BUILDINGENERGY BOSTON

Optimizing Passive Building for Cost Effectiveness: Tools and Methods

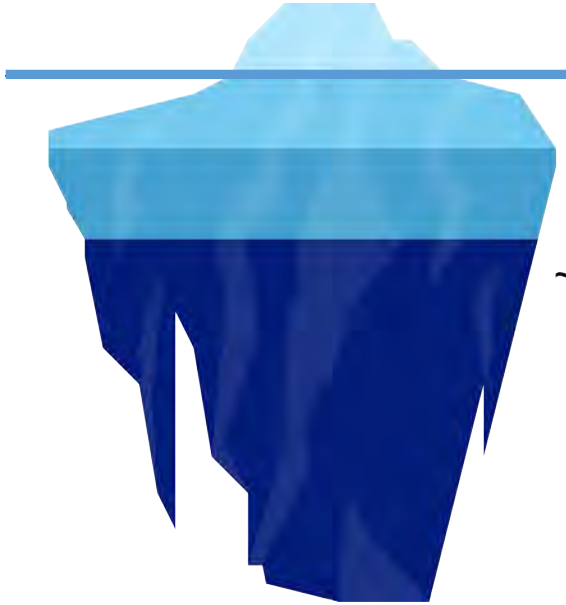
Ryan Abendroth, Build Zero Consulting
Stefan Goebel, Build Zero Consulting
Shannon Pendleton, Sanderson Sustainable Design

Curated by Ken Neuhauser and Colin Richardson

Northeast Sustainable Energy Association (NESEA) | March 24, 2026

PASSIVE MULTIFAMILY MASSIVE PASSIVE

2025 Q3



2,056 Certified Units

4,988 Design Certified Units

7,892 Registered Units

~21,000 MEPA Reviewed units

2026 Q1

2,477 Certified Units

6,382 Design Certified Units

11,174 Certifier Registered Units

20,946 Mass Save Registered Units

PASSIVEhouse MASSACHUSETTS

*Massachusetts Environmental Policy Act (MEPA)

NESEA
NORTHEAST SUSTAINABLE ENERGY ASSOCIATION

BUILDINGENERGY BOSTON

Optimizing Passive Building for Cost Effectiveness: Tools and Methods

LEARNING OBJECTIVES:

- IDENTIFY how Passive House modeling tools—such as energy, thermal and hygrothermal analysis—can be used to assess and address technical and financial challenges in multifamily housing projects.
- ANALYZE modeling outputs related to comfort, condensation risk, and enclosure performance to inform clear, data-driven design and team decision-making.
- APPLY collaborative strategies to mitigate risk, improve constructability, and enhance cost-effectiveness.
- COMPARE design and mechanical system strategies that balance affordability, constructability, and certification requirements to achieve replicable high-performance multifamily housing outcomes.

AGENDA:

WORKFLOW OVERVIEW

- APPROACH TO PROJECTS + TYPOLOGIES

CASE STUDIES

- LIVONIA
- 45 REMSEN
- JOHN GRACE ARMS

PERFORMANCE + COST SUMMARY

Q+A

CEUS:

This session is pre-approved for 1 credit hour toward AIA (LU|HSW), BPI, MA CSL, and NARI certification. Those who attend a full day of the conference are additionally eligible for credit toward Phius and RESNET certification. Session ID BOS26-225

WELCOME TWO FIRMS ONE MISSION

Stefan Goebel
Build Zero Consulting
Building Envelope & Energy Consultant | Net Zero Energy & Passive Building Advocate

stefan@buildzeroconsulting.com

Ryan Abendroth
Build Zero Consulting
Phius Trainer
Phius technical Committee
Senior Lecturer, Washington University

ryan@buildzeroconsulting.com

Shannon Pendleton, CPHC
Sanderson Sustainable Design
Passive House Accelerator
Source 2050
Aquetong Watershed Assoc.

shannon@sandersondesign.net

WELCOME TWO FIRMS ONE MISSION

SILVERGREEN | MULTIFAMILY PHIUS 2018+ CERTIFIED SOURCE ZERO ALL ELECTRIC | BRYN ATHYN, PA

45 REMSEN | 11 UNIT MULTI-FAMILY AFFORDABLE DESIGN REGISTERED | NEW BRUNSWICK, NJ

JOHN GRACE ARMS | MULTI-FAMILY DESIGN CERTIFIED DETROIT MI

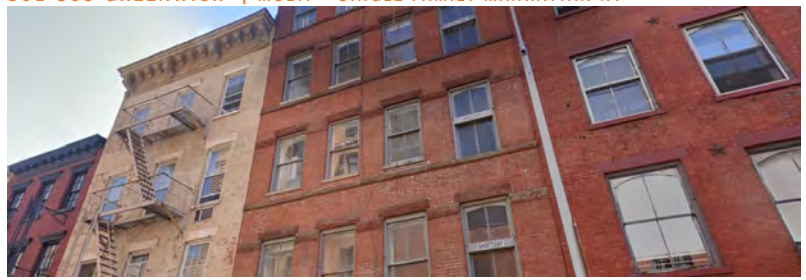
LIVONIA | MULTIFAMILY PHIUS DESIGN CANDIDATE | BROOKLYN NY

33 JORALEMON | SINGLE FAMILY MARKET RATE DESIGN CERTIFIED PASSIVE HOUSE | BROOKLYN, NY

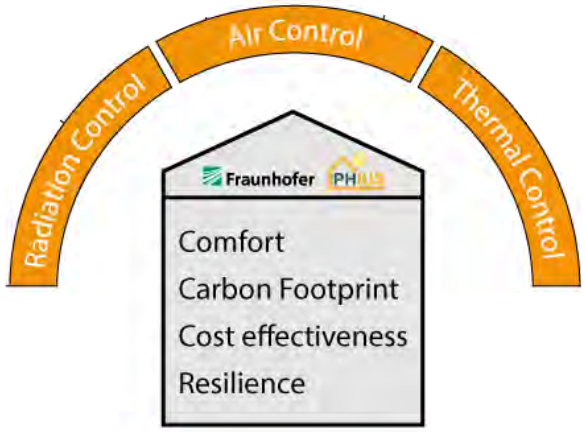
NEW HOPE HOUSE | SINGLE FAMILY PHIUS DESIGN CERTIFIED ALL ELECTRIC | NEW HOPE, PA

CASA YORK WELCOME CENTER | ROOSEVENT AVENUE YORK , PA

801-803 GREENWICH | MULTI + SINGLE FAMILY MANHATTAN NY



PASSIVE BUILDING DESIGN PRINCIPLES



S/M/L MULTIFAMILY CASE STUDIES

LIVONIA

MULTIFAMILY
Phius CORE 2024 - CANDIDATE
BROOKLYN –NY

Affordable Housing 283 units
Mixed Use: First floor Commercial

ARCHITECT: Quatela-Architects
RATER: KOW
DEVELOPER: TBD

Copyright 2024 Quatela-Architects
https://www.quatela-architects.com/multi-family-projects

JOHN GRACE ARMS

MULTIFAMILY
Phius CORE 2021 - DESIGN CERTIFIED
DETROIT–MI

Affordable Senior Housing 42 units
Multifamily Only

ARCHITECT: Department01 / John Abela AIA
DEVELOPER: MiSide Community Impact Network
RATER/VERIFIER: McNeely Building Group

Copyright City of Southfield
https://www.cityofsouthfield.com/sites/default/files/inline-files/John%20Grace%20Revitalization%20Plan%20FINAL%2003302022.pdf

45 REMSEN

MULTIFAMILY
Phius CORE 2024 - CANDIDATE
NEW BRUNSWICK –NJ

Affordable Family Housing 11 units
Mixed Use: Caseworker Commercial unit

ARCHITECT: Kurt Ludwig AIA
DEVELOPER: Coming Home of Middlesex County
RATER/VERIFIER: ReVerio

Copyright Coming Home of Middlesex County
https://www.cominghomemiddlesex.org/

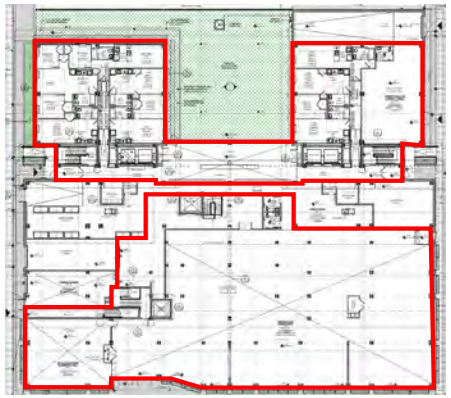
AS DESIGNED ANALYSIS

S/M/L MULTIFAMILY CASE STUDIES

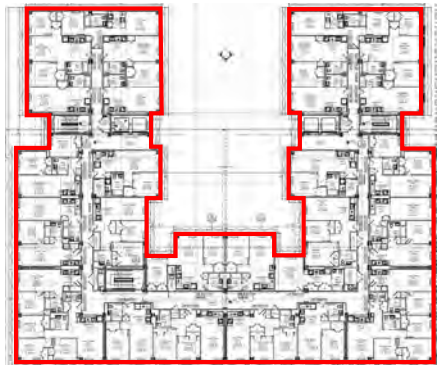
LIVONIA

283 units 14 Stories

VENTILATION FLOW RATES



1ST FLOOR

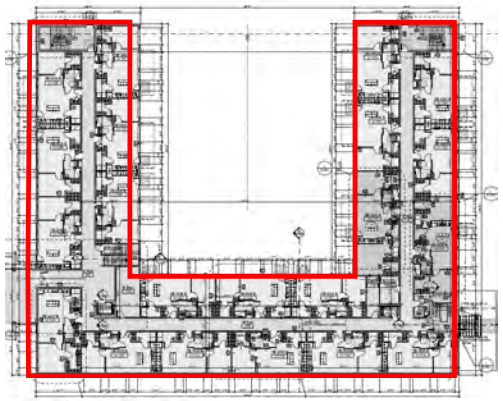


4TH FLOOR

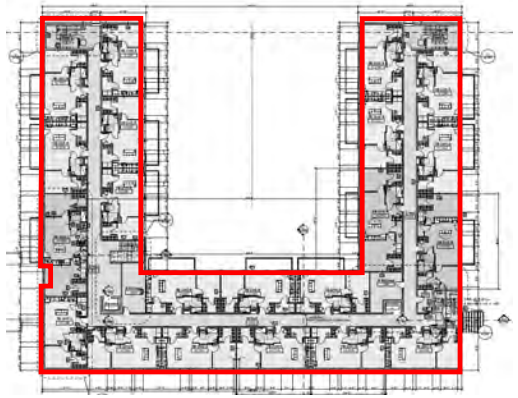
JOHN GRACE

45 units 2 Stories

ERV + PERIMETER INSTALLATION



1st Floor Plan

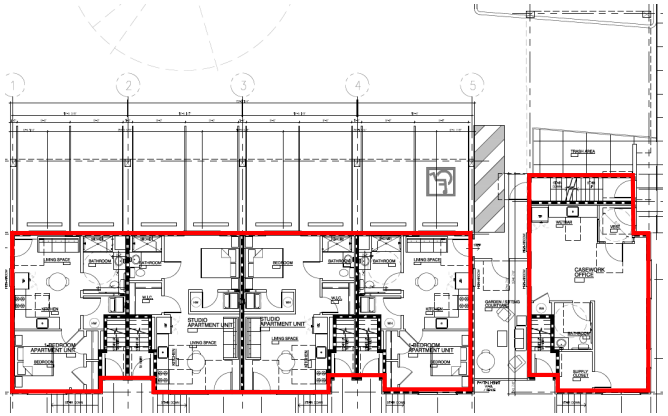


2nd Floor Plan

45 REMSEN

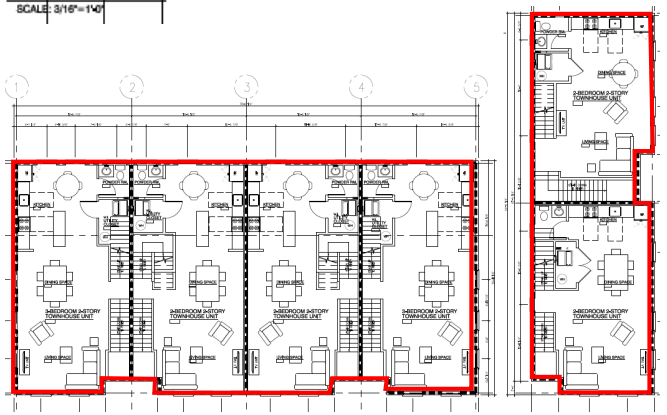
11 units 3 Stories

ERV SYSTEM LOCATIONS



FIRST FLOOR PLAN

SCALE: 3/16"=1'-0"



SECOND FLOOR PLAN

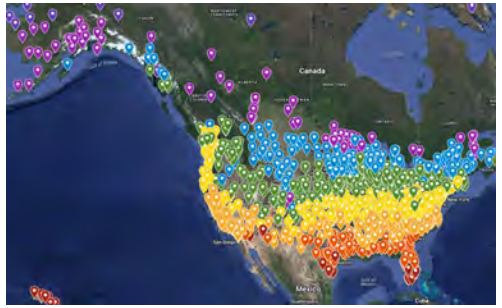
SCALE: 1/4"=1'-0"

PHIUS CERTIFICATION: WORKFLOW TOOLS + TARGETS

PASSIVE BUILDING ANALYSIS

PROJECT DATA | PHIUS TARGETS | WUFI ENERGY MODEL

LOCATION



CLIMATE

PRESCRIPTIVE DATA

City NEW YORK
State NY
Climate Data NEW YORK CENTRAL
Climate Zone 4A
Max Window U-value (Btu/hr.sf.F) 0.19
Max SHGC 0.4
Min SRE for E/HRVs 0.77
Min TRE for E/HRVs 50%
Min Wall R-value 37
Min Roof R-value 67
Min Uncond. Basement / Crawlspace Ceiling R-value 24
Min Below-grade walls / floors R-value 19
Min Rating Req'd for ASHP Min COP @ 5°F: 1.75
Min SEER Required for ASHP (Air-Source Heat Pumps) 15

CALCULATOR INPUTS

Phius 2024
New Construction*
Performance Criteria Calculator v24.1

UNITS:	IMPERIAL (IP)
BUILDING FUNCTION:	RESIDENTIAL
STATE / PROVINCE	NEW YORK
CITY	NEW YORK J F KENNEDY
ASHRAE 169 Climate Zone	4A
Envelope Area (ft²)	220,536.0
iCFA (ft²)	240,479.0
Dwelling Units (Count)	283
Total Bedrooms (Count)	335

TARGETS

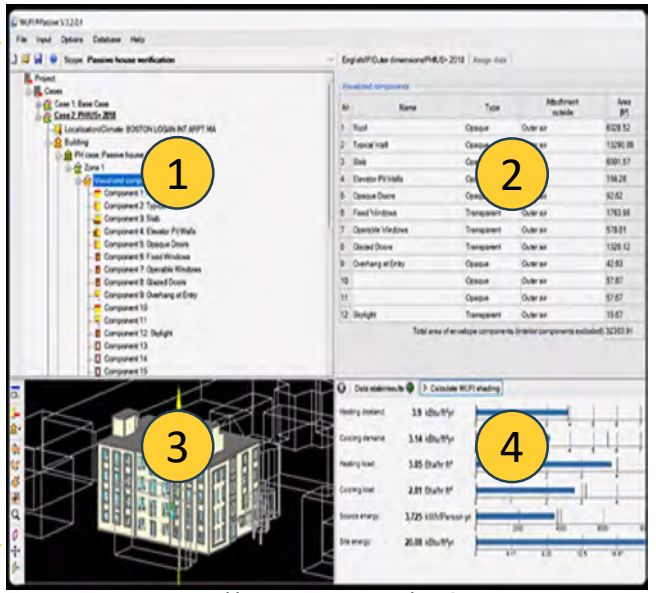
Space Conditioning Criteria

Annual Heating Demand	4.6	kBtu/ft²yr
Annual Cooling Demand	10.5	kBtu/ft²yr
Peak Heating Load	4.7	Btu/ft²hr
Peak Cooling Load	2.7	Btu/ft²hr

Source Energy Criteria

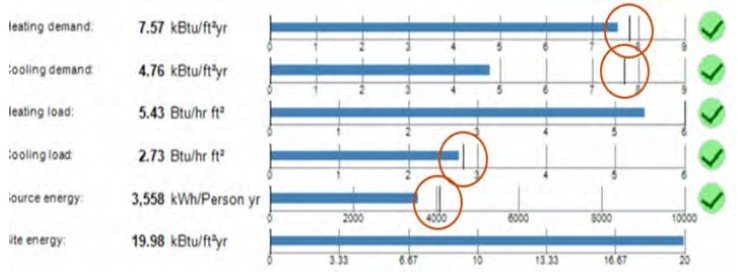
Phius CORE	5725	kWh/person.yr
Phius ZERO	0	kWh/person.yr

OPTIMIZE



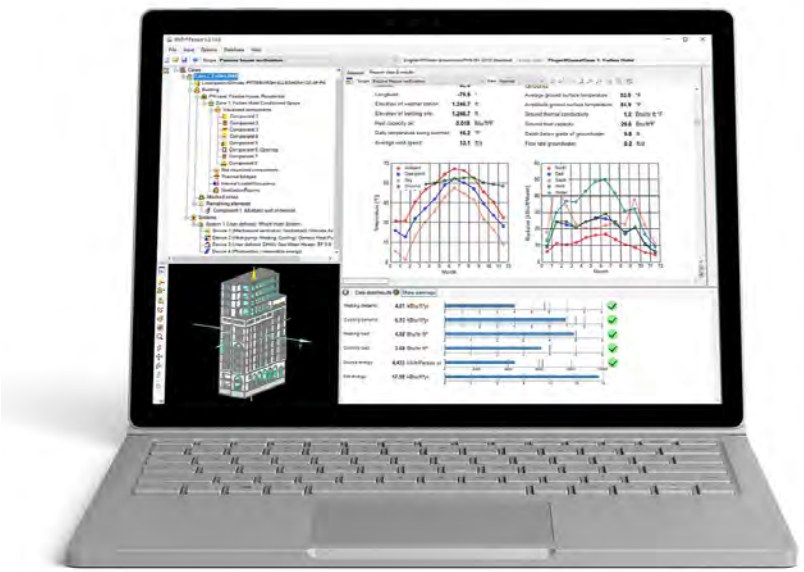
https://www.phius.org/wufi-passive-tutorials

