**Design Drawing**  
**Narrative**  
**Video** | - This 3+ Retrofit Design adds an additional 3 story unit (of 1,100 sq. ft.) and future living units adjacent to the building. Existing tenants at the rear of the building.  
- Estimated construction cost: $620,010 ($288,210 to retrofit the existing structure and $331,800 for the new unit)  
- 80% decrease in annual energy use; HERS rating change: 173 to 34  
- 3,900 kgCO2e embodied carbon emissions in proposed building material  
- Solar PV: 4kW  
- Heating & Cooling: Air-source heat pumps (ductless), Hot Water: Heat pump |
POOR EXISTING CONDITION MEANS DEEP ENERGY SAVINGS POSSIBLE

- 3 to 5 times more energy use than similar new construction
  - HERS ratings started between 170 and 297

- Proposals reduced energy usage from 61% to 104%

- Cost w/o solar ranged from $150,000 to $530,000
ON-SITE SOLAR PV

• All but one of the Triple Decker Design Challenge submissions installed Solar PV

• Solar PV was always a good investment with a payback of ~8 years

• What areas should the solar PV power?

Making Cents of Carbon, DiMella Shaffer
WHY ADD AN ADDITIONAL UNIT?

• Adding an additional unit could change the economics of the project if the revenue from the additional unit could pay for the retrofit of the existing building

• Way to add gentle density to a city

AFFORDABLE RFP NOW OPEN

• 10 pilot buildings will get up to $120,000 of additional incentive above MassSave low income incentives.
AI INFORMED SUSTAINABLE DESIGN

Faster, Smarter, More Sustainable, Design + Design Process

NESEA, February 28, 2022

Presented by Prudence Ferreira, Sr Associate, BR+A Consulting Engineers
Prepared by Trevor Fedyna, Principal, Unconstrained Development LLC
CONSTRUCTION COST PREMIUM

<1%

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02 The Importance of Persuasive and Informed Early Phase Design Tools

03 Proj_LrAx

04 Combining Human Expertise, PINNs and Data-Reuse

The Road Ahead
Evolutionary Optimization

Brute Force Iteration

Neuro-Evolution of Augmenting Topologies

Physics Informed Neural Network

How to Apply Them?
Brute Force Iteration Example
Single Objective Evolutionary Optimization

Heat Loss Form Factor Minimization Via SOEO
MULTI-OBJECTIVE EVOLUTIONARY OPTIMIZATION
THE ELEPHANT IN THE ROOM

1% of world energy use is cloud computing

Cloud computing is accepted as ~50% more energy efficient than local server farms.

+1 for cloud compute! But we can do better still, we can utilize a “sustainable data recycling ecosystem” and further minimize the impact of computational design and engineering.
Importance of Persuasive, Accurate, Informed Early Phase Design

Setting the Tone, Leading the Charge With Confidence and Precision
THE ROAD AHEAD

Preliminary Regression Modeling, Scoring ~0.05 (max score: 1)
NEXT STEPS

• Create initial proof-of concept PINN using the $Q_H = Q_T + Q_V - [\eta \times (Q_S + Q_I)]$ Family of equations

• Continue Parametric studies, utilizing in-house data schema for uniformed training materials

• Learn, Do, Teach, Share
THANK YOU!

Prudence Ferreira, CPHC
Sr Associate, Passive House Practice Lead
BR+A Consulting Engineers
pferreira@brplusa.com
Agenda

1. MISSION FIRST
2. MODEL SECOND
3. WHAT WE’VE MADE
4. LESSONS LEARNED
1. MISSION FIRST
PT’s mission is to facilitate Boston’s rapid transition to Future Housing; healthy for the person, healthy for the community, healthy for the planet.
4 CRISSES IN BOSTON

Climate crisis

Housing crisis

Community / Gentrification crisis

Health crisis
WHAT WE DO:

*Design, development and innovation for hyper-sustainable urban housing.*

Placetailor is transforming Boston into the ultimate practice-based R&D project. Through solving the challenge of Boston, the blueprint to reforming the planet’s cities will be cast, and shared.
Every project we've designed or built since founding in 2008 has been Passive House or Zero Net Energy.

