

BUILDINGENERGY BOSTON

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**

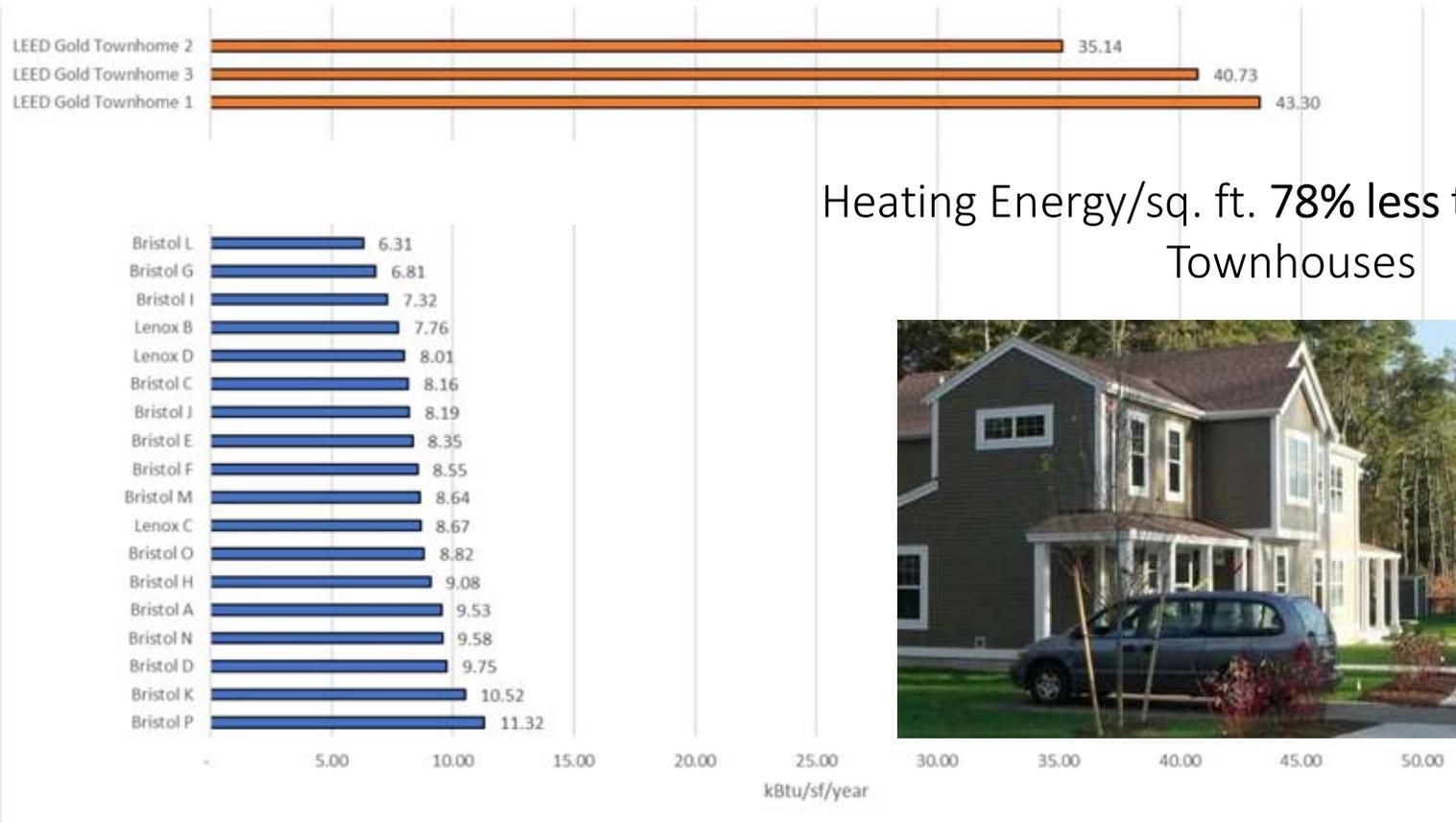
500,000

**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 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

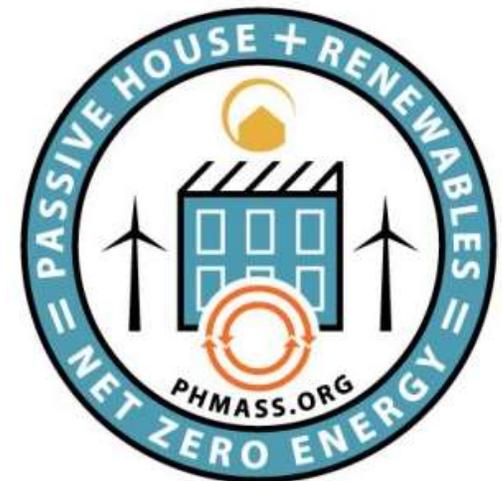


- 116 buildings enrolled for PH incentives
- Represents 6,500+ units
- 70 buildings have completed PH feasibility studies

Passive House Education

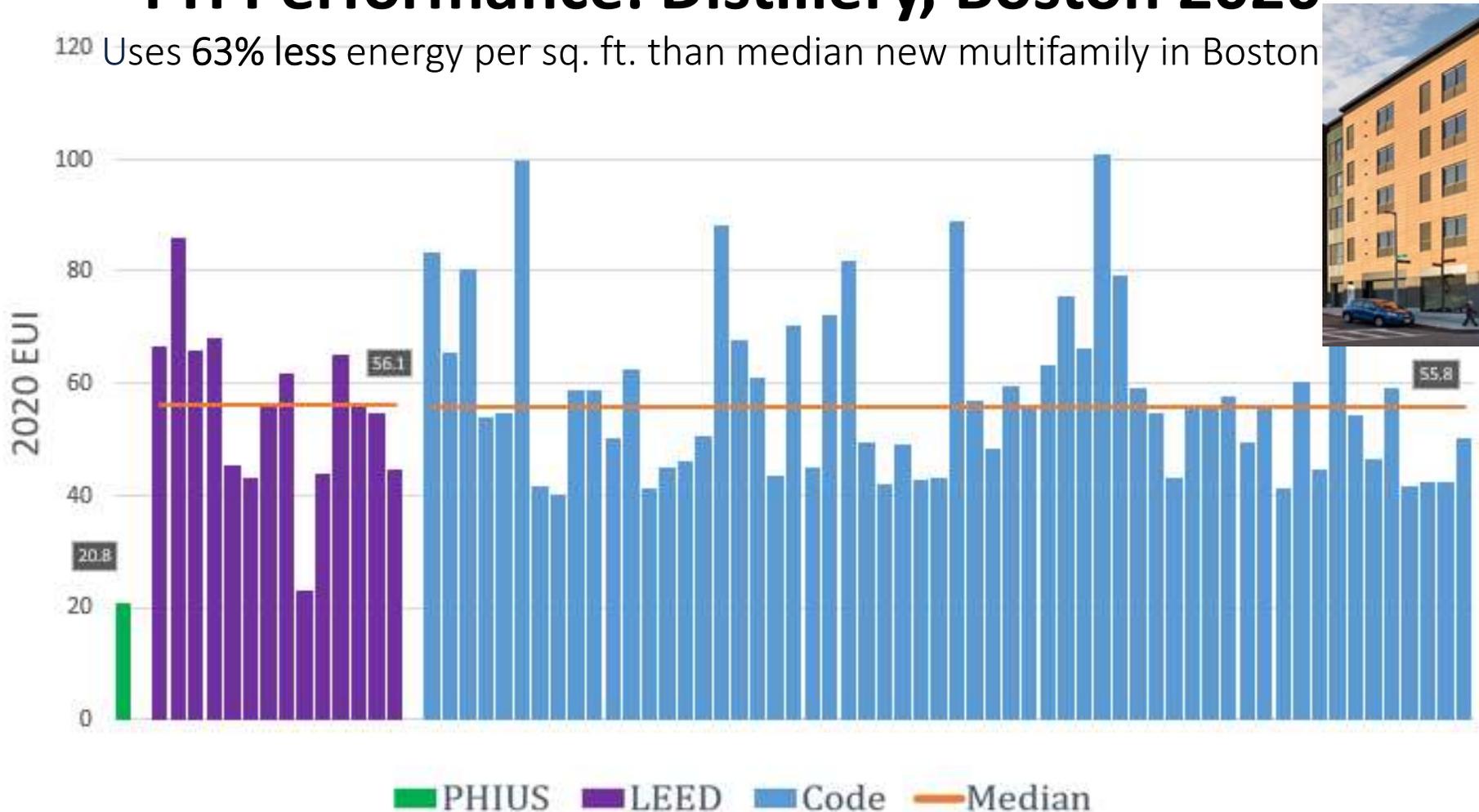
- PH Lunch & Learns/Workshops: 59
- Total Attendees: 2,497
- PHIUS/ PHI Accreditation Reimbursements: 107