1. TREE STRUCTURE 2. INPUT MASK
3. 3D VIUSALIZER 4. RESULTS



MULTIFAMILY PROJECT CHARACTERISTICS

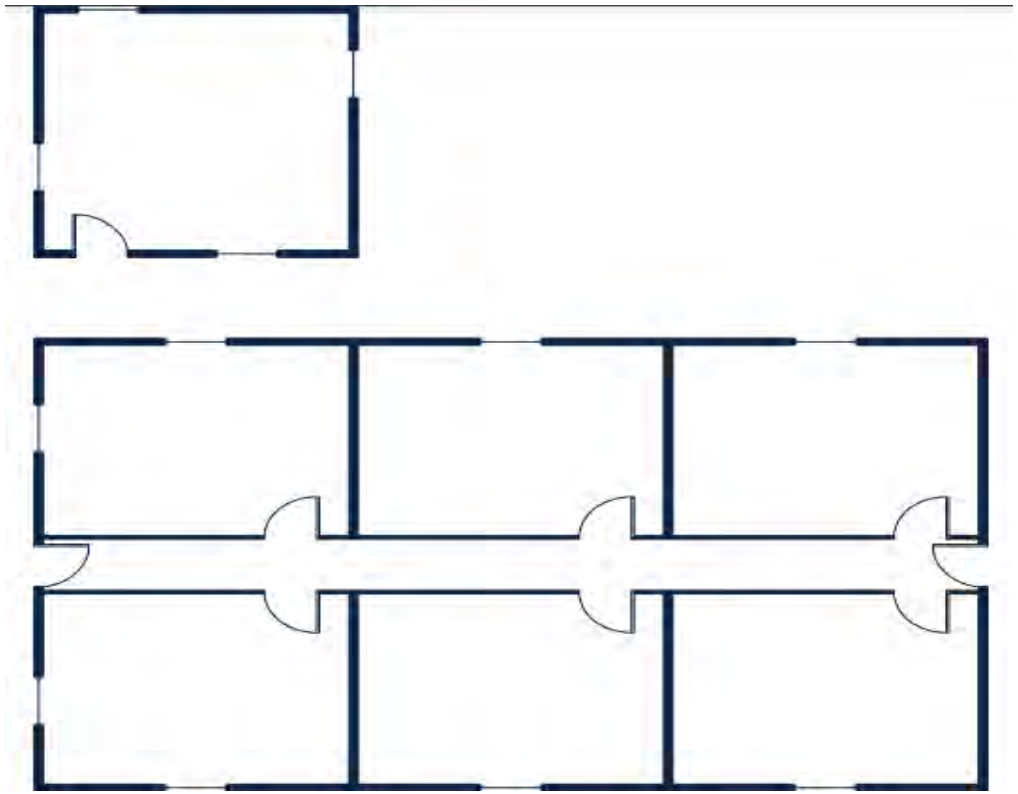
Copyright: AI-generated illustration (ChatGPT)



Copyright: Phius

MULTIFAMILY PROJECT CHARACTERISTICS

Building Physics Advantage & **Scalability**



Copyright: AI-generated illustration (ChatGPT)

Massachusetts Department of Energy Resources

TABLE 2: Residential Specialized code requirements summary by building/dwelling unit size

Building Size	Fuel Type	Minimum Efficiency	Electrification	Min. EV wiring	Renewable Generation
Dwelling units up to 4,000 sf	All Electric	HERS 45 or Phius CORE or PHI	Full	1 parking space	Optional
Dwelling units up to 4,000 sf	Mixed-fuel	HERS 42 or Phius CORE or PHI	Pre-wiring	1 parking space	Solar PV (except shaded sites)
Dwelling units > 4,000 sf	All Electric	HERS 45 or Phius CORE or PHI	Full	1 parking space	Optional
Dwelling units > 4,000 sf	Mixed-fuel	HERS 0 or Phius ZERO	Pre-wiring	1 parking space	Solar PV or other renewables
Multi-family >12,000 sf	All Electric	Phius CORE or PHI	Full	20% of spaces	Optional
Multi-family >12,000 sf	Mixed-fuel	Phius CORE or PHI	Pre-wiring	20% of spaces	Optional

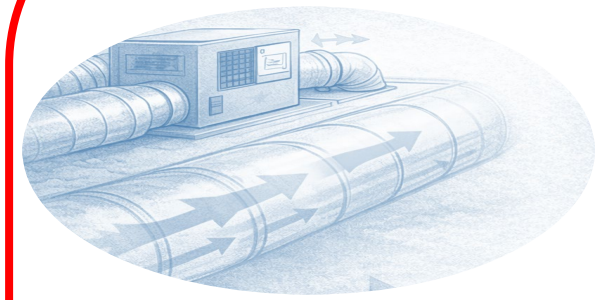
Copyright: MA Specialized Residential summary

MULTIFAMILY PROJECT CHARACTERISTICS

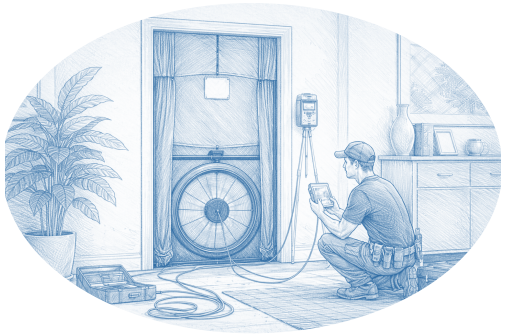
LEVERS THAT DRIVE PERFOMANCE

HIGH BASELINE ASSUMPTION FOR PROJECTS TARGETING PH

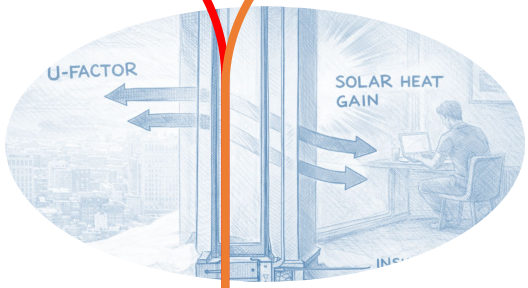
Flow rate



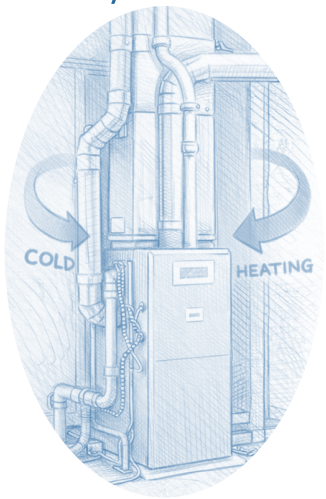
Air Tightness



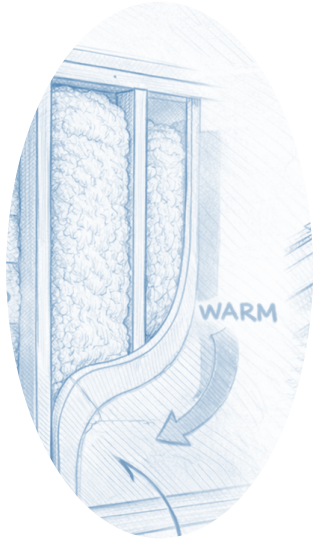
Window U-Value



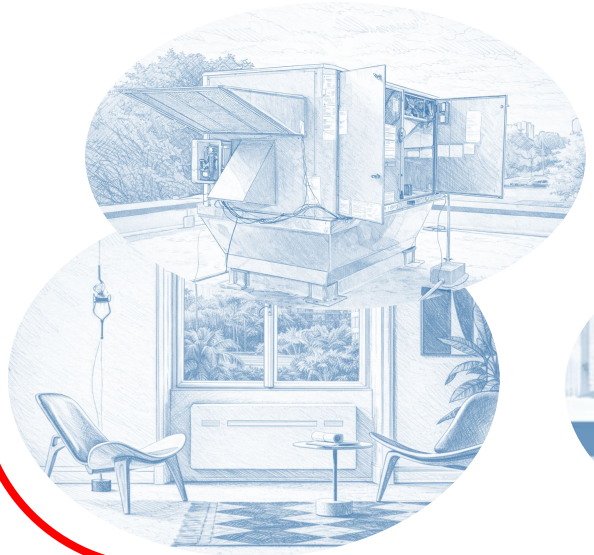
Heating/Cooling Systems



Wall Insulation

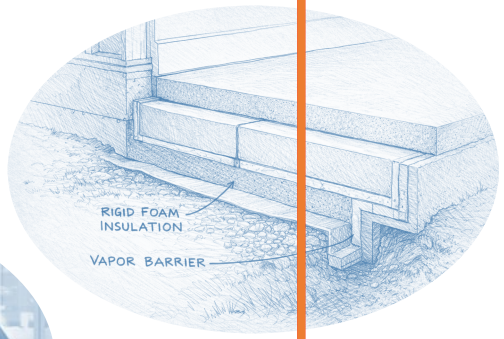


ERV

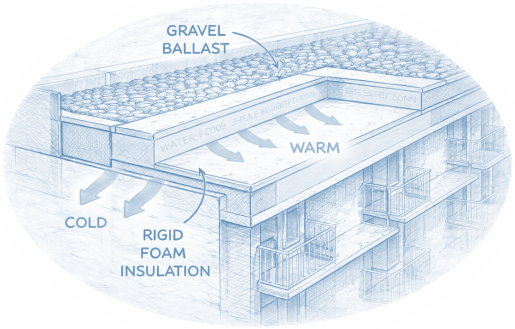


Major Thermal Bridges

Foundation Insulation



Roof Insulation

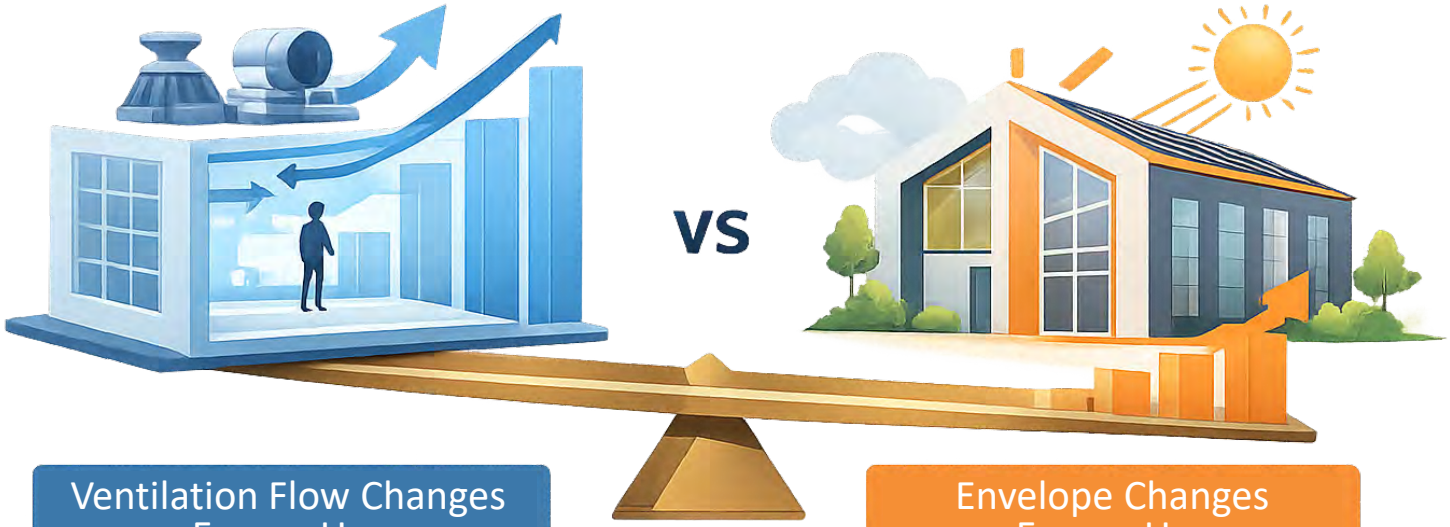


AI-generated illustration (ChatGPT)

MULTIFAMILY LOADS

MECHANICAL SYSTEMS VS ENCLOSURE UPGRADES

When internal loads dominate:



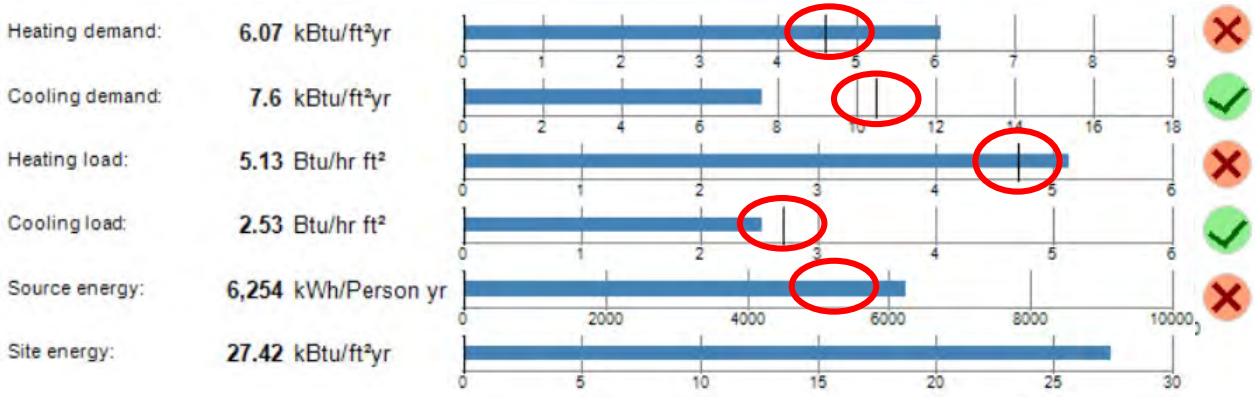
Ventilation Flow Changes Energy Use	Envelope Changes Energy Use
?	?

LIVONIA

LESSON 1: OPTIMIZING ENVELOPE

AS-DESIGNED VENTILATION & ENVELOPE:

- Slab: Uninsulated
- Wall: R14-R28.5 (Majority R22)
- Roof: R42
- Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC
- Storefront: 0.244 BTU/hr·ft² / 0.21 SHGC
- Airtightness: 0.12 CFM/ft² ; ACH50: 0.8 1/hr
- Ventilation Flow Rate: 85 CFM/unit
- HVAC: Heat Pump COP2 @17F / COP3@47F
- ERV: 0.7 Sensible Recovery, 0.5 Humidity Recovery
- DHW: HPWH
- Lighting: LED



Phius 2024
New Construction*
Performance Criteria Calculator v24.1

UNITS:	IMPERIAL (IP)
BUILDING FUNCTION:	RESIDENTIAL
STATE / PROVINCE	NEW YORK
CITY	NEW YORK J F KENNEDY
ASHRAE 169 Climate Zone	4A
Envelope Area (ft²)	220,536.0
iCFA (ft²)	240,479.0
Dwelling Units (Count)	283
Total Bedrooms (Count)	335

Space Conditioning Criteria

Annual Heating Demand	4.6	kBtu/ft²yr
Annual Cooling Demand	10.5	kBtu/ft²yr
Peak Heating Load	4.7	Btu/ft²hr
Peak Cooling Load	2.7	Btu/ft²hr

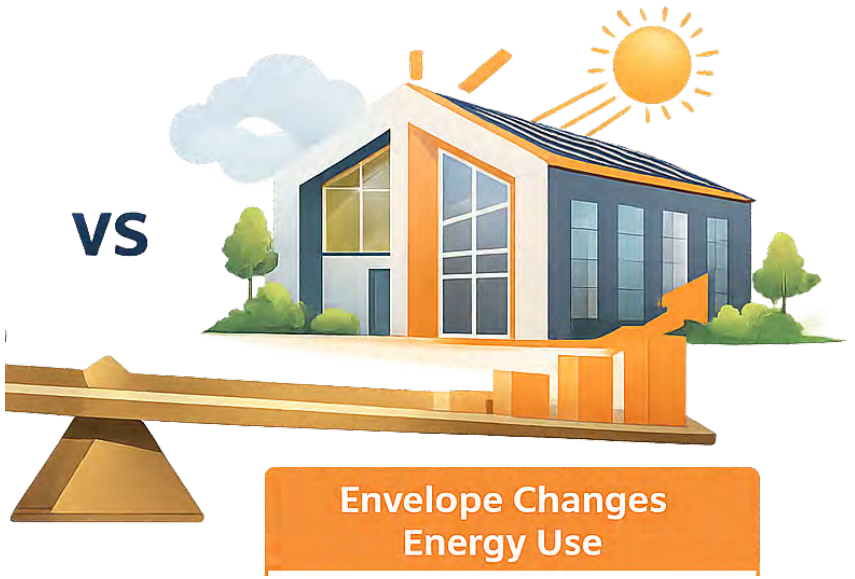
Source Energy Criteria

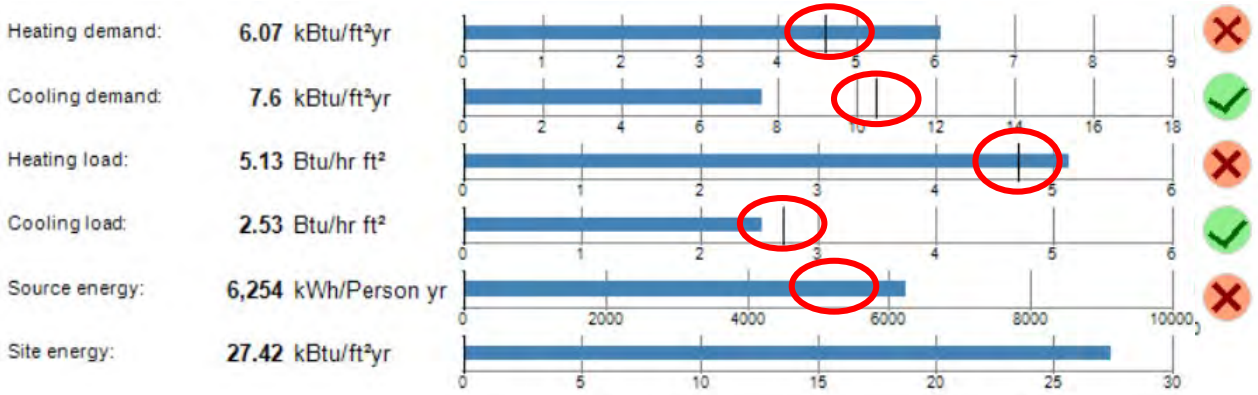
Phius CORE	5725	kWh/person.yr
Phius ZERO	0	kWh/person.yr

AS-DESIGNED VENTILATION & ENVELOPE:

- Slab: Uninsulated
- Wall: R14-R28.5 (Majority R22)
- Roof: R42
- Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC
- Storefront: 0.244 BTU/hr·ft² / 0.21 SHGC
- Airtightness: 0.12 CFM/ft² ; ACH50: 0.8 1/hr
- Ventilation Flow Rate: 85 CFM/unit
- HVAC: Heat Pump COP2 @17F / COP3@47F
- ERV: 0.7 Sensible Recovery, 0.5 Humidity Recovery
- DHW: HPWH
- Lighting: LED

