



# BALANCING ENERGY, VENTILATION, AND IAQ

Case Study of a LEED Home Rehab  
Maureen McGeary Mahle

# Course Description

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## Balancing Energy, Ventilation and IAQ: Case Study of a LEED Home Rehab

This case study highlights the lessons learned when those who certify actually GET CERTIFIED. Describes a 5+ year occupied renovation of this 1915 home located in an urban infill setting, including decision-making, results, and the pros and cons of LEED v4 for Homes applied to rehabs.



# Learning Objectives

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1. Identify the easiest and most challenging LEED v4 for Homes credits for rehab projects
2. Understand where Energy and IAQ objectives conflict in a rehab project
3. Learn the top 3 mistakes made by an “expert” during a green home renovation, so that you never, ever repeat them
4. Define and track energy and IAQ metrics on your next project



# Case Study Background

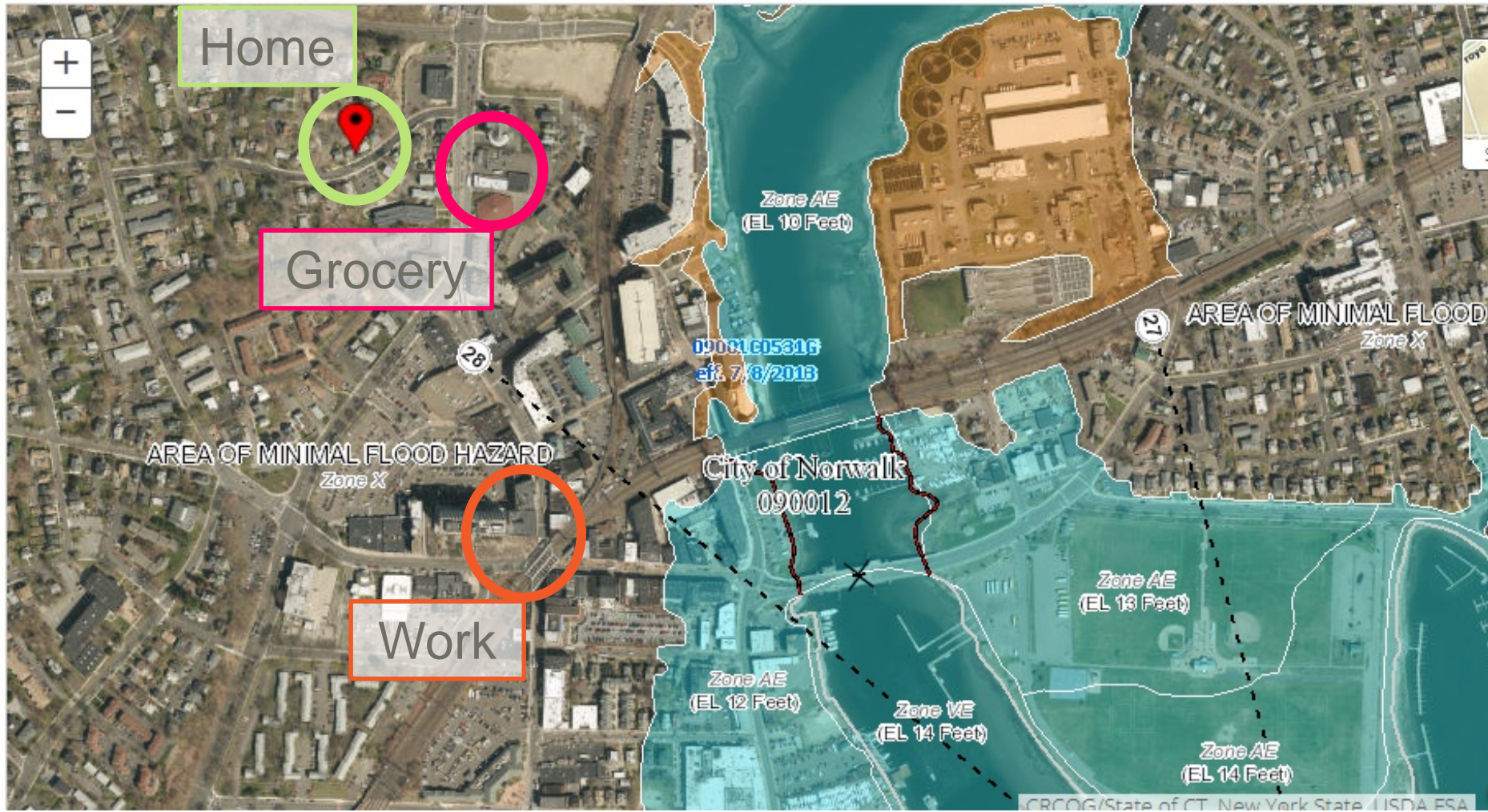
# Timeline

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- 2012 Aug to Oct House purchase
- 2012 Nov – 2013 Dec Boiler, floors, kitchen, baths, insulate attic + basement
- 2014 July to Nov Exterior: siding, insulation, windows, foundation, trim
- 2015 April to Sept Landscaping - sides
- 2016 June to Aug Garage
- 2017 June to Aug Landscaping - front & back
- 2017 Nov to Dec Energy Recovery Ventilator
- 2015 Feb to present Interior paint, trim



Purchase decision: Walk to work and train, but avoid possible flood zones



Tan: 500-year flood zone; Blue: 100-year flood zone (1% chance every year)

# Home purchased Oct 26, 2012

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- \$235,000
- Built 1915
- Wood frame
- 4-bed, 1-bath
- 1794 conditioned SF
- Hydronic heat





# Hurricane Sandy Oct 29, 2012

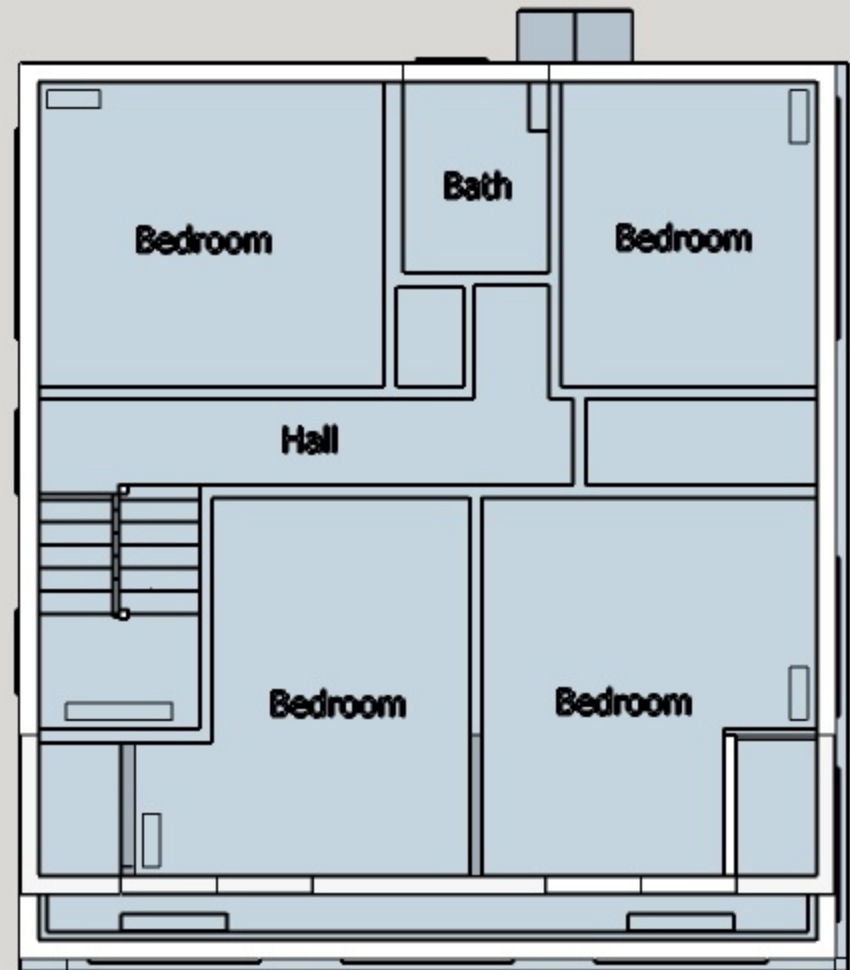
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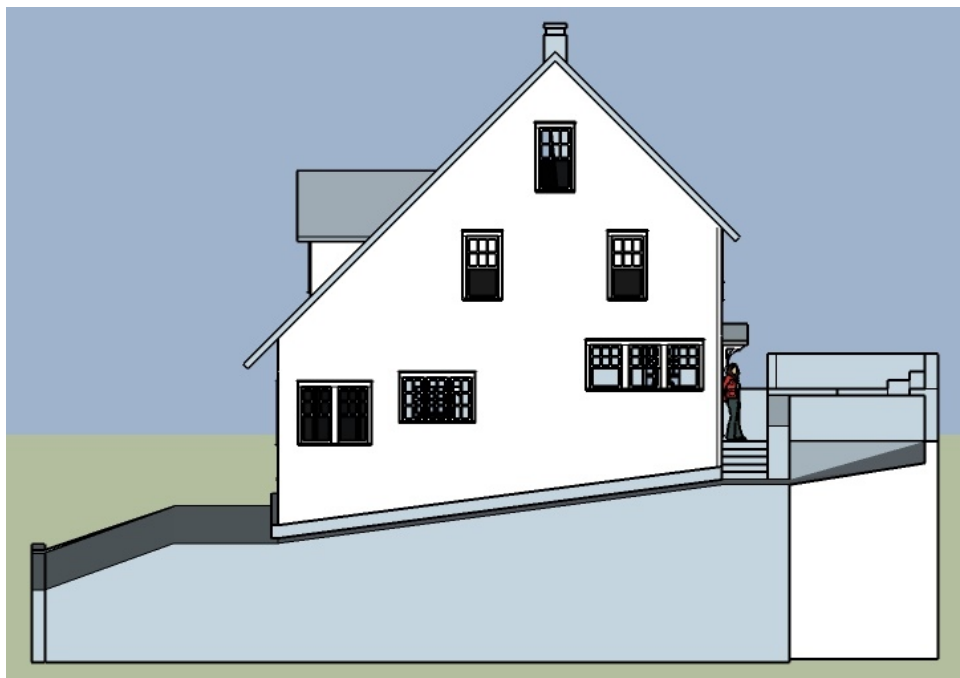
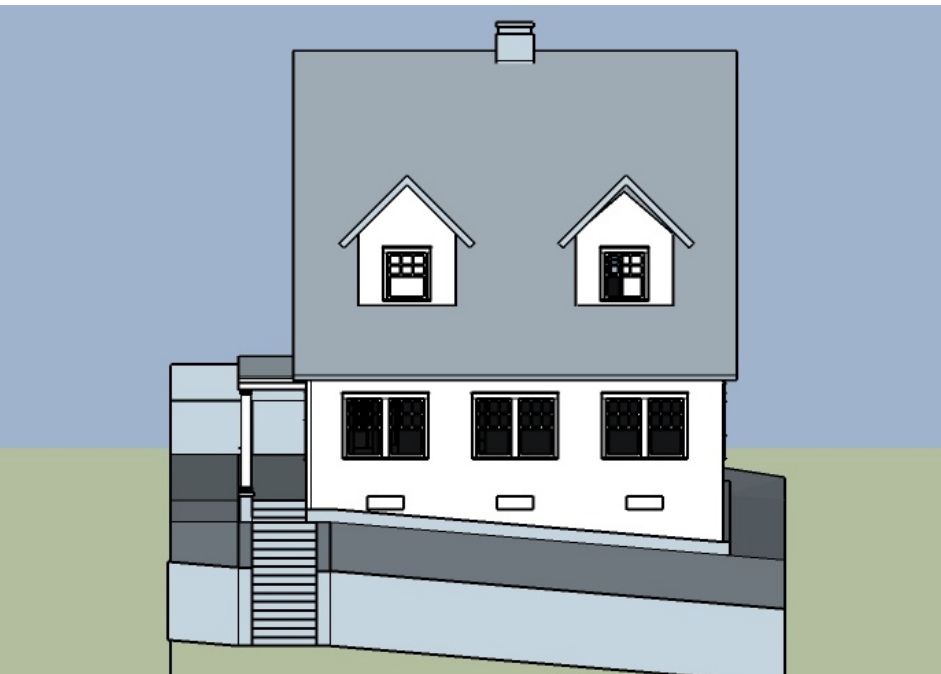