- **See phmass.org video library for free recordings**



PH Performance: Distillery, Boston 2020

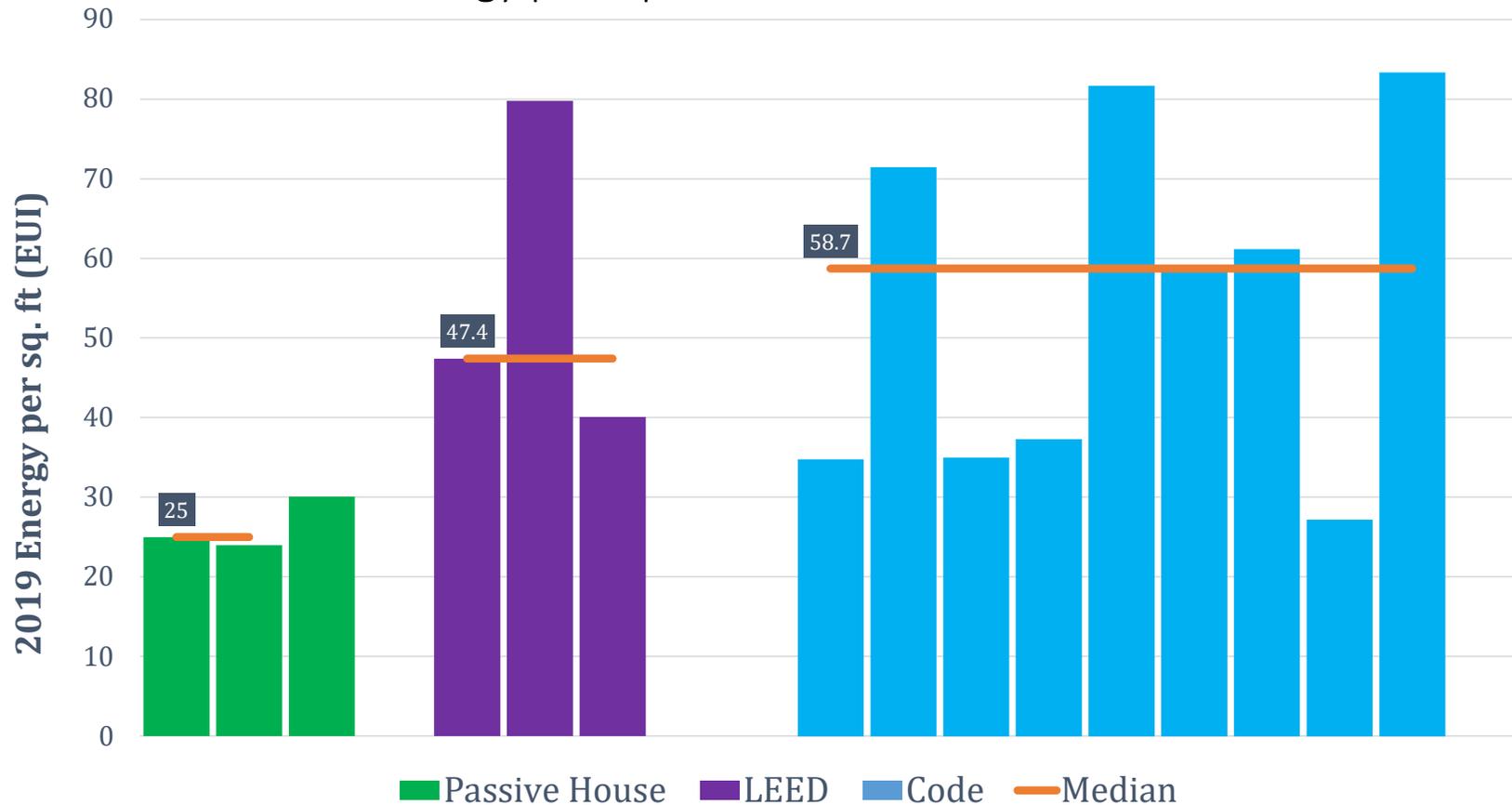
120 Uses 63% less energy per sq. ft. than median new multifamily in Boston



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

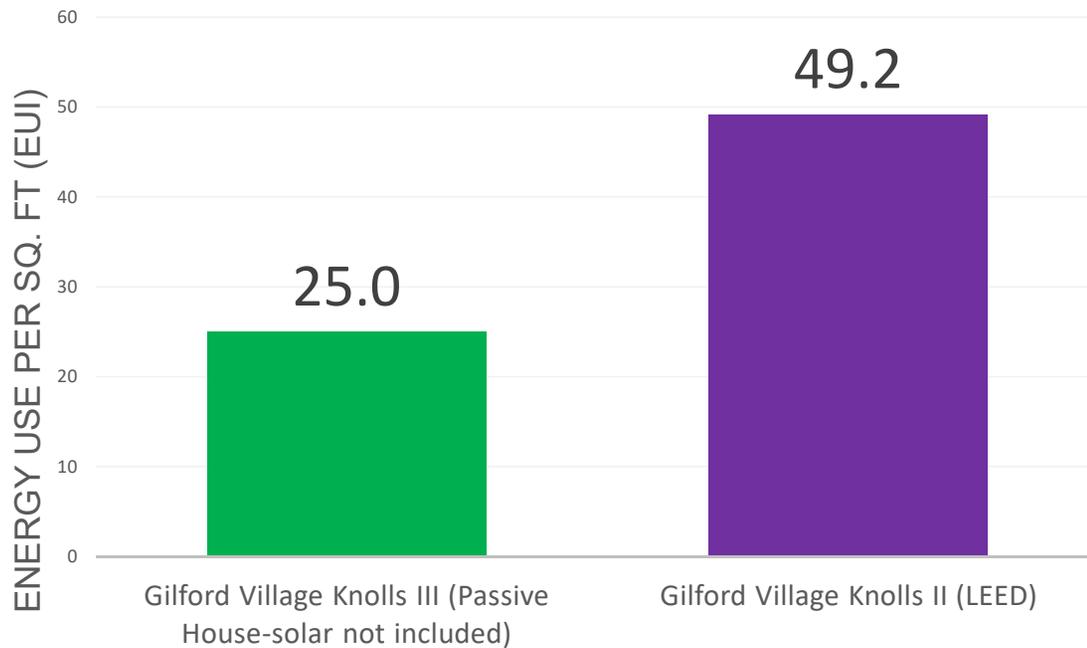
57% less energy per sq. ft. than Median Code Built



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

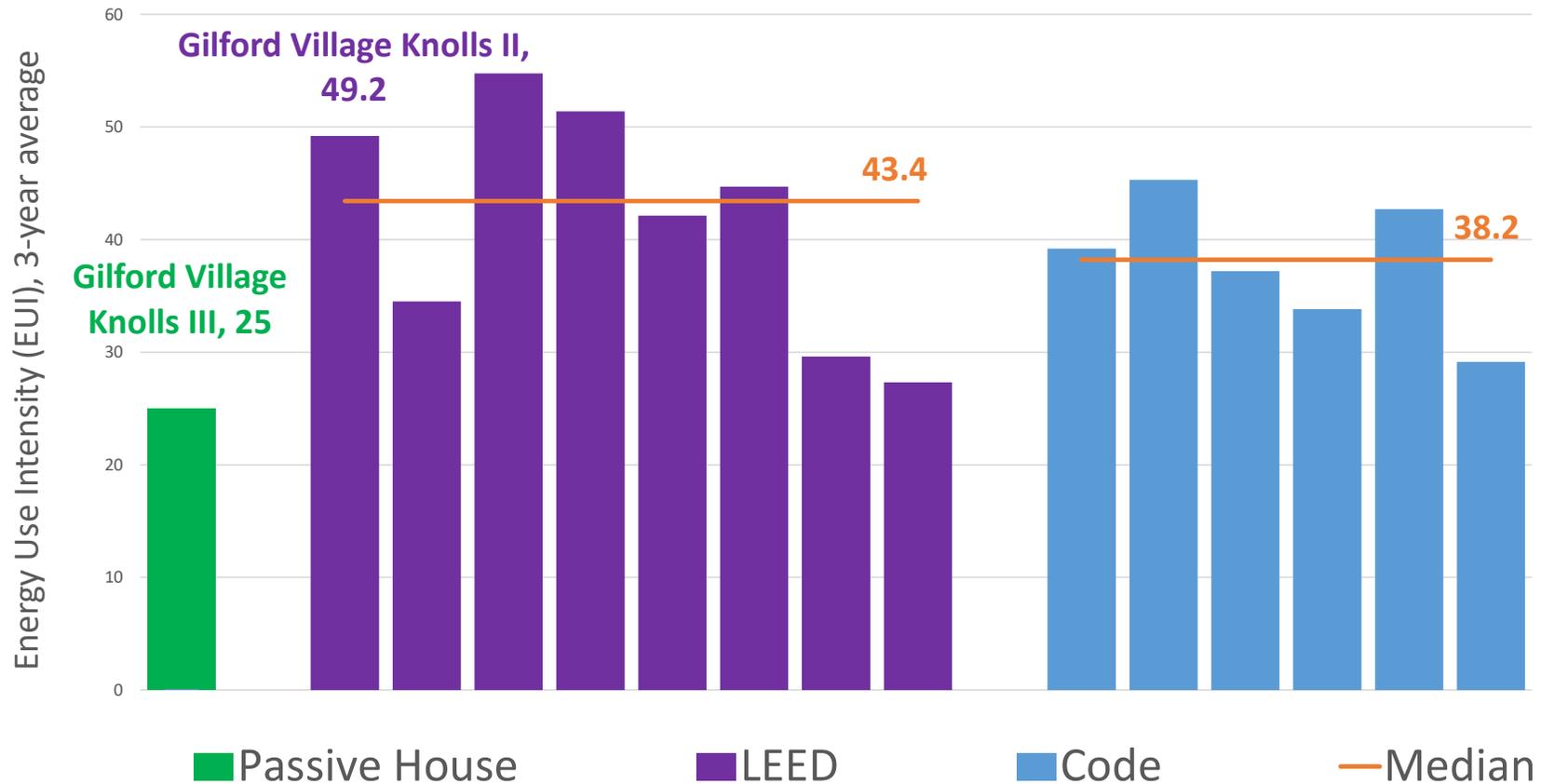
PH uses 49% less energy per sq. ft. than Gilford Village Knowles II LEED built 2008
(same building, different standard)



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

MA Low Income Housing Tax Credits (QAP Scoring draft)



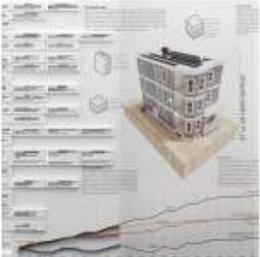
- Two paths now for energy performance: New Construction and Rehab (Preservation)
- 5 points more for new construction Passive proposal
- Rehab now must meet Enterprise Green Communities mandatory requirements
- 3 points for reduced embodied carbon