As-Designed Ventilation with Upgraded Envelope





LIVONIA

LESSON 1: OPTIMIZING ENVELOPE

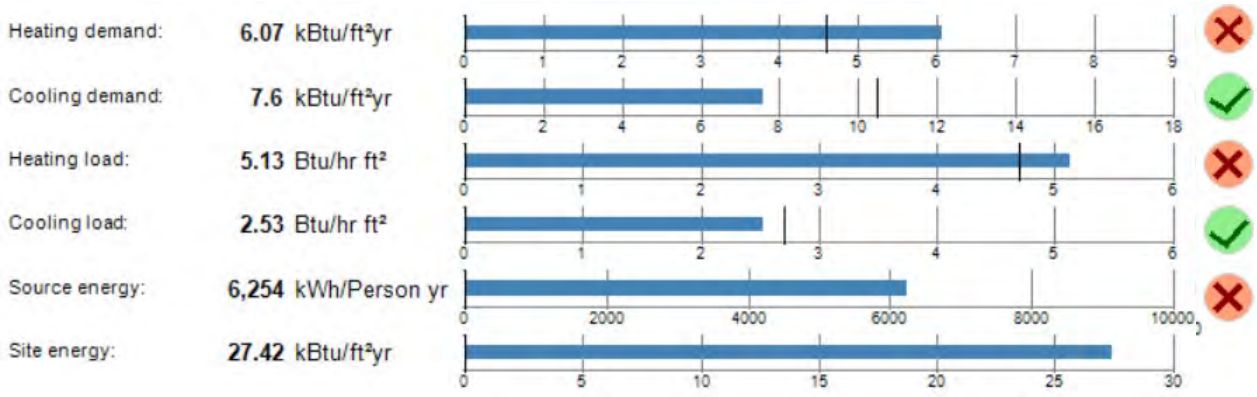
As-Designed Ventilation & Envelope:

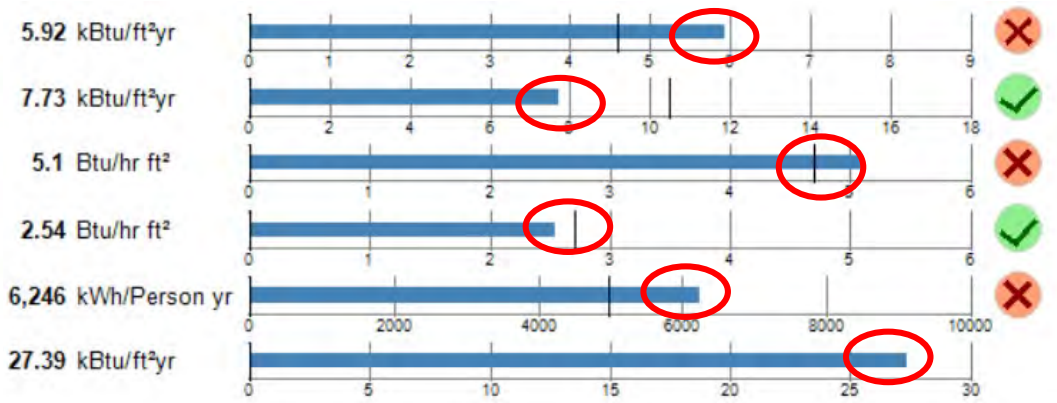
- Slab: Uninsulated
- Wall: R14-R28.5 (Majority R22)
- Roof: R42
- Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC
- Storefront & Doors: 0.244 BTU/hr·ft² / 0.21 SHGC
- Airtightness: 0.12 CFM/ft² ; ACH50: 0.8 1/hr
- Ventilation Flow Rate: 85 CFM/unit
- HVAC: Heat Pump COP2 @17F / COP3@47F
- ERV: 0.7 Sensible Recovery, 0.5 Humidity Recovery
- DHW: HPWH
- Lighting: LED

As-Designed Ventilation with Upgraded Envelope

Slab: R10

- Target Impact:
  - HD: - 0.15 kBtu/ft²yr
  - CD: + 0.13 kBtu/ft²yr
  - HL: - 0.03 Btu/hr ft²
  - CL: + 0.01 Btu/hr ft²
  - SE: 18 kWh/Person yr saving
- SE: - 0.03 kBtu/ft²yr
  - - 2,874 kWh/yr * $0.32/kWh = **-$919.68/yr**
  - Material Cost: +$1.75/sqft → **+$24,300**
    (Labor Incl.: $3.25 /sqft)





LIVONIA

As-Designed Ventilation & Envelope:

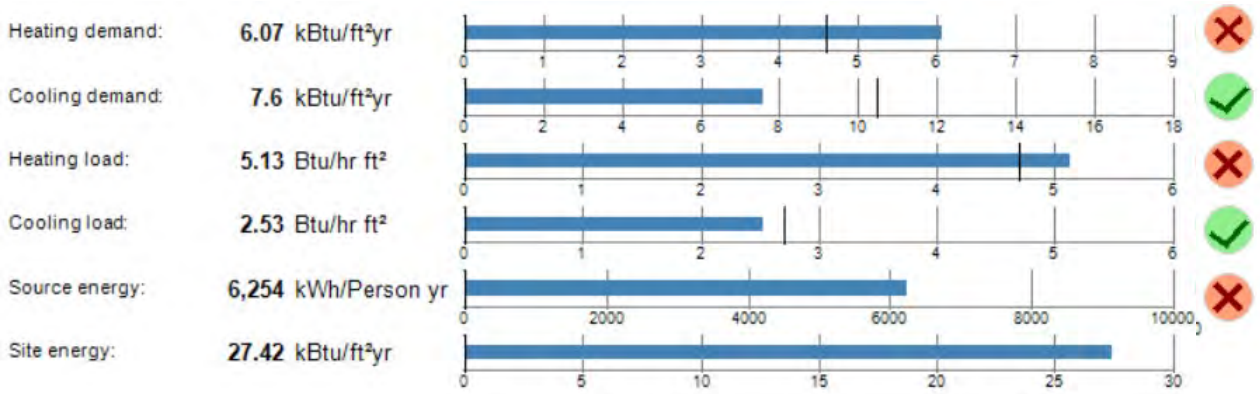
- Slab: Uninsulated
- **Wall: R14-R28.5 (Majority R22)**
- Roof: R42
- Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC
- Storefront & Doors: 0.244 BTU/hr·ft² / 0.21 SHGC
- Airtightness: 0.12 CFM/ft² ; ACH50: 0.8 1/hr
- Ventilation Flow Rate: 85 CFM/unit
- HVAC: Heat Pump COP2 @17F / COP3@47F
- ERV: 0.7 Sensible Recovery, 0.5 Humidity Recovery
- DHW: HPWH
- Lighting: LED

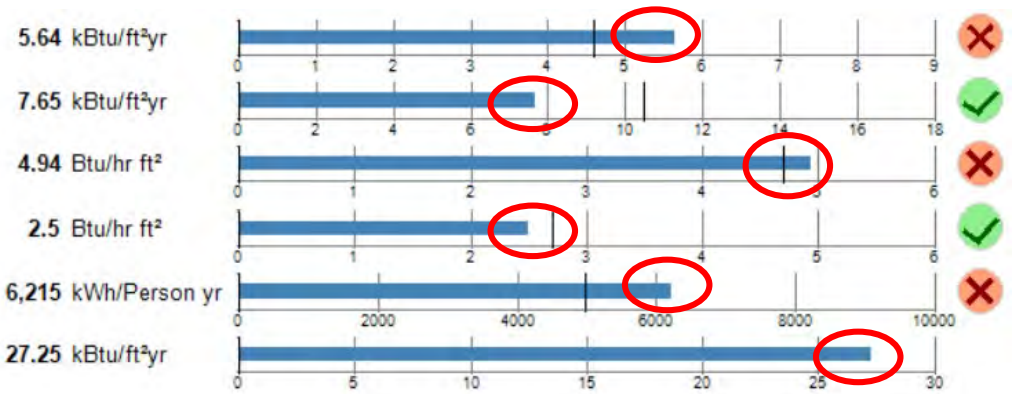
LESSON 1: OPTIMIZING ENVELOPE

As-Designed Ventilation with Upgraded Envelope

Wall: R21-R38 (Majority R29), **+R7** (2" add. ext. CI)

- Target Impact:
  - HD: - 0.41 kBtu/ft²yr
  - CD: + 0.05 kBtu/ft²yr
  - HL: - 0.19 Btu/hr ft²
  - CL: + 0.03 Btu/hr ft²
  - SE: 41kWh/Person yr saving
  - SE: - 0.17 kBtu/ft²yr
    - - 12,599 kWh/yr * $0.32/kWh = **-$4,028.8/yr**
    - Material Cost: +$2/sqft → **+$440,000**
      (Labor Incl.: ~$3.25/sqft)





LIVONIA

As-Designed Ventilation & Envelope:

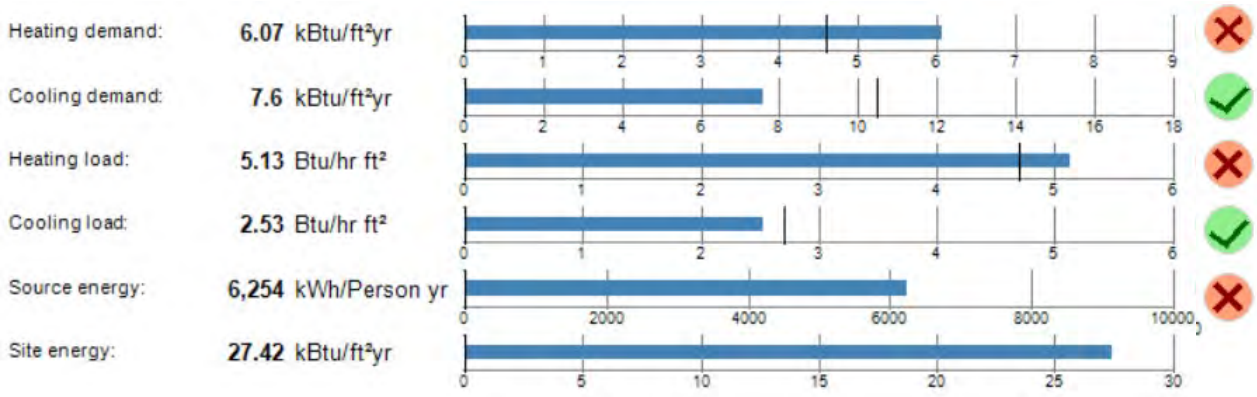
- Slab: Uninsulated
- Wall: R14-R28.5 (Majority R22)
- Roof: R42
- Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC
- Storefront & Doors: 0.244 BTU/hr·ft² / 0.21 SHGC
- Airtightness: 0.12 CFM/ft² ; ACH50: 0.8 1/hr
- Ventilation Flow Rate: 85 CFM/unit
- HVAC: Heat Pump COP2 @17F / COP3@47F
- ERV: 0.7 Sensible Recovery, 0.5 Humidity Recovery
- DHW: HPWH
- Lighting: LED

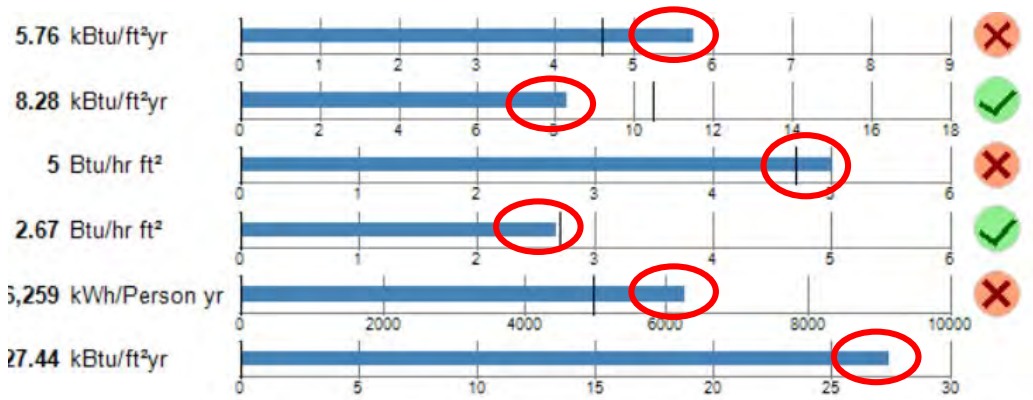
LESSON 1: OPTIMIZING ENVELOPE

As-Designed Ventilation with Upgraded Envelope

Window: 0.35 SHGC

- Target Impact:
  - HD: - 0.31 kBtu/ft²yr
  - CD: + 0.68 kBtu/ft²yr
  - HL: - 0.13 Btu/hr ft²
  - CL: + 0.14 Btu/hr ft²
  - SE: 5 kWh/Person yr saving
  - SE: + 0.02 kBtu/ft²yr
    - + 1,153 kWh/yr * $0.32/kWh = **+$368.96/yr**
    - Material Cost: +$0/sqft → **+$0**





LIVONIA

LESSON 1: OPTIMIZING ENVELOPE

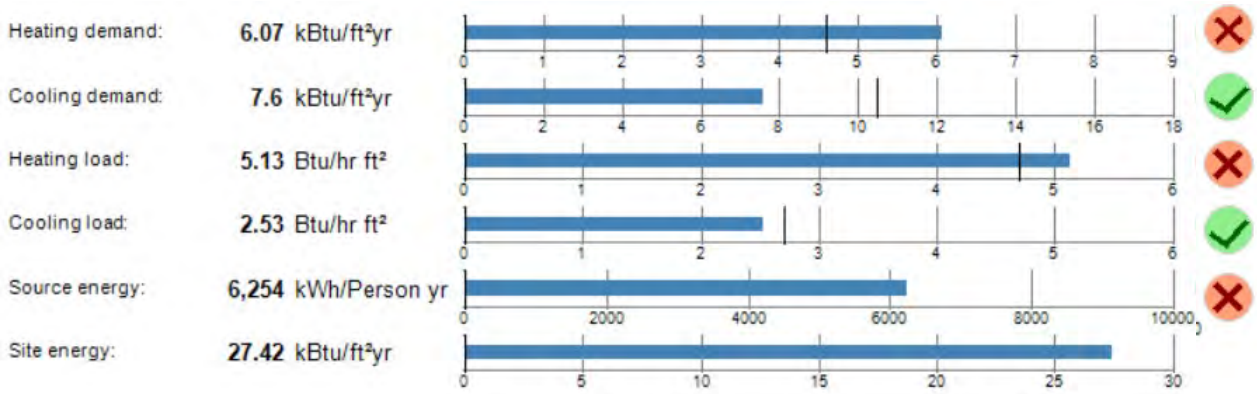
As-Designed Ventilation & Envelope:

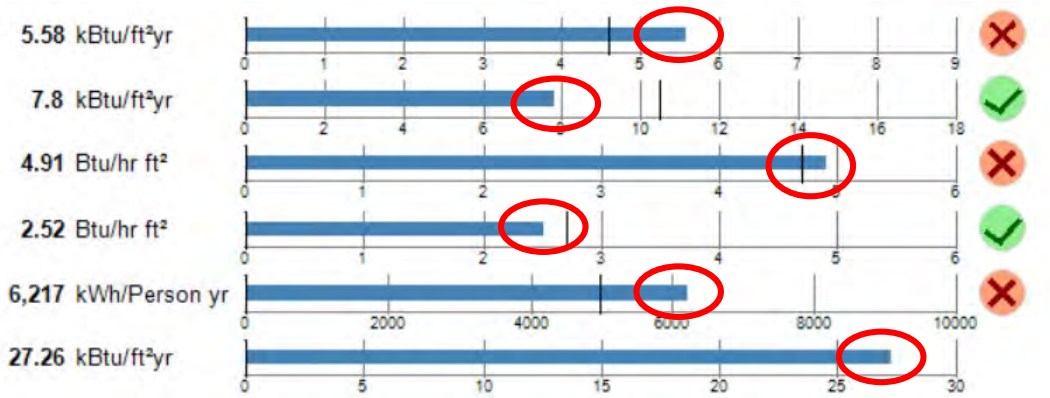
- Slab: Uninsulated
- Wall: R14-R28.5 (Majority R22)
- Roof: R42
- Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC
- Storefront & Doors: 0.244 BTU/hr·ft² / 0.21 SHGC
- Airtightness: 0.12 CFM/ft² ; ACH50: 0.8 1/hr
- Ventilation Flow Rate: 85 CFM/unit
- HVAC: Heat Pump COP2 @17F / COP3@47F
- ERV: 0.7 Sensible Recovery, 0.5 Humidity Recovery
- DHW: HPWH
- Lighting: LED

As-Designed Ventilation with Upgraded Envelope

Window: 0.17 BTU/hr·ft²

- Target Impact:
  - HD: - 0.49 kBtu/ft²yr
  - CD: + 0.2 kBtu/ft²yr
  - HL: - 0.21 Btu/hr ft²
  - CL: - 0.01 Btu/hr ft²
  - SE: 37kWh/Person yr saving
  - SE: - 0.16 kBtu/ft²yr
    - - 11,862 kWh/yr * $0.32/kWh = **-$3,795.84/yr**
    - Material Cost: +$20/sqft → **+$490,000**





LIVONIA

As-Designed Ventilation & Envelope:

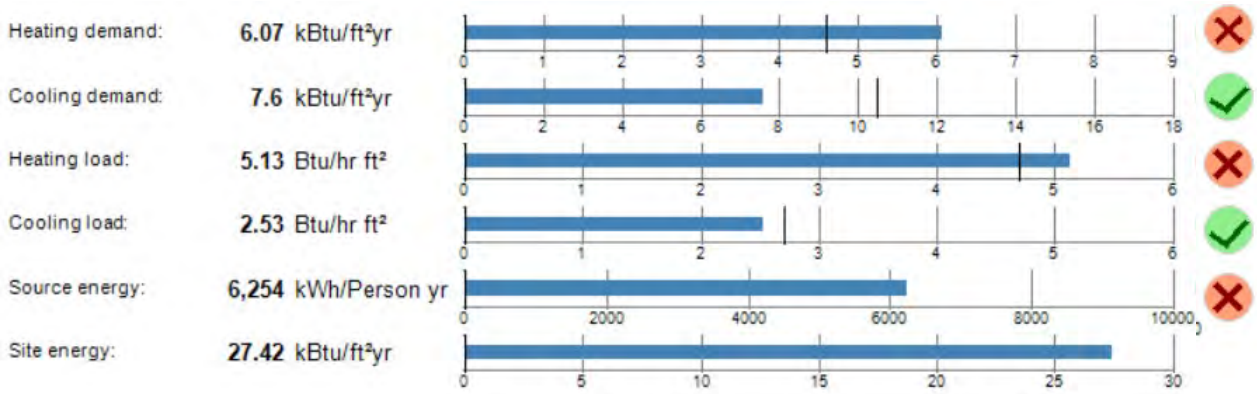
- Slab: Uninsulated
- Wall: R14-R28.5 (Majority R22)
- Roof: R42
- Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC
- Storefront & Doors: 0.244 BTU/hr·ft² / 0.21 SHGC
- Airtightness: 0.12 CFM/ft² ; ACH50: 0.8 1/hr
- Ventilation Flow Rate: 85 CFM/unit
- HVAC: Heat Pump COP2 @17F / COP3@47F
- ERV: 0.7 Sensible Recovery, 0.5 Humidity Recovery
- DHW: HPWH
- Lighting: LED