Every project has exceeded the AIA 2030 goals.
2. MODEL SECOND
Each division shares common management resources, such as marketing, accounting, etc.

Each division can work independently on their own projects.
Each division can collaborate with one another on a specific project.
3. WHAT WE’VE MADE
P-B R&D DNA

- 100% commitment to mission
- Model follows the mission
- IP value is captured
- R&D master plan
- R&D on every project
- Culture of DO LEADERSHIP
MODEL A

R and D in various high performance stick-built assemblies
MODEL B

Innovations in delivery model for high performance panelized prefab
MODEL C

First Boston full CLT
MIT R and D meets mission-first PT
PRODUCT R&D

Integrated analysis from perspectives of energy design, constructability, and development bottom-line
DECARB’ING THE TRIPLE DECKER

Prefab retrofit panel system
+ scalable delivery model
lowered with application of insulating envelope; gas-fired boilers are replaced with Energy Recovery Ventilators and mini-split Heat Pumps.

Neighborhood-based projects provide opportunities to upgrade houses and the fabric that weaves them together: the preservation and/or incorporation of urban green spaces, trees, & accessible entrances to existing houses.
<table>
<thead>
<tr>
<th>Feature</th>
<th>Site Built-Up Siding w/ Insulation</th>
<th>Nail Built Insulated Panel</th>
<th>Exterior Insulation and Finish System</th>
<th>PT Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Neutral Product</td>
<td>○</td>
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<td>●</td>
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<tr>
<td>Low Waste Production</td>
<td>○</td>
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<td>Minimized On-Site Labor</td>
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<tr>
<td>Customized Patterns + Textures</td>
<td>○</td>
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<td>OSHA Friendly Install</td>
<td>○</td>
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<td>●</td>
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<tr>
<td>Cost Competitive vs. Traditional Siding</td>
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<td>○</td>
<td>●</td>
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</tbody>
</table>
Melnea Cass

- 200 Units
- LEED Platinum
- 100% Affordable
Castle Square

- 500 Units
- In-Place Deep Energy Retrofit
- LEED Silver
63 Moreland

- 7 Unit
- Model B
- Net Zero Ready
31 Tufts

- 15 Units
- Model A
- ILFI zero carbon cert pilot
- Pursuing PHIUS Cert
201 Hampden

- 14 Units
- First full CLT in Boston
- Affordable commercial ground
- Pursuing PHUIS Certification
Dudley St.

- 22 Units
- Model B
- Community Space
- HNEF II Fund
1 Elmwood

- 45 Units
- Model C
- Ground floor commercial
- “Civic Entrepreneur” client
City of Boston - Department of Neighborhood Development

2020

guidebook for Zero Emission Buildings (ZEBs)
A higher r-value also means an improved energy balance because less heat is lost in the winter and gained in the summer.
parametric energy modeling

To perform the analysis the team utilized parametric energy modeling, where many combinations of building approaches and features are rapidly and automatically tested by computer programs in order to help find the most energy-efficient and cost-effective combined strategies. Each typology was simulated with approximately 38,000 combinations of variables including envelope air-tightness, opaque envelope R-Values, window and glazing properties, ventilation system alternatives, heating/cooling systems, and domestic hot water systems. The large-batch optimization studies used WUFI-Plus from Fraunhoffer IBP, with the results post-processed and analyzed using Thornton Tomasetti’s Design Explorer, an interactive and multi-dimensional data visualization tool that allowed the team to filter iterations for specific outcomes such as CO2e footprint per person and operational utility cost.
building v portfolio

Further supporting the portfolio approach to reaching zero emissions, the top diagram shows how important it is for smaller buildings to actually be net energy positive. They generate excess power that larger buildings can not. The lower diagram illustrates the portfolio concept: Not all the buildings need to be Zero Emissions, but as a community of buildings are measured together the same outcome is reached.

Applying this approach of a carbon budget per person to existing buildings would be the first step in generating a Zero Emissions plan for the City as a whole.

