BUILDING SCIENCE LIVE
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How to Plan and Build Multifamily Passive House for Less

Monte Paulsen
Passive House Specialist, RDH

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How to Build Multifamily Passive House for Less

- Budget: How much does Passive House cost?
- Examples: Four Passive House projects built below market rate.
- Milestones: How to lower the cost of your first project.
- Strategies: Four patterns for affordable Passive House design.

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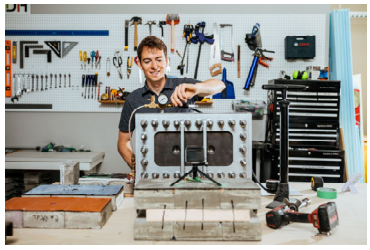

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240+ staff

9 offices

Projects across North America

Focus on building science & building enclosures

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RDH, Canada's largest Passive House team

- More than five million square feet of project experience
- Consultants to PHI, PHIUS+, Net Zero, Living Building, et al
- Building Certifiers for Passive House Institute (PHI)

Monte Paulsen, Passive House Specialist

- Specialize in helping development teams choose targets
- Teach: "A Pattern Language from Passive House"
- Host: "Global Passive House Happy Hour"

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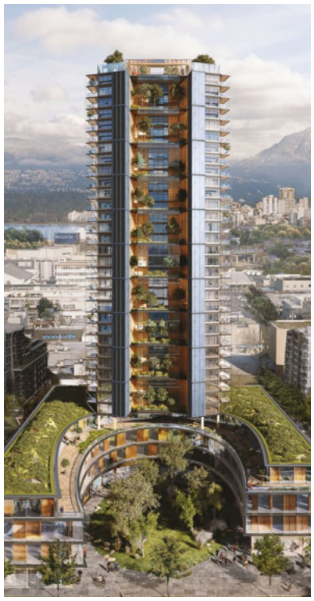

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Why developers are choosing Passive House:

- → Reduced GHG Emissions
  - → Less gas, lower emissions
- → Easier to Electrify
  - → Small heat pumps less costly
- → Indoor Air Quality
  - → 100% fresh air, 100% of the time
- → Comfort & Quiet
  - → "City living without the noise"
- → Thermal Resiliency
  - → Three-day blackout test
- → Stepwise Retrofits
  - → Sequential energy upgrade plans
- → 3rd Party Quality Assurance
  - → PHI or PHIUS+
- → Future Proof Standard
  - → Won't be obsolete by next code
- → Training for Coming Codes
  - →"Where the puck is going"
- → Cost Neutral
  - → Savings exceed amortized cost

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How Much Does Passive House Cost?

Reported construction cost premiums

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Data Set #1: RDH Projects

0% to 9%

Construction cost premium

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Data Set #1: RDH Projects

Development Costs

Construction typically accounts for less than half the cost of a new building.

Land, financing costs, community amenity contributions, and other development expenses account for between one-half to two-thirds of the up-front cost of a new building.

Operational Costs

Passive House buildings pay lower utility bills than other buildings, because demand for heating and cooling is lower.

Monthly operational savings can exceed monthly cost of slightly higher mortgage.

Therefore, in at least one instance, a 9% construction cost premium works out to less than 3% more up-front cost, and is predicted to result in cash savings during the first year of operation.

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Data Set #2: Steven Winter Associates Projects

Characteristics	Min	Max	Average
# of Units	30	385	184
Floors	6	37	15
% Increase for PH	1%	8%	4%

Average construction cost premium of 16 recent SWA Passive House projects.

Steven Winter Associates, Inc.

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Source: "Hitting Milestones & Budgets" presentation by Lois Arena to North American Passive House Conference, June 4, 2020.

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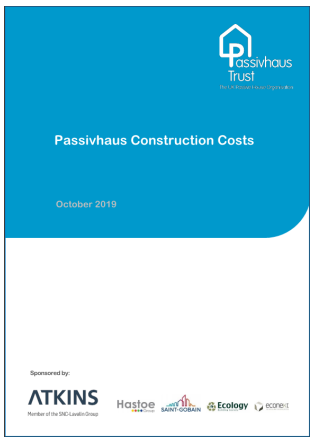
#3: Passive House in the UK



Surveyed 12 developments to derive cost premium of Passive House standard.

Average was **9% more** than baseline.

The report projects that once Passive House is adopted at scale, the cost premium will fall to **4%** or less.

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Source: "Passivhaus Construction Costs" published by Passivhaus Trust, October 2019. www.passivhaustrust.org.uk

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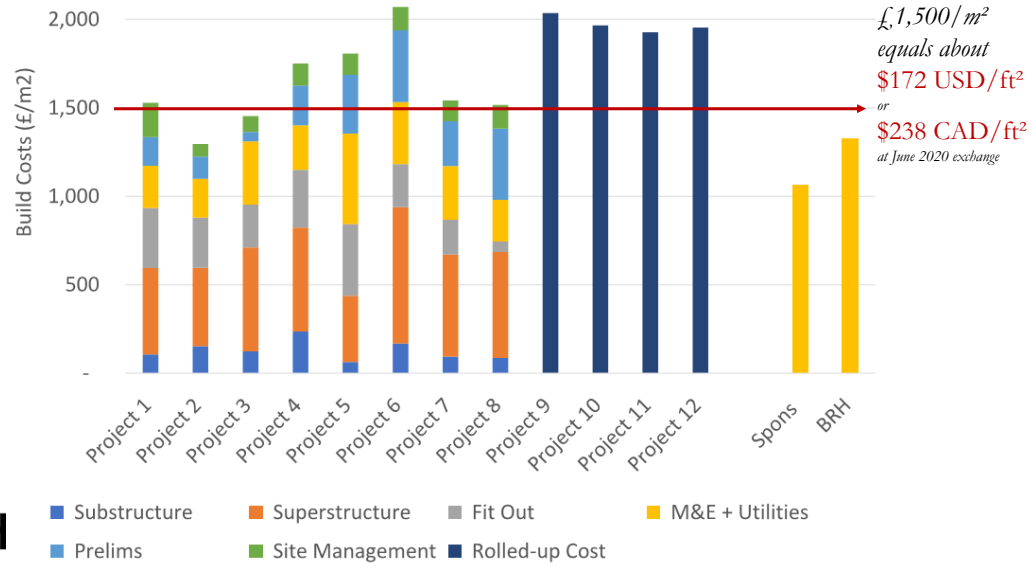
#3: Passive House in the UK



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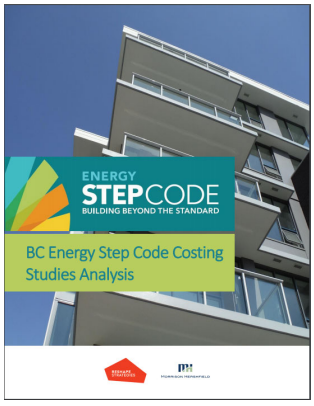
#4: B.C. Energy Step Code Research



Survey of 10 costing studies prepared in advance of the BC Energy Step Code.

Considered various levels of Step Code compliance for different building types in multiple climate zones within B.C.

Source: "BC Energy Step Code Costing Studies Analysis." energystepcode.ca

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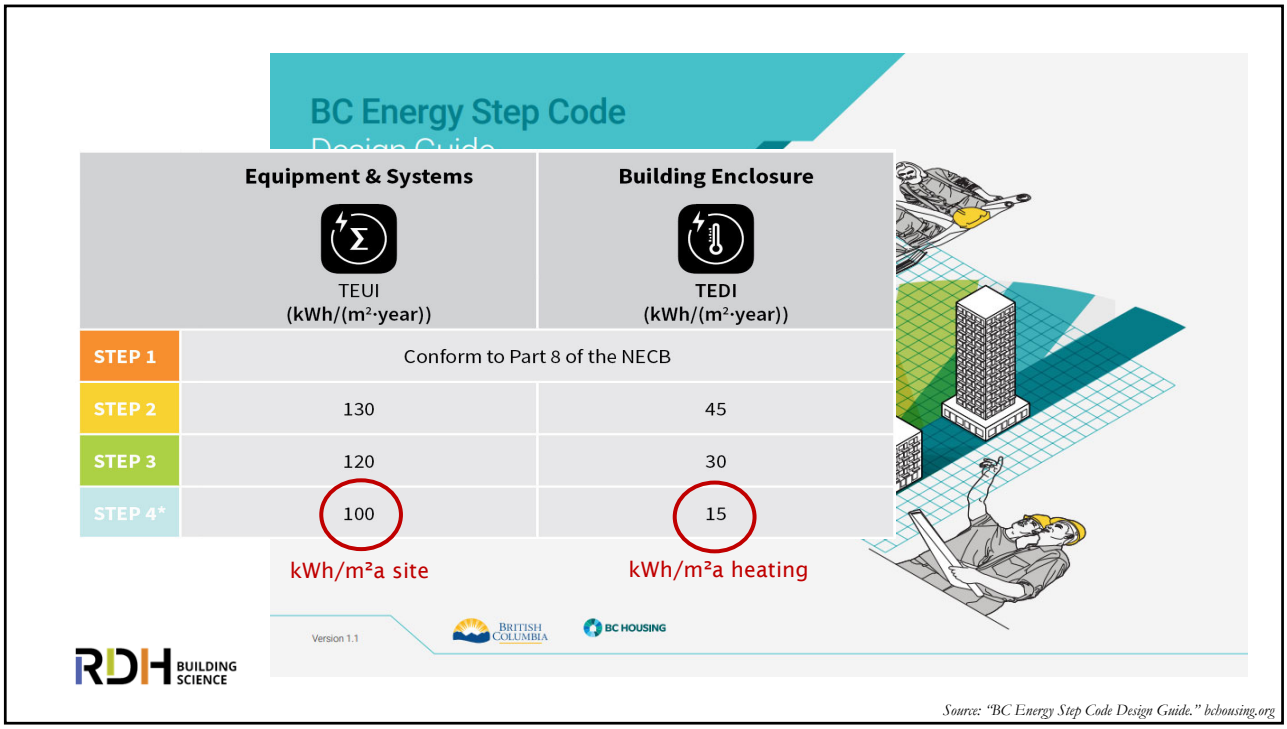