# First Floor

# Second Floor







# Existing Conditions

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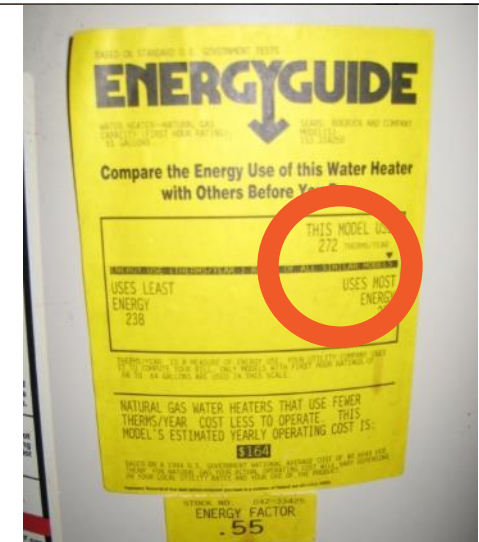
- Intentionally slanted rubble foundation
- Rear and front drainage issues
- Termite damage (slight)
- 4" rafters, 4" balloon framed wall cavities
- Aluminum storms + original wood windows
- Oil tanks & boiler (5 yrs old) w/ converted steam radiators
- Atmospheric gas water heater
- Fiberglass in attic floor
- No intentional ventilation

**HERS 173**  
**25.6 ACH<sub>50</sub>**

15-25 year old appliances



**HERS 173**  
**25.6 ACH<sub>50</sub>**





# 2012-2013: Interior, attic, basement

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- Replace boiler with condensing gas tankless + indirect tank

**HERS 143**  
**25.6 ACH**

- Kitchen gut

- Full bath gut

- Add half bath

- Interior air sealing (HES)

**HERS 128**  
**18.5 ACH**

- Spray foam attic @ sheathing

- Spray foam basement @ ceiling

**HERS 111**  
**9.7 ACH**

Insulation day!



Intumescent paint on closed cell in attic



Crawl space, basement ceilings foamed



Condensing gas boiler  
95 AFUE





Nook in living room makes space for ...



...a half bath



Doug fir floors, before...



...and after





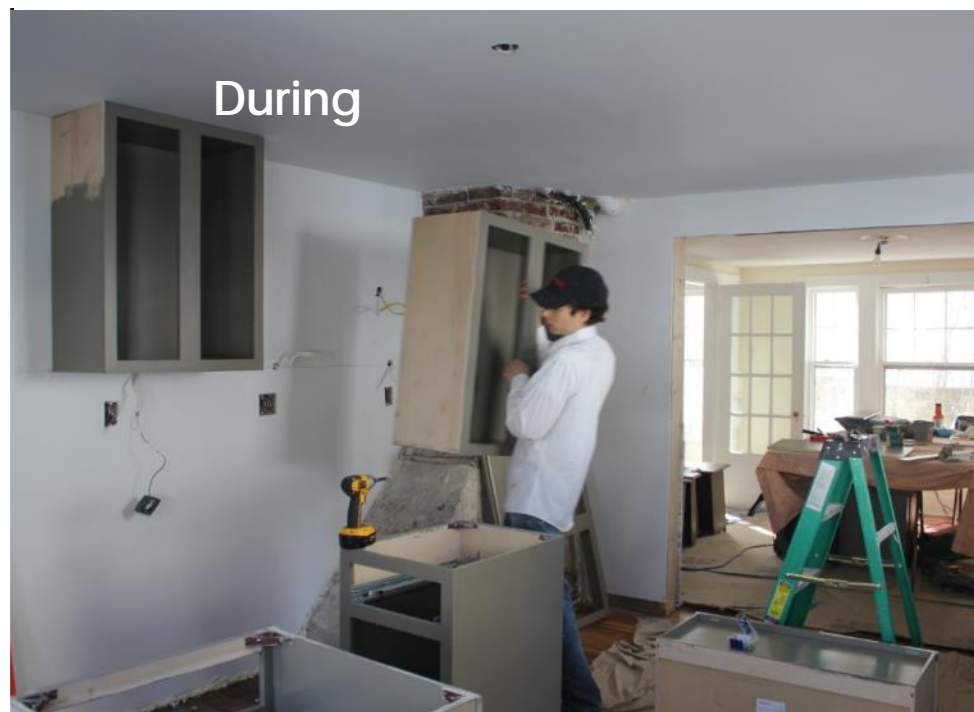
Before



Demo



After



During





Roughing it



Tile experiment



Before



After



During

# 2014: Exterior envelope

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- Remove cedar siding (1924) & stucco
- Rebuild stone foundation
- Repair tongue-and-groove sheathing
- Add 1" foil faced Polyiso (R-6.5)
- Cold-pour open cell foam in walls (R-13)
- New flashed vinyl windows
- New fiber cement siding
- Repoured sidewalks adjacent to 2 sides

**HERS 62**  
**5.6 ACH**





HERS 111 to 62  
9.7<sub>ACH50</sub> to 5.6



# Summers 2015, 2017: Landscaping

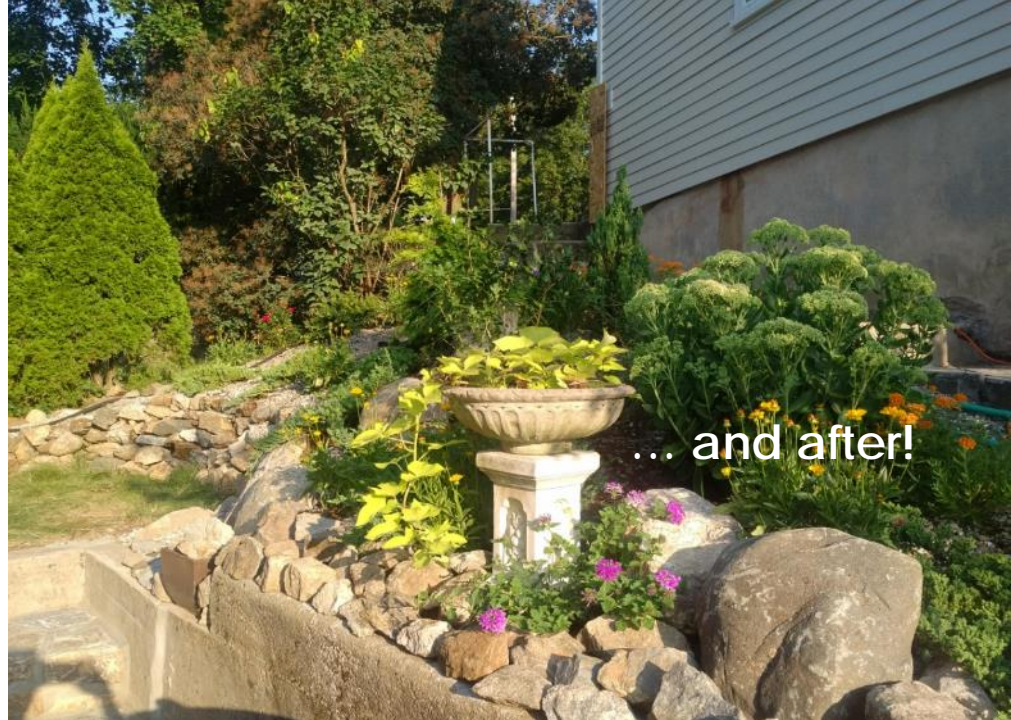
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- Retained 28 existing shrubs and trees
- Added 216 additional native or adapted plants
- Includes 409 SF no-mow lawn
- Built 6 new retaining walls
- Installed 3 rain barrels (210 gallons total)
- Repaired existing retaining walls, concrete patio and front steps
- Added permeable pea-stone walkways





Before...