In cities like Boston with dense housing, there is more opportunity for increasing efficiency when accounting for the entire urban fabric. Zero Emission Buildings are a key component to implementing a clean energy future.
building elements and operation - cost analysis

<table>
<thead>
<tr>
<th></th>
<th>Small Multifamily</th>
<th>2 Story Multifamily</th>
<th>4 - 5 Story Multifamily</th>
<th>6 Story Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 unit bldg</td>
<td>14 unit bldg</td>
<td>50 unit bldg</td>
<td>52 unit bldg</td>
</tr>
<tr>
<td>Stretch Code Baseline Building</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stretch Code EUI (kBtu/sf/yr)</td>
<td>24</td>
<td>34.2</td>
<td>25.5</td>
<td>26.8</td>
</tr>
<tr>
<td>CO2e / per person baseline Stretch Code (mTons/kwh)</td>
<td>0.86</td>
<td>1.19</td>
<td>0.8</td>
<td>0.82</td>
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<tr>
<td>Annual Utility Cost per living unit - 1.52 (dollar / therm)**</td>
<td>$1,820</td>
<td>$1,211</td>
<td>$1,368</td>
<td>$1,481</td>
</tr>
<tr>
<td>Stretch Code Baseline Build cost ($)*</td>
<td>$358,766</td>
<td>$387,988</td>
<td>$1,298,574</td>
<td>$1,464,522</td>
</tr>
<tr>
<td>Zero Emission Building</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZEB EUI (kBtu/sf/yr)</td>
<td>18</td>
<td>26</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>CO2e / per person ZEB (mTons/kwh)</td>
<td>0.77</td>
<td>0.77</td>
<td>0.77</td>
<td>0.77</td>
</tr>
<tr>
<td>Annual Operational Cost per Unit ZEB - 22.61 (cents/kWh)</td>
<td>$1,450</td>
<td>$1,200</td>
<td>$1,100</td>
<td>$1,100</td>
</tr>
<tr>
<td>ZEB Baseline build cost ($)*</td>
<td>$361,913</td>
<td>$390,312</td>
<td>$1,310,419</td>
<td>$1,496,920</td>
</tr>
<tr>
<td>Stretch Code vs ZEB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incremental Cost difference to ZEB ($) Total project cost</td>
<td>$3,148</td>
<td>$2,324</td>
<td>$1,145</td>
<td>$3,398</td>
</tr>
<tr>
<td>Incremental Cost to ZEB (% increase)</td>
<td>0.88%</td>
<td>0.60%</td>
<td>0.91%</td>
<td>2.23%</td>
</tr>
<tr>
<td>Incremental change per person CO2e ZEB (% decrease)</td>
<td>-25%</td>
<td>-24%</td>
<td>-18%</td>
<td>-33%</td>
</tr>
<tr>
<td>Incremental Cost difference to ZEB (% decrease) operational cost</td>
<td>-20%</td>
<td>-1%</td>
<td>-20%</td>
<td>-26%</td>
</tr>
<tr>
<td>Renewables - Rebates and Incentives are not included</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar PV size (KW) - 75% of Roof Areas</td>
<td>37 KW</td>
<td>40 KW</td>
<td>156 KW</td>
<td>104 KW</td>
</tr>
<tr>
<td>PV cost installed (Average $3.16 / watt)</td>
<td>$117,000</td>
<td>$126,000</td>
<td>$492,000</td>
<td>$338,000</td>
</tr>
</tbody>
</table>

* Baseline cost is per modeled building component only (U-value, SHGC, Air-Tightness, Heat Recovery efficiency, Domestic Hot Water, Heating, Roof R, Walls R, Floor R)

** Stretch code operating cost - Operating costs based on 2018/2019 and 2019/2020 Mass DCCER heating cost data.
Plug loads were normalized based on DND occupant criteria (1 people per bedroom) for both Stretch Code and ZEB operating costs.

How to use this table:
Modeled categories are compared across each typology using stretch code as a baseline standard for energy use, carbon emissions, and construction cost. The table highlights the benefits associated with Zero Emissions Buildings, energy and carbon reductions. The table also displays the incremental change associated with operational cost, construction cost, and carbon reduction for the modeled building elements.
4. LESSONS LEARNED
Cost Offsets

1. Operational Costs
2. Zoning Approval Process
3. Incentives / Rebates / Grants
4. Sales / Rental Prices
Thank you.

Colin Booth
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