Source: "BC Energy Step Code Design Guide." bchousing.org

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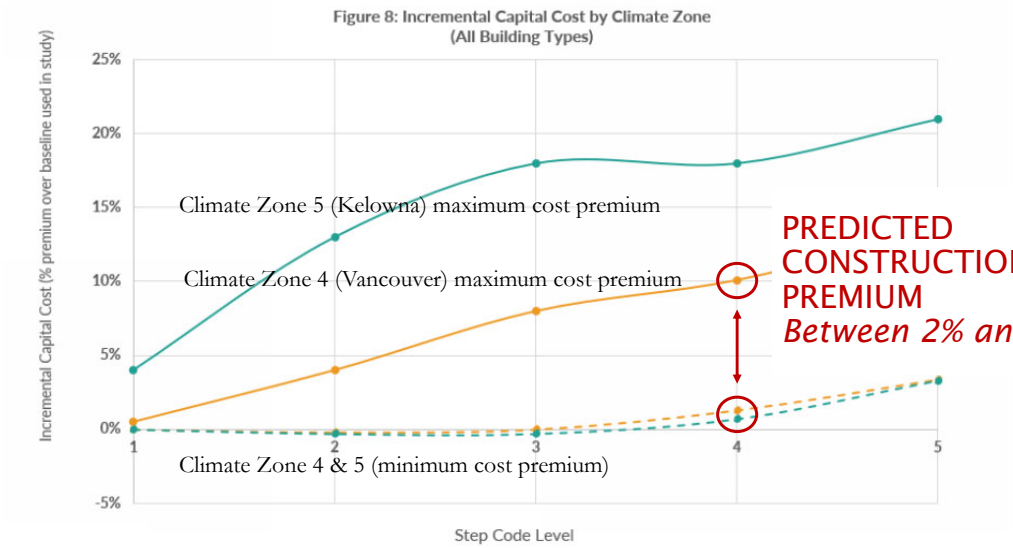
#4: B.C. Energy Step Code Research



PREDICTED CONSTRUCTION PREMIUM
Between 2% and 10%

Source: "BC Energy Step Code Costing Studies Analysis." energystepcode.ca

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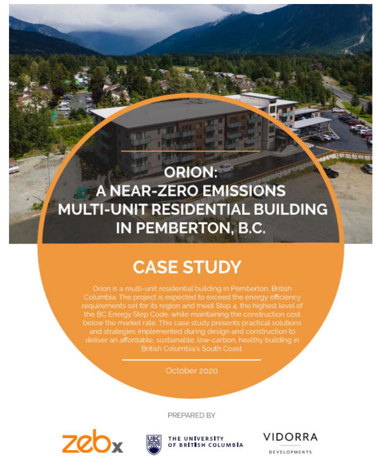
Actual construction premium closer to zero

ORION
Pemberton, British Columbia

$248 CAD per square foot in 2020
($183 USD)



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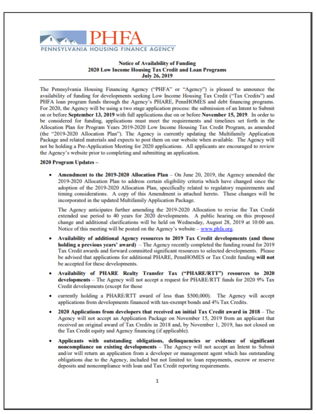
#5: Pennsylvania Housing Finance Agency



The Pennsylvania Housing Finance Agency issues periodic notices of available funding.

Housing providers propose projects. Each proposal is scored according to a point system. Projects are funded in order of total points, until funding is gone.

In 2015, the PHFA added ten additional points for certified Passive House projects.

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Pennsylvania Housing Finance Agency (phfa.org)

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#5: Pennsylvania Housing Finance Agency

POINTS-BASED SYSTEM	
Total points	120
Community and Economic Impact	30
- Underserved Areas	
- Senior Occupancy Developments	
- Preservation	
Development Characteristics	25
- Smart Site Selection	
- Enterprise Green Communities	
Resident Population and Services	50
- Income and Rent Targeting	
- Designated Populations and Supportive Services	
- Accessible Units	
- Large Families	
Development Process	15
- Noncompliance	
- Ability to Proceed	
Development Cost Savings	10

POINTS-BASED SYSTEM	
Total points	130
Community and Economic Impact	30
- Underserved Areas	
- Senior Occupancy Developments	
- Preservation	
Development Characteristics	25
- Smart Site Selection	
- Enterprise Green Communities	
- PASSIVE HOUSE	10
Resident Population and Services	50
- Income and Rent Targeting	
- Designated Populations and Supportive Services	
- Accessible Units	
- Large Families	
Development Process	15
- Noncompliance	
- Ability to Proceed	
Development Cost Savings	10

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#5: Pennsylvania Housing Finance Agency

St, John Nueman
Phila, PA
52 Units

Wynne
Phila, PA
51 Units

Sacred Heart
Allentown, PA
61 Units

WhiteHall
Spring City, PA
49 Units

Hillcrest
Pittsburgh, PA
65 Units

Washington Square Townhomes
Chambersburg, Pa
54 Units

Mann Edge
Lewistown, Pa
34 Units

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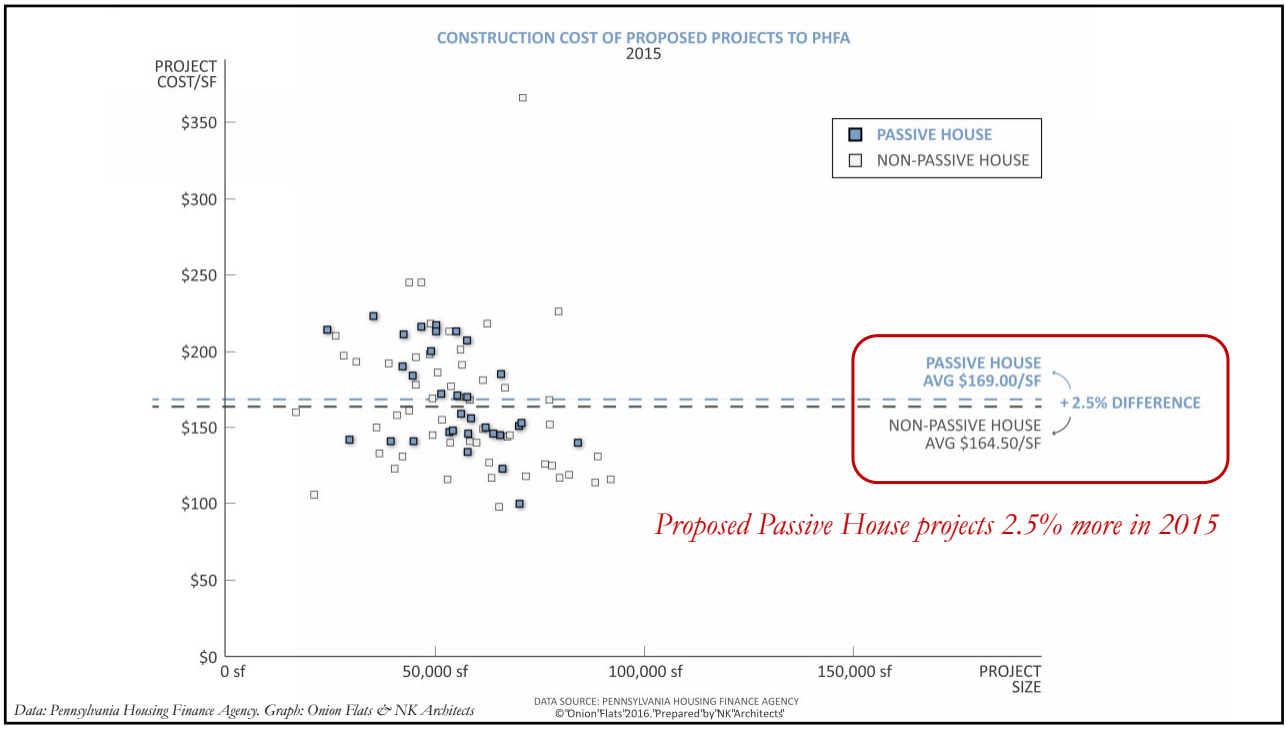