... and after!

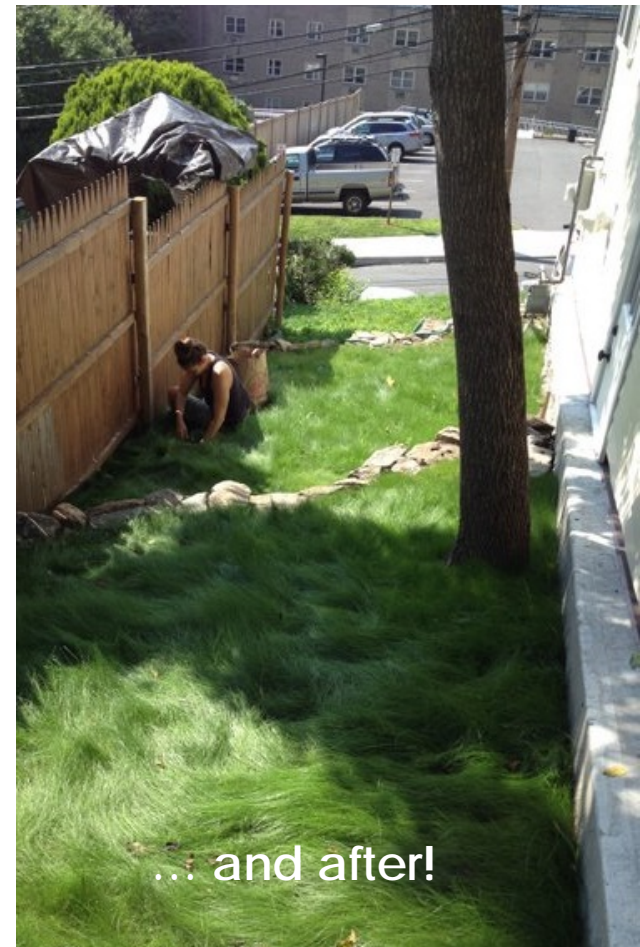


During...

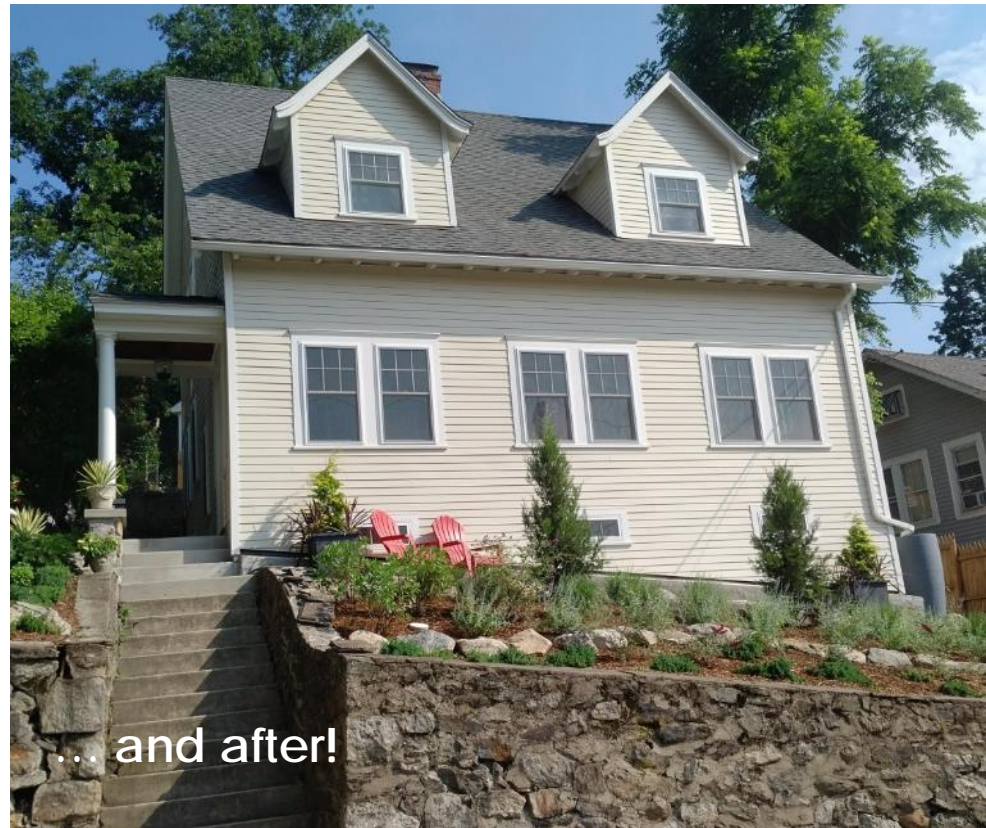


... and after!









LEED Estimated Total Water Reduction:  
**68%**

# 2016-2018: Ventilation and IAQ

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- Installed wood fireplace insert & lined chimney

**HERS 58**  
**3.1 ACH**

ISSUE! -11Pa with bath + kitchen exhaust

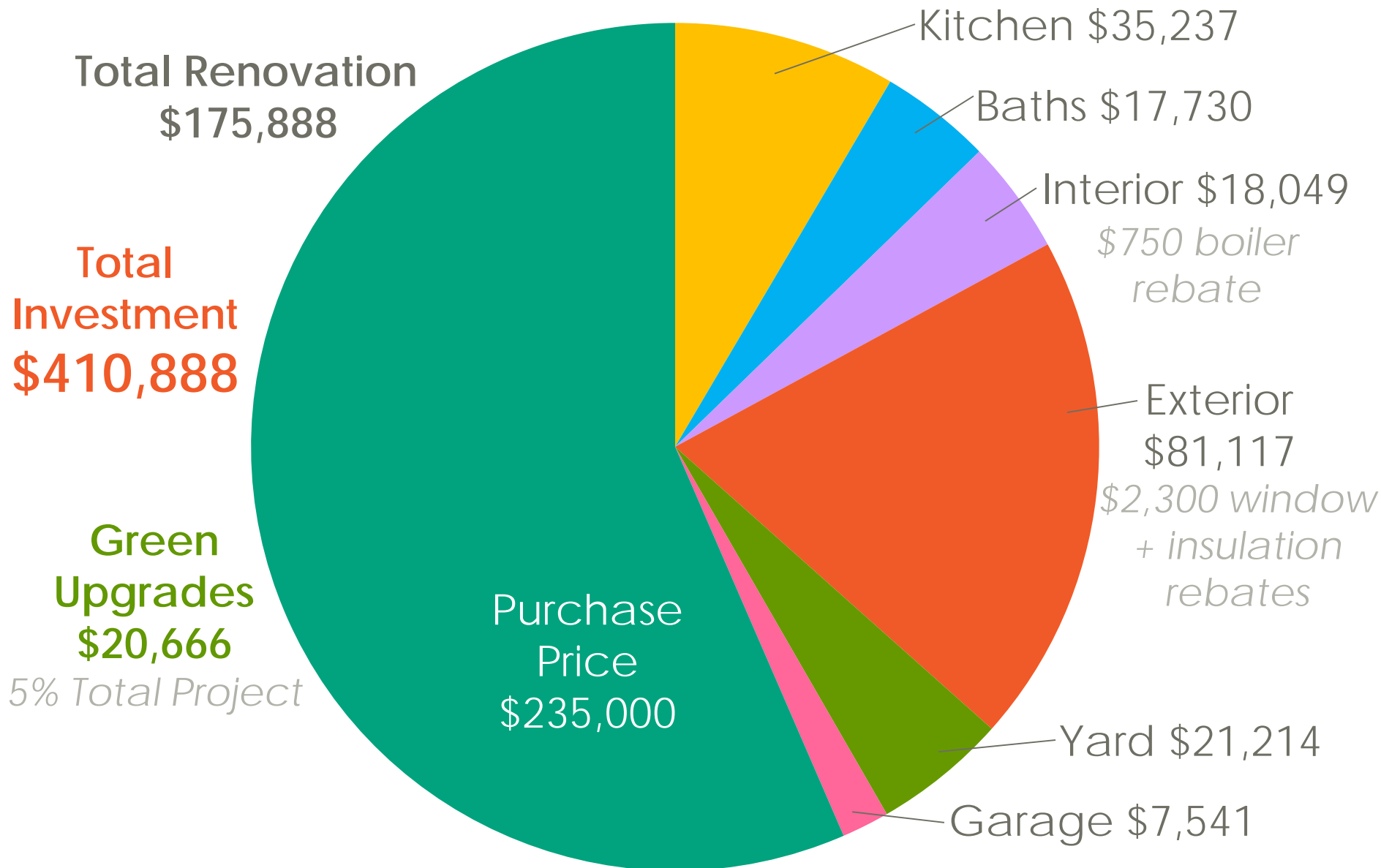
ISSUE! Often felt stuffy upstairs

- Added fresh air makeup + limited kitchen range hood to pass combustion safety worst-case depressurization
- Added ERV to replace exhaust-only strategy