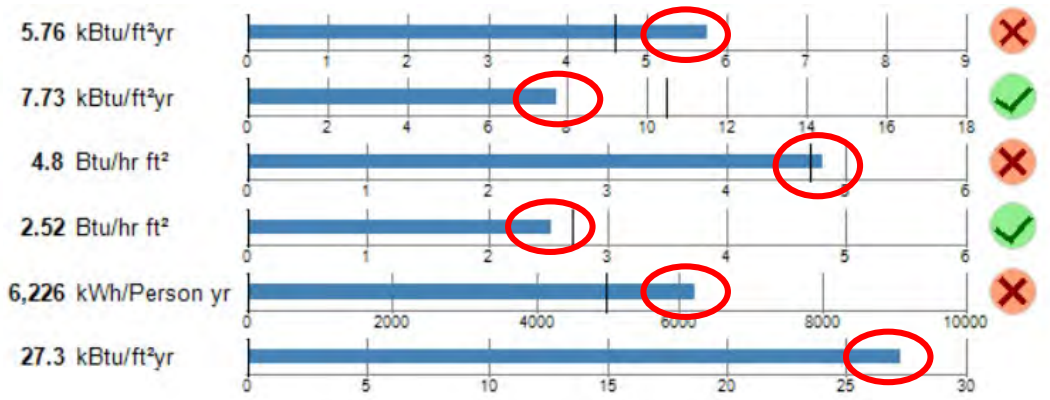
LESSON 1: OPTIMIZING ENVELOPE

As-Designed Ventilation with Upgraded Envelope

Air Tightness: 0.08 CFM/ft²

- Target Impact:
  - HD: - 0.31 kBtu/ft²yr
  - CD: + 0.13 kBtu/ft²yr
  - HL: - 0.33 Btu/hr ft²
  - CL: - 0.01 Btu/hr ft²
  - SE: 28kWh/Person yr saving
  - SE: - 0.12 kBtu/ft²yr
    - - 8,997 kWh/yr * $0.32/kWh = **-$2,879.04/yr**
    - Material Cost: +$0.5-1.5/sqft → **+$110,000-$350,000** (Upper range: $5/sqft)





LIVONIA

LESSON 1: OPTIMIZING ENVELOPE

As-Designed Ventilation & Envelope:

- Slab: Uninsulated
- Wall: R14-R28.5 (Majority R22)
- Roof: R42
- Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC
- Storefront & Doors: 0.244 BTU/hr·ft² / 0.21 SHGC
- Airtightness: 0.12 CFM/ft² ; ACH50: 0.8 1/hr
- Ventilation Flow Rate: 85 CFM/unit
- HVAC: Heat Pump COP2 @17F / COP3@47F
- ERV: 0.7 Sensible Recovery, 0.5 Humidity Recovery
- DHW: HPWH
- Lighting: LED

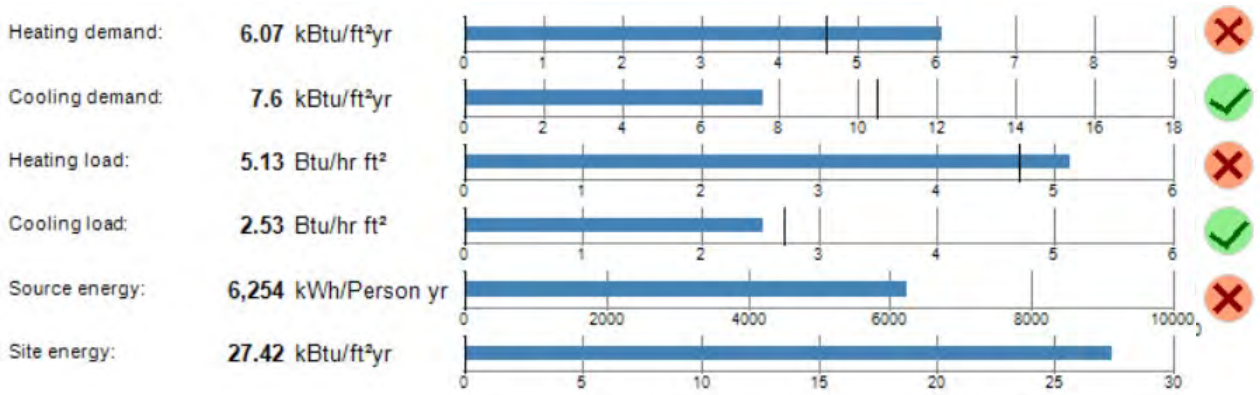
As-Designed Ventilation with Upgraded Envelope

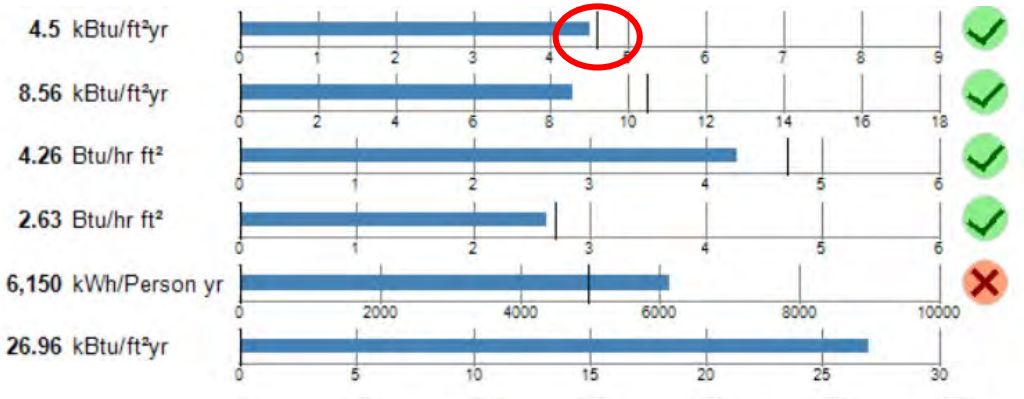
- **Air Tightness** (0.08 CFM/ft²) **& Wall**: (+R7)
- + **Windows** (0.17 BTU/hr·ft²)
- + **Storefront & Doors** (0.2 BTU/hr·ft²)
- + **Windows** (0.35 SHGC)

→ **Savings**: 32,768 kWh/yr * $0.32/kWh = **-$10,485.76/yr**

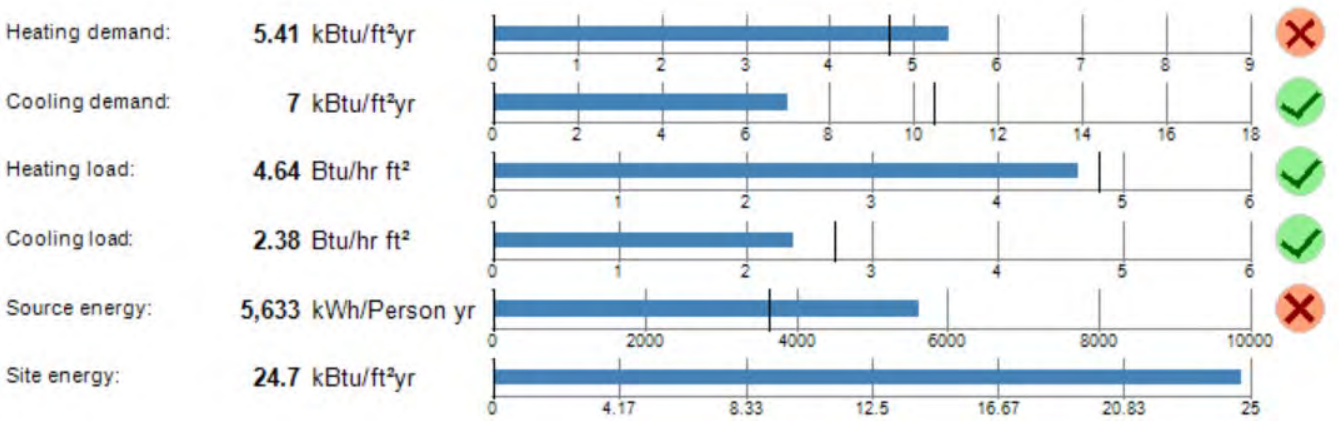
→ **Add Cost: 1M+**

- Wall: +$440,000
- Windows: +$490,000
- Air tightness: +$110,000-350,000

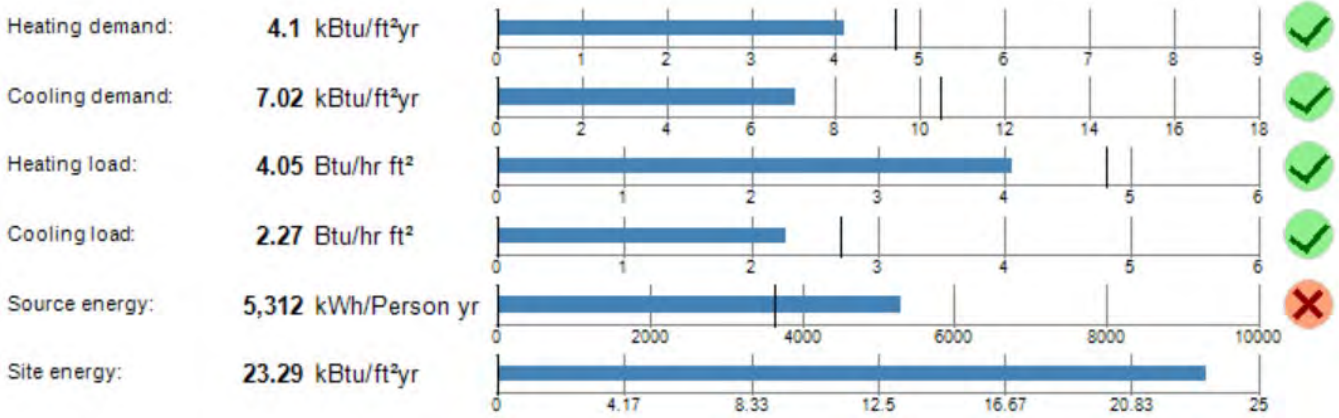




Massive Impact:
Optimize Ventilation Airflow for Efficient, Cost-Effective Building Performance!



As Designed
Ventilation System



Optimized
Ventilation System

Option 1: Move Less Air (than Rated Capacity)

Benefits:

- Less fan energy
  - If inside the thermal envelope, internal heat gain impact
  - Lower energy use and utility cost
  - Potentially longer life due to lower temperatures and running fans at an “easier” speed.
  - Lower source energy to help meet Phius Core in buildings with limited renewable energy production.

- Higher Efficiency
  - If the size of the heat exchanger is held constant: then, air moves much slower through the core and more heat and moisture is able to transfer from one airstream to the other.

Option 2: Increase size of the heat exchanger

Benefits:

- Less fan energy
  - If inside the thermal envelope, internal heat gain impact
  - Lower energy use and utility cost
  - Potentially longer life due to lower temperatures and running fans at an “easier” speed.
  - Lower source energy to help meet Phius Core in buildings with limited renewable energy production.

- Higher Efficiency
  - If the size of the heat exchanger is increased: then, air moves much slower through the core and more heat and moisture is able to transfer from one airstream to the other.

LIVONIA

Optimized Ventilation Performance:

For all units with 1 bath (typ. Studio, 1, and 2 bedroom)

As Designed:

- 85 CFM/unit

Code Minimum:

- 45 CFM/unit

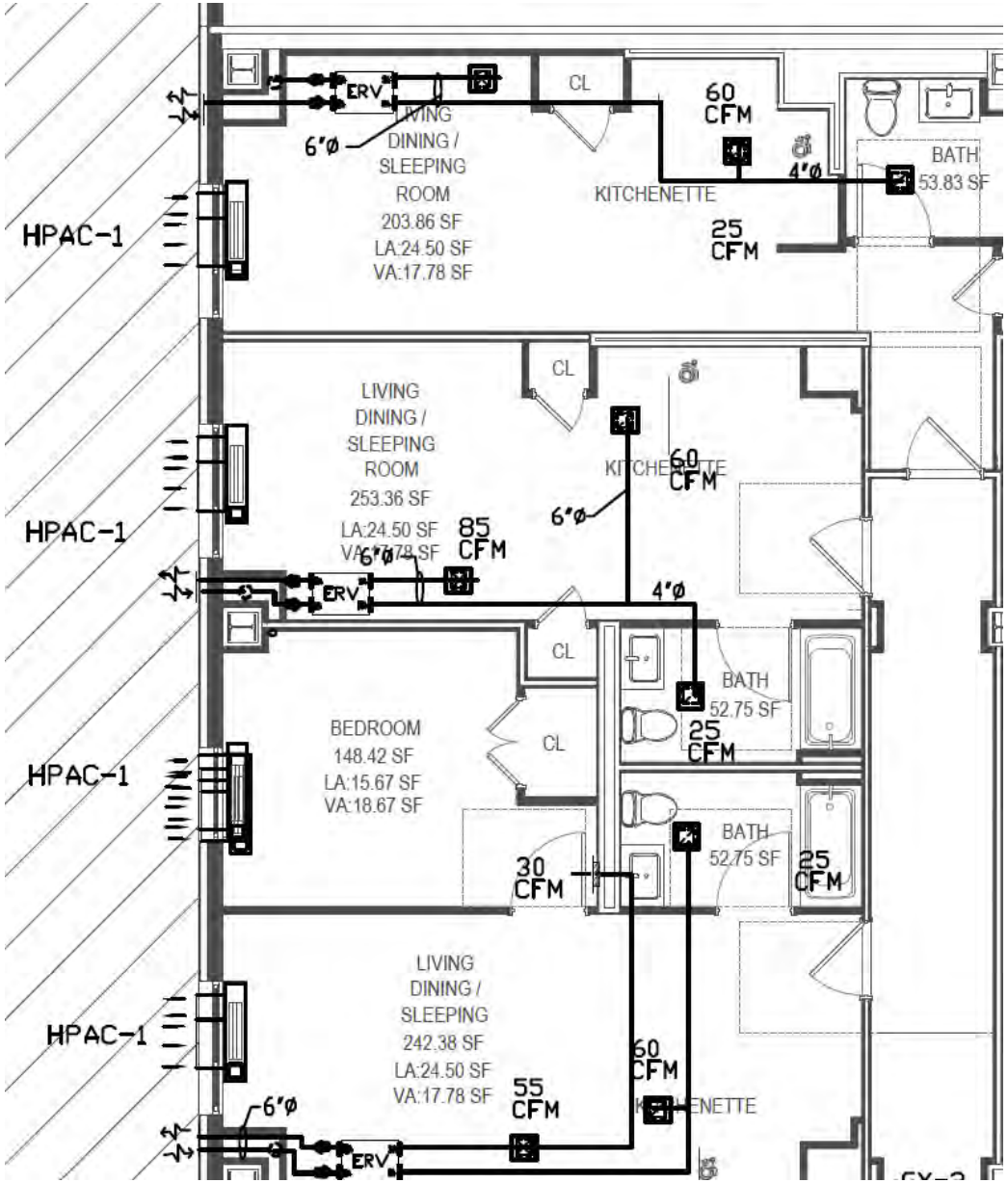
Optimized:

- 60 CFM/unit

Reasons for optimizing at 60 cfm:

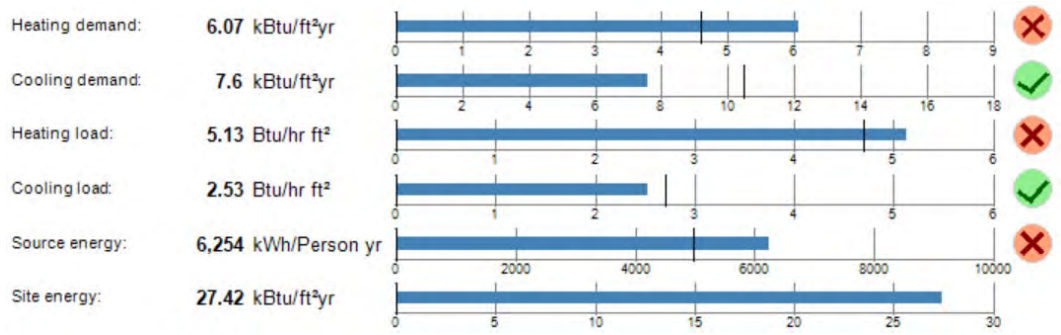
1. Balancing is easier than balancing to the minimum.
2. Gives engineer flexibility on meeting needs of different unit types
3. The energy savings from 25 cfm for 283 units was substantial already
4. Real life performance of engineer recommending 25 cfm in baths instead of 20cfm, for smell and moisture removal

AS DESIGNED VS OPTIMIZED AIRFLOW



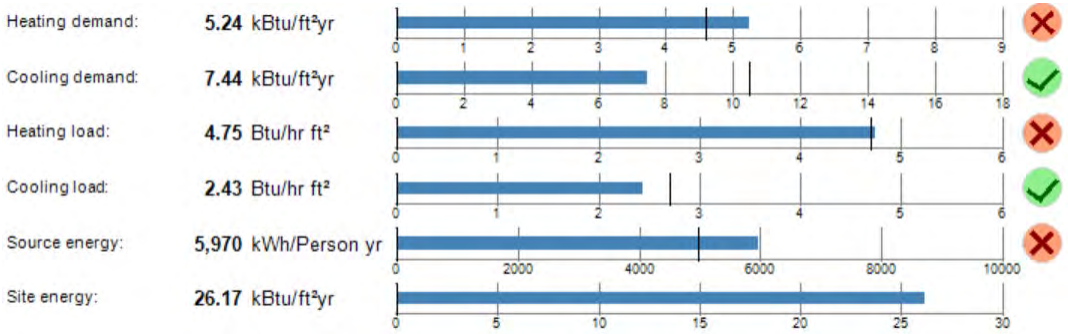
LIVONIA

AS DESIGNED VS OPTIMIZED AIRFLOW



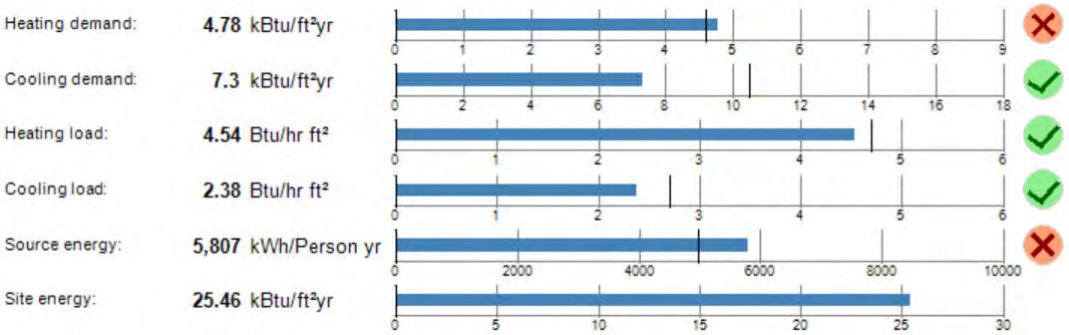
As Designed:
85 CFM/unit

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	24555	0
Residential	0	24555
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225