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

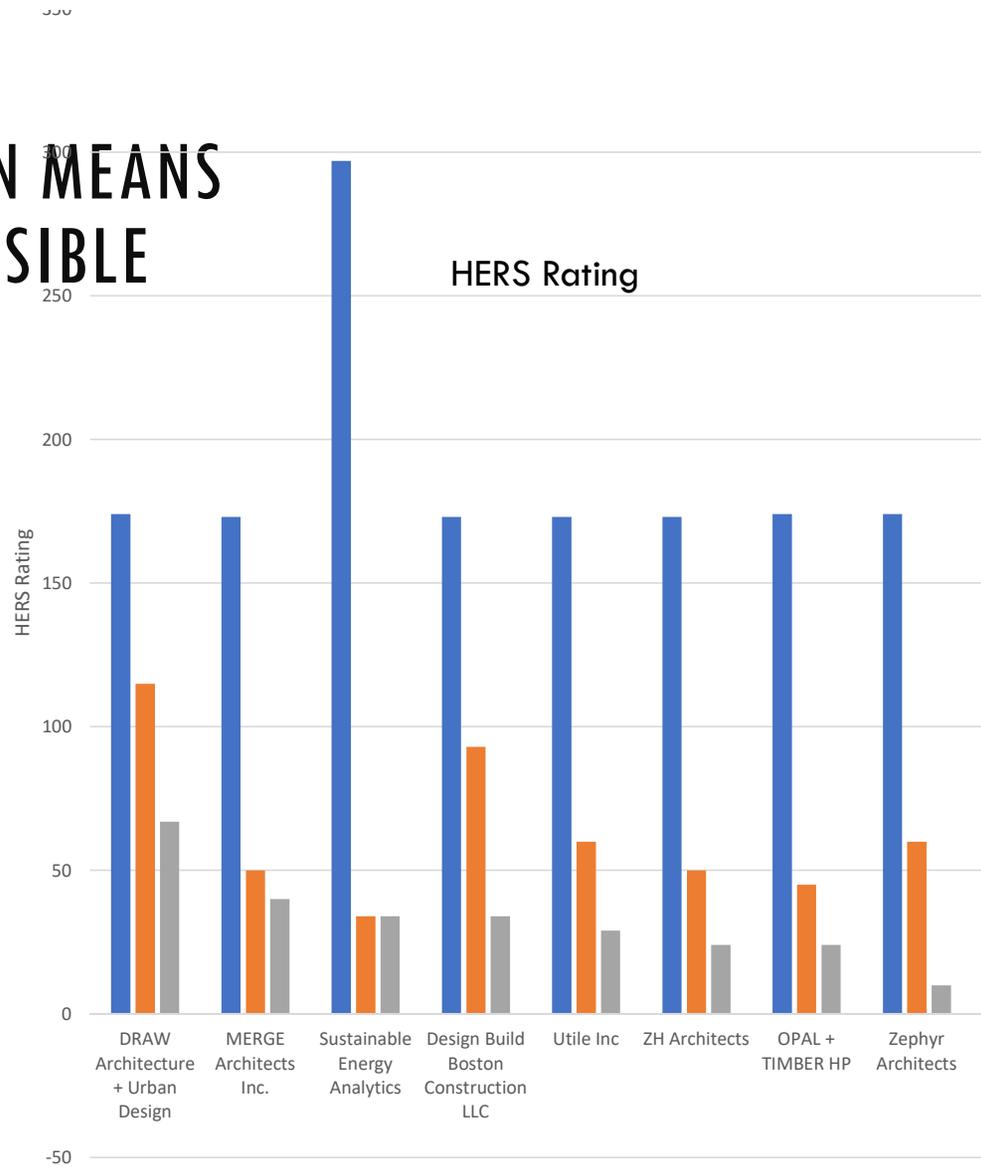


Bit.ly/3Decker

| Poster | Project Name and Summary | Description |
|--|--|--|
|  | <p>Winner: Triple Decker Retrofit Design</p> <p>TDC Retrofit Toolkit: by Zephyr Architects</p> <p>Design Drawing</p> <p>Narrative</p> <p>Video</p> | <ul style="list-style-type: none"> • This Triple Decker Retrofit Design provides a series of tools to help homeowners find the most effective ways to renovate their buildings, balancing immediate needs with long-term goals. • 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 heat pump |
|  | <p>Winner: 3+ Retrofit Design</p> <p>The Back Stack: by MERGE Architects Inc.</p> <p>Design Drawing</p> <p>Narrative</p> <p>Video</p> | <ul style="list-style-type: none"> • This 3+ Retrofit Design adds an additional 3 story unit (of 1,100 sq. ft.) and retrofits 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 additional 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.



*The Back Stack: MERGE
Architects, Inc.*



*Fort Hill Triple Decker: West
Faulkner & Placetaylor*



Boston HiP: ZH Architects

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





BRA+

CONSTRUCTION COST PREMIUM

<1%

<1%

<1%

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TABLE OF CONTENTS

The Importance of Persuasive
and Informed Early Phase Design
Tools

The Road Ahead



Introduction to Computational Optimization

Proj_LrAx

Combining Human Expertise, PINNs and
Data-Reuse



01

**Evolutionary
Optimization**

**Neuro-Evolution of
Augmenting Topologies**

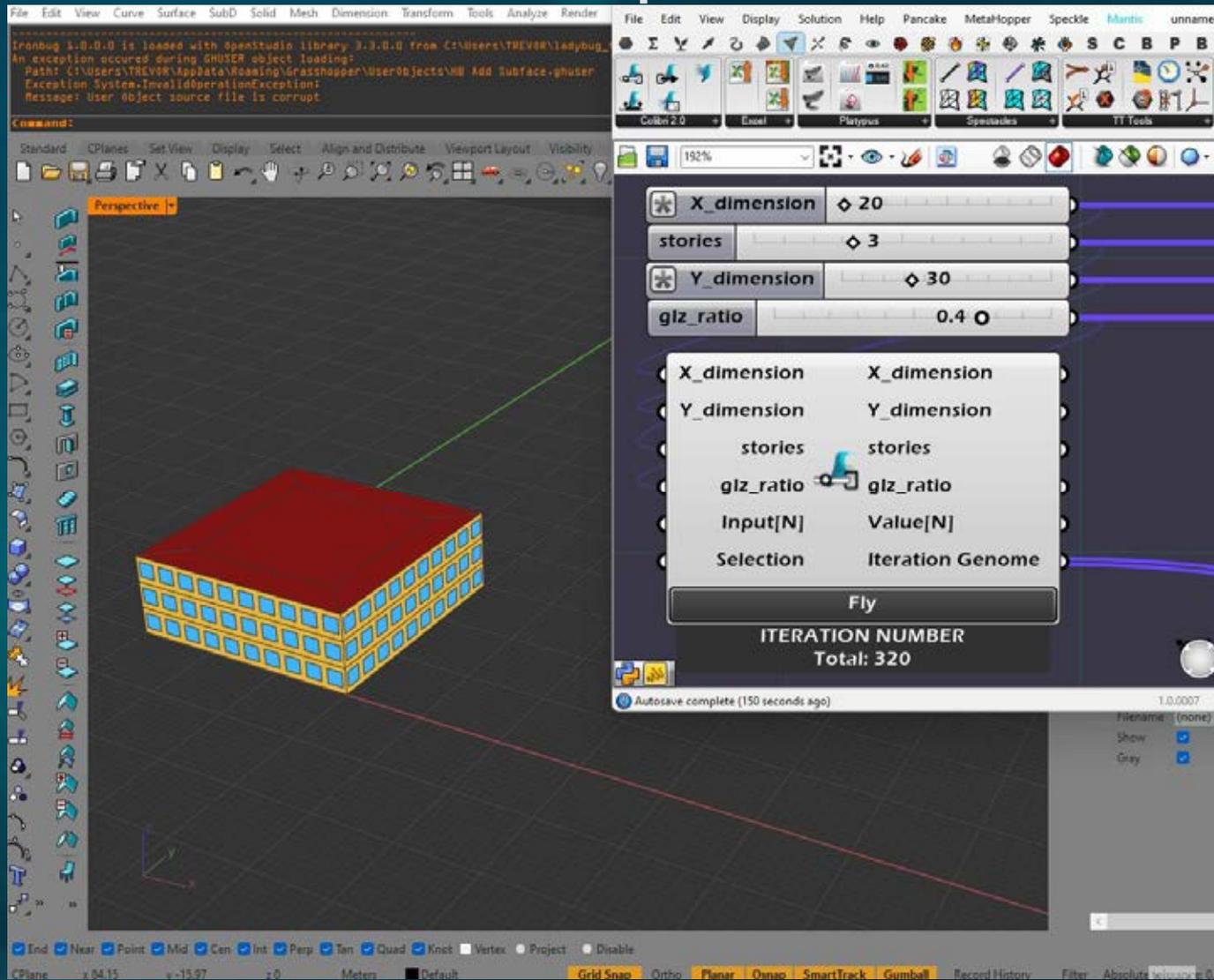
**Brute Force
Iteration**

How to Apply Them?

Physics Informed Neural Network



Brute Force Iteration Example



Single Objective Evolutionary Optimization

The image displays a software interface for evolutionary optimization, likely OpenStudio. The main window shows a 3D perspective view of a building model with a red roof and yellow walls. The interface includes a menu bar (File, Edit, View, Curve, Surface, SubD, Solid, Mesh, Dimension, Transform), a command line, and a toolbar. A 'Solvers' panel is open, showing a 'Start Solver' button and a 'Stop Solver' button. Below the solver panel, there are two visualization windows: one showing a scatter plot of points (black dots and red crosses) and another showing a mesh of a building facade. To the right of these windows is a 'Display' section with a 'Reinstate' button and a list of numerical values with corresponding progress bars.

The bottom part of the image shows a workflow diagram titled 'Heat Loss Form Factor Minimization Via SOEO'. The diagram consists of several interconnected components:

- Genome Fitness**: A green box at the top right, connected to the workflow.
- Rooms**: A box labeled 'rooms' with 'log_area' and 'Enc' outputs.
- ext_wall_area**: A box with 'ext_min_area' and 'volume' outputs.
- rooms**: A box with 'floor_area' and 'floor_ep_carpet' outputs.
- Input**: Two boxes labeled 'Input' with 'Result' and 'Partial Results' outputs.
- Result**: A box labeled 'Result' with 'A' and 'B' outputs.
- X coordinate**: A box with 'Count', 'Length', and 'nb_npt' outputs.
- Data**: A box with 'Data' output.
- Stores**: A box with 'Stores' output.

The status bar at the bottom indicates 'Autosave complete (230 seconds ago)' and '1.0.0007'.

MULTI-OBJECTIVE EVOLUTIONARY OPTIMIZATION

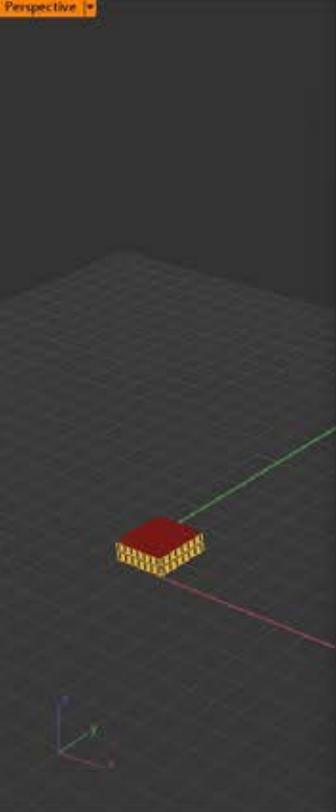
File Edit View Curve Surface SubD Solid Mesh Dimension

Ironbug 1.0.0.0 is loaded with openstudio library 1.2.0.
An exception occurred during GHUSER object loading:
Path: C:\Users\TREVOR\AppData\Roaming\Grasshopper\User
Exception System.InvalidOperationException:
Message: User Object source file is corrupt

Command:

Standard CPanes Set View Display Select Align and Dist

Perspective



End Near Point Mid Cen Int Perp Tan Qul

CPlane x: 49.76 y: 31.51 z: 0 Melec.