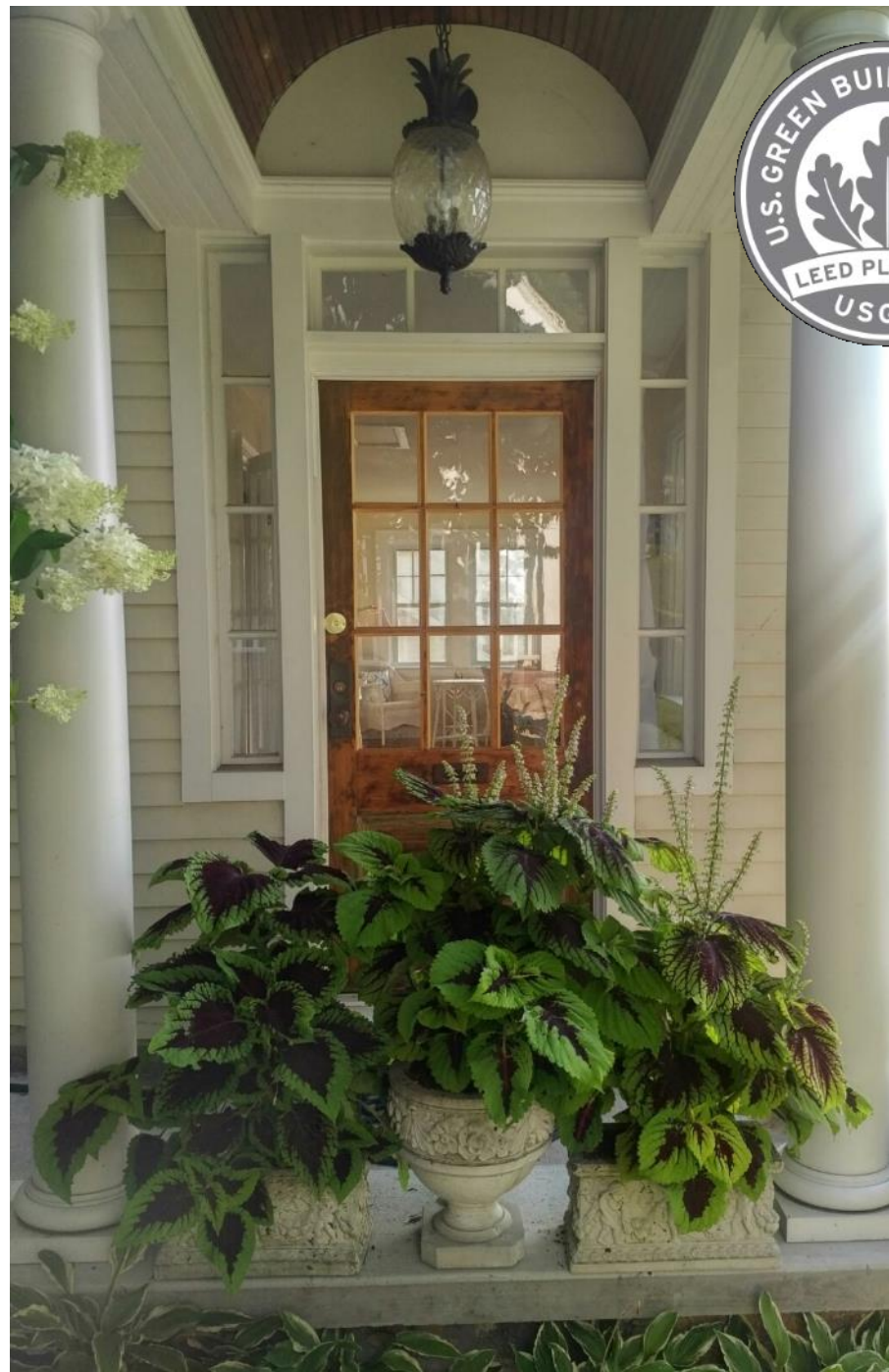
**HERS 59**  
**3.1 ACH**



# "The Fiscal Cliff" Cost Data












# LEED-H Occupied Rehab





# v4 Platinum Scorecard:

85 of 110

	Integrative Process	2 of 2
	Location & Transportation	14.5 of 15
	Sustainable Sites	3 of 7
	Water Efficiency	12 of 12
	Energy & Atmosphere	26.5 of 38
	Materials & Resources	10 of 10
	Indoor Environmental Quality	6 of 16
	Innovation	6 of 6
	Regional Priority	4 of 4

# Easiest Rehab Credits in LEED-H v4

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## #1 Site Selection +9pts

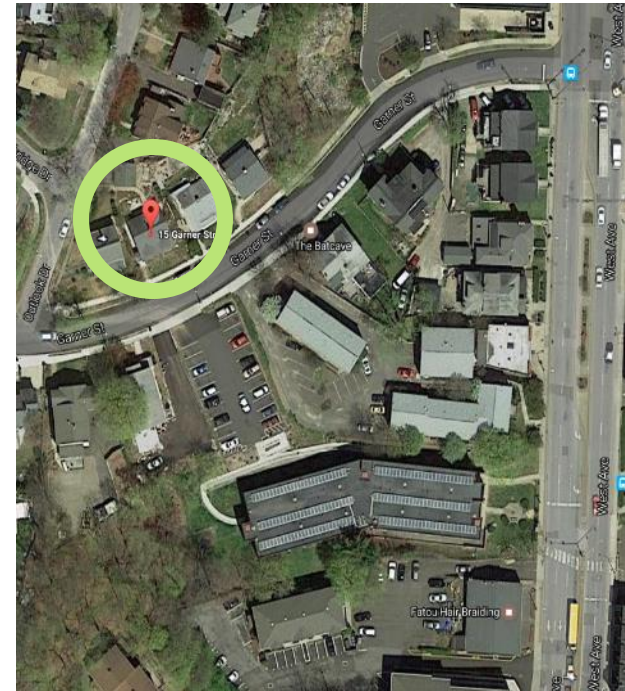
+4 Previously Developed

+2 Infill

+1 Open Space

+1 Street Network

+1 Bonus Regional Priority



Location + Transportation Category

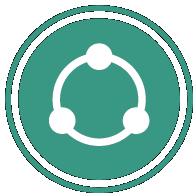


# Easiest Rehab Credits in LEED-H v4

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## #2 Integrative Project Team +1pt

When you are living through an occupied rehab, it is difficult NOT to be involved in every phase. Requires at least 3 skill sets are present (architecture, engineering, building science, sustainability, etc.)



Location + Transportation Category

# Easiest Rehab Credits in LEED-H v4

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## #3 Environmentally Preferable Products +7.5

+1.5 Local – now 100 miles

+4 Requires just 25% per component reclaimed: flooring, sheathing, roofing, gypsum board (or plaster), floor covering

+1 Reclaimed for 90% of 3 of trim, doors, decking, etc.

+1+ Innovation – Exemplary Performance



Materials & Resources Category



# Easiest Rehab Credits in LEED-H v4

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## #4 Low-Emitting Products: Composite Wood +1pt

- With over 95% of interior trim and doors preserved, there was very little new wood to worry about.
- Kitchen cabinets were NAUF



Indoor Environmental Quality Category

# Easiest Rehab Credits in LEED-H v4

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## **#5** Construction Waste Management +3pts

LEED v4 now requires you to count recycled waste at only a 25% reduction (75% still counts as waste), AND limits are lower. Only rehabs are likely to score high

## **Material Efficient Framing +2pts**

Rehabs can count only new components, OR take credit for no new material



Materials & Resources Category



# Easiest Rehab Credits in LEED-H v4

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## #6 Advanced Utility Tracking +1pt

Easy when end-users are known! Requires signing up for a WegoWise or WegoHome (free!) account and linking utility data. If your utility doesn't automatically link, upload automatically, or get 10 neighbors and ask Wego to set up the link.



Energy & Atmosphere Category

## 15 Garner Street 🔍 ✎ ✕

Summary View

View Data

Utility Accounts

Building Upgrades

&lt; 2016

2017

2018 &gt;

Monthly ☐ Annual ☒

## Water

Entire building usage in Gallons / bedroom

Efficient ✓



- 61% less than the median building
- 40% less than efficient buildings

[View meter-level data](#)

## Electric

Entire building usage in kWh / 1k sqft

Efficient ✓



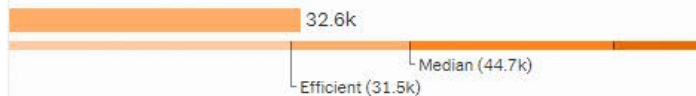
- 49% less than the median building
- 17% less than efficient buildings

[View meter-level data](#)

## Gas

Entire building usage in Btu / sqft

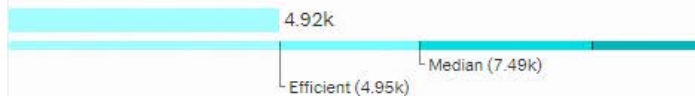
Better than median ✓



- 27% less than the median building
- 3% more than efficient buildings

[View meter-level data](#)CO<sub>2</sub>lbs. CO<sub>2</sub> / sqft

Efficient ✓



- 34% less than the median building
- 1% less than efficient buildings

CO<sub>2</sub> combines emissions for all energy uses. [Learn more](#)

## Cost

Amount spent in \$ this year

Water	\$90.35	6%
Electric	\$413.12	28%
Gas	\$969.23	66%

Suggestion: sign up for free benchmarking today!



# IAQ Challenges



# Toughest IAQ Challenges for Rehabs

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## **#1** Contaminant Control (0.5-1pt)

- In occupied rehab situation, you are living in the jobsite.
- Most likely can't take credit for either Pre-Occupancy flush (0.5pt) or for Air Testing (1pt)



Indoor Environmental Quality Category



## Walk-Off Mat (+0.5)

Rotten joists and flooring gave our framer the idea for a recessed walk-off mat (it continues outside) to help catch Schnoodle debris



# Toughest IAQ Challenges for Rehabs

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## #2 Combustion Venting (Prereq + 1pt)

- Fireplaces must have doors (OK)
- If fireplace/stove doesn't have closed combustion or power venting, must be  $< -5\text{Pa}$  with worst-case depressurization (required makeup for range hood)