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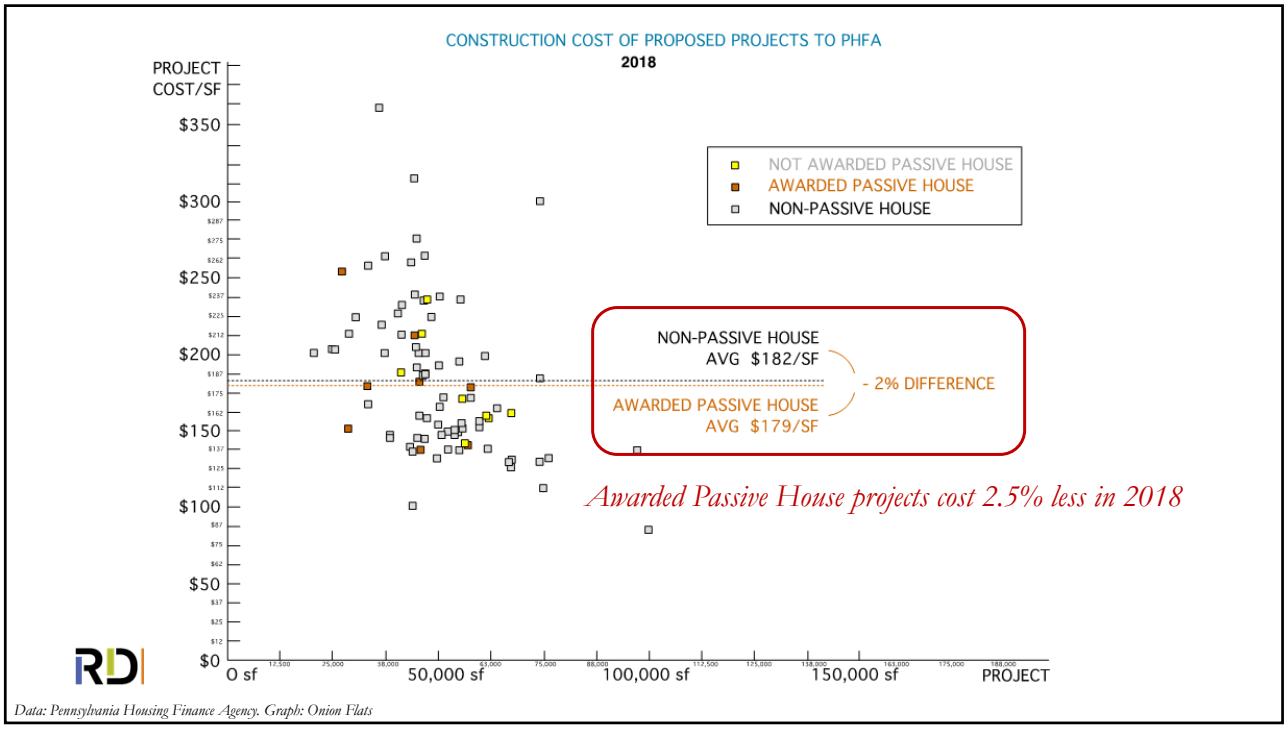

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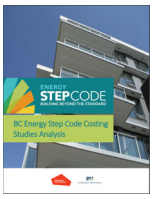
How much does Passive House cost?

→ RDH projects 2020: 0% to 9%
→ SWA projects 2020: 2% to 8%
→ Passivhaus Trust 2019: 4% to 9%
→ B.C. Energy Step Code 2016: 2% to 10%
→ PHFA 2015-2018: -2% to +3%

→ Approximate midpoint: **5.5%**



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Examples: Four Passive House Projects Built At or Below Market Rate

Projects in U.S. and Canada

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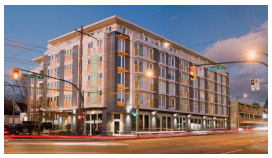

$170 p.s.f in VANCOUVER, BC. ⌂

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The first large multifamily Passive House in Vancouver

November 2016

Spring 2017

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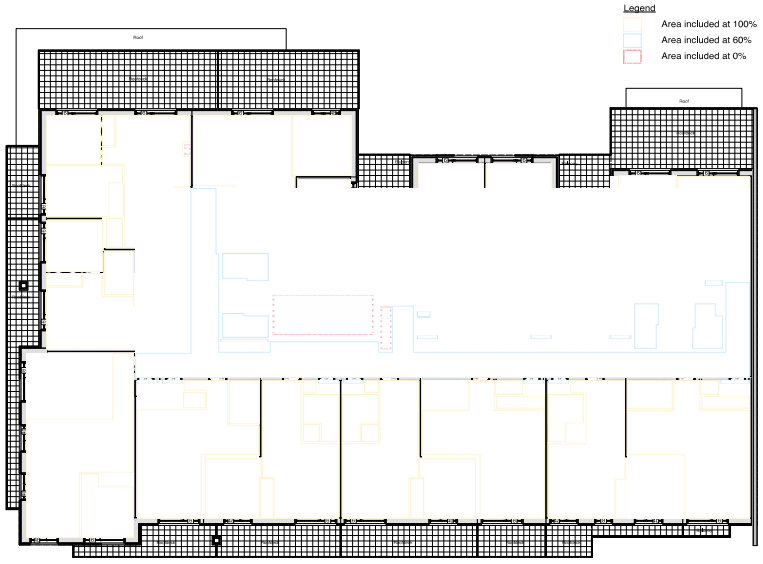
Challenge: The Heights was 'retrofitted' to Passive House



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Design by Cornerstone Architecture, Vancouver

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Challenge: The Heights was 'retrofitted' to Passive House

→ Not initially conceived as a Passive House
→ First Passive House project by Cornerstone Architects
→ First project by Peak Construction

→ Site: Zoning required step-backs.
→ Supply: Only one HRV in market at that time.
→ Supply: Only one PHI-certified window in market at that time.

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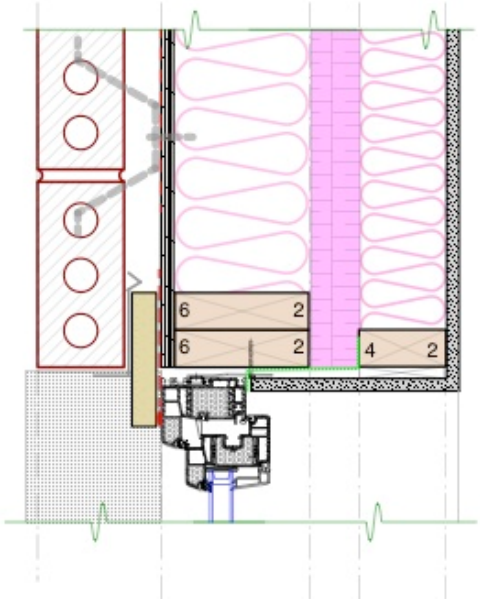
The 'Ice Cream Sandwich' wall

Exterior framing & brick ledges same as standard practice



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Design by Cornerstone Architecture, Vancouver

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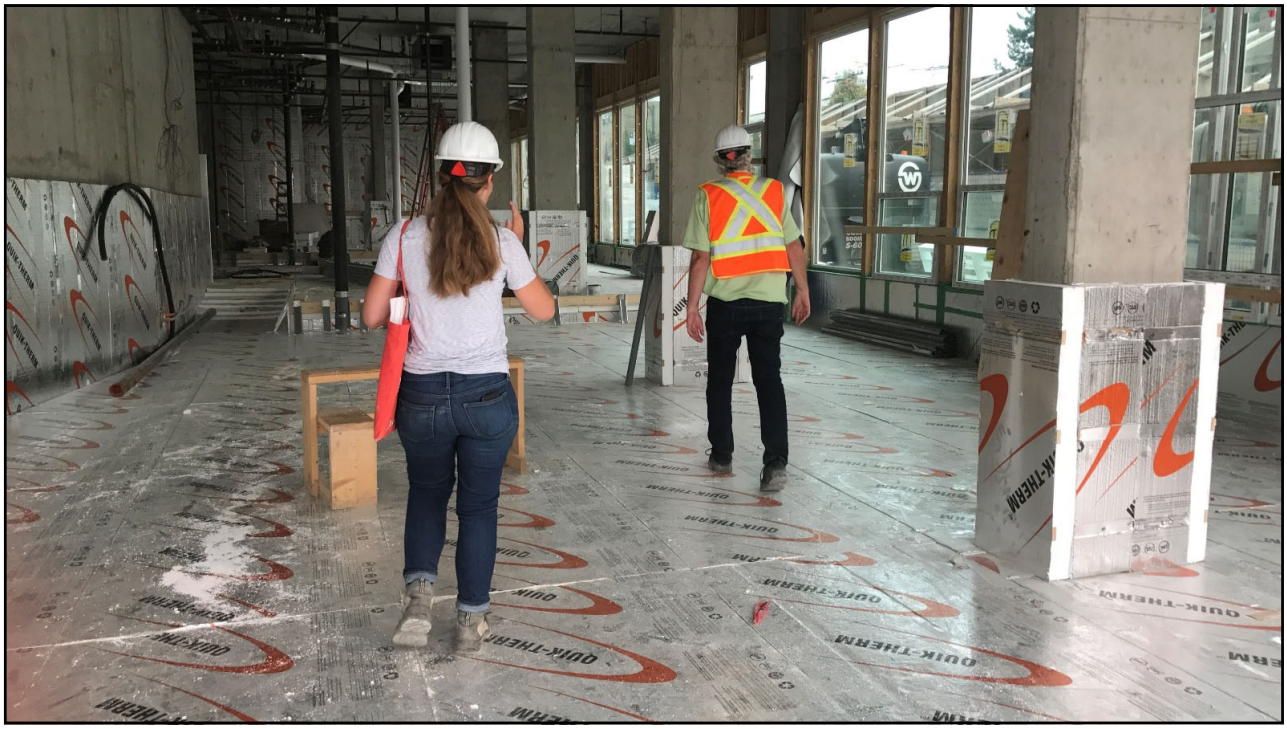