Optimized:
60 CFM/unit

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	17500	0
Residential	0	17500
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225



Code Minimum:
45 CFM/unit

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	13500	0
Residential	0	13500
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225

LIVONIA

DESIGNED VS OPTIMIZED SRE

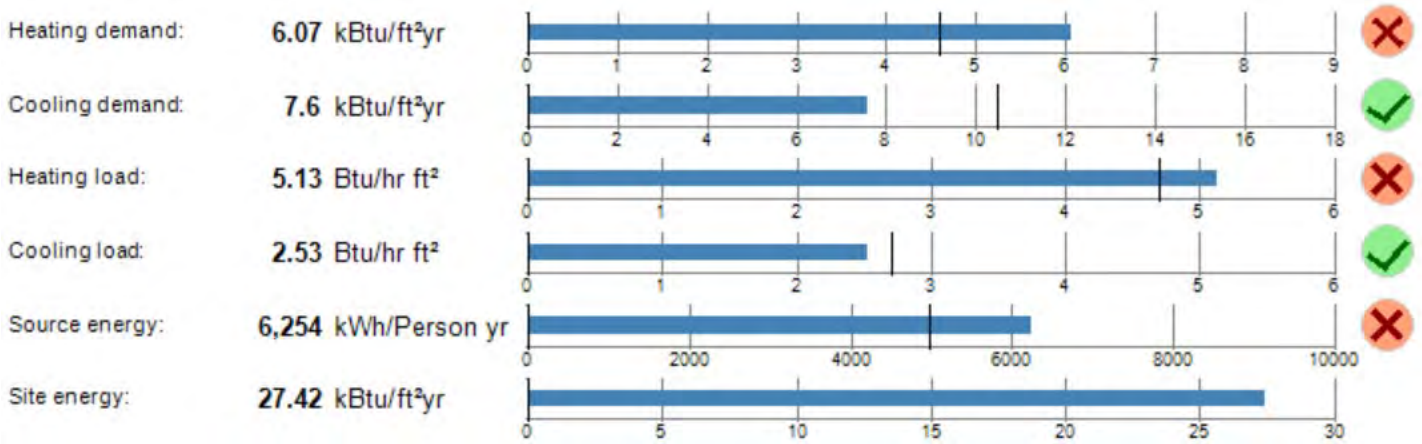
Brand Name	Model	Temp Mode ↓	C	F	Net Outdoor Airflow (L/s) ↑	Net Outdoor Airflow (cfm) (cfm)	Power Consumed (Watts)	Rated Efficacy (L/s/W)	Rated Efficacy (cfm/W)	SRE	ASRE	NMT	TRE	ATRE
RenewAire	SL75	HEATING	0	32	24.0	51	30	0.80	1.7	78.0	82	0.64		
RenewAire	SL75	HEATING	0	32	36.0	76	50	0.72	1.5	74.0	79	0.56		
RenewAire	SL75	HEATING	0	32	47.0	100	79	0.59	1.2	70.0	75	0.50		
RenewAire	SL75	COOLING	35	95	25.0	53	32	0.78	1.6			0.53	57	59

Source: HVI.org

SRE = Sensible Recovery Efficiency
ASRE = Adjusted Sensible Recovery Efficiency
TRE = Total Recovery Efficiency
ATRE = Adjusted Total Recovery Efficiency
NMT = Net Moisture Transfer

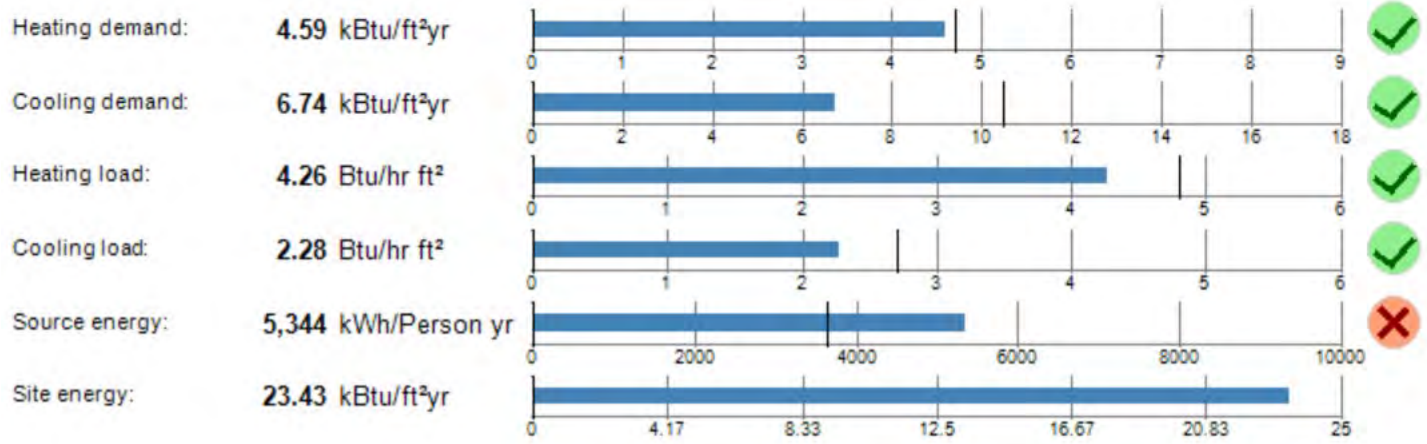
LIVONIA

DESIGNED VS OPTIMIZED AIRFLOW



As Designed:
85 CFM/unit
SRE: 75 %
NMT: 60 %
FAN: .8 w/cfm

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	24555	0
Residential	0	24555
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225

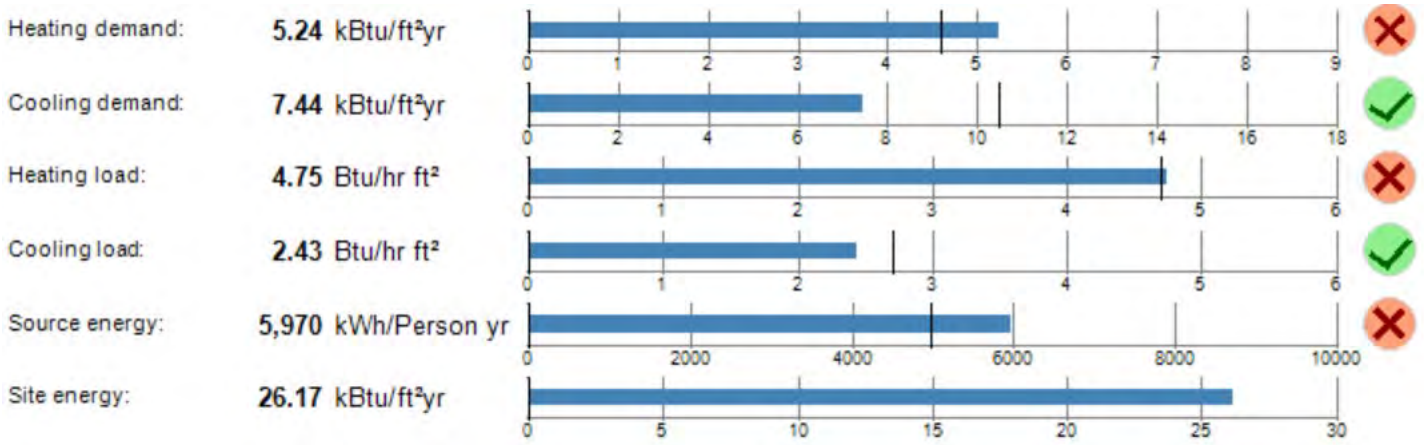


Optimized Airflow From Earlier:
60 CFM/unit
SRE: 75 %
NMT: 60 %
FAN: .8 w/cfm

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	17500	0
Residential	0	17500
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225

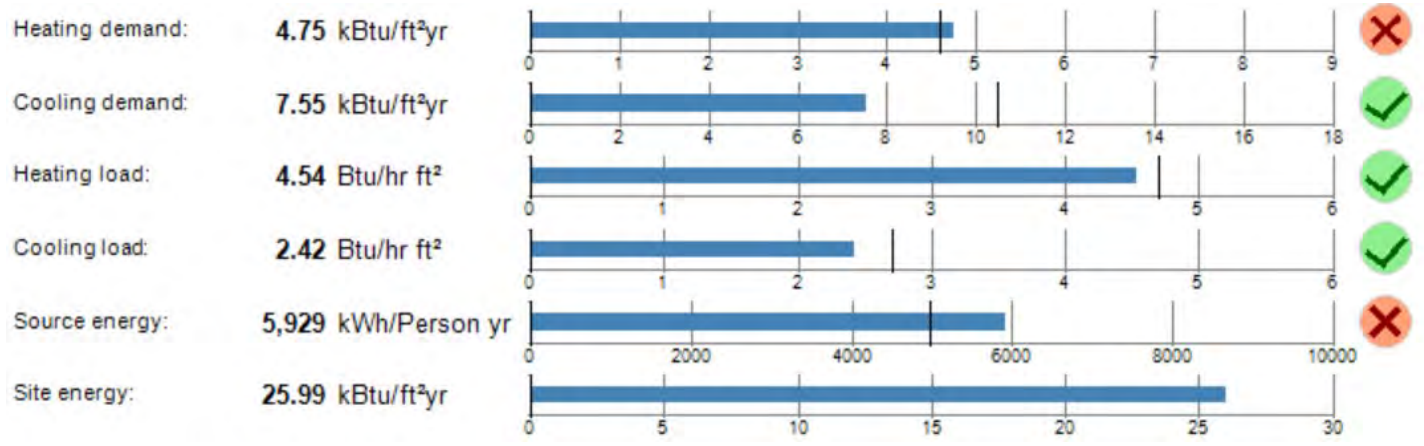
LIVONIA

DESIGNED VS OPTIMIZED SRE



Optimized Airflow From Earlier:
60 CFM/unit
SRE: 75 %
NMT: 60 %
FAN: .8 w/cfm

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	17500	0
Residential	0	17500
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225

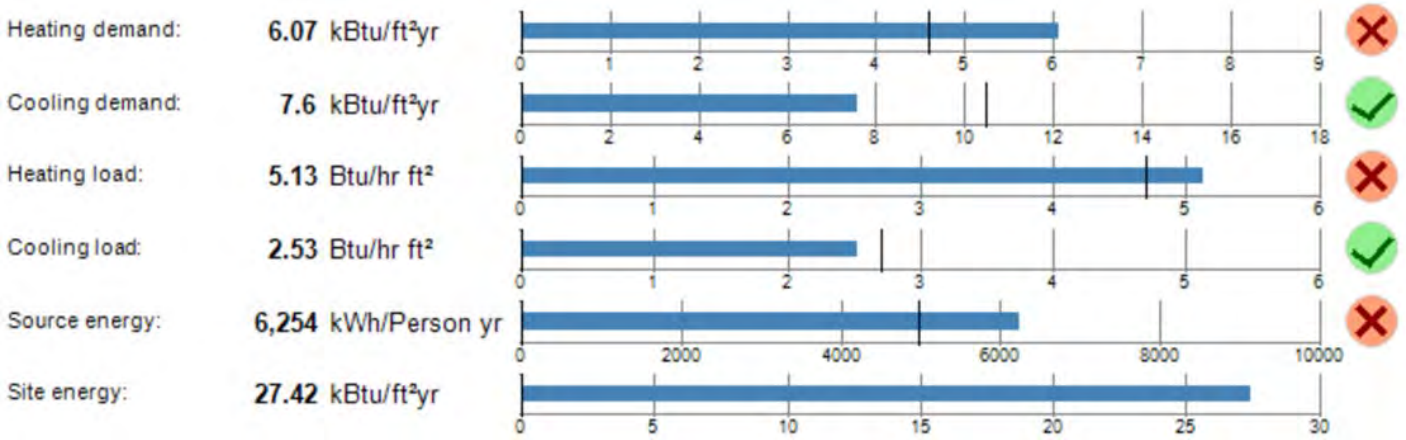


Optimized Airflow and SRE:
SRE: 81 %
NMT: 60 %
FAN: .8 w/cfm

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	17500	0
Residential	0	17500
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225

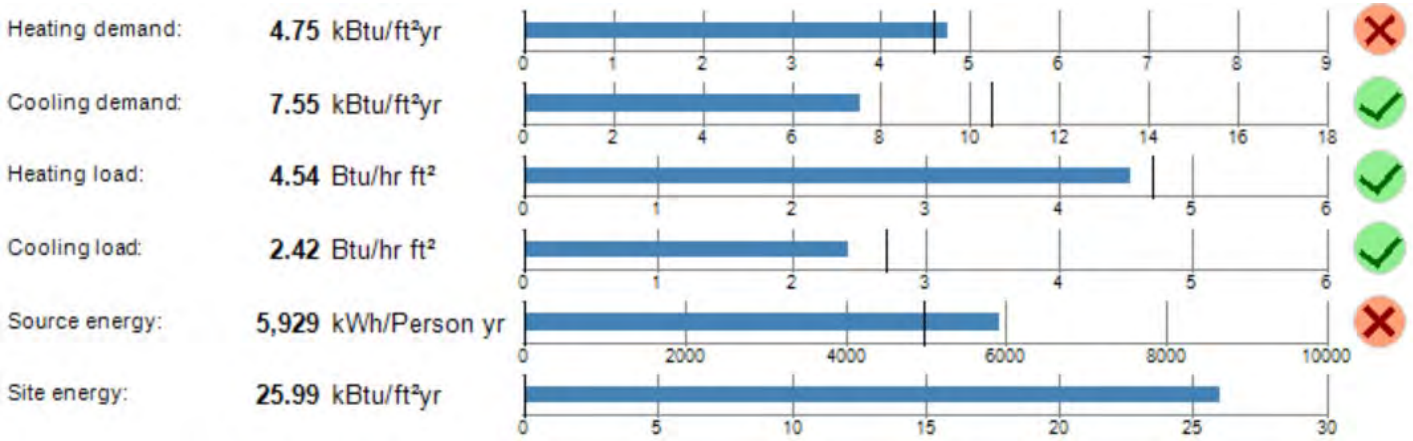
LIVONIA

DESIGNED VS OPTIMIZED AIRFLOW + SRE



As Designed:
85 CFM/unit
SRE: 75 %
NMT: 60 %
FAN: .8 w/cfm

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	24555	0
Residential	0	24555
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225



Optimized Airflow and SRE:
60 CFM/unit
SRE: 81 %
NMT: 60 %
FAN: .8 w/cfm

Name	Design volume flow rate [cfm]	
	Supply Air	Exhaust Air
Resi= 60cfm = 17500	17500	0
Residential	0	17500
ERV-3	2150	0
ERV-3	0	2150
ERV-1	1650	0
ERV-1	0	1650
ERV-2	2225	0
ERV-2	0	2225

ENCLOSURE IMPROVEMENTS TO MATCH OPTIMIZED VENTILATION

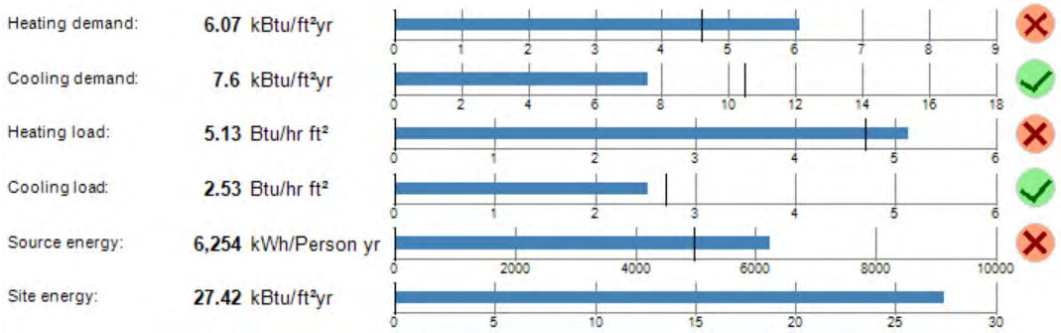
What does it take to overcome “poor” ventilation system design?

Specifically: 85 CFM at 75% SRE vs 60 CFM at 81% SRE

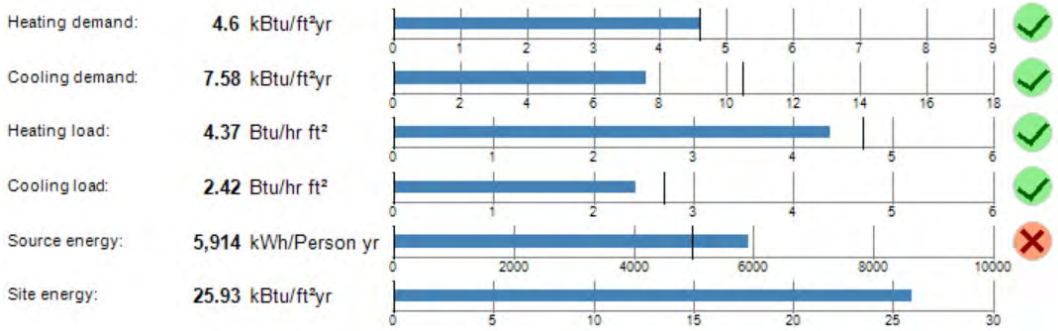
Still not quite there….