Indoor Environmental Quality Category





## MISTAKE: RANGE HOOD TYPE

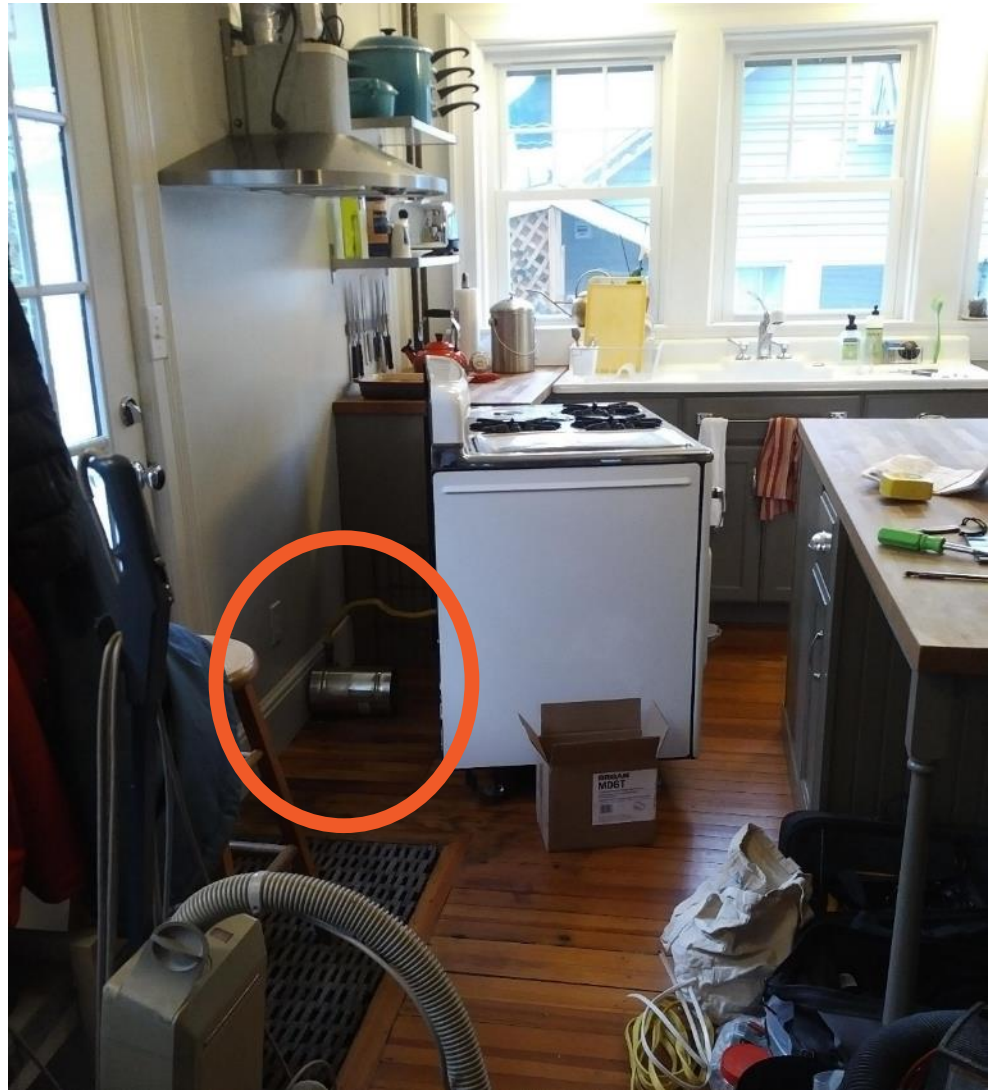
- Chose range hood based on looks and cost, pre-LBNL research, for infrequent use
- Had to limit the flow rate (124 low, 290 high) and put in motorized fresh air damper to avoid excess depressurization
- Too high, too shallow. **Next time, COVER ALL BURNERS!**
- TOO LOUD. Not unusually so, but bad for conversation. **Next time, REMOTE MOUNT FAN!**

## RANGE SOLUTION:

Added motorized 6" damper tied to hood to alleviate -11Pa depressurization with 124 cfm hood and 42 cfm bath.

After: -3.3 Pa

Energy: same?







## POSSIBLE MISTAKE: GAS RANGE?

- Chambers 61C, circa 1950
- *"Cooks with the gas turned off"*
- My favorite thing ever, BUT...
- Cooking with gas is not the best for IAQ!



## POSSIBLE MISTAKE: FIREPLACE?

- Love this EPA-listed wood burning insert for aesthetics, slow burn, heat output
- Lining the chimney + installing the unit dropped ACH50 from 5.6 to 3.1!
- Before the fresh air damper, definitely smelled ashes when range hood was on
- They really are not great for IAQ 😞

# Toughest IAQ Challenges for Rehabs

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## #3 Whole House Ventilation (Prereq +2pts)

- Exhaust-only allowed in ASHRAE 62.2
- Points given for ERV or balanced



Indoor Environmental Quality Category





## MISTAKE: EXHAUST-ONLY

- Low-cost, minimally invasive in a home with interior preserved
- Suitable for moderately tight homes in moderate climates
- Bath fan upstairs pulling **45cfm** continuous with boost controller
- Home got progressively tighter, to 3.1 ACH50
- **We found bedrooms stuffy.** Monitored humidity, but did not seem unusually high

## FRESH AIR SOLUTION:

Added a 100cfm ERV in the attic. Ducted supply to each of 4 beds. Returns from main bath and register in stairwell.

After: Noticeably more comfortable! BUT Watch out for outdoor contaminants.

Next Time: put shut-off on main level for easy access.

Energy: 438 kwh/yr, \$83/yr

Comfort: 2° warmer/colder upstairs... re-balance heat!



# Toughest IAQ Challenges for Rehabs

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## #4 Radon Mitigation (Prereq)

- Radon resistant construction required in Zone 1 (high risk); OR
- Rehabs can test to show compliance



Indoor Environmental Quality Category





## MISTAKE: THINKING 4 pCi/L SAFE

- Sealed basement away from living space with ccspf, gaskets
- 4 day tests initially showed Radon levels of 1-3 pCi/L
- After home was tightened, increased to right around 4 pCi/L
- “There is NO safe level of radon” (World Health Organization)

## RADON SOLUTION:

Added continuously operating 50 cfm 13 watt fan exhausting from crawlspace.

After: 1.2-1.4 pCi/L

Next time, aim for  
Radon <2 pCi/L

Energy: 114 kwh/yr, \$21







# Energy Challenges



# Toughest Rehab Credit in LEED-H v4

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## **#1** Annual Energy Use (Prereq + 1-30pts)

Requires meeting **HERS Index Target** & earning **ENERGY STAR**. Rehabs get exceptions to parts of the Thermal Enclosure System Checklist (*4.1 attic insulation*) and Water-Managed Site and Foundation (*1.3 capillary break, unless water damaged*)

However, Rehabs may have limitations (e.g. that limit earning EA points cost-effectively).



Energy & Atmosphere Category

## CHALLENGE: LEDGE FOUNDATION



SOLUTION: ISOLATE & LEAVE IT BE, DEHUMIDIFY

## CHALLENGE: LIMITED INSULATION SPACE

- Wanted to preserve footprint, interior plaster & trim
- Avoid re-framing to limit costs
- Maintain the option to finish out the attic







## SOLUTION: VARIOUS FOAMS

- Closed cell (attic, basement), open cell (cold-pour exterior walls), and 1" rigid exterior foams for best R-per-inch plus vapor resistance
- Aimed for lower ozone depletion products, but choices still impact environment + health
- Added intumescent paint in attic for fire protection

IAQ: short-term impacts during and shortly after install

## CHALLENGE: CLADDING

- Removed beautiful 90-year old cedar siding (and stucco beneath) to address drainage and add continuous insulation

## DECISION: RE-HOME, ADD NEW

- 75% cedar was in perfect condition and taken away free via Craigslist
- Replaced with fiber cement, high embodied energy but good durability, low maintenance





## CHALLENGE: WINDOWS

- \$11,000 for 35 Paradigm ENERGY STAR double pane, double hung vinyl windows U-0.28, SHGC 0.25.
- Wood \$12,000 more. Triple pane \$5,000 more. PH \$38,000 more.

## DECISION: VINYL DOUBLE PANE

- Good energy performers, tight for double-hung, good divided light look, in our budget... BUT VINYL
- 100% of old windows were rehomed, listed FREE on Craigslist

Next time, casements? But harder for coverings/privacy.





## CHALLENGE: EXISTING HEATING

- 5-year old oil boiler; 99-year old radiators (steam converted to H2O)

## DECISION: CONDENSING GAS BOILER FOR HEAT + HOT WATER, NO A/C

- Traded boiler for moving services
- Kept radiators except LR; added radiant tubing kitch + bath
- NEST thermostat works well to manage high-mass system
- 6,000 and 8,000 BTU window A/C

Next time, add REAL A/C!