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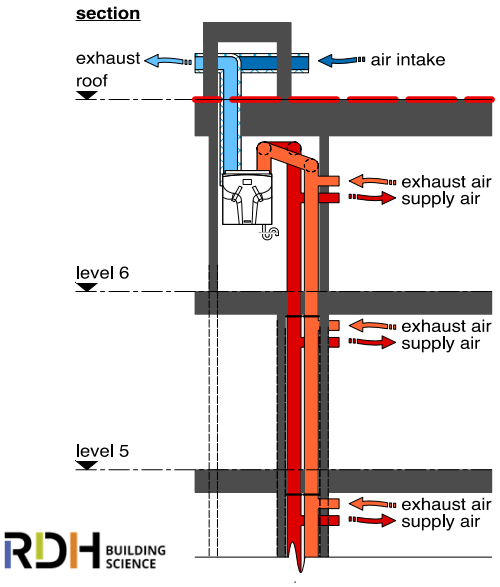
Supply chain: No large ERVs in market at that time



→ No Canadian mfg *at that time*

→ Only one local supplier, only carried residential-scale units (Zehnder)

→ One Zehnder atop each "stack" of apartments

→ Whole stack boosts together

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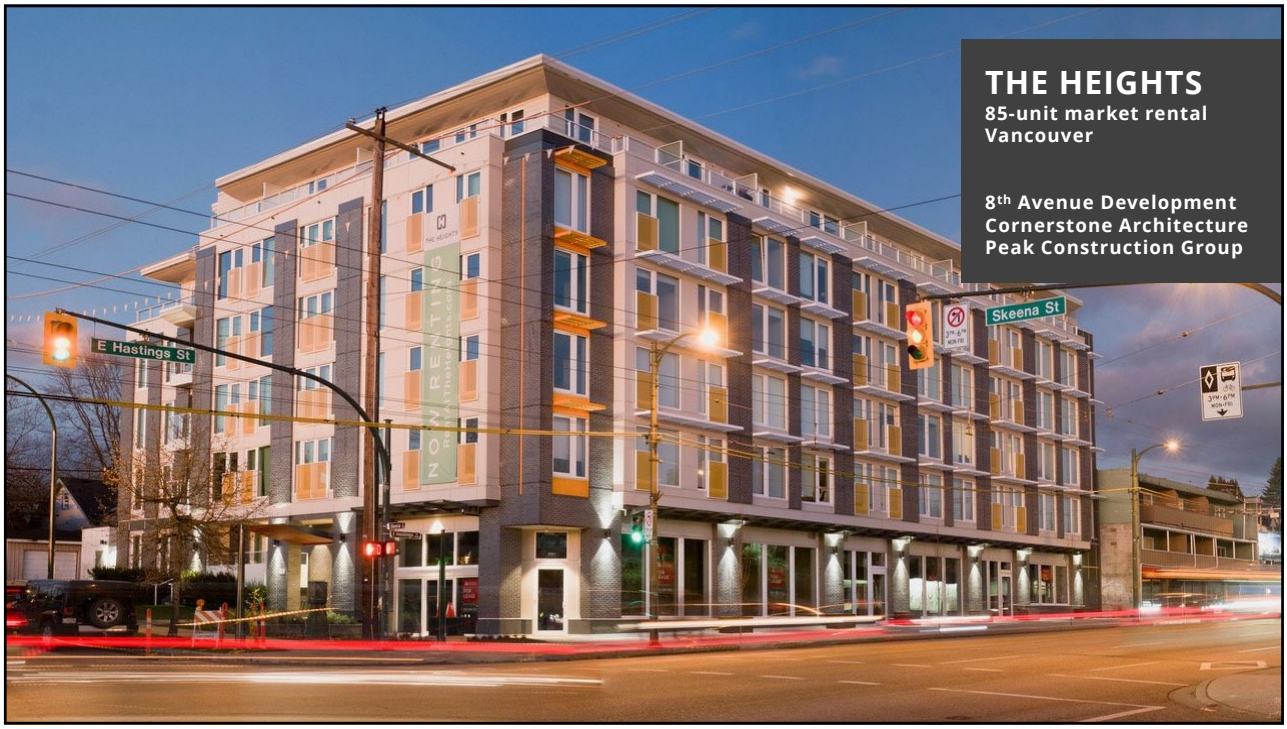

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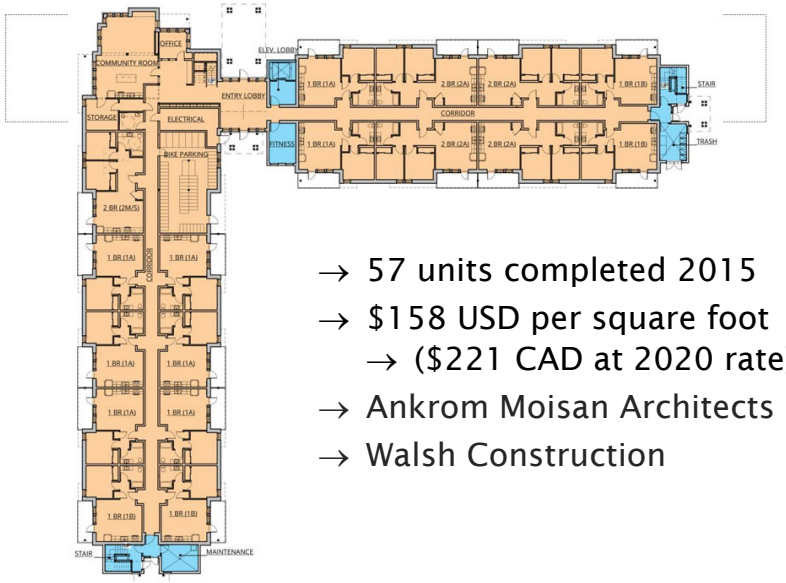
ORCHARDS *at* ORENCO



- → 57 units completed 2015
- → $158 USD per square foot
  - → ($221 CAD at 2020 rate)
- → Ankrom Moisan Architects
- → Walsh Construction

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Image: Ankrom Moisan Architects

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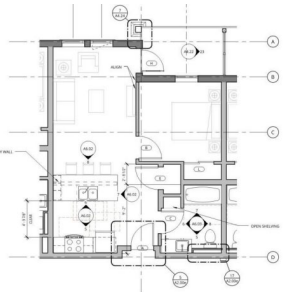
Orchards Ph. I: 656 square feet
30 feet wide


Orchards Ph. II: 608 square feet
23 feet wide

Phase I

→ 57 units in 2015

→ $158 per square foot

→ $159,527 per unit

Phase II

→ 58 units in 2016

→ $173 per square foot

→ $147,097 per unit

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Source: "Exploring a Path Toward Cost-Efficient, Energy-Efficient (Passive House) Affordable Housing," Mike Steffen, Walsh Construction, 2019

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CAPITAL FLATS
Philadelphia, Pennsylvania

→ 25 one-bedroom suites
→ Passive House + Net Zero
→ Completed 2017
→ Construction: $3,664,986
→ $169 per square foot
  → *($237 CAD at current rate)*
→ $146,600 per unit

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Two Ventacity ERVs, 82% efficient