LIVONIA

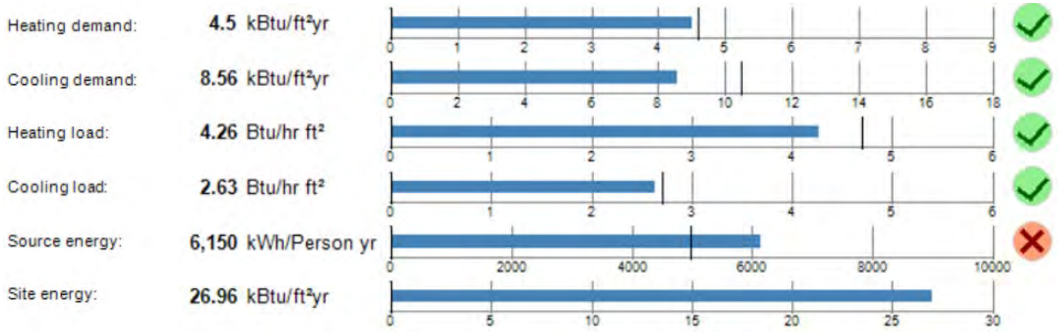
ENCLOSURE IMPROVEMENTS TO MATCH OPTIMIZED VENTILATION



Improvements:
As Designed



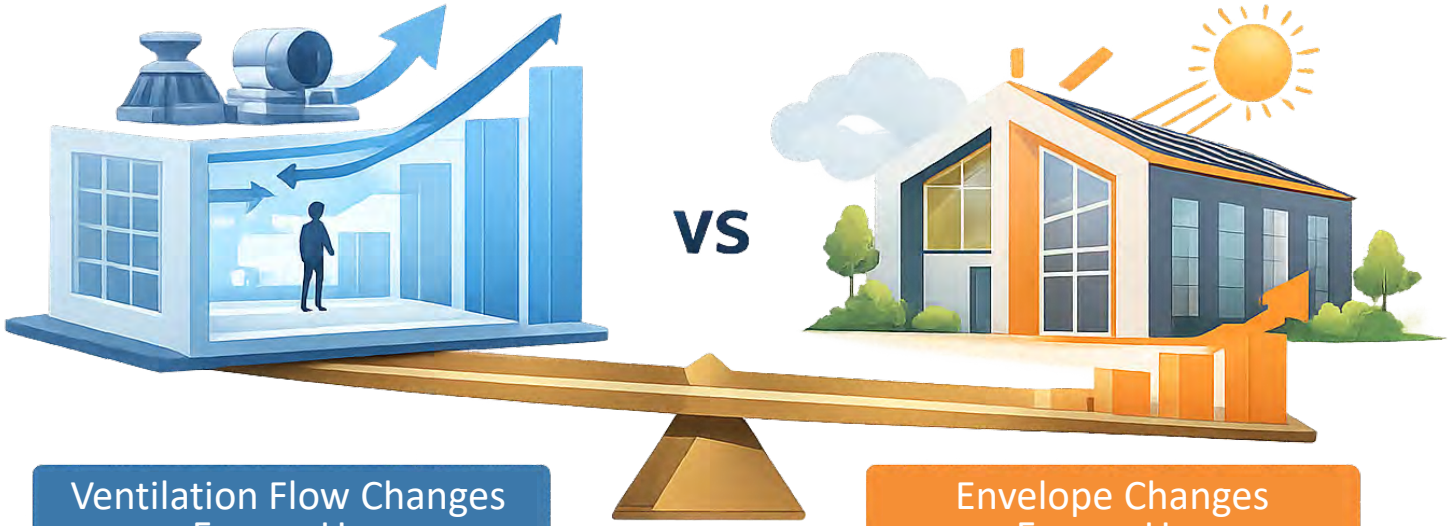
Improvements:
Lowering the flow rate within the units to 60cfm from 85cfm.
Airtightness from 0.12 to 0.1 cfm50/ft2



Improvements:
Wall: R14-R28.5 (Majority R22) → **+R7**
Windows: 0.2-0.22 BTU/hr·ft² / 0.244 SHGC → **0.17 BTU/hr·ft² / 0.35 SHGC**
Storefront & Doors: 0.244 BTU/hr·ft² / 0.21 SHGC→ **0.2 BTU/hr·ft²**
Airtightness: 0.12 CFM/ft² → **0.08 CFM/ft²**

MECHANICAL SYSTEMS VS ENCLOSURE UPGRADES

When internal loads dominate:



45 REMSEN: EAST & WEST BUILDINGS

TAKEAWAYS: Modeled as 2 buildings

MAIN RESIDENCE

- Better floor area ratio
- Better orientation
- Easier to meet certification criteria

EAST RESIDENCE

- Conflict between Heating Demand and Cooling Load
- Cooling Load is the most challenging
- Hard to meet certification criteria

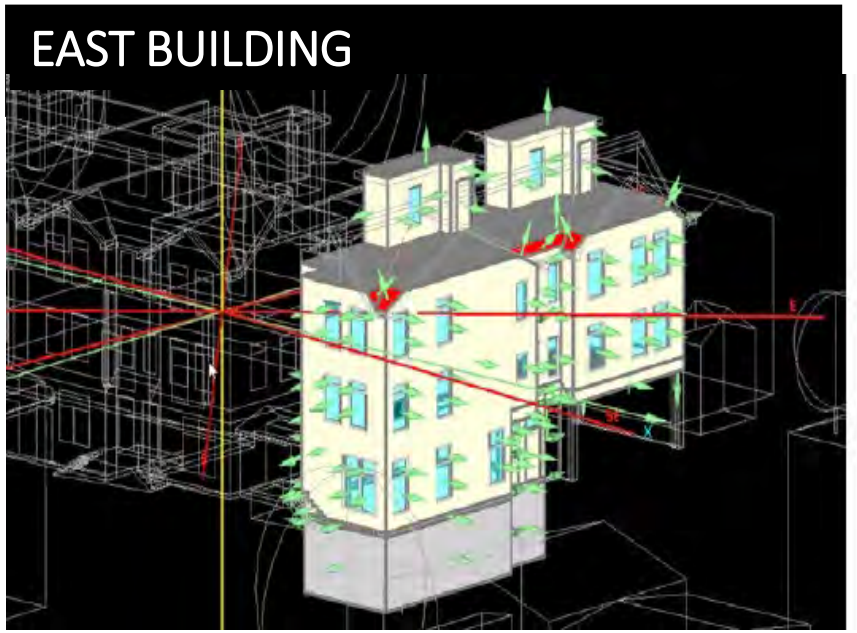
EXTERIOR ENVELOPE AS DESIGNED:

- SLAB 8" total thickness (slab + insulation)
- WALLS BELOW GRADE 10'-0" Utility Room Wall Ht.
- WALLS ABOVE GRADE 8-1/2"
    - 2x6 walls w/ 2" exterior insulation
    - Additional dimension available to Interior ½" to 1" max
    - Additional dimension available to Exterior 1-1/2" max
    - TBD: Zip R-9 on a 2x8 w/ dense pack blown in
- ROOF 2'-2 5/8" thickness

RECOMMENDATIONS / OPTIONS:

- WALLS Above Grade
    - Increase to R-35 (drops Annual Heating Demand (AHD)
    - Consider different wall thicknesses on different elevations
- WINDOWS:
    - Lower SHGC
    - Reduce sizes 10-20% to increase wall area + Remove window mullion
    - Add Exterior fixed shading element for summer shade + winter free heat

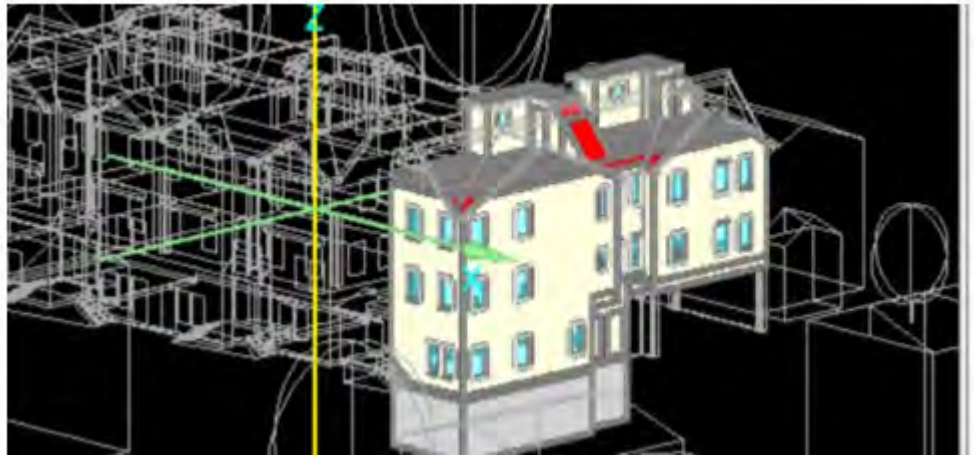
ENCLOSURE IMPROVEMENTS



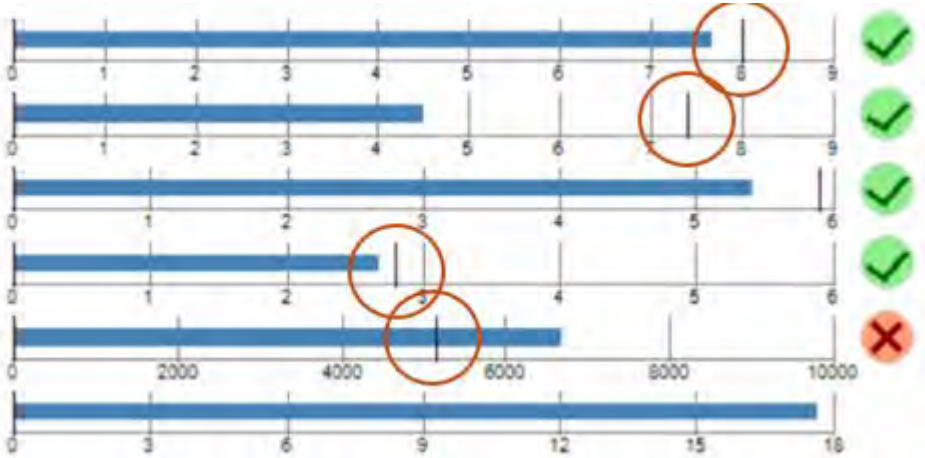
45 REMSEN EAST

ENCLOSURE VS. VENTILATION

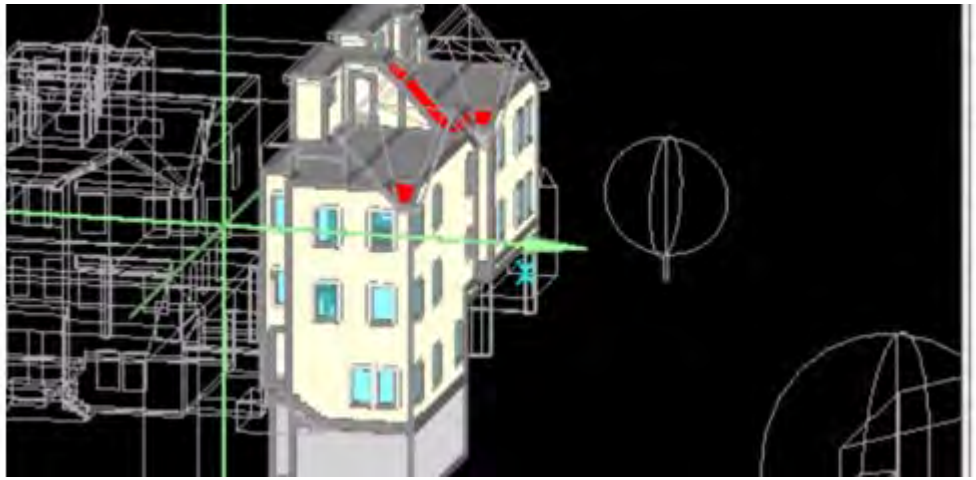
BASE MODEL



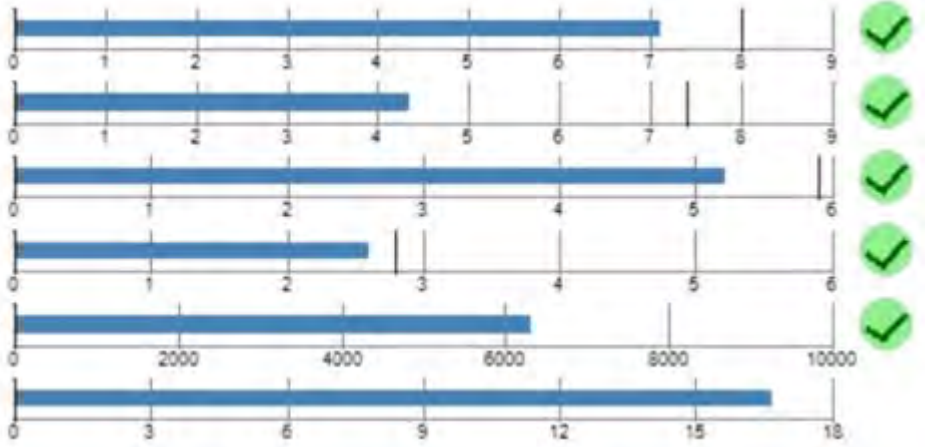
Heating demand:	7.68	kBtu/ft²yr
Cooling demand:	4.49	kBtu/ft²yr
Heating load:	5.41	Btu/hr ft²
Cooling load:	2.67	Btu/hr ft²
Source energy:	6,701	kWh/Person yr
Site energy:	17.67	kBtu/ft²yr



OPTIMIZED MODEL



Heating demand:	7.12	kBtu/ft²yr
Cooling demand:	4.35	kBtu/ft²yr
Heating load:	5.22	Btu/hr ft²
Cooling load:	2.6	Btu/hr ft²
Source energy:	6,320	kWh/Person yr
Site energy:	16.66	kBtu/ft²yr

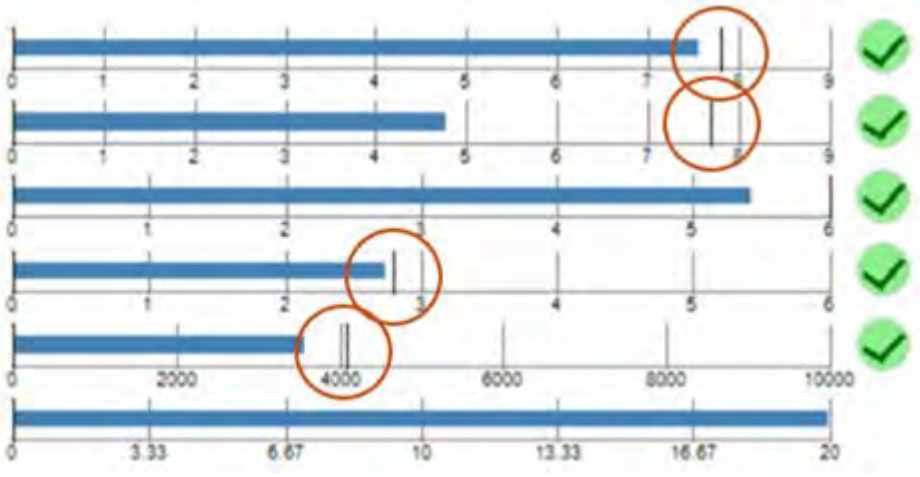


45 REMSEN WEST

ENCLOSURE VS. VENTILATION

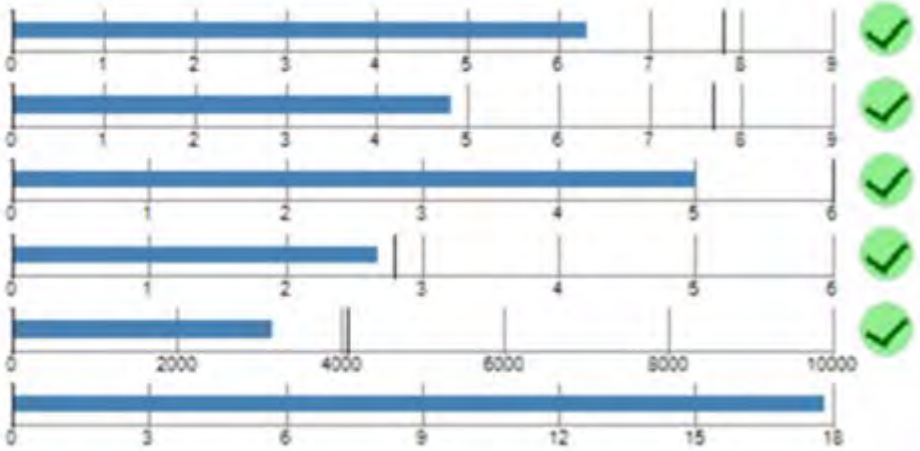
BASE MODEL

Heating demand:	7.57 kBtu/ft²yr
Cooling demand:	4.76 kBtu/ft²yr
Heating load:	5.43 Btu/hr ft²
Cooling load:	2.73 Btu/hr ft²
Source energy:	3,558 kWh/Person yr
Site energy:	19.98 kBtu/ft²yr



OPTIMIZED MODEL

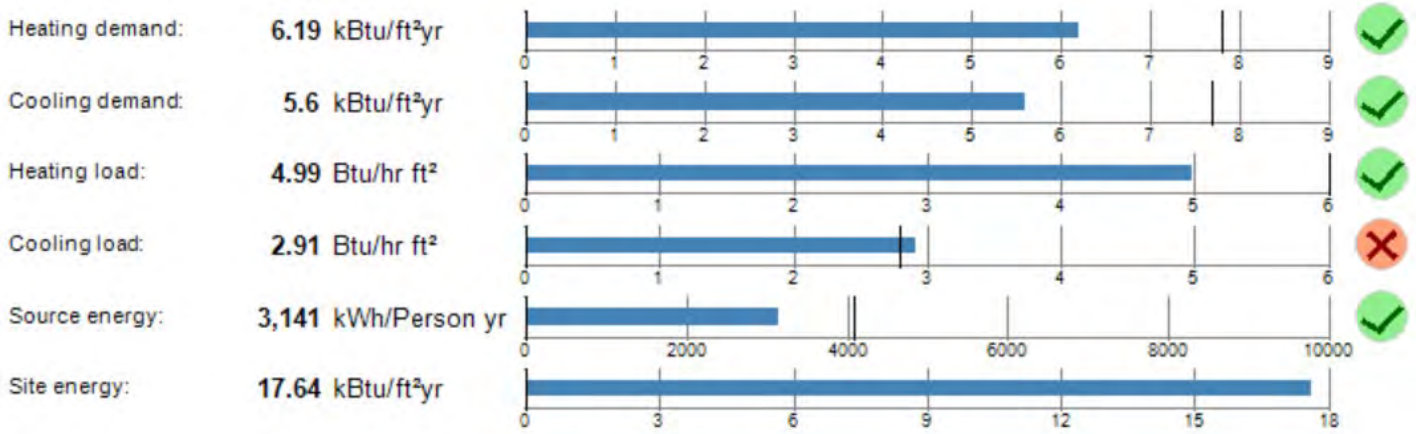
Heating demand:	6.32 kBtu/ft²yr
Cooling demand:	4.81 kBtu/ft²yr
Heating load:	5.01 Btu/hr ft²
Cooling load:	2.67 Btu/hr ft²
Source energy:	3,180 kWh/Person yr
Site energy:	17.86 kBtu/ft²yr