# By the Numbers

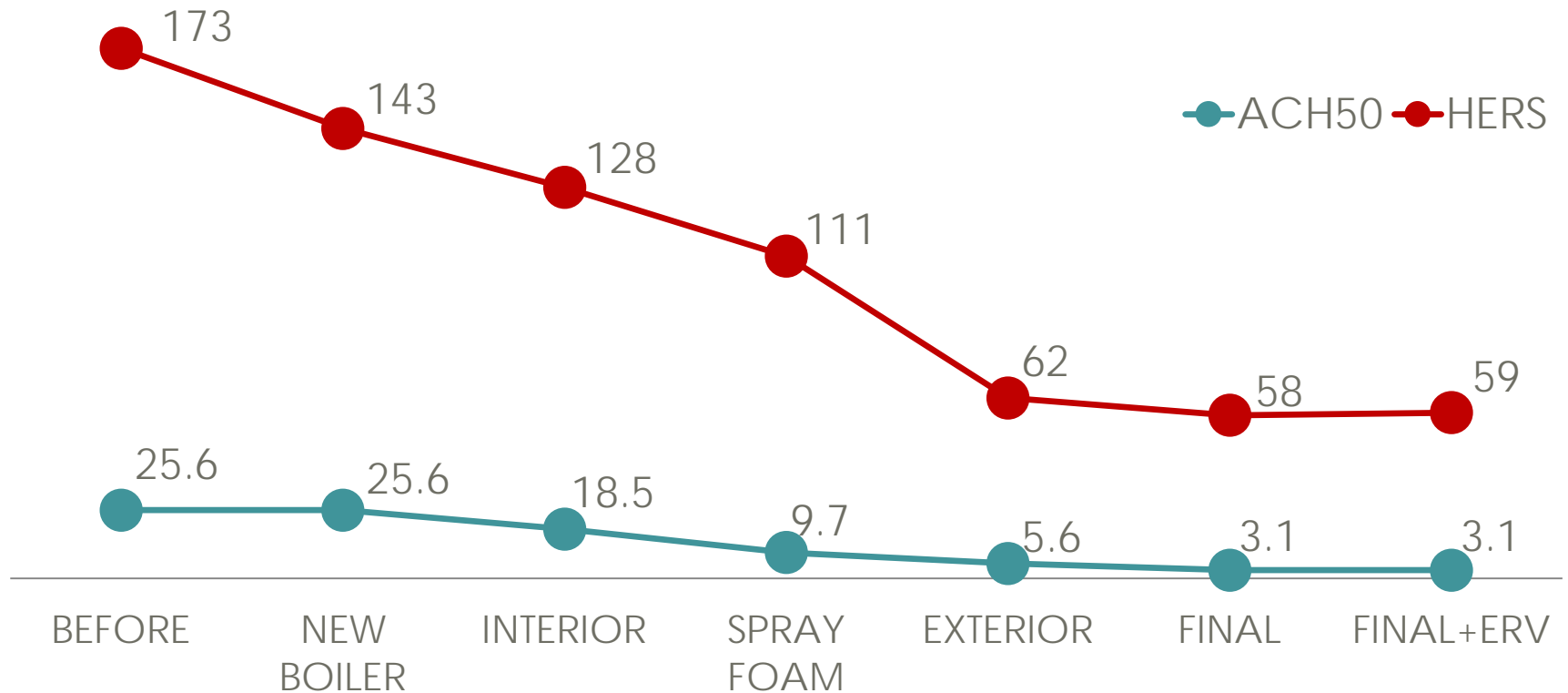




# Drops in HERS Index and ACH50

HERS drops from 173 to 59

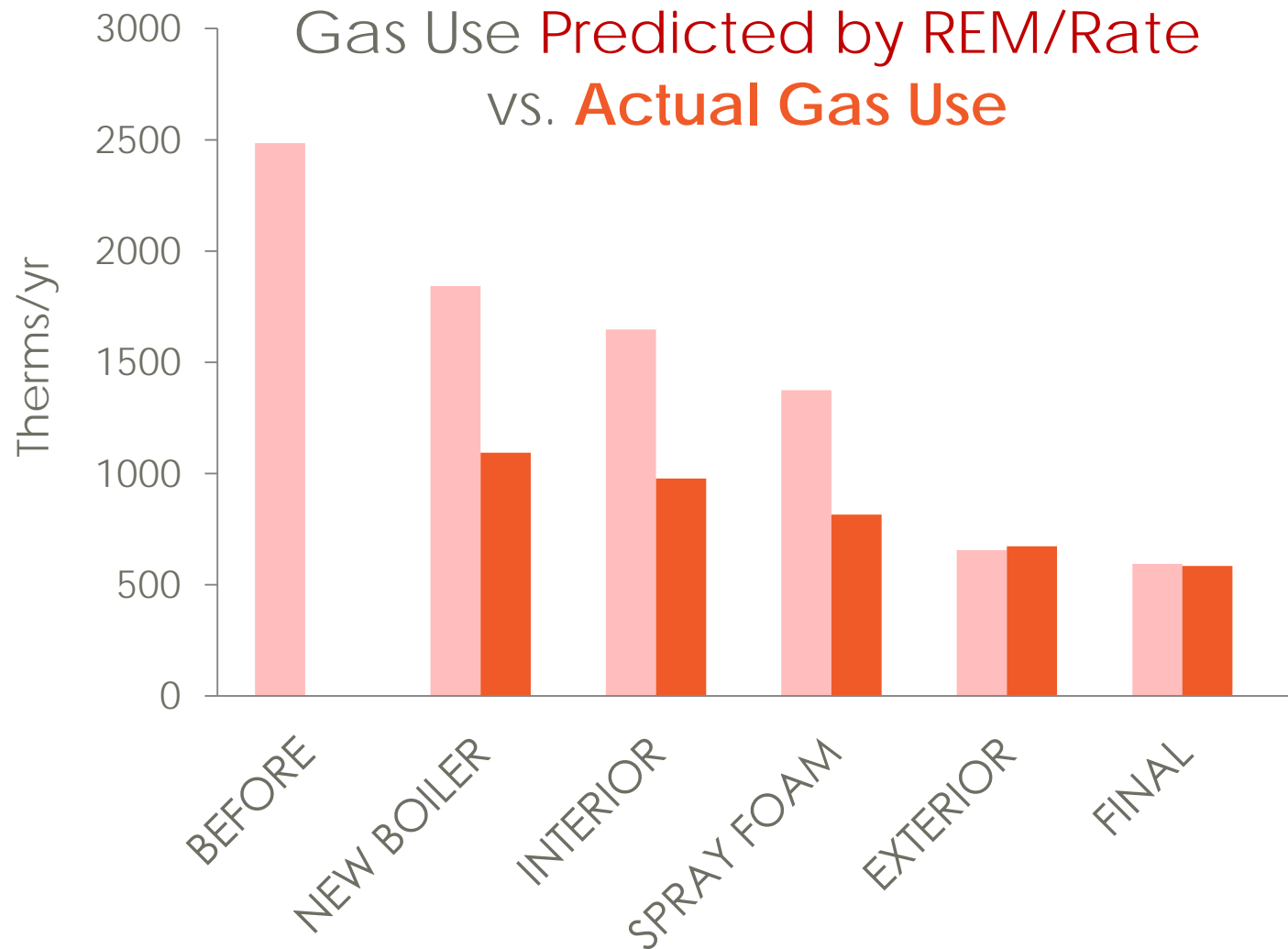
ACH50 drops from 25.6 to 3.1





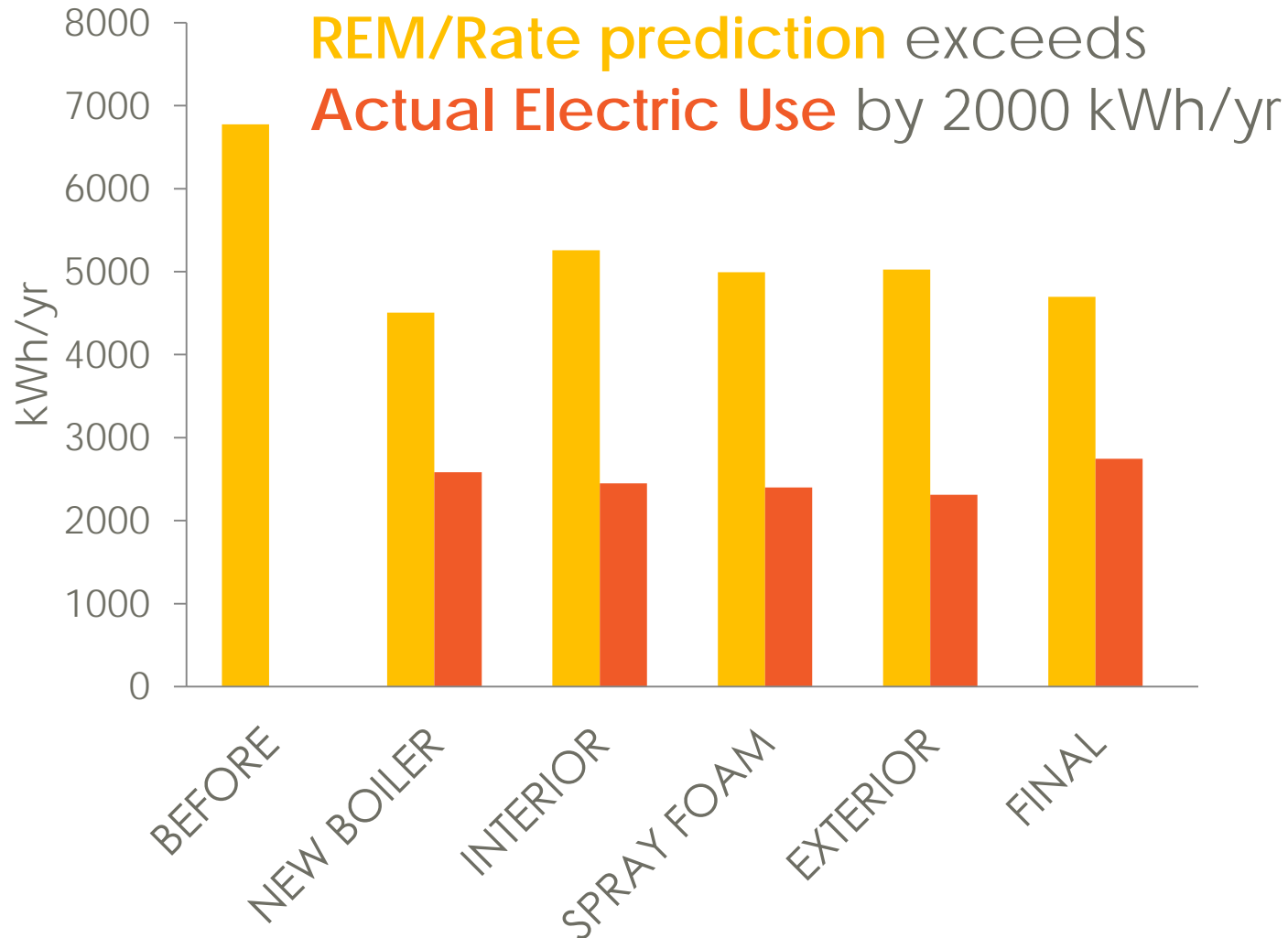
# Gas Use: now close to 600 Therms/yr

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# Electric Use: Predicted exceeds Actual