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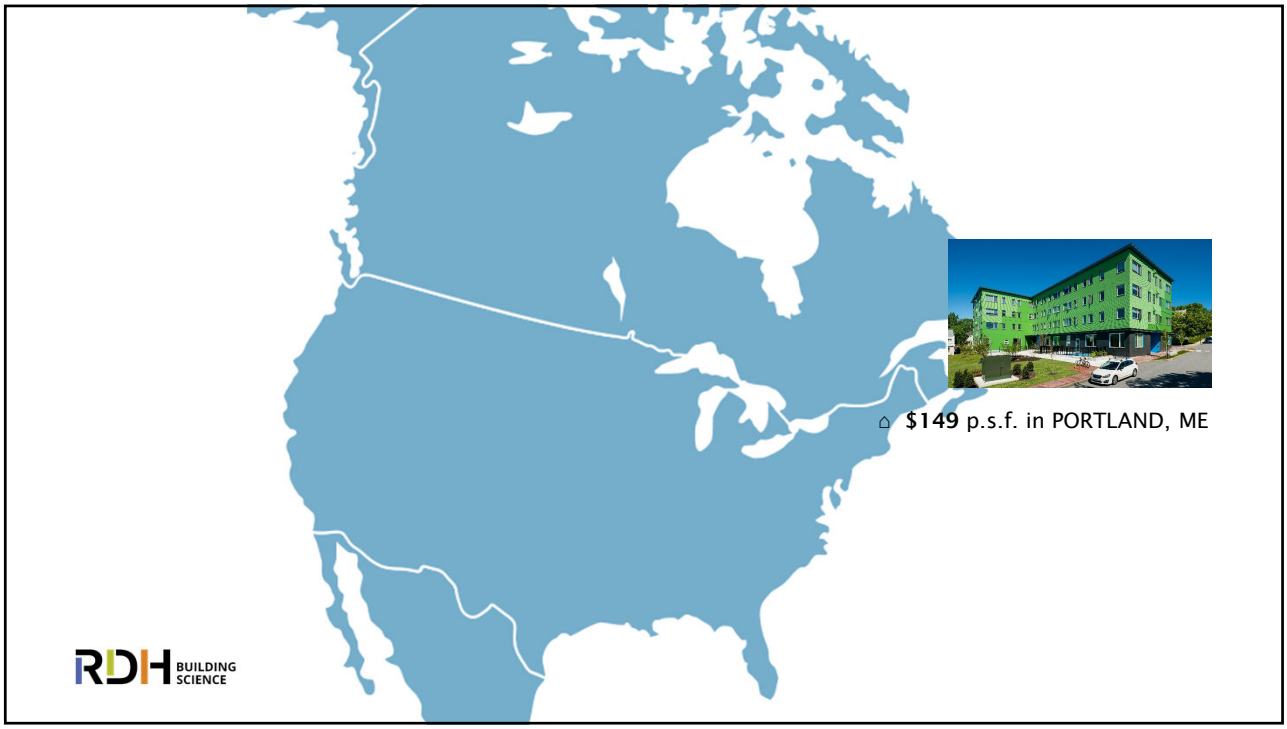

⌂ **$149** p.s.f. in PORTLAND, ME

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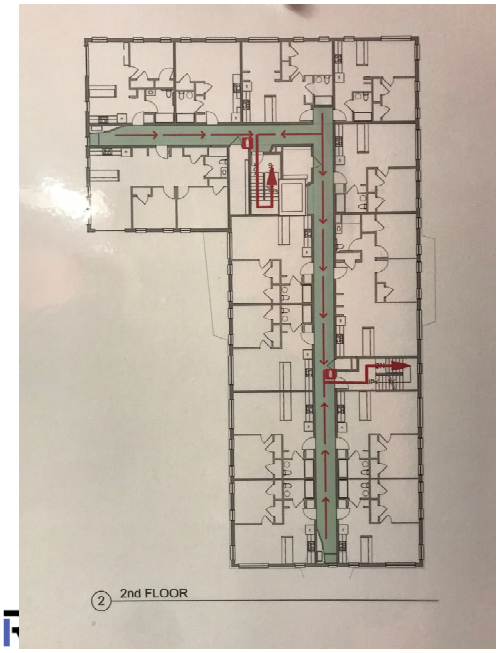

BAYSIDE ANCHOR
Portland, Maine

- → 45 Units – Family Housing
- → Infill at social housing site
- → Service hub, aka “Anchor”
- → Wood Frame Construction
- → Electric Baseboard, Solar Array
- → Natural Gas DHW
- → Completed in 2017
- → $149 USD per square foot
  - → ($210 CAD at current exchange)

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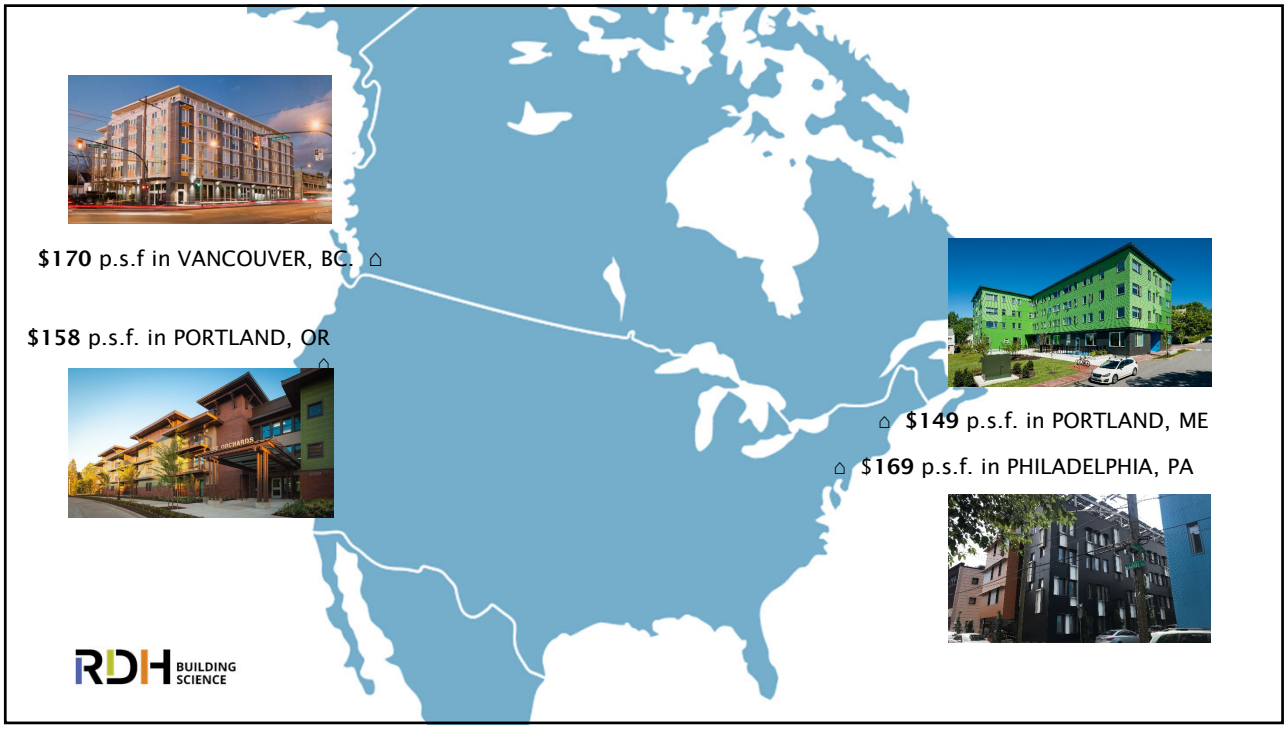

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How does $149 to $170 p.s.f. compare to market?

CITY	1-3 STORY APARTMENT	4-7 STORY APARTMENT	8-24 STORY APARTMENT
ATLANTA	185.26	183.26	220.26
AUSTIN, TEXAS	170.22	169.01	201.34
CHARLOTTE	174.08	172.71	206.86
CHICAGO	266.80	261.95	308.78
COLUMBUS, OHIO	192.27	190.16	226.15
JACKSONVILLE, FLA.	171.60	170.39	202.62
NASHVILLE	179.00	177.64	210.55
RALEIGH, N.C.	173.43	171.93	206.66
SEATTLE	226.91	223.38	264.48
TEMPE, ARIZ.	182.10	180.50	214.00

Note: All costs for Q4 2018. Square foot models are used for planning and budgeting and are not meant for detailed estimates.

RSMeans data reported in Building Design + Construction magazine

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RSMeans data. https://www.bdcnetwork.com/cost-living-apartment-construction-costs-2019

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Milestones: How to Lower the Cost of Your First Passive House Project

Retrofit approach costs more. So rethink milestones.

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How to lower the cost of your Passive House

Cost to construct the worst building you are legally able to build = 100%

Cost to build a Certified Passive House: 105% to 110%

So the question I hope you're asking is…

"How do I manage the 0% project, not the 10% project?"

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How to lower the cost of your Passive House

Cost to construct the worst building you are legally able to build = 100%

Cost to build a Certified Passive House: 105% to 110%

Answer:

If you don't design differently, you'll pay more.