45 REMSEN WEST

VENTILATION RELOCATION

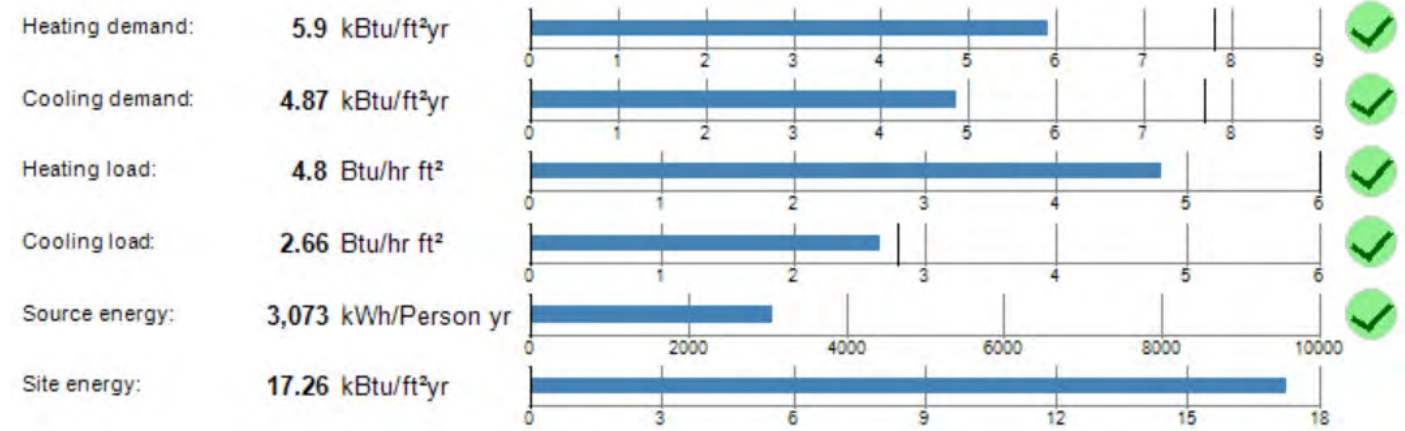
BASE MODEL



Inside the Thermal Envelope

Relatively low fan energy: 0.8 w/cfm

OPTIMIZED MODEL



Outside the Thermal Envelope

Relatively low fan energy: 0.8 w/cfm

45 REMSEN EAST & WEST

VENTILATION OPTIMIZATION

VENTILATION RECOMMENDATIONS: SPECIFY LARGER UNIT + VARY LOCATION BY FLOOR

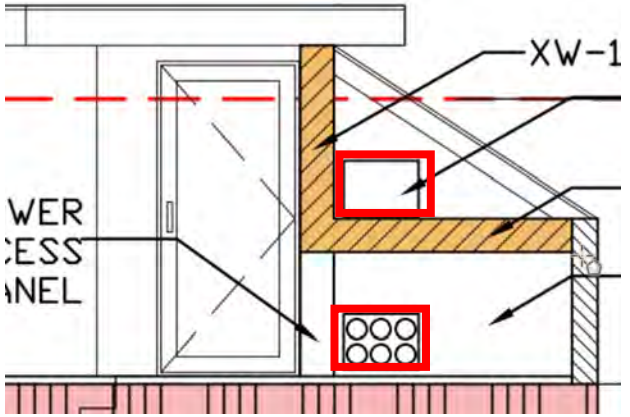
Q350ERV vs Q200ERV

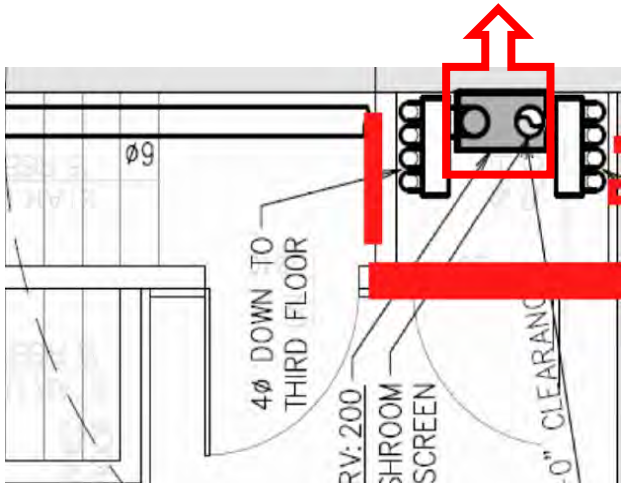
Brand Name	Model	Temp Mode ↓	F	Net Outdoor Airflow (cfm) (cfm)	Power Consumed (Watts)	Rated Efficacy (cfm/W)	SRE	ASRE	NMT	TRE	ATRE
Zehnder	CAQ350 ERV	HEATING	32	95	28	3.3	83	85	0.72		
Zehnder	CAQ350 ERV	HEATING	32	138	47	2.9	80	82	0.65		
Zehnder	CAQ350 ERV	HEATING	32	184	90	2.0	76	79	0.59		
Zehnder	CAQ350 ERV	COOLING	95	97	30	3.2			0.72	73	74
Zehnder	CAQ350 ERV	COOLING	95	138	56	2.4			0.65	67	69

Brand Name	Model	Temp Mode ↓	F	Net Outdoor Airflow (cfm) (cfm)	Power Consumed (Watts)	Rated Efficacy (cfm/W)	SRE	ASRE	NMT	TRE	ATRE
Zehnder	CA200 ERV	HEATING	32	64	30	2.1	82	86	0.71		
Zehnder	CA200 ERV	HEATING	32	83	42	1.9	78	82	0.75		
Zehnder	CA200 ERV	HEATING	32	106	60	1.7	75	79	0.61		
Zehnder	CA200 ERV	COOLING	95	64	32	2.0			0.64	66	68

- LOWER FAN SPEED = HIGHER EFFICIENCIES
- 50% LESS POWER USAGE
- 5-6% BETTER SENSIBLE RECOVERY
- 10-11% BETTER HUMIDITY RECOVERY
- INCREASED DURABILITY

RELOCATE FLOOR 2 UNITS OUTSIDE THERMAL ENVELOPE





UNIT LOCATION BY FLOOR:

- FLOOR 1 UNITS IN THERMAL ENVELOPE
- FLOOR 2 UNITS OUTSIDE THERMAL ENVELOPE
- VE DESIGN OPTION: (VIA RED FLAG REVIEW)

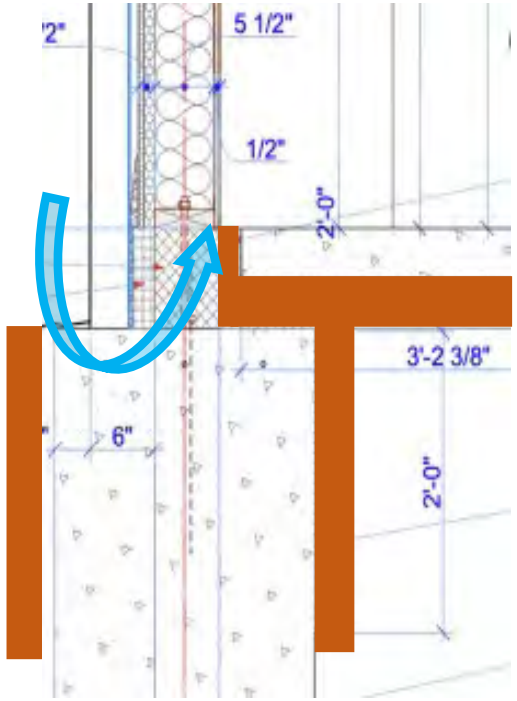
CENTRALIZED SYSTEM W/ LARGER UNITS / FANS AT EXTERIOR
1 UNIT FOR 4 RESIDENCES – 3-1/2" DUCTS FROM UPPER TO LOWER
ISSUE: HOW TO BILL TENANTS

JOHN GRACE ARMS

FOUNDATION DETAIL: PERIMETER INSULATION

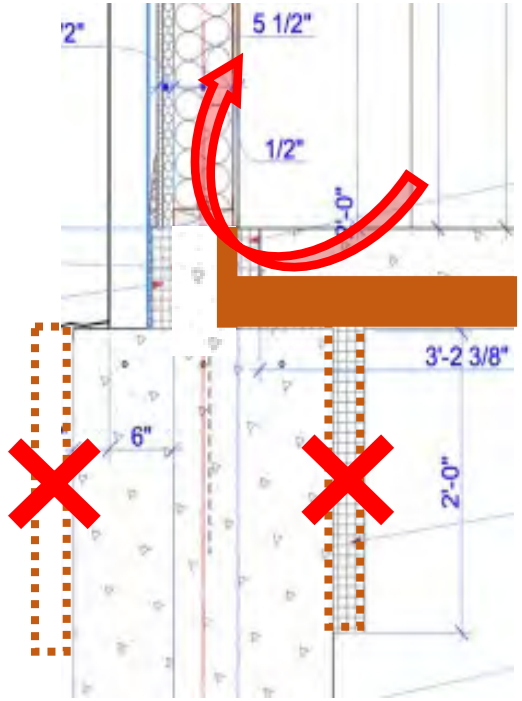
AS DESIGNED

- Thermal bridge (psi value = .035)
- Creates condensation risk
- Exceeds Heating Load



RECOMMENDED:

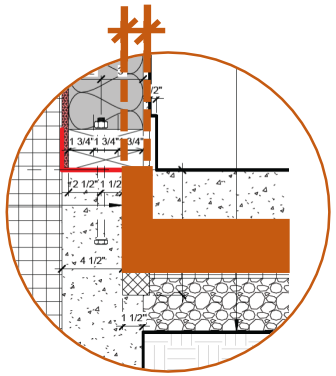
- No Thermal bridge (psi value = .022)
- Mitigates condensation risk
- Satisfies Heating Load

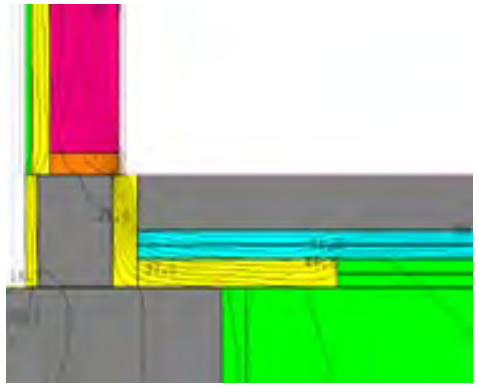


OPTIMIZED:

- No Thermal bridge (psi value = .016)
- Remove int + ext vertical wall insulation
  60-80 yr payback
- Reduce underslab insulation to 2" EPS
  20 yr payback
- Shift block (Alt. pour temporary 2x10 form)
  Standard dimension + 5" stud bearing
- Upgrade 1" insulation to XPS (yellow)
  16" in width (3 strips per sheet)
- **OVERLAP SLAB EDGE INSUL + SILL PLATE 1-1/2"**

1-1/2"

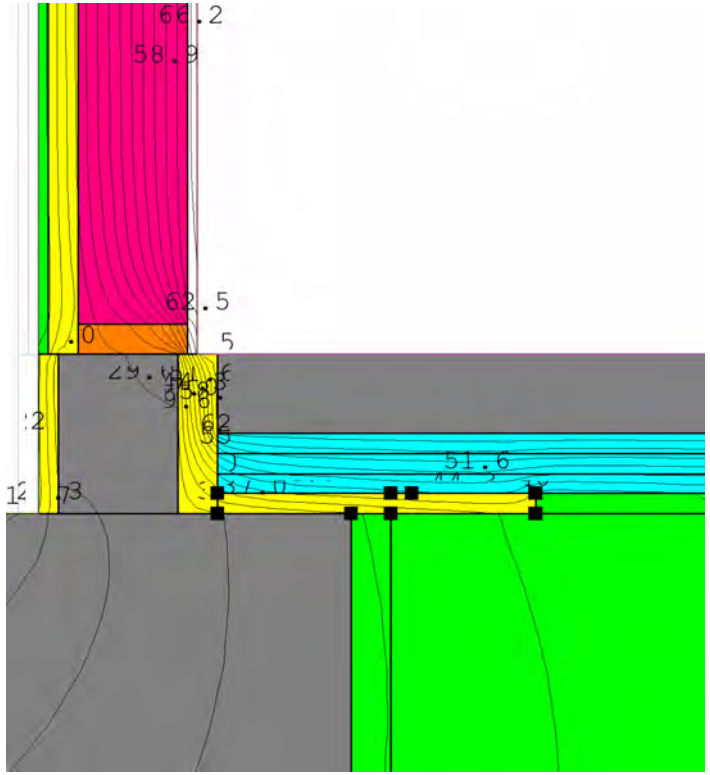




JOHN GRACE ARMS

FOUNDATION DETAIL: PERIMETER INSULATION

THERMAL BRIDGE MODEL @ SLAB EDGE – **3" UNDERSLAB INSULATION**



2D model

	U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Interior	0.0089	54	520.99	20.87	4.80%
Exterior	0.0425	54	109.01	20.85	4.80%

Component

		U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Component A	Interior	0.0320	54	55.00	7.92	0.00%
Wall	**Exterior**	**0.032**	**54.00**	**55.00**	**7.92**	**0.00%**
Component B	Interior	0.0758	27	69	11.77	0.00%
Slab	**Exterior**	**0.0758**	**27.00**	**69.00**	**11.77**	**0.00%**

Psi

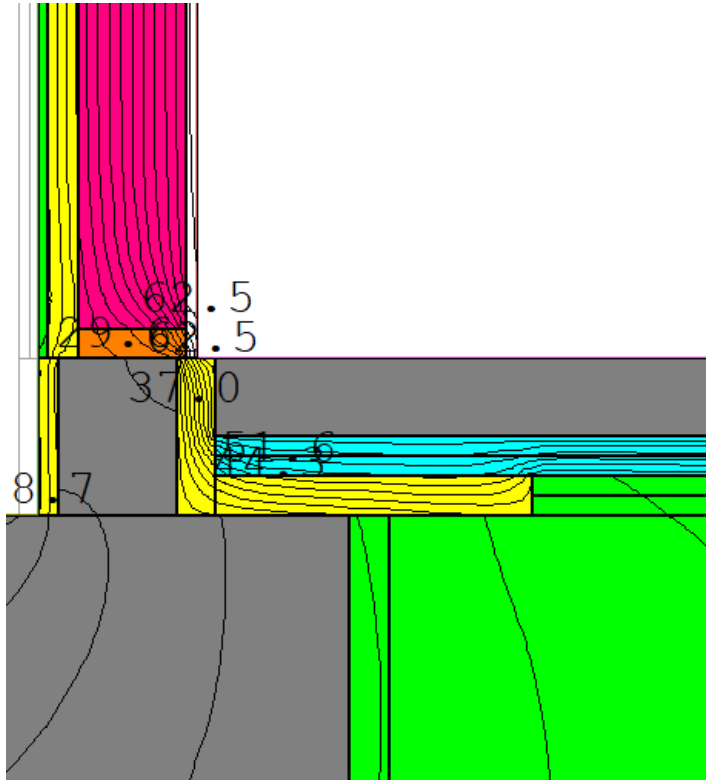
	PsidT (btu/hr.ft)	dT (F)	Psi (btu/hr.ft.F)	Psi for WUFI (btu/hr.ft.F)
Interior	1.18	54.00	0.022	**0.022**
Exterior	1.16	54.00	0.021	

JOHN GRACE ARMS

ENCLOSURE OPTIMIZED

FOUNDATION DETAIL: PERIMETER INSULATION

THERMAL BRIDGE MODEL @ SLAB EDGE – **2" UNDERSLAB INSULATION**



2D model		U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
	Interior	0.0102	54	520.99	23.91	4.80%
	Exterior	0.0486	54	109.01	23.84	4.80%

Component		U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Component A	Interior	0.0320	54	55.00	7.92	0.00%
Wall	**Exterior**	**0.032**	**54.00**	**55.00**	**7.92**	**0.00%**
Component B	Interior	0.1082	27	69	16.80	0.00%
Slab	**Exterior**	**0.1082**	**27.00**	**69.00**	**16.80**	**0.00%**

Psi		PsidT (btu/hr.ft)	dT (F)	Psi (btu/hr.ft.F)	Psi for WUFI (btu/hr.ft.F)
	Interior	-0.80	54.00	-0.015	-0.016
	Exterior	-0.88	54.00	-0.016	

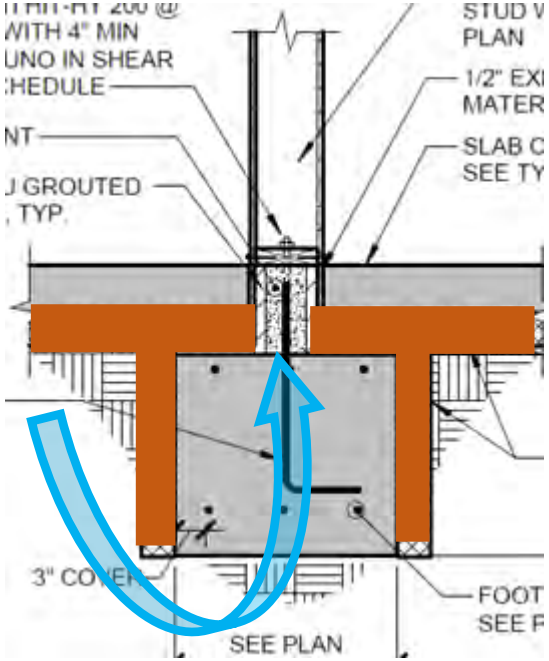
JOHN GRACE ARMS

FOUNDATION DETAIL: CORRIDOR INSULATION

THERMAL BRIDGE MODEL @ INTERIOR SHEAR WALL

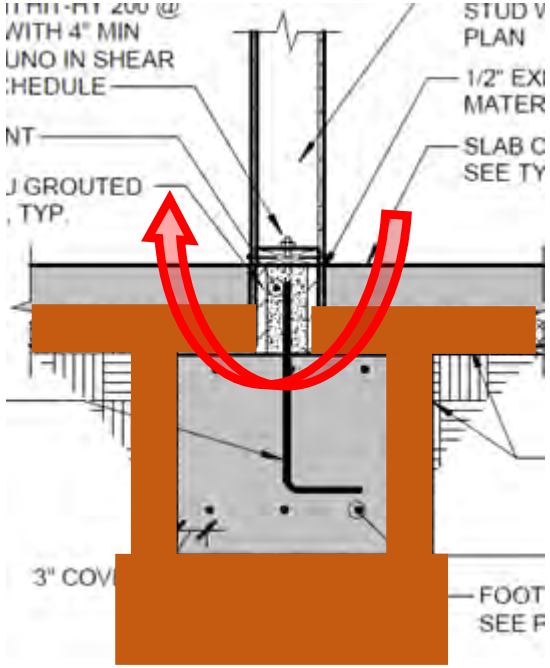
AS DESIGNED

- Internal Structural Lateral Loads
- Yields a positive thermal bridge.
- Creates condensation risk
- May exceed heating load