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# Utility Costs - Benchmark

Current Water: \$165/year

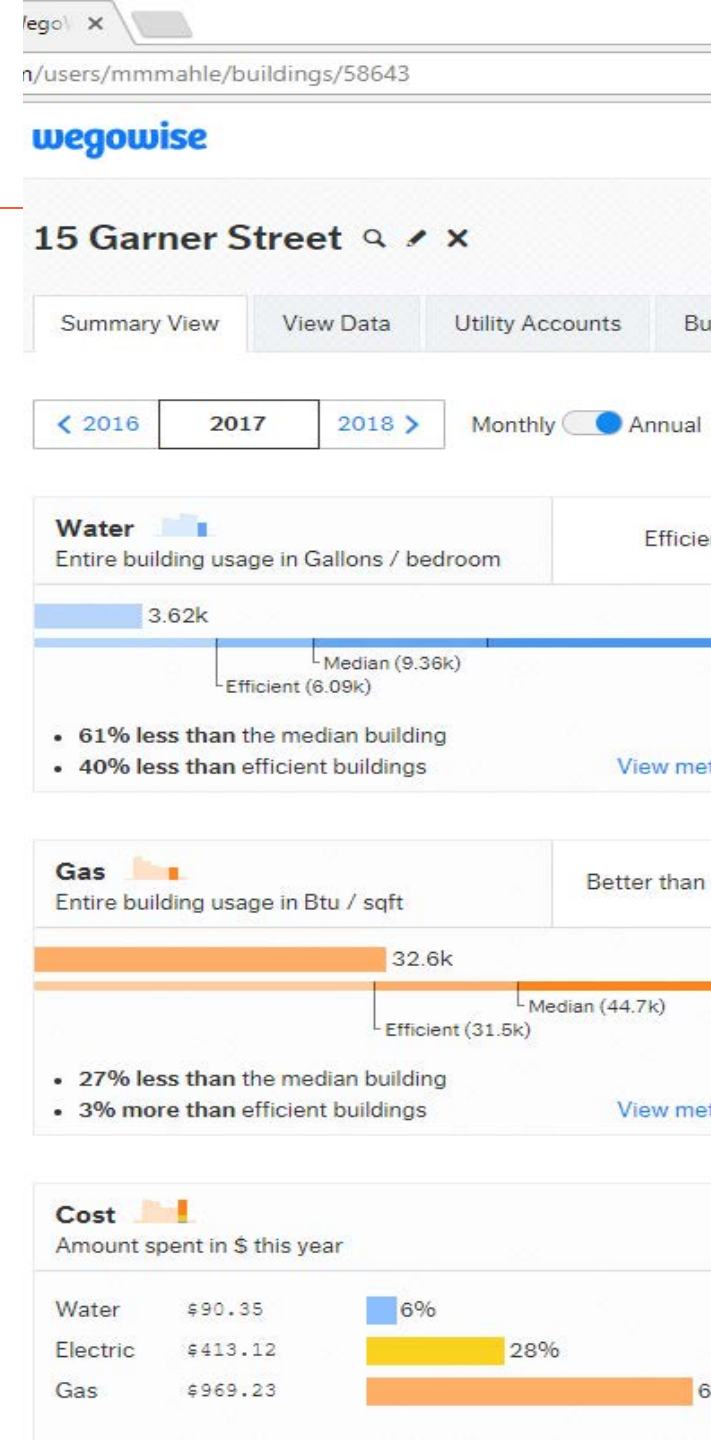
- \$59 landscaping install summer
- \$37 winter/shoulder month
- \$43 average month over 5 yrs

Current Electric: \$590/year

- \$50 summer month
- \$34 shoulder month
- \$44 average month over 5 yrs

Current Gas: \$965/year

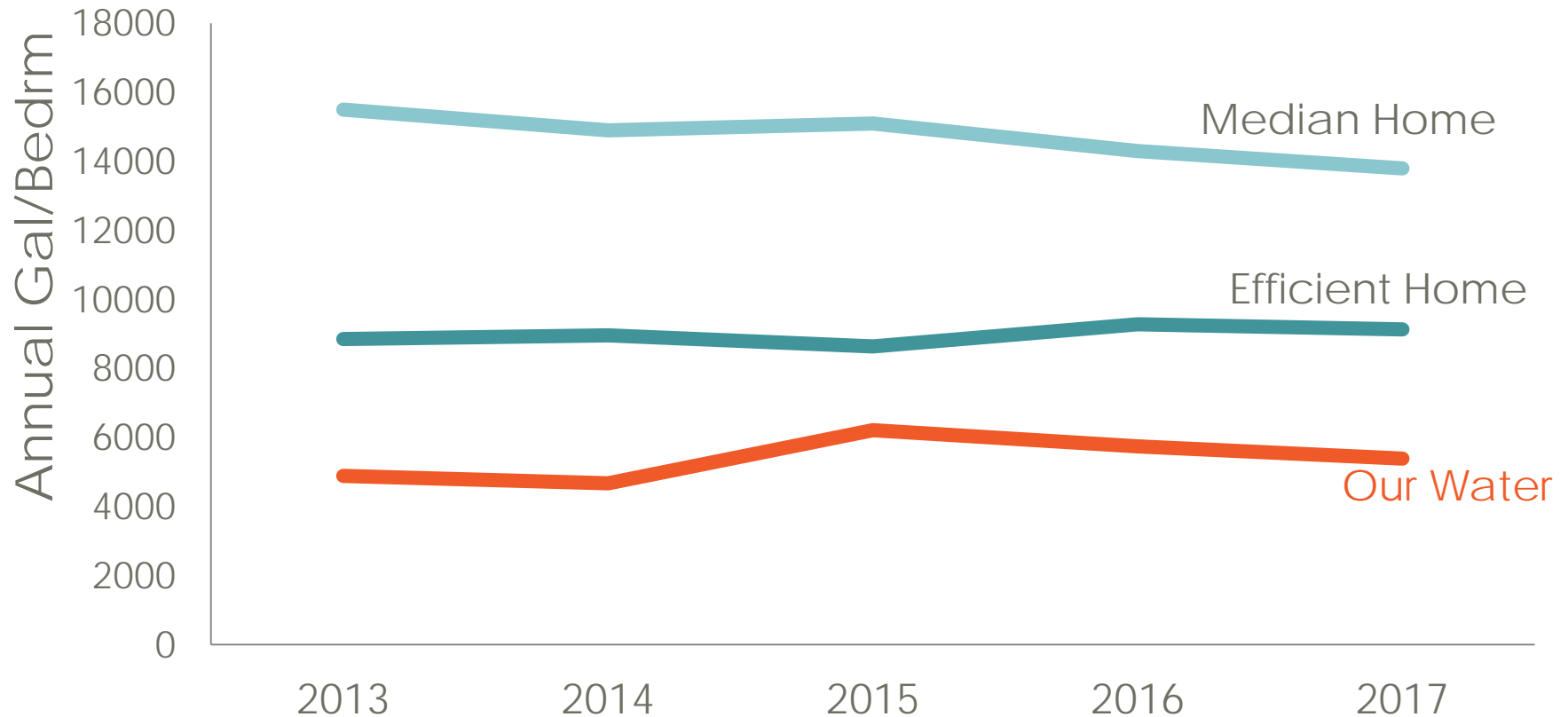
- Was \$280 winter high, now \$160
- \$24 summer months
- \$98 average month over 5 years





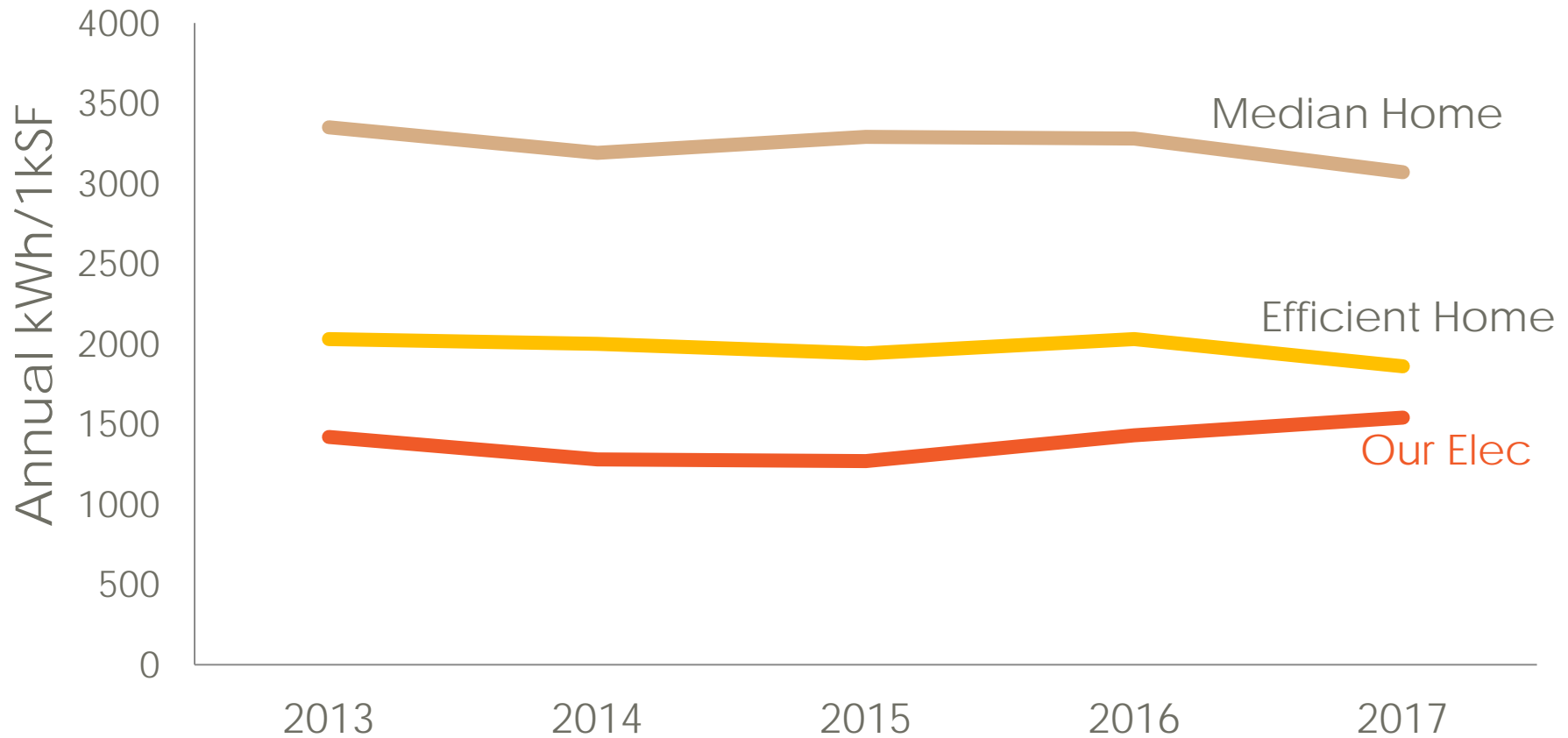
# Water Use: 40% better than “Efficient”