Wallace Settings Wallace Analytics Wallace Selection Wallace Forum Wallace Primer

Control Panel

Population
 Generation Size: 6
 Generation Count: 1000
 Population Size: 6000

Algorithm Parameters
 Crossover Probability: 0.9
 Mutation Probability: 1/n
 Crossover Distribution Index: 20
 Mutation Distribution Index: 20
 Random Seed: 1

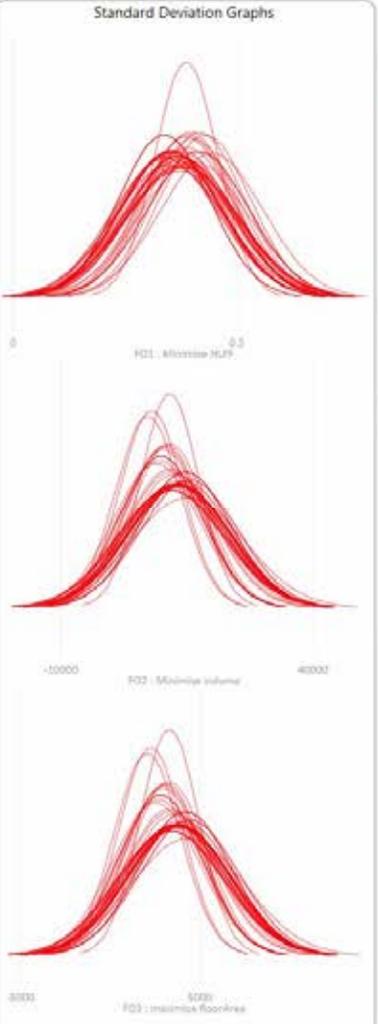
Simulation Parameters
 No. of Genes (Sliders): 4
 No. of Values (Slider Values): 17
 No. of Fitness Objectives: 3
 Size of Search Space: 3.2e3

RunTime ● Number of Nulls: 0
 Current Solution / Generation: 1 / 56
 Number of Pareto Front Solutions: 6
 Eval. Time Per Solution: 0:00
 Estimated Time Remaining: 0:31:2
 Simulation Runtime: 0:1:51

Dynamic Graphs Preferences
 Dynamic Parallel Coordinate Plot:
 Dynamic Standard Deviation Plot:
 Dynamic Objective Space:
 Dynamic Pareto Front Solutions:
 Autoseve:
 Minimize Rhino On Start:

Snap Start Stop Reset

Standard Deviation Graphs

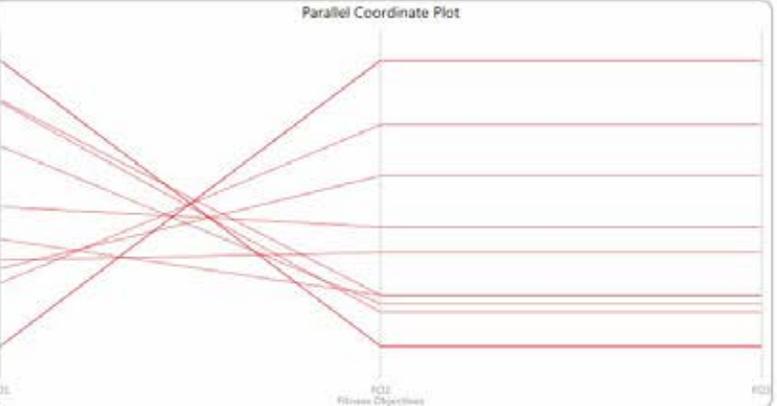


F01 : minimize height

F02 : Minimize volume

F03 : maximize floorarea

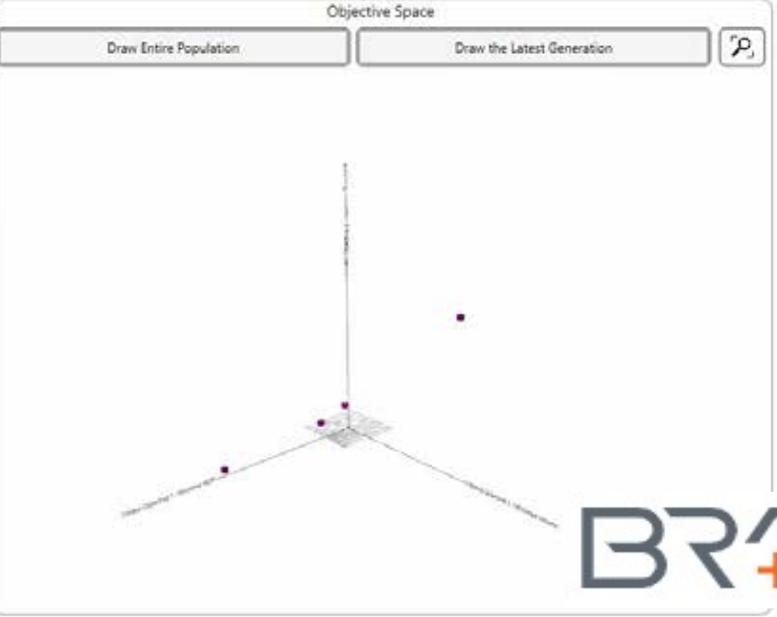
Parallel Coordinate Plot



F01 Fitness Objectives F02 F03

Objective Space

Draw Entire Population Draw the Latest Generation



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.

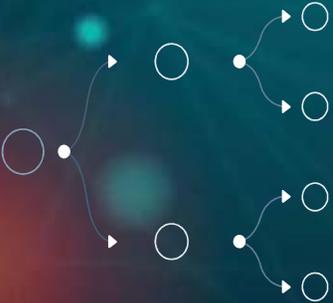


02

Importance of Persuasive, Accurate, Informed Early Phase Design

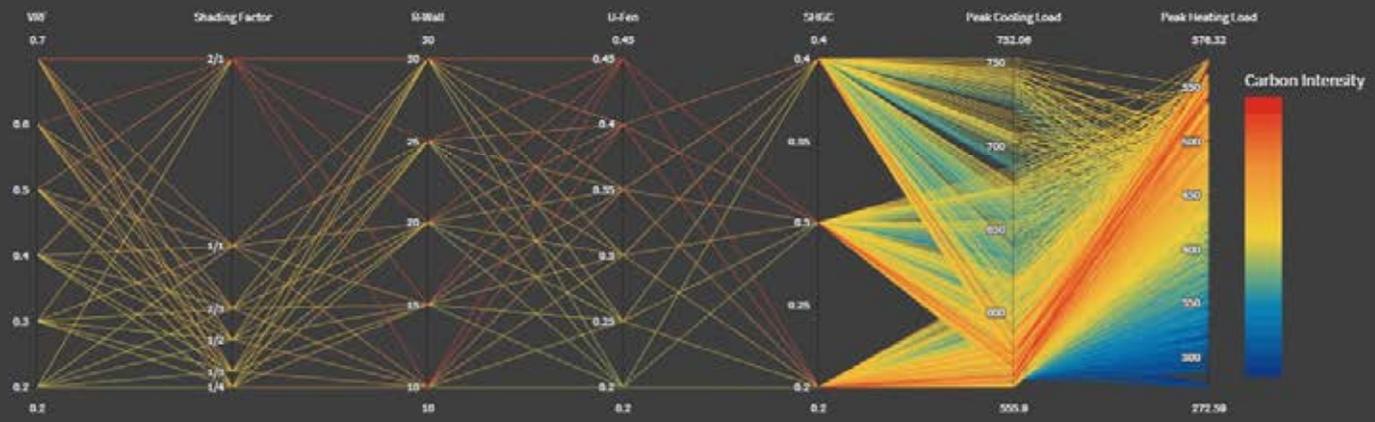


Setting the Tone, Leading the Charge With Confidence and Precision





Early Phase Envelope Sensitivity



Sweet's 17
2.1.3
Get updates, docs & report issues here
Created & maintained by François Bertrand
Graphic design by Jean-François Hébert

| EDA | | NO COMPARISON TARGET |
|----------|-------------|----------------------|
| 3930 | ROWS | |
| 0 | DUPLICATES | |
| 408.7 kb | RAM | |
| 12 | FEATURES | |
| 7 | CATEGORICAL | |
| 5 | NUMERICAL | |
| 0 | TEXT | |

ASSOCIATIONS

03



Human Expertise



PINN



Data-Reuse

Proj_LrAx

Min-GHG



Min-\$\$\$

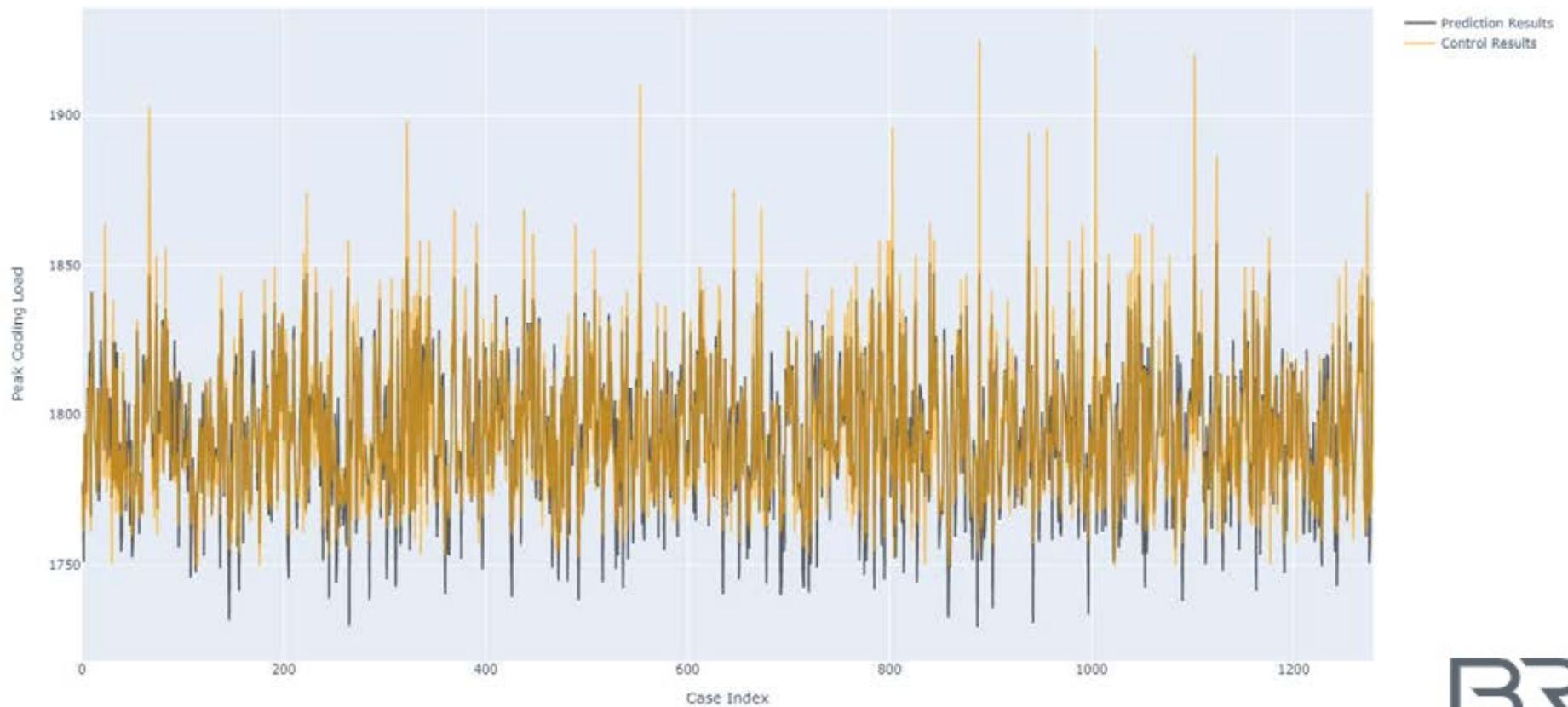


Max-Effi



THE ROAD AHEAD

Preliminary Regression Modeling, Scoring ~0.85 (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**