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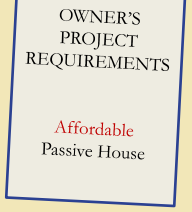
Step One: Design a simpler building

First, simplify the building in ways that save both cost and energy

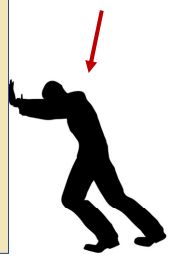
→ Require simple, efficient mechanical layout
→ Minimize building surface area
→ Limit glazing area in the O.P.R.
→ Repeat what works

Make tough choices before hiring Architect.

Put metrics in Owner's Project Requirements.



This is the owner. No one else can do this.



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(How NOT to write an OPR…)

This Project will not be pursuing LEED certification, but it will be using LEED Platinum at a minimum, with net zero plus site energy and net zero water as targets. [redacted]

pushing the boundaries of green materials and systems, as well as testing the limits of what can be permitted [redacted]. I want this property to exceed the highest metrics set by existing programs such as Zero Waste, Passive House, Net Zero Plus, or Living Building Challenge.

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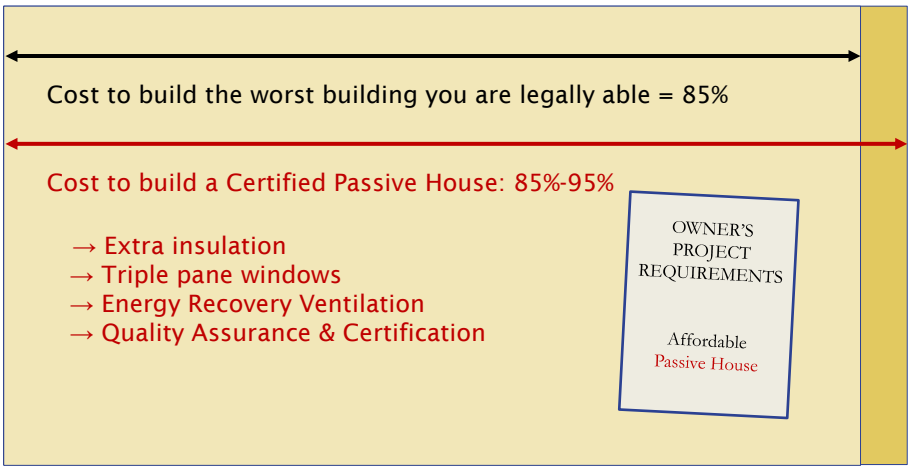
Step Two: Pre-tender key components



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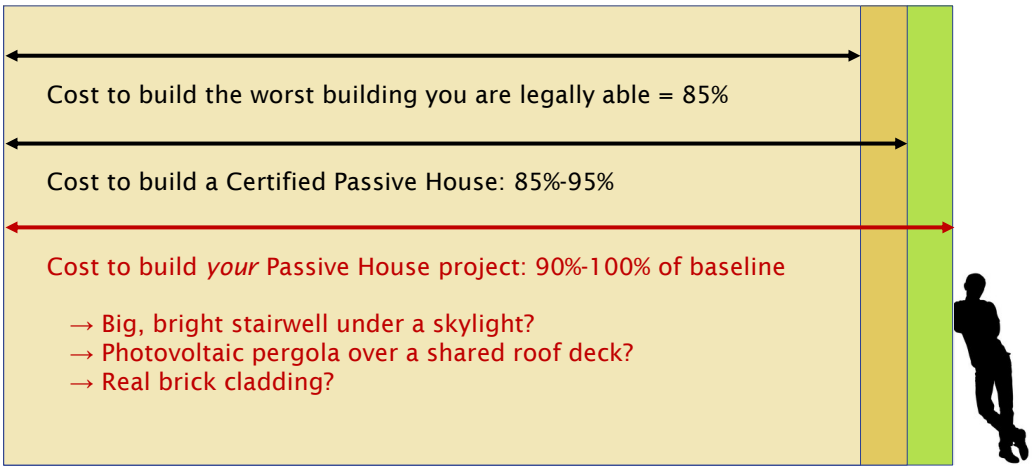
Step Three: Add back something you love



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If your design approach is to start with the same code-minimum building you built last time, then add Passive House components…

Then your project is going to cost the same as a code-minimum building, ***plus*** the cost of those Passive House components.

Put another way…

If you don't change your milestones, your project will cost more.

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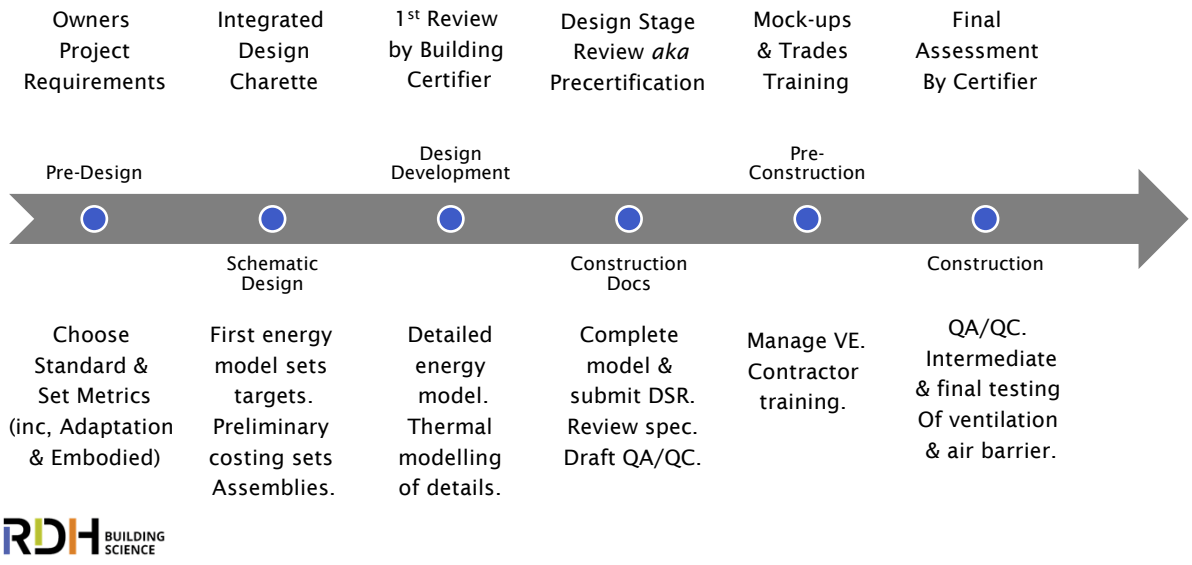
Milestones for an affordable Passive House project



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Strategies: Four Patterns for Affordable Passive House Design

Change your design approach from the get-go.

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Four patterns for affordable Passive House design

Pattern № 1: LAY OUT MECHANICAL FIRST
Specify approach to ventilation, hot water, cooling.

Pattern № 2: MINIMIZE SURFACE AREA
Specify form factor ratio.

Pattern № 3: FORCE FAÇADE TO FOLLOW FUNCTION
Specify window-wall area.

Pattern № 4: REPEAT WHAT WORKS
Demand creative repetition.

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LAY OUT MECHANICAL FIRST

Poorly planned ventilation systems cost more to install, cost more to maintain, and perform less efficiently.

Remediation of poorly planned mechanical systems is a leading source of change orders and cost over-runs on multiunit Passive House projects.

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Photo: Allison Bailes, Energy Vanguard.

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LAY OUT MECHANICAL FIRST

Problem

Multiunit residential buildings require highly efficient heat recovery ventilation, well-insulated domestic hot water pipes, and right-sized cooling/heating systems.

Yet many teams literally ignore the space these systems will require until after the floorplan (and budget) is set.

As a result, systems get "shoehorned" into inadequate space, resulting in higher upfront cost and lower performance.

Solution

Lay out mechanical space first.

Identify ventilation strategy (local or central) at beginning of schematic design; locate units & ducts prior to floorplan.

Plan plumbing to minimize pipe lengths. Short DHW runs costs less to build, cuts heat loss, and reduces cooling expense.

Identify true cooling & heating load early, and insist on right-size systems.

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Example: Local vs. central ventilation

Local

Local ERVs are affordable and efficient, but **must be installed on an exterior wall** inside every unit. Maintenance requires entering the unit.

Central

Central ERVs may be installed on roof or in basement, but **must be connected to every unit** via appropriately-sized ducts with fire dampers.

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LAY OUT MECHANICAL FIRST

Hire a Passive House consultant with multiunit experience, and an MEP with Passive House experience, prior to commencing Schematic Design.

Identify mechanical strategies and allot space for high-performance systems before laying out floorplans.

If you complete S.D. before laying out mechanical, you may have already lost $100,000.

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MINIMIZE SURFACE AREA

The 1977 book, "A Pattern Language" famously advised "wrinkle the edge, turn corners" to achieve light on two sides.

Many planning guidelines advise "break up the massing" with bays or balconies.

These practices drive up construction costs, and drive down energy performance.

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HABITAT 67 in Montreal, by Moshe Safdie

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MINIMIZE SURFACE AREA

Problem

Bays, step-backs, balcony insets, and other "wrinkle the edge" strategies raise housing costs in two ways:

Each corner or step-back raises the cost of construction materials and labour.