## wegowise Annual Water Use



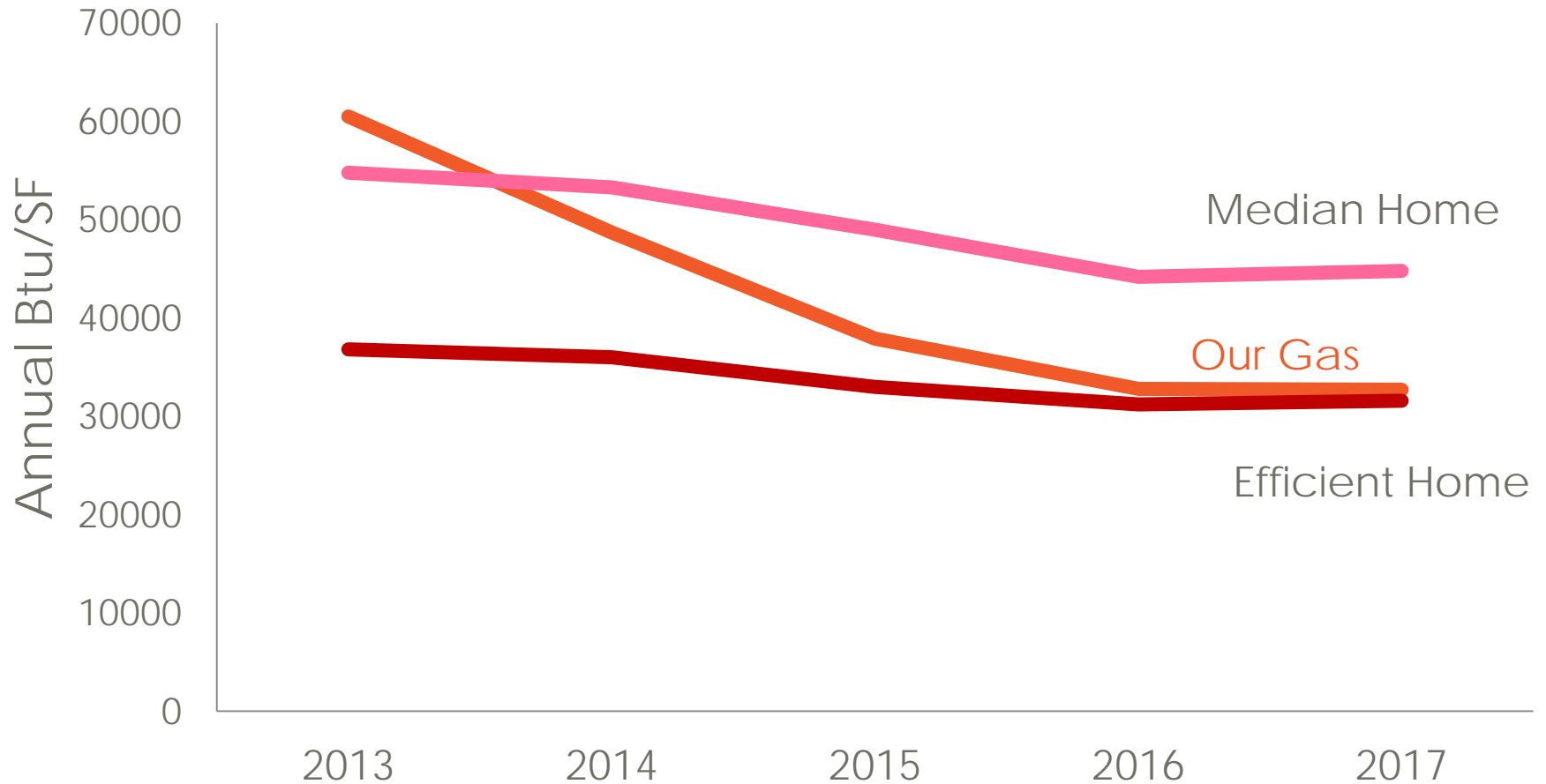
# Electric Use: 20% better than “Efficient”

## wegowise Annual Electric Use



# Gas Use: 2% worse than "Efficient"

## wegowise Annual Gas Use

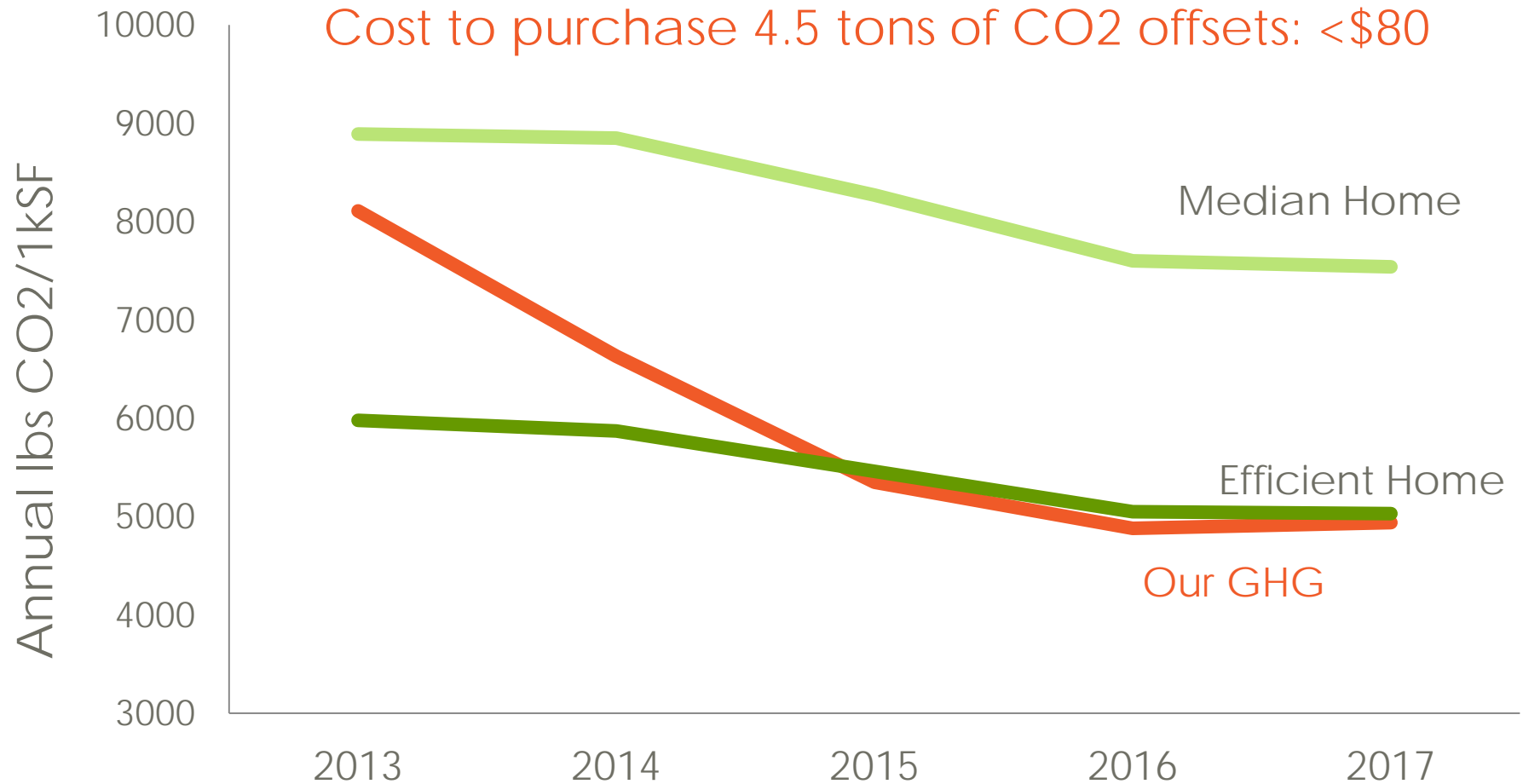




# Greenhouse Gas: 2% better than Efficient

wegowise Annual Greenhouse Gas

Cost to purchase 4.5 tons of CO<sub>2</sub> offsets: <\$80





Takeaways



# LEED Favors Rehabs

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V4 recognizes the total environmental benefits of a rehab, even with modest energy savings.





# New health impact data should be changing the way you design and build

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- Double fresh air for better cognitive function #THECOGFXSTUDY
- Avoid new chemicals of concern (e.g. phthalates)
- Stronger filtration (4" MERV 13)
- Dehumidification
- Circadian lighting (for better sleep)
- Design for active occupants
- Radon no more than 1-2 pCi/L
- **FIX KITCHEN EXHAUST!** Quieter, wider, deeper, lower, & with makeup

# To be replicable, be affordable

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We met our goal to stay within the 'market price' of our home (free labor helps).

Recently appraised at \$460,000.

Next step: rent this home out, do it again!



Our mothers planting

There is no silver bullet, but there are thoughtful decisions

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Look for the option that meets the largest quantity of your objectives. Use multi-attribute analysis.





# To live is to learn!

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The actual comfort and costs experienced do not always match our predictions.

Adjustments are an essential part of achieving a high performance home!

Expect 'retroCx' in your process, especially for heating, cooling, and ventilation!



# Takeaway Quiz

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- The LEED categories most favorable to rehabs are...
- TRUE or FALSE: Kitchen exhaust is usually done well
- REM/Rate probably overestimates the amount of (a) electricity, or (b) gas used by a modern single family home
- Everyone should consider tracking their utilities with online...



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Thank you!  
Any questions?



Maureen Mahle  
Director, Sustainable Housing Services  
[mmahle@swinter.com](mailto:mmahle@swinter.com)