PLACETAIIOR

Urban
Design
Build

**Occupy
the Future.**

Agenda

1. MISSION FIRST
2. MODEL SECOND
3. WHAT WE'VE MADE
4. LESSONS LEARNED

1. MISSION FIRST

ACTI VISM ARCH ITECTURE



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 CRISES IN BOSTON

Climate crisis

Housing crisis

Community / Gentrification crisis

Health crisis

WHAT WE DO:

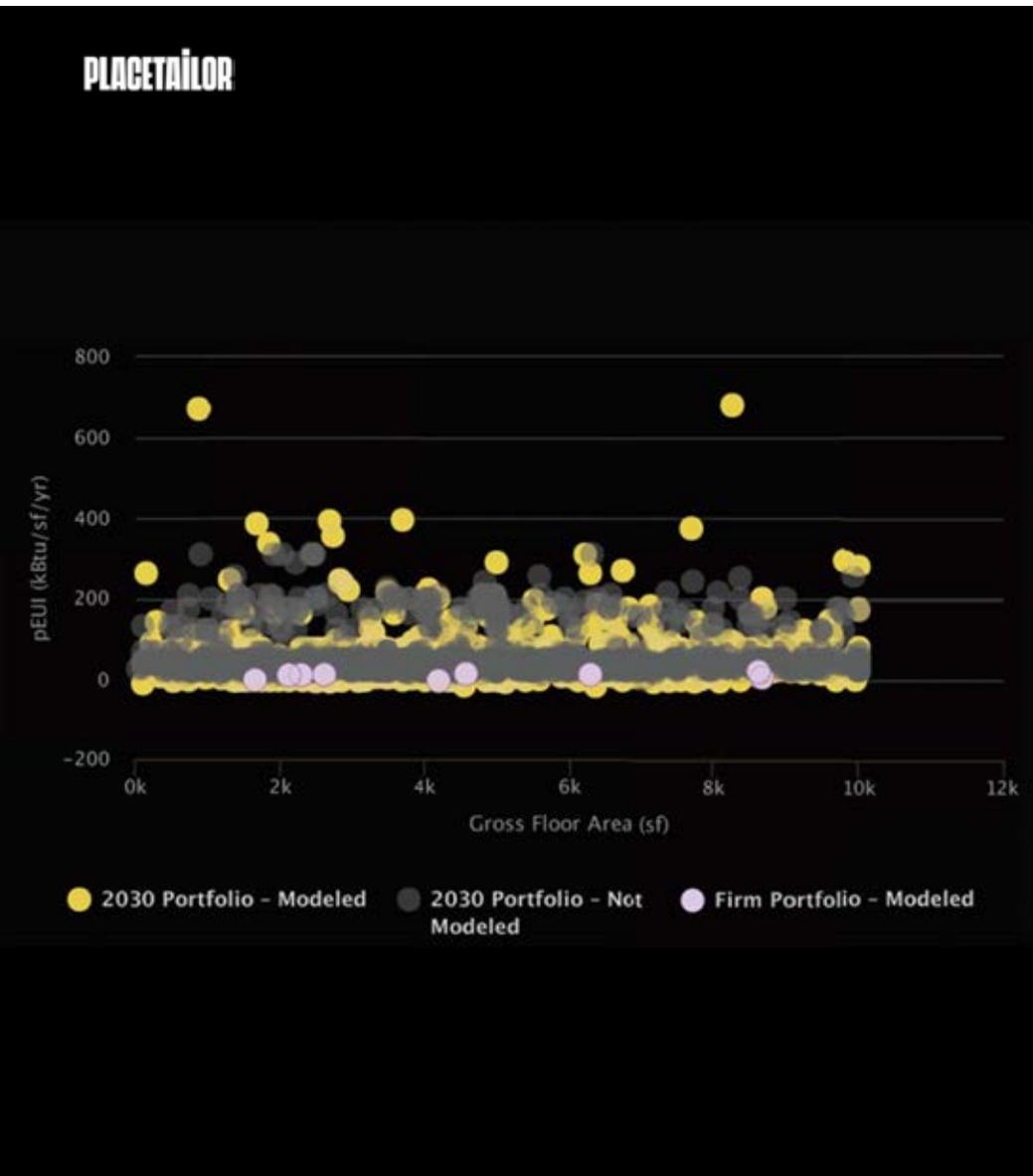
*Design, development and
innovation for hyper-
sustainable urban
housing.*

Placetaylor 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.

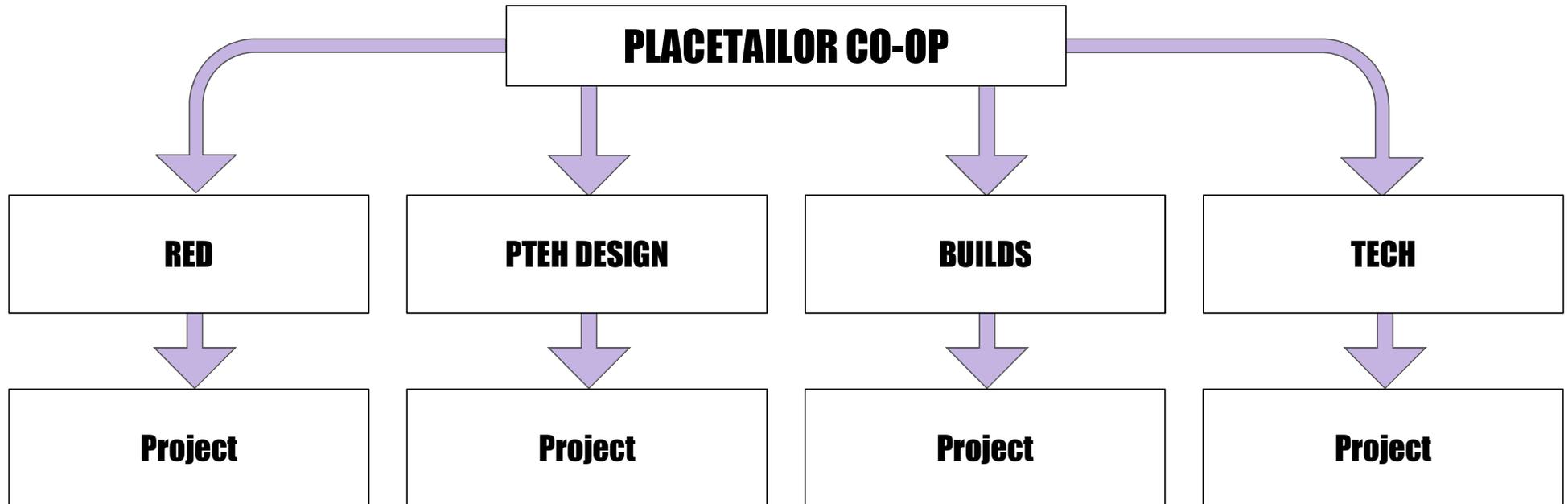
AIA 2030

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.

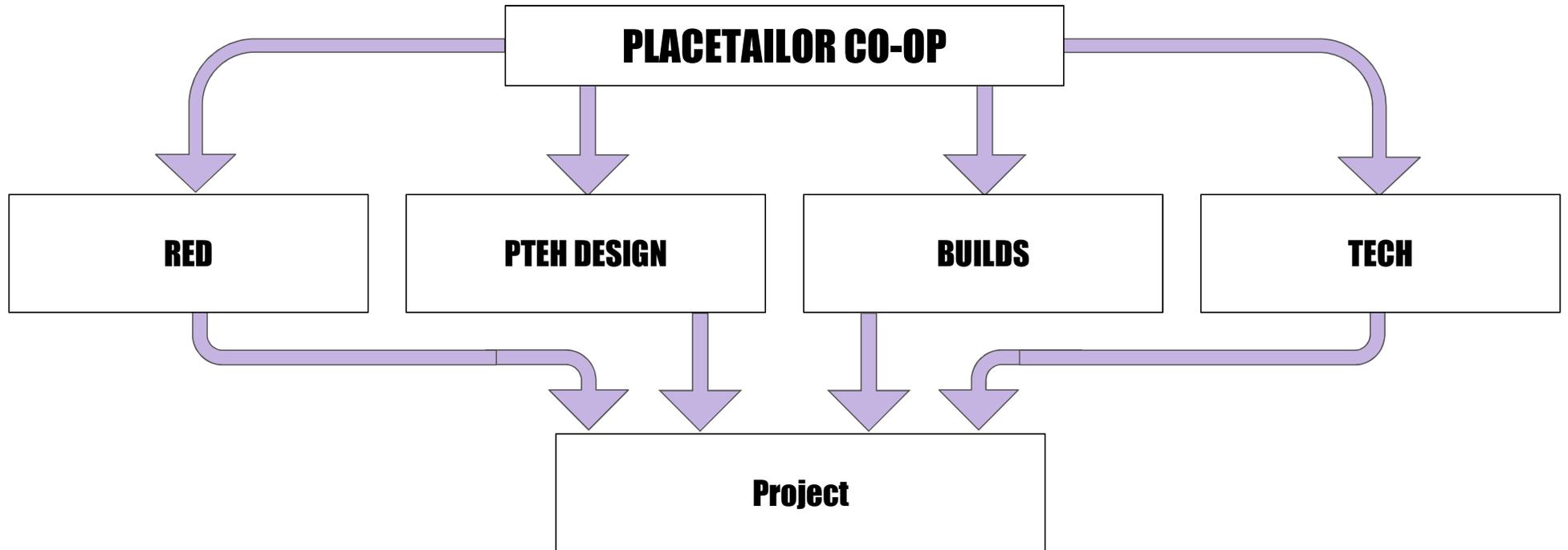


2. MODEL SECOND



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.