The additional thermal bridging and heat loss area created by these wrinkles must be compensated for through additional insulation.

Solution

Require mid-rise affordable housing achieve a form factor close to 1:1.

Count corners. Cut corners. Eliminate as many "wrinkles" as feasible.

Reduce step backs.

Avoid structural cantilevers.

"Decorate the enclosure. Don't decorate with the enclosure."

These steps reduce construction cost while saving energy.

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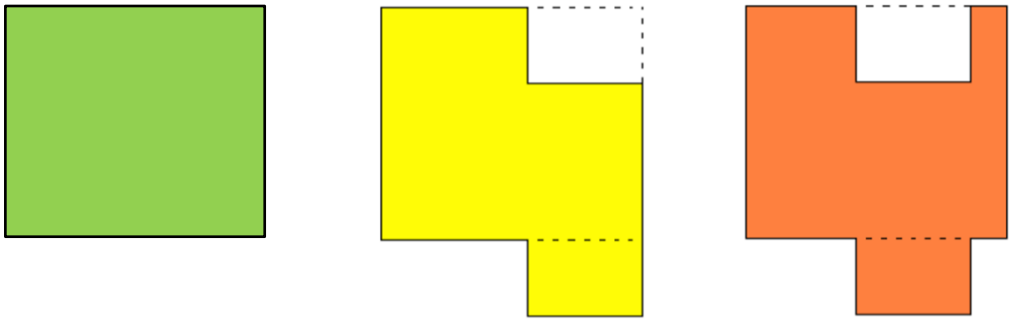
MINIMIZE SURFACE AREA



Four corners.

Eight corners.
10% more surface area.
One inch extra insulation.

Twelve corners.
20% more surface area.
Two inches extra insulation.

Every corner costs. Every inch of insulation costs.

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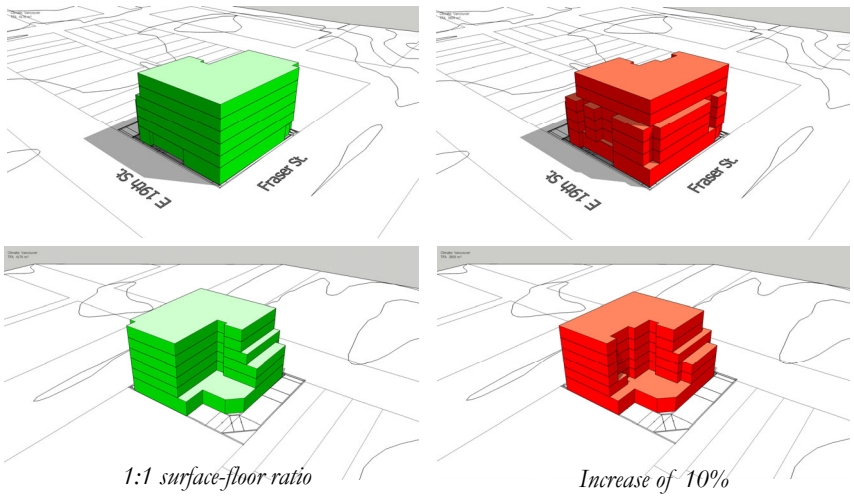
MINIMIZE SURFACE AREA



1:1 surface-floor ratio

Increase of 10%

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Image: RDH Building Science

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MINIMIZE SURFACE AREA

Set a surface area target, and require the design team achieve that target.

Evaluate the form demands of your site, then set a target between 1:1 and 1.3:1.

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Rendering of Brixton Flats by Gair Williamson Architects, Vancouver.

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FORCE FACADE *to* FOLLOW FUNCTION

Problem

Glazing in lieu of design, and glazing as design, are common mistakes.

Too many teams design from the "outside in" and use windows to decorate the façade. This introduces unrealistic expectations in the minds of clients and authorities having jurisdiction.

Solution

Only place a window where it has a specific function, and where it is the best solution to serve that purpose.

Purposes: Daylight, view, ventilation.

Every window must answer to its purpose. If it has no function, or if it does not serve the function, take it out.

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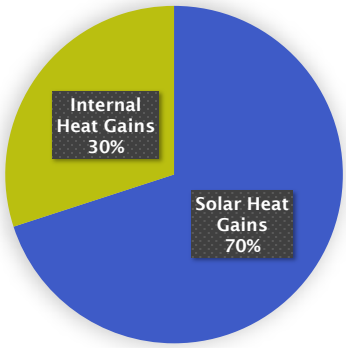
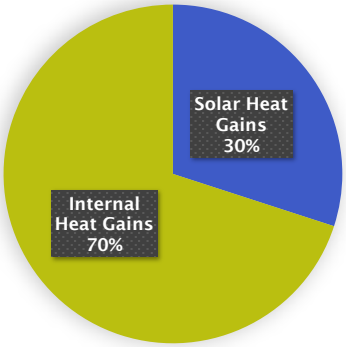
Glass boxes have no function



Small Building

Internal Heat Gains



Large Building

Internal Heat Gains

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These types of buildings may not survive climate change

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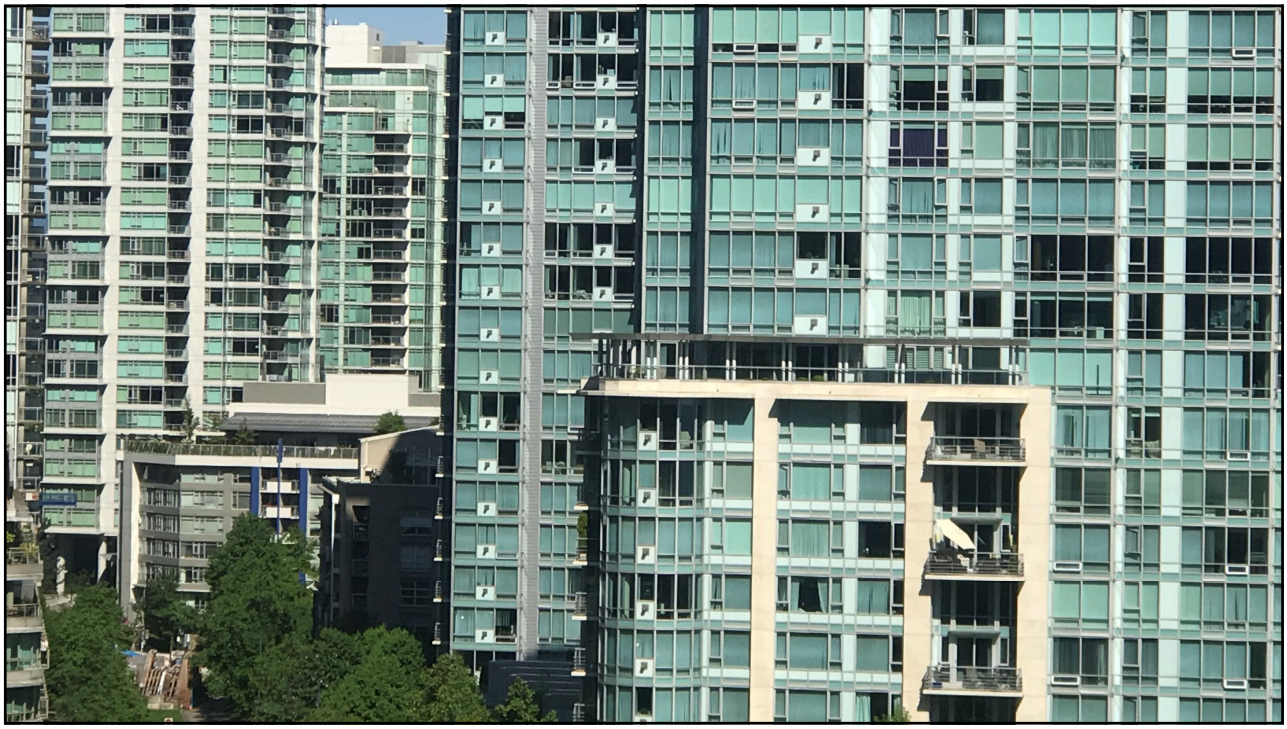