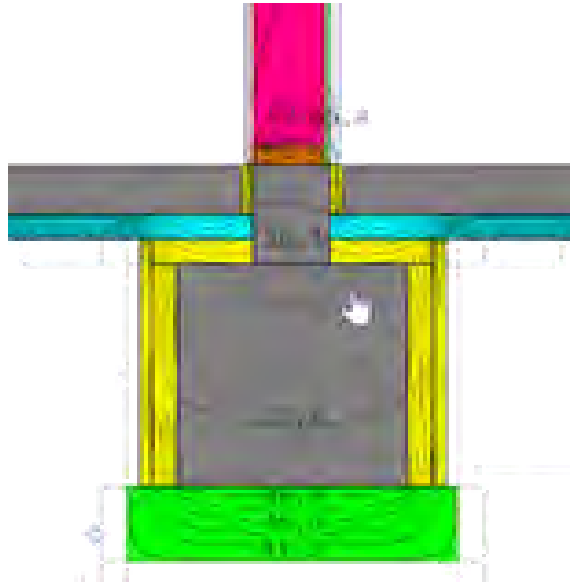
RECOMMENDED:

- Yields a negative thermal bridge.
- Mitigates condensation risk
- Satisfies heating load



OPTIMIZED:

- 8" Foamed Glass Aggregate below footings:
- 1’0” depth x Total LF (verify w/ structural)
- 2-1/2” XPS Both Sides / Ea. Footing
  - ALT: 3” XPS both sides of each footing
  - ALT: EPS @ horiz. underslab insulation
    - Better thermal bridge mitigation
    - Less expensive

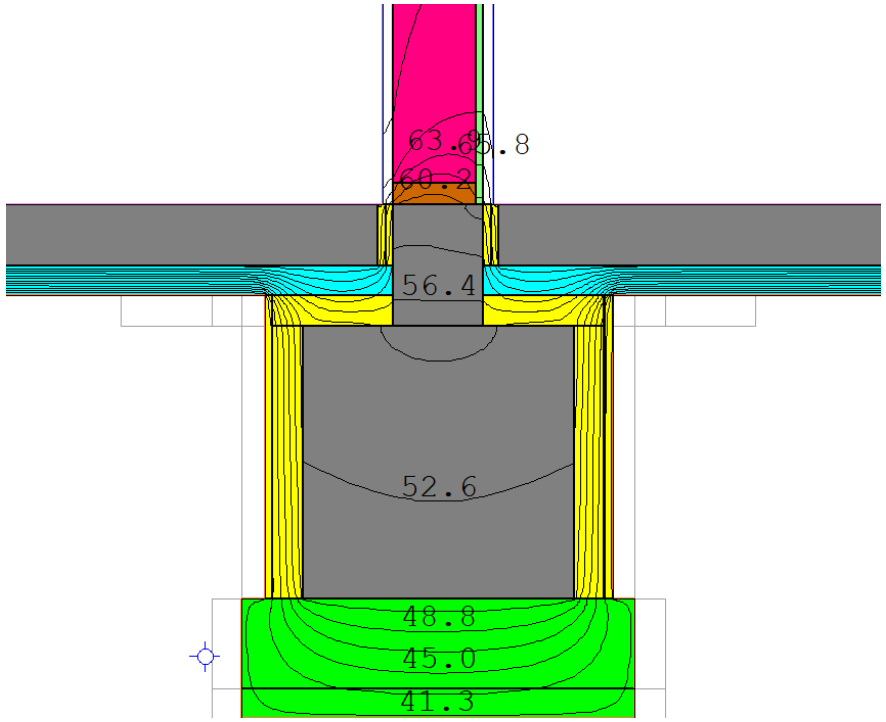


JOHN GRACE ARMS

ENCLOSURE OPTIMIZED

FOUNDATION DETAIL: CORRIDOR INSULATION

THERMAL BRIDGE MODEL @ INTERIOR SHEAR WALL



2D model

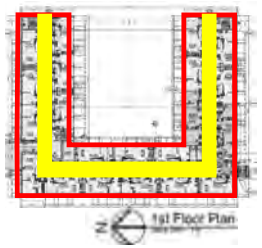
	U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Interior	0.0564	27	150.00	19.04	3.52%
Exterior	0.0604	27	139.94	19.02	3.52%

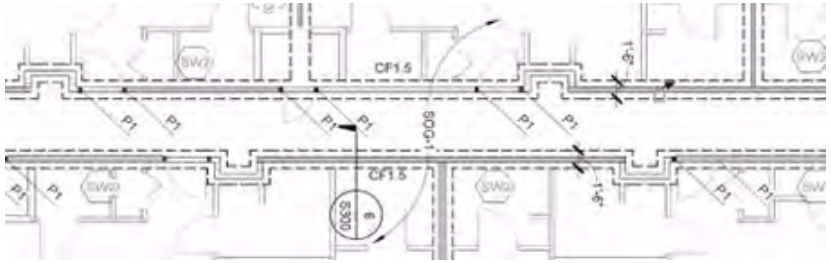
Component

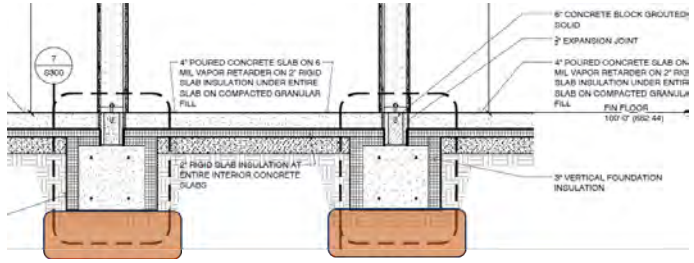
		U (btu/hr.sf.F)	dT (F)	L (in)	ULdT (btu/hr.ft)	error (%)
Component A	Interior	0.1082	27	78.00	18.99	0.00%
Slab	Exterior	0.108	27.00	78.00	18.99	0.00%
Component B	Interior				0.00	
	Exterior	0.0000	0.00	0.00	0.00	0.00%

Psi

	PsidT (btu/hr.ft)	dT (F)	Psi (btu/hr.ft.F)	Psi for WUFI (btu/hr.ft.F)
Interior	0.05	27.00	0.002	0.001
Exterior	0.03	27.00	0.001	



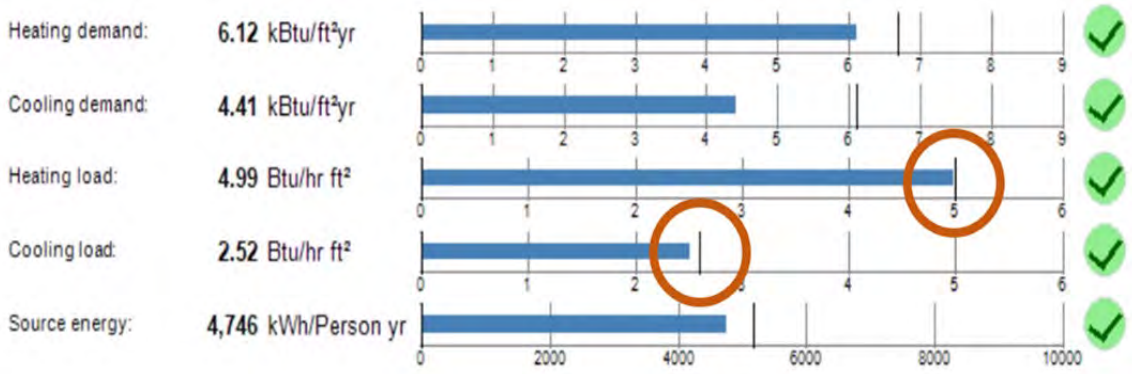




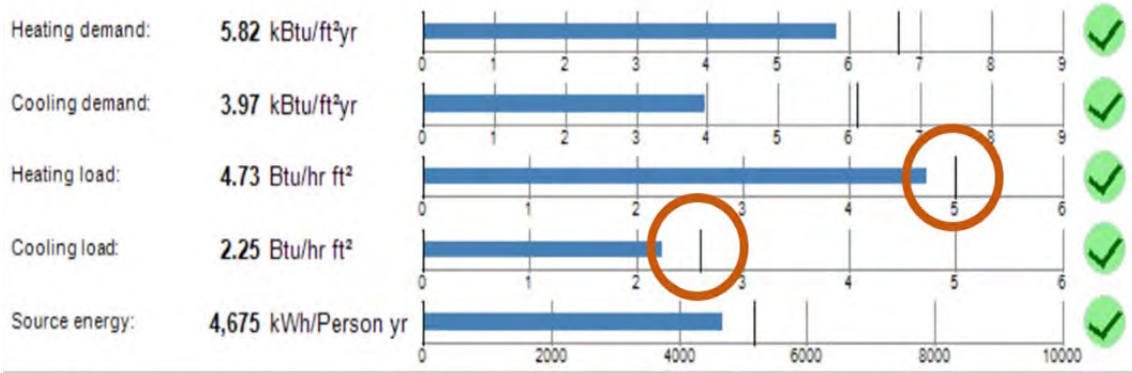
JOHN GRACE ARMS

VENTILATION IMPROVEMENTS

BASE MODEL



OPTIMIZED MODEL



OPTIMIZED ENERGY MODEL TAKEAWAYS:

1. Overall Results are below certification limits
2. Heating Load is improved
3. Windows, Air Infiltration + Ventilation have the largest impact.
4. Increased airtightness will benefit heating and cooling demands
5. R-values below slab reduced to increase efficiency + affordability.
6. ADDED ENVELOPE UPGRADES MAY ALLOW FOR SMALLER LESS EFFICIENT MECHANICAL SYSTEMS ...BUT TOP OF THE LINE MECHANICAL SYSTEMS ARE RECOMMENDED OVER ENVELOPE IMPROVEMENTS FOR INCREASED PERFORMANCE, COMFORT, AFFORDABILITY, + DURABILITY.
7. Phius v2021+ selected OVER V2024+ for EV Ready requirements

Phius 2021
Performance Criteria Calculator v3.3

Envelope Area (ft²)	63,403.4
iCFA (ft²)	38,033.7
Dwelling Units (Count)	42
Total Bedrooms (Count)	47

Space Conditioning Criteria		
Annual Heating Demand	6.7	kBtu/ft²yr
Annual Cooling Demand	6.1	kBtu/ft²yr
Peak Heating Load	5.0	Btu/ft²hr
Peak Cooling Load	2.6	Btu/ft²hr

Source Energy Criteria		
Phius CORE	5175	kWh/person.yr
Phius ZERO	0	kWh/person.yr

Phius 2024
New Construction
Performance Criteria Calculator v24.1

Envelope Area (ft²)	63,403.4
iCFA (ft²)	38,033.7
Dwelling Units (Count)	42
Total Bedrooms (Count)	47

Space Conditioning Criteria		
Annual Heating Demand	8.0	kBtu/ft²yr
Annual Cooling Demand	6.8	kBtu/ft²yr
Peak Heating Load	6.0	Btu/ft²hr
Peak Cooling Load	2.5	Btu/ft²hr

Source Energy Criteria		
Phius CORE	5975	kWh/person.yr
Phius ZERO	0	kWh/person.yr

JOHN GRACE ARMS

VENTILATION OPTIMIZED

OPTIMIZED VENTILATION TAKEAWAYS:

1. 20% ANNUAL HEATING DEMAND REDUCTION
2. MORE BALANCED SUPPLY AND EXHAUST AIR FLOWS
3. 7% SITE ENERGY DECREASE
   - 229,519.7 kwh/yr to 213.926.7 kwh/yr.
   - Saving 15,593 kwh/yr
   - Equivalent to 35 PV panels
   - Equivalent to $1876/yr in electricity costs.
4. POTENTIAL ADDITIONAL COST SAVINGS
   - Smaller ERV unit / DHX/ER coil / Ductwork / Electrical louvered screen/curb, etc.

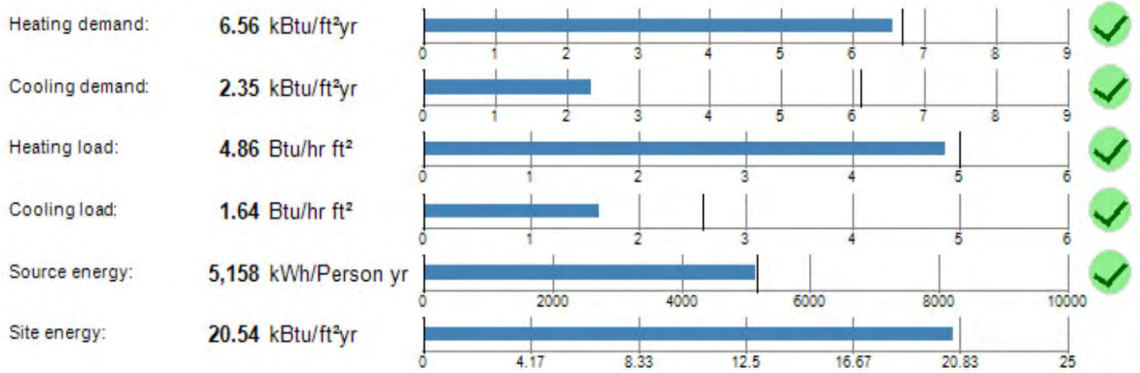
   MEP comment: To adhere to the 10% separation criteria for OA and EA the total exhaust cfm will need to be a minimum of 1962 cfm

VENTILATION BALANCING RECOMMENDATIONS:

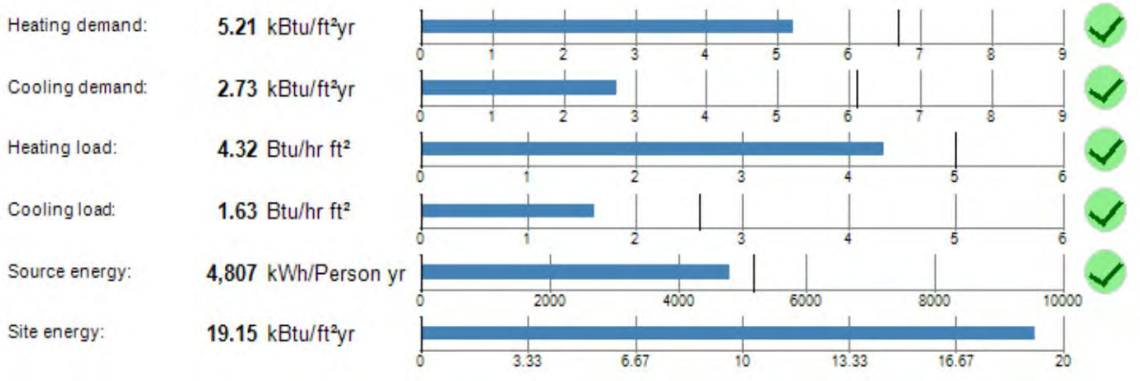
Balance ERV exhausts at 2180 cfm to match supply requirement.

- *This provides flexibility to the balancer as the 10% requirement must be achieved during on-site testing. Experience often yields a 2-4% imbalance during commissioning resulting from duct length variance and ensuring minimum flows at each register, etc.*

AS DESIGNED 3150 CFM



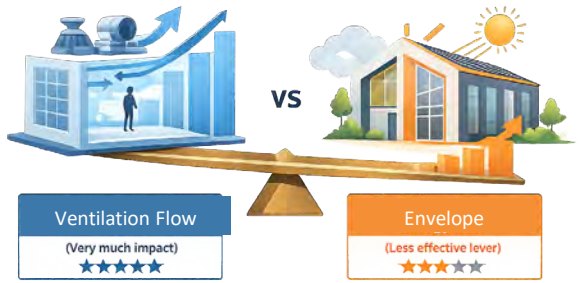
PROPOSED 2180 CFM



MULTIFAMILY CASE STUDIES

LIVONIA

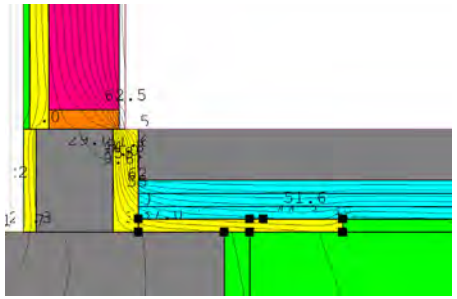
VENTILATION FLOW RATES



Copyright 2024 Quatela-Architects
https://www.quatela-architects.com/multi-family-projects

JOHN GRACE ARMS

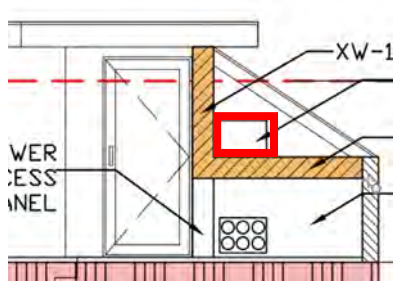
ERV + PERIMETER INSULATION

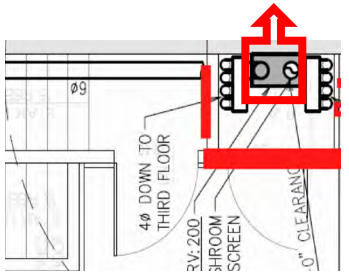


Copyright City of Southfield
https://www.cityofsouthfield.com/sites/default/files/inline-files/John%20Grace%20Revitalization%20Plan%20FINAL%2003302022.pdf

45 REMSEN

ERV SYSTEM LOCATIONS





Copyright Coming Home of Middlesex County
https://www.cominghomemiddlesex.org/

THANK YOU! QUESTIONS??

Stefan Goebel
Build Zero Consulting
Building Envelope & Energy Consultant | Net Zero Energy & Passive Building Advocate

stefan@buildzeroconsulting.com

Ryan Abendroth
Build Zero Consulting
Phius Trainer
Phius technical Committee
Senior Lecturer, Washington University

ryan@buildzeroconsulting.com

Shannon Pendleton, CPHC
Sanderson Sustainable Design
Passive House Accelerator
Source 2050
Aquetong Watershed Assoc.

shannon@sandersondesign.net

BUILDINGENERGY BOSTON

Please fill out an evaluation for this session

or: *nesea.org/eval*

Northeast Sustainable Energy Association (NESEA)