Nick Elton, RA
Principal, PTEH
Design



Juliet Borja, RA, LEED AP
Senior Project Manager,
PTEH Design



Katherine Faulkner, FAIA
Director of Technologies,
PT Tech



Elizabeth Hauver, CP
Energy Design Manager
PTEH Design



Minkoo Kang
Design & Development
Manager, PT RED



Brad Prestbo, FAIA
Director of
Operations,
Placetaylor



Bruce Hampton, AIA
Principal, PTEH
Design



Colin Booth
Managing Director,
Placetaylor



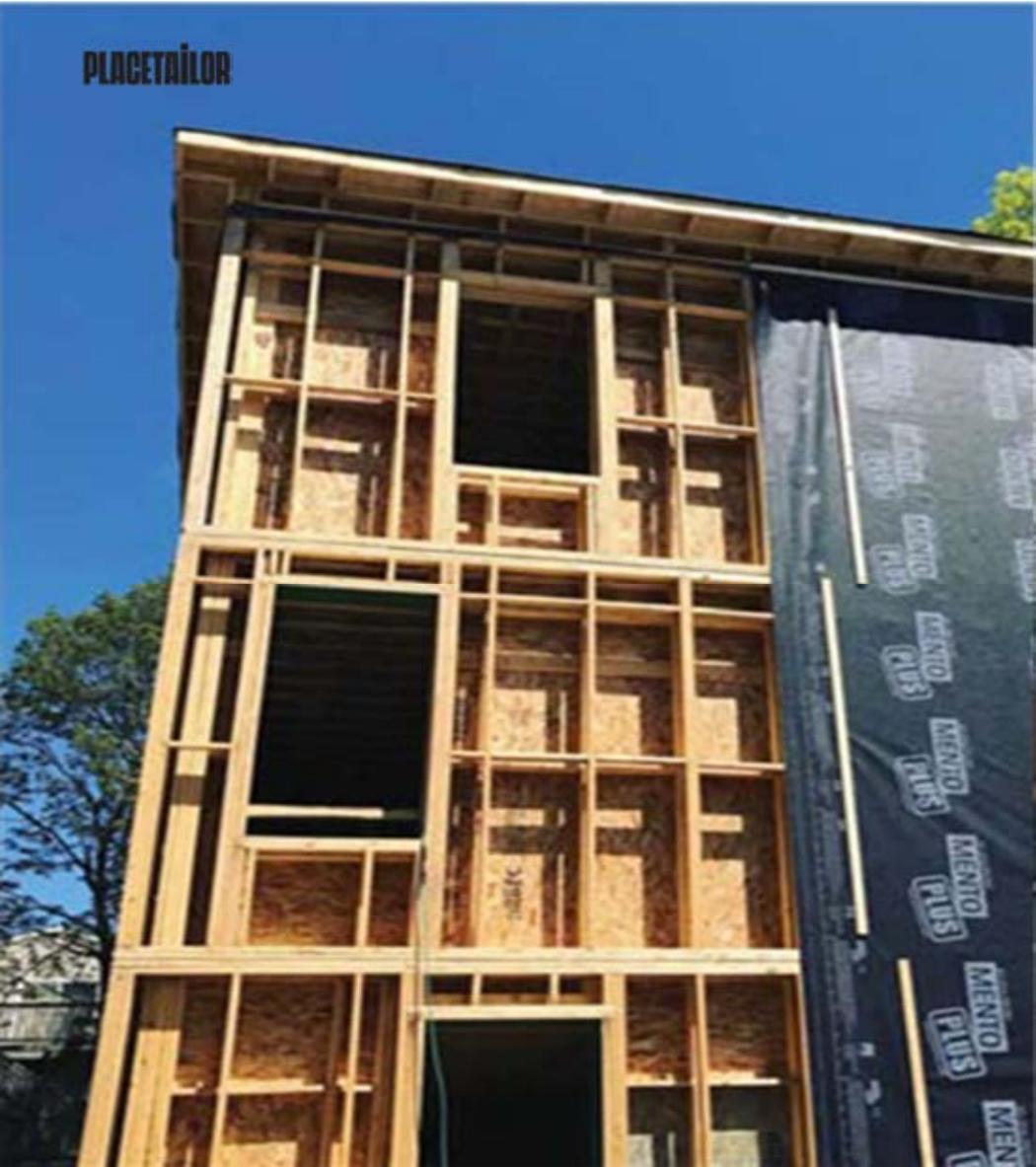
Evan Smith
Director of Real
Estate Development,
PT RED