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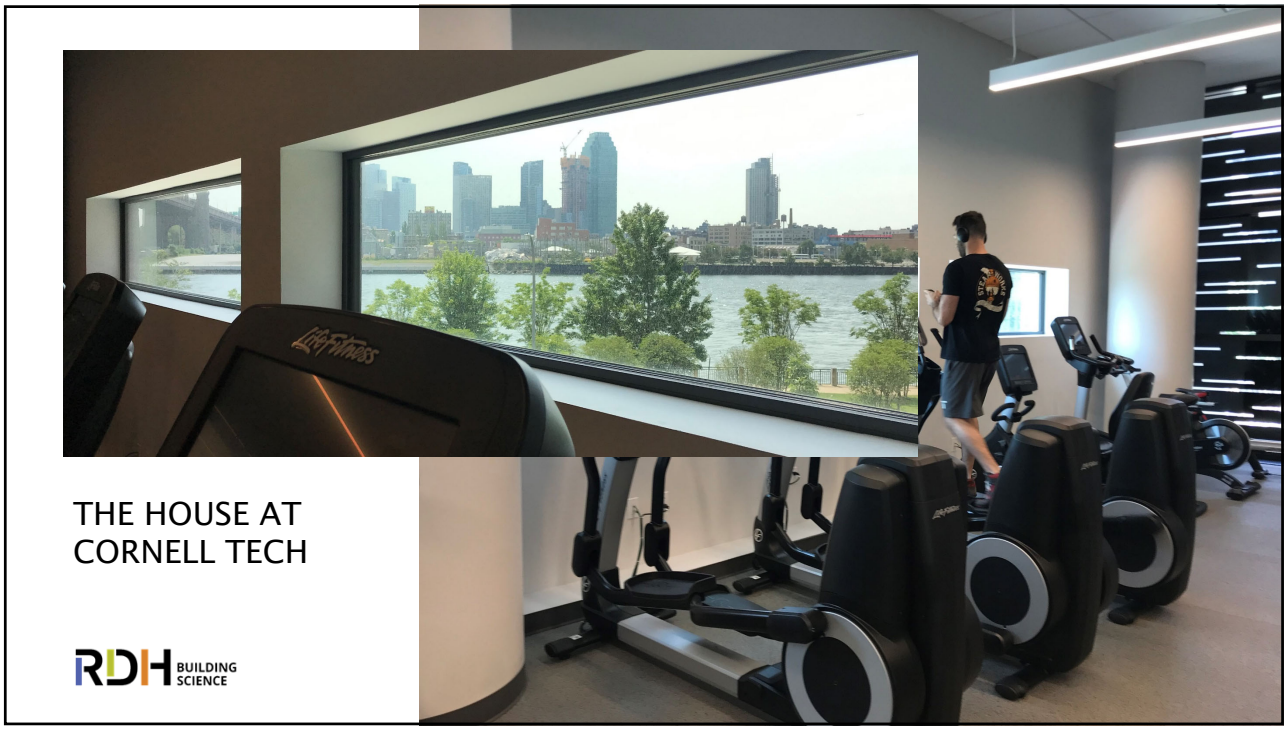

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FORCE FACADE *to* FOLLOW FUNCTION

Specify a window-wall ratio in OPR.

Demand that every window answer to a purpose. If it has no function, or if it does not serve the function, take it out.

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REPEAT WHAT WORKS

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REPEAT WHAT WORKS

Most architectural practices have a set of standard details. Developed over time, these stock details allow a firm to produce exhaustive drawing sets at reasonable cost.

The same principle can be applied to all components of a project.

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REPEAT WHAT WORKS

Problem

Many municipal planners have developed a rigid aversion to repetitive design. Many are strictly opposed to the idea that two or more identical buildings in the same city.

Ironically, prescriptive design guidelines often lead to many buildings looking the same.

Solution

Repeat what works. Embrace repetition of excellent design.

Repeat details.

Repeat components.

Repeat wall panels.

Repeat modular units.

Repeat entire buildings.

Thoughtful repetition does not threaten character.

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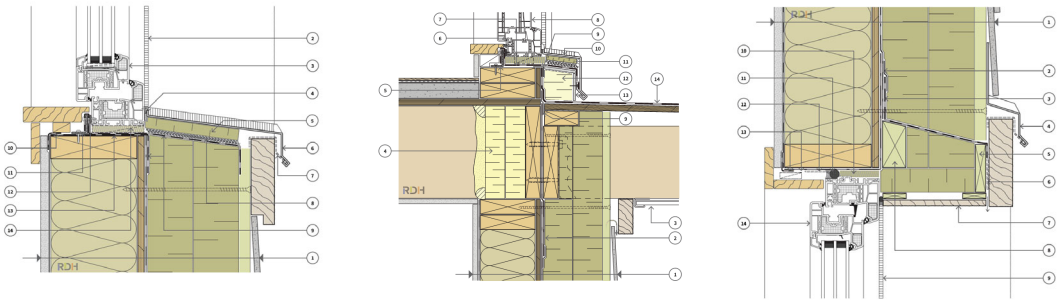
REPEAT WHAT WORKS



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REPEAT WHAT WORKS

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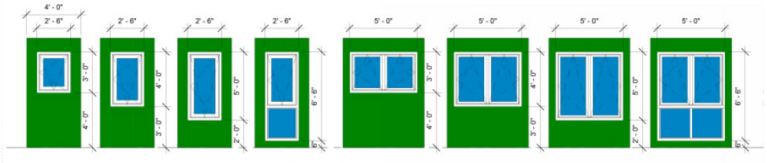
REPEAT WHAT WORKS



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REPEAT WHAT WORKS

Bella Bella Passive House, constructed by Metric Modular.

Yale First Nations Passive House, constructed by Metric Modular.

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REPEAT WHAT WORKS

Affordability via repetition.

Repeat floors. Align units.

Repeat details, contract team for multiple projects.

Repeat whole buildings on site, or across multiple sites.

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How to Build Multifamily Passive House for Less

- Budget: Multifamily Passive House may cost 5.5% more than code.
- Examples: Passive House projects have been built below market rate.
- Milestones: Don't retrofit an old design. Adopt new milestones.
- Strategies: Mech first, less surface, façade must function, repetition.

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A PATTERN LANGUAGE *from* PASSIVE HOUSE

№ 1: LAYOUT MECHANICAL FIRST *
№ 2: MINIMIZE SURFACE AREA **
№ 3: COURTYARDS THAT COOL
№ 4: FAT STAIRS, SLIM HALLS
№ 5: TRIAGE BALCONIES *
№ 6: THE SPACE BETWEEN
№ 7: REPEAT WHAT WORKS **
№ 8: DON'T BUILD, RETROFIT **
№ 9: BUILD LESS PARKING
№ 10: LIGHT CONSTRUCTION
№ 11: LOW-CARBON MATERIALS
№ 12: BUILD IN WALKABLE PLACES
№ 13: INTERIOR INSULATION
№ 14: EXTERIOR INSULATION
№ 15: SPLIT INSULATION
№ 16: STANDING PANELS *
№ 17: HANGING PANELS *
№ 18: MODULAR CONSTRUCTION *
№ 19: PATTERNS for SUSENDED SLABS
№ 20: THREE BALCONY PATTERNS
№ 21: MINIMIZE PENETRATIONS
№ 22: SHADING BEFORE WINDOWS
№ 23: OPERABLE EXTERIOR SHADING
№ 24: FAÇADE FOLLOWS FUNCTION
№ 25: LARGE PANES
№ 26: FOUR FOOT SQUARE WINDOW
№ 27: FIXED WINDOW, FRAMED VIEW
№ 28: DOOR AS A WINDOW
№ 29: INWARD OPENING FRAMES
№ 30: WINDOW SEAT
№ 31: COOLING *via* VENTILATION
№ 32: WINDOW AIR CONDITIONERS
№ 33: COOLING via HYDRONIC
№ 34: COOLING *via* VRF
№ 35: NEGOTIATE EARLY
№ 36: THE MOST EFFICIENT ERV
№ 37: FILTER THE AIR
№ 38: LOCALIZE VENTILATION
№ 39: CENTRALIZE VENTILATION
№ 40: SEAL DUCTS PERFECTLY
№ 41: THE BEST RANGE HOOD
№ 42: MONITOR INDOOR AIR
№ 43: OPEN THE WINDOWS
№ 44: TRIM HOT WATER HEAT LOSS
№ 45: HEAT PUMP WATER HEATERS
№ 46: DAYLIGHT THE CORRIDORS
№ 47: DOWNSIZE APPLIANCES
№ 48: COOK *with* INDUCTION
№ 49: MANAGE PLUG LOADS
№ 50: TOO CHEAP TO METER?

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Please credit Monte Paulsen and RDH Building Science if you share this list in whole or in part.

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- Dates: November 24, 26, December 1, 3
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Join the (free) Global Passive House Happy Hour

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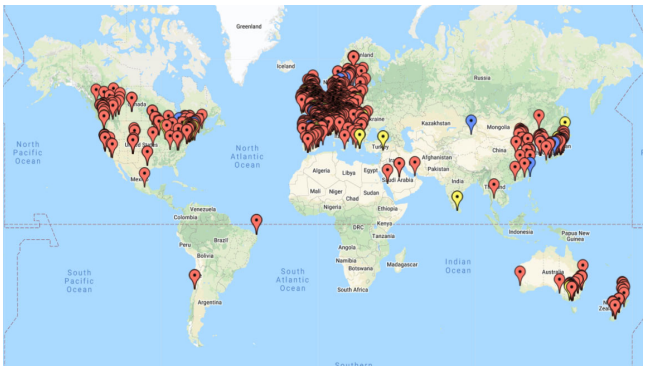
Talk to us!

Monte Paulsen
RDH Building Science
mpaulsen@rdh.com
@montepaulsen



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