3. WHAT WE'VE MADE



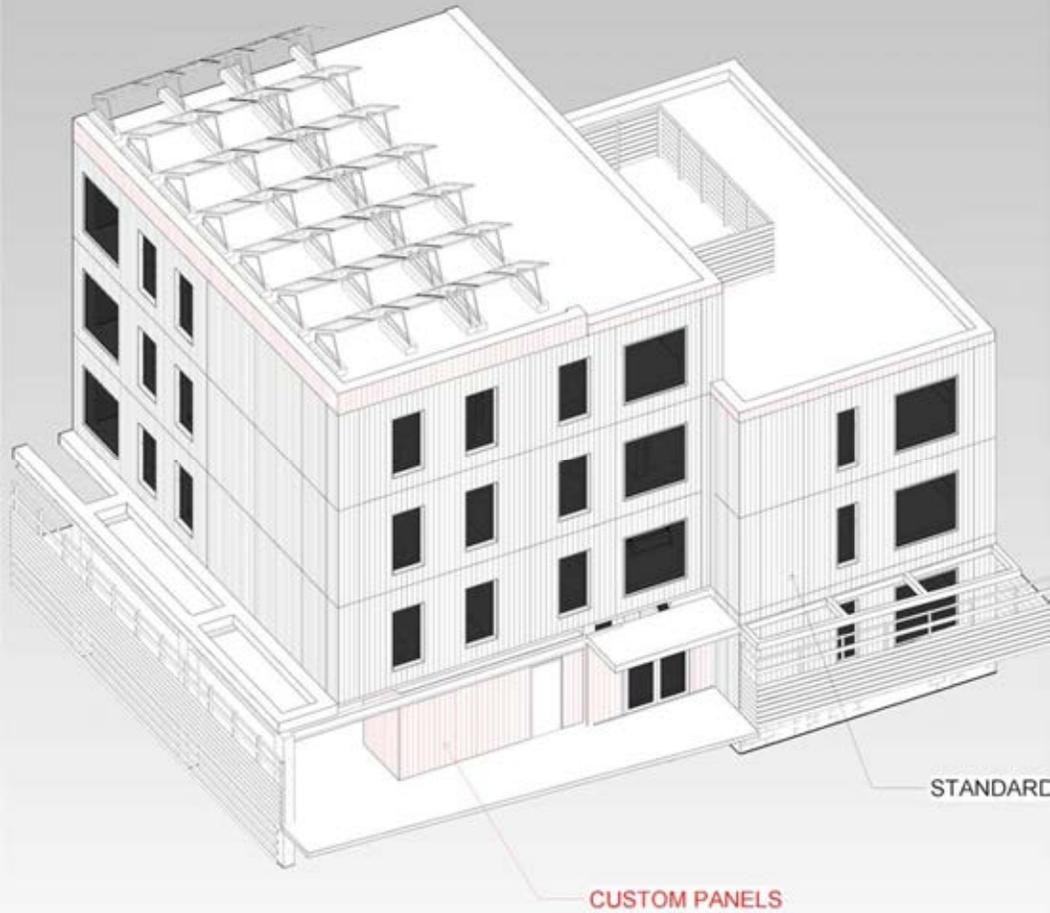
P-B R&D DNA

- 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

PLACETAÏLOR



NESEA

Page52

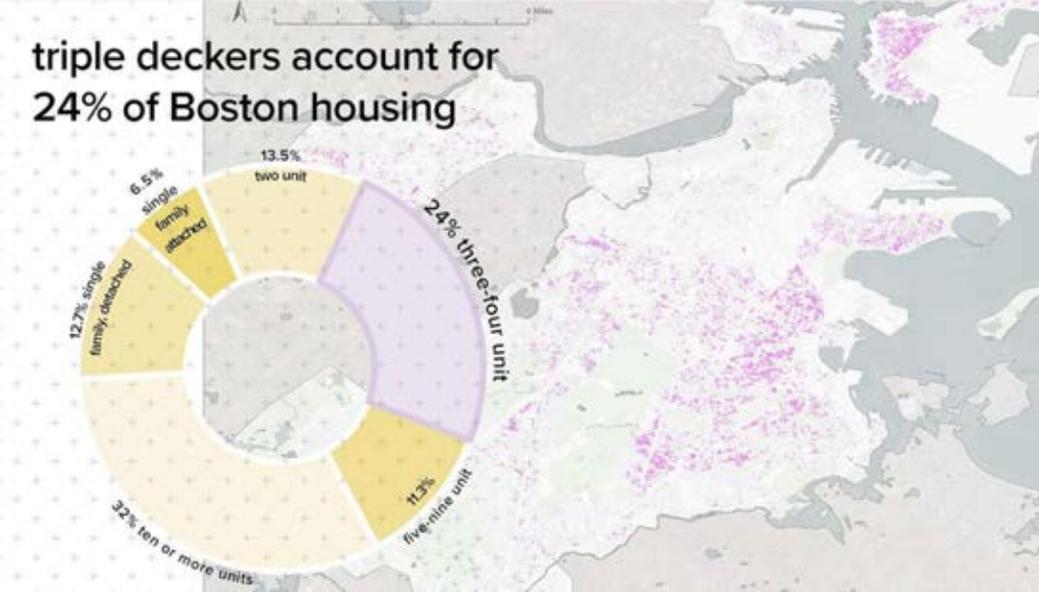
MODEL C

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

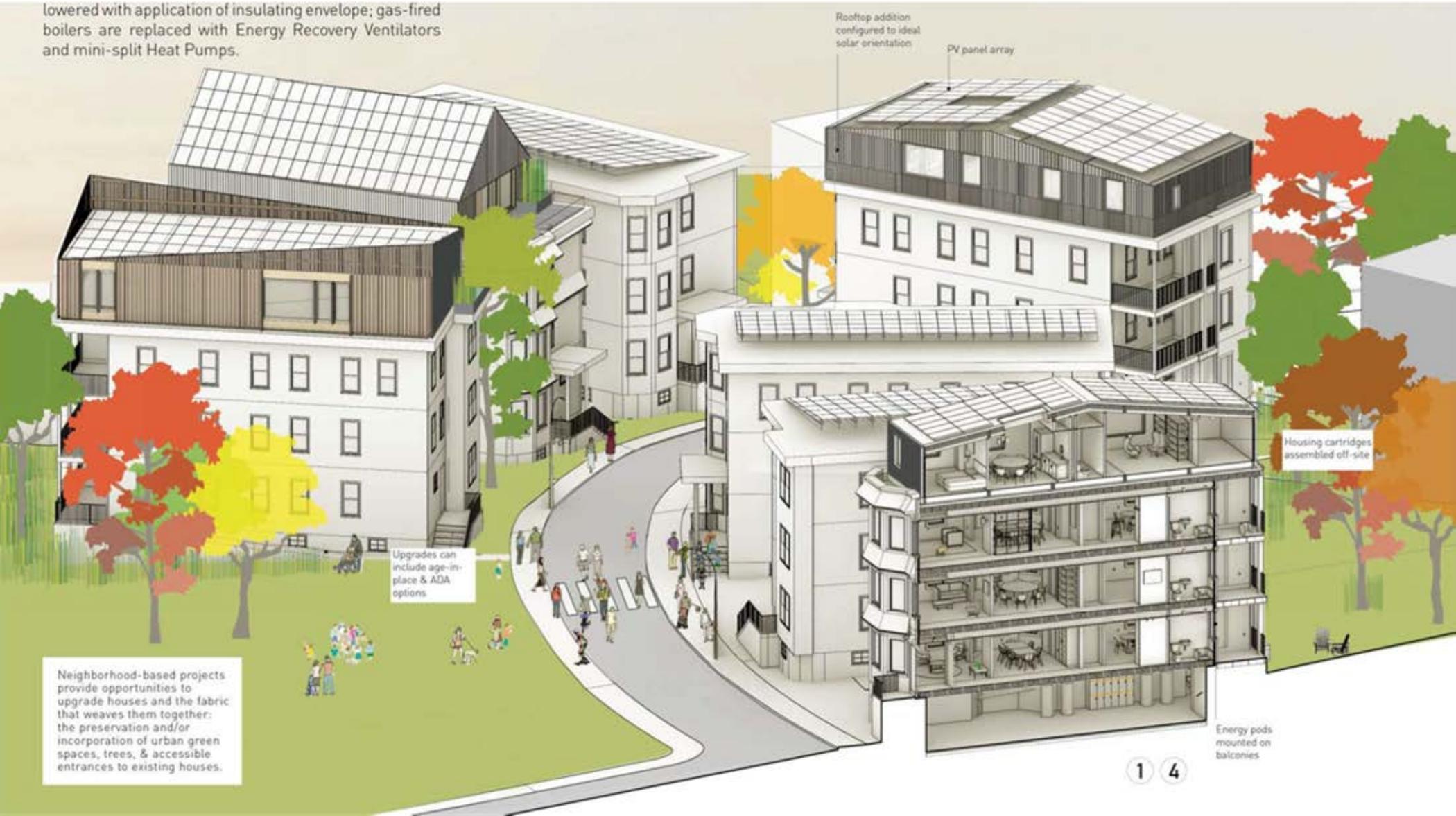




DECARB'ING THE TRIPLE DECKER

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.



Rooftop addition configured to ideal solar orientation

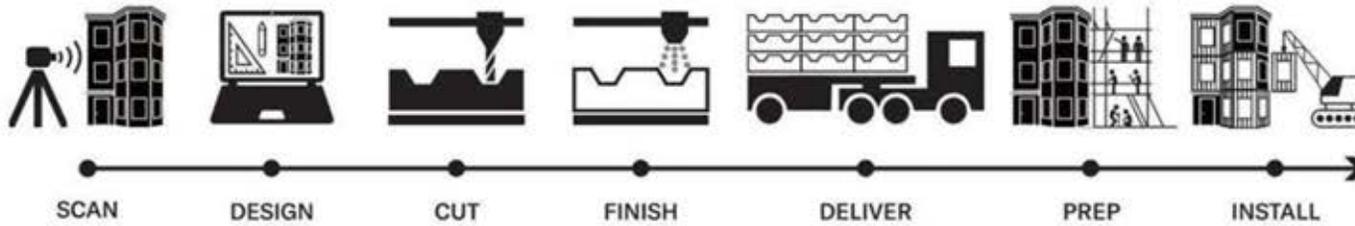
PV panel array

Upgrades can include age-in-place & ADA options

Housing cartridges assembled off-site

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.

Energy pods mounted on balconies



| | Site Built-Up Siding w/ Insulation | Nail Built Insulated Panel | Exterior Insulation and Finish System | PT Panel |
|---|------------------------------------|----------------------------|---------------------------------------|----------|
| Carbon Neutral Product | ○ | ○ | ○ | ● |
| Low Waste Production | ○ | ◐ | ○ | ● |
| Minimized On-Site Labor | ○ | ◐ | ○ | ● |
| Customized Patterns + Textures | ○ | ◐ | ◐ | ● |
| OSHA Friendly Install | ○ | ● | ○ | ● |
| Cost Competitive vs. Traditional Siding | ● | ○ | ● | ● |



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



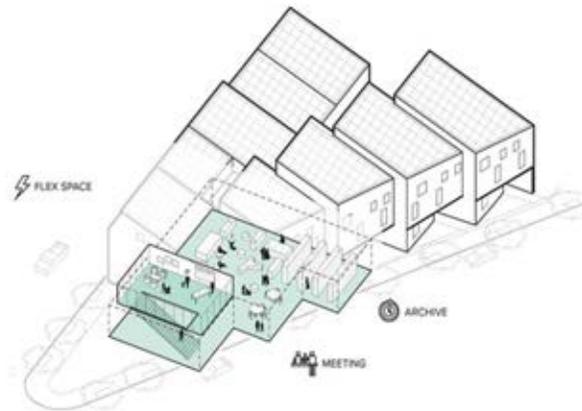
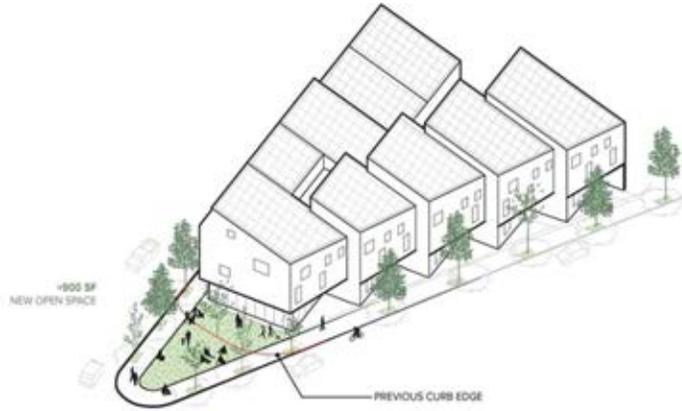
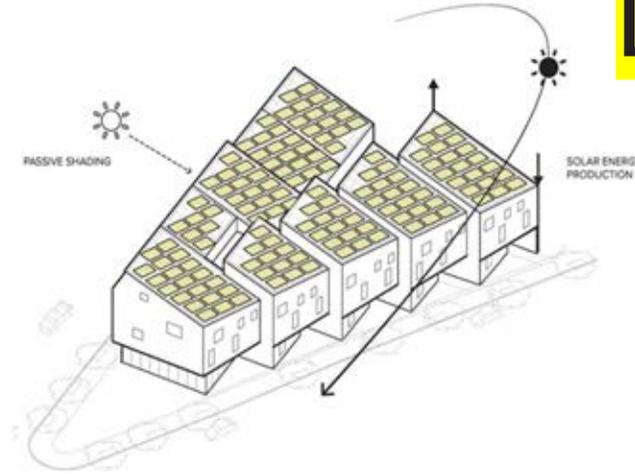
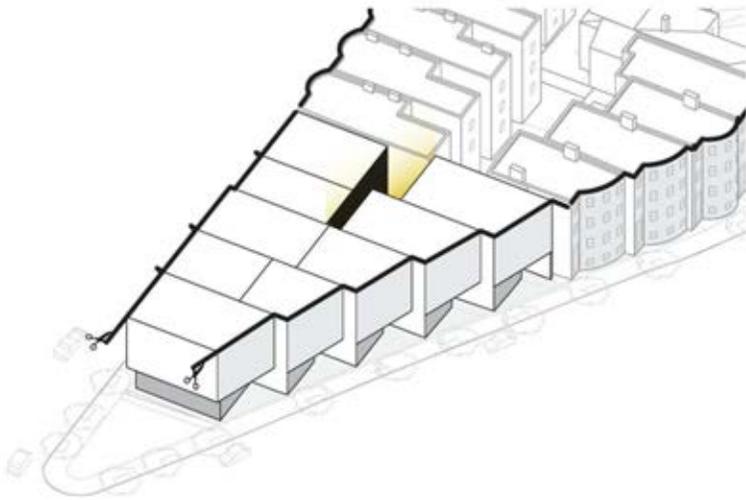
201 Hampden

- 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

FREDERICA M. WILLIAMS BUILDING
35' — 5 lvl

ISLAMIC SOCIETY OF BOSTON
130' — 3.5 lvl

SITE
69' — 7 lvl

286 ROXBURY
50' — 4 lvl

60' — 4 lvl

60' — 4 lvl

ROXBURY CC

88' — 6 lvl

1419 TREMONT ST.
60' — 5 lvl

60' — 4 lvl

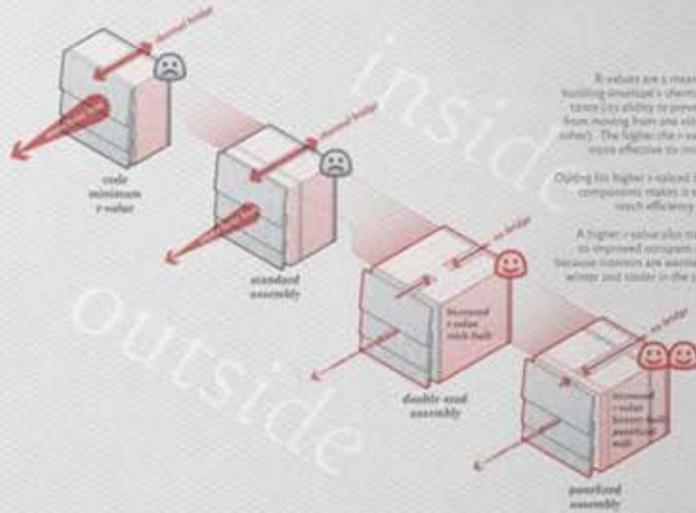


City of **Boston** - Department of
**Neighborhood
Development**

2020

guidebook for **Zero Emission Buildings (ZEBs)**

thermal bridging and ψ -value

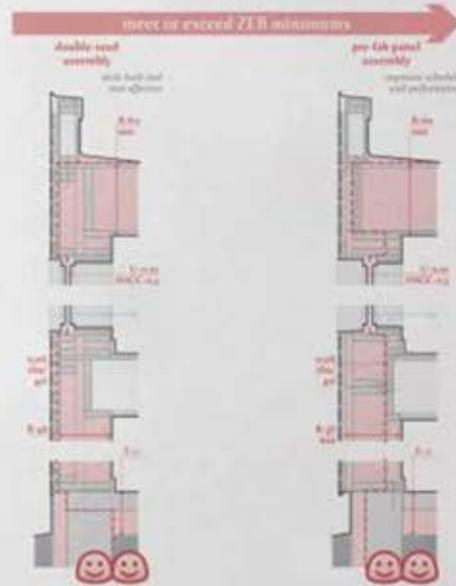


ψ -values are a measure of a building element's thermal resistance (its ability to prevent heat from moving from one side of the other). The higher the ψ -value, the more effective its insulation.

Opting for higher ψ -valued building components makes it easier to reach efficiency targets.

A higher ψ -value also translates to improved occupant comfort, because interiors are warmer in the winter and cooler in the summer.

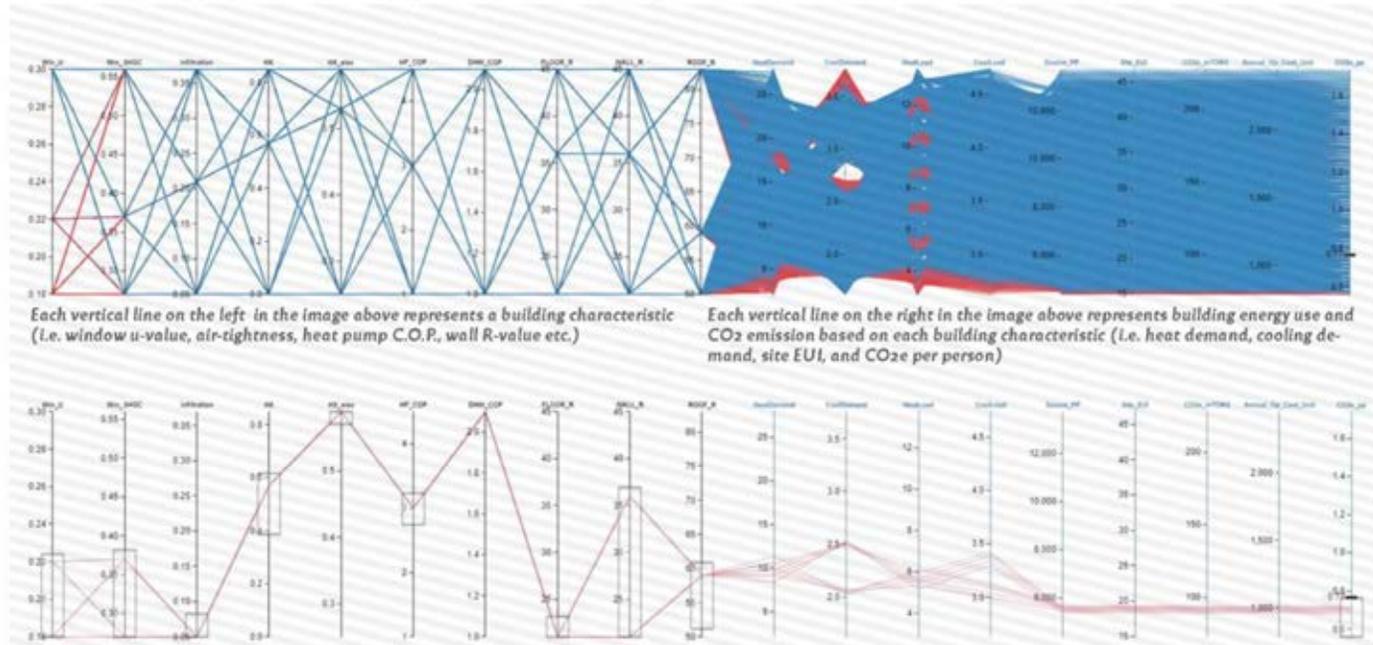
assembly summary



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 Fraunhofer 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.



Each vertical line on the left in the image above represents a building characteristic (I.e. window u-value, air-tightness, heat pump C.O.P., wall R-value etc.)

Each vertical line on the right in the image above represents building energy use and CO2e emission based on each building characteristic (I.e. heat demand, cooling demand, site EU, and CO2e per person)

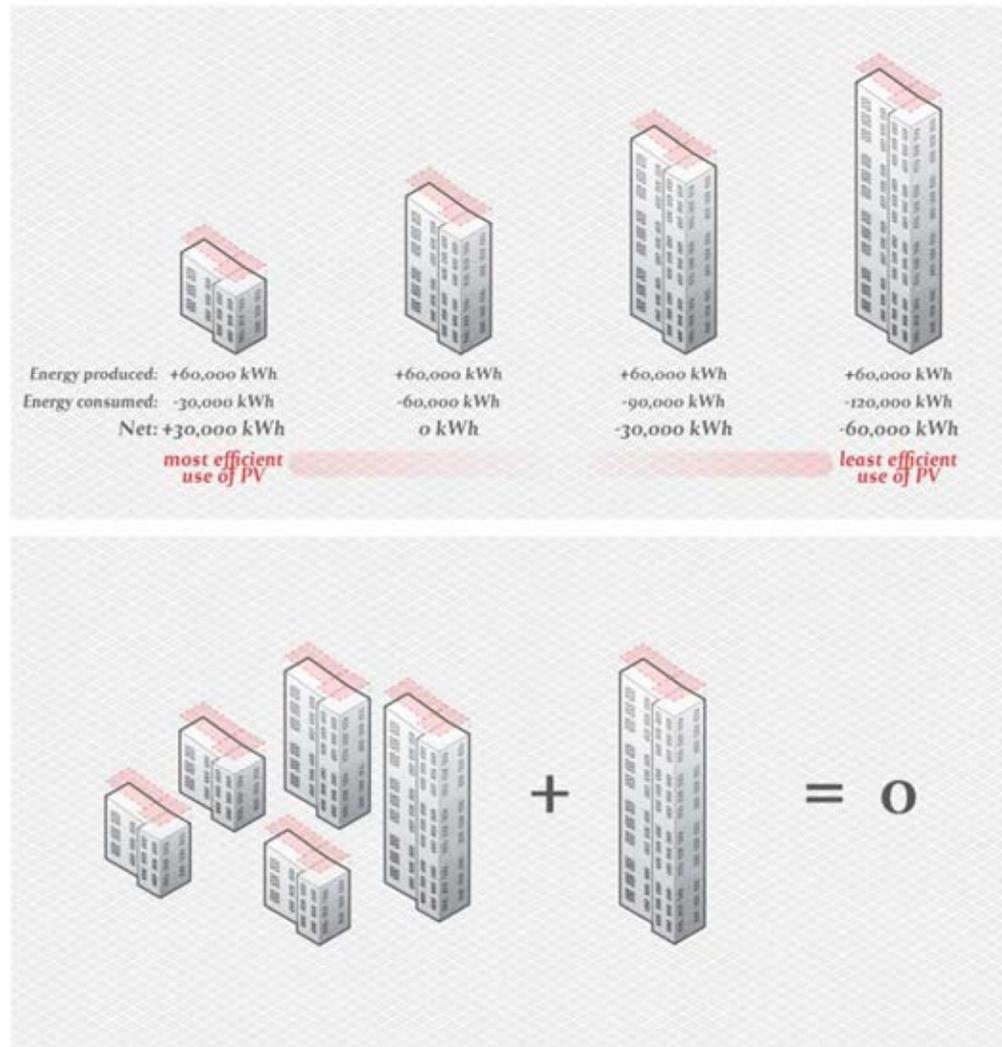
In the image above the CO2e emission for the building has been set to the 0.77 Co2e per person target. The matrix above is generated and a series of building characteristics are selected based on cost and performance. The end result is the optimal combination of building characteristics to produce a Zero Emission Building.

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.



| | Small Multifamily 6 unit bldg | 3 Story Multifamily 14 unit bldg | 4 - 5 Story Multifamily 50 unit bldg | 6 Story Multifamily 51 unit bldg |
|--|---|--|--|--|
| Stretch Code Baseline Building | | | | |
| Stretch Code EUI (kBtu/sf/yr) | 24 | 34.2 | 25.5 | 26.8 |
| CO _{2e} / per person baseline Stretch Code (mTons/kwh) | 0.86 | 1.19 | 0.8 | 0.82 |
| Annual Utility Cost per living unit - 1.52 (dollar / therm)** | \$1,820 | \$1,211 | \$1,368 | \$1,481 |
| Stretch Code Baseline Build cost (\$)* | \$358,766 | \$387,988 | \$1,298,574 | \$1,464,522 |
| Zero Emission Building | | | | |
| ZEB EUI (kBtu/sf/yr) | 18 | 26 | 21 | 18 |
| CO _{2e} / per person ZEB (mTons/kwh) | 0.77 | 0.77 | 0.77 | 0.77 |
| Annual Operational Cost per Unit ZEB - 22.61 (cents/kWh) | \$1,450 | \$1,200 | \$1,100 | \$1,100 |
| ZEB Baseline build cost (\$)* | \$361,913 | \$390,312 | \$1,310,419 | \$1,496,920 |
| Stretch Code vs ZEB | | | | |
| Incremental Cost difference to ZEB (\$) Total project cost | \$3,148 | \$2,324 | \$11,845 | \$32,398 |
| Incremental Cost to ZEB (% increase) | 0.88% | 0.60% | 0.91% | 2.21% |
| Incremental change per person CO _{2e} ZEB (% decrease) | -25% | -24% | -18% | -33% |
| Incremental Cost difference to ZEB (% decrease) operational cost | -20% | -1% | -20% | -26% |
| Renewables - Rebates and Incentives are not included | | | | |
| Solar PV size (kW) - 75% of Roof Areas | 37 KW | 40 KW | 156 KW | 104 KW |
| PV cost installed (Average \$3.16 / watt) | \$117,000 | \$126,000 | \$492,000 | \$328,000 |

* 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 DOER heating cost data
Plug loads were normalized based on DND occupant criteria (2 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

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Thank you.

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