BALANCING ENERGY, VENTILATION, AND IAQ
Case Study of a LEED Home Rehab
Maureen McGeary Mahle
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

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

- **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

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

• 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 ACH₅₀
5-yr-old 80 AFUE oil boiler; separate atmospherically vented gas water heater; Oil tanks; Beam popping up flooring above 15-25 year old appliances; 83 AFUE oil boiler; Atmospheric gas water heater; HERS 173; 25.6 ACH50; Oil tanks; Fireplace; ENERGYGUIDE
2012-2013: Interior, attic, basement

- Replace boiler with condensing gas tankless + indirect tank
- Kitchen gut
- Full bath gut
- Add half bath
- Interior air sealing (HES)
- Spray foam attic @ sheathing
- Spray foam basement @ ceiling

HERS 143
25.6 ACH

HERS 128
18.5 ACH

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                                               After                         During
Roughing it Tile experiment

Before                                               After                         During
2014: Exterior envelope

- 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
Insulation day!
Intumescent paint on closed cell in attic
Crawl space, basement ceilings foamed
Condensing gas boiler
95 AFUE
HERS 111 to 62
9.7 ACH50 to 5.6
Summers 2015, 2017: Landscaping

- 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
Insulation day!

Crawl space, basement ceilings foamed

Condensing gas boiler 95 AFUE

Before...                                 ... during...                           ... and after!
Before...                … and after!

LEED Estimated Total Water Reduction: 68%
2016-2018: Ventilation and IAQ

- Installed wood fireplace insert & lined chimney

**ISSUE!** -11 Pa 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 58** 3.1 ACH

**HERS 59** 3.1 ACH
“The Fiscal Cliff” Cost Data

- Total Renovation $175,888
- Green Upgrades $20,666
- Yard $21,214
- Exterior $81,117
- Kitchen $35,237
- Interior $18,049
- Baths $17,730
- Garage $7,541
- Purchase Price $235,000

Total Investment $410,888

5% Total Project Purchase Price $235,000

$750 boiler rebate
$2,300 window + insulation rebates
$2,300 window + insulation rebates
LEED-H
Occupied Rehab
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Easiest Rehab Credits in LEED-H v4

#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

#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

#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 trim, doors, decking, etc.
+1+ Innovation – Exemplary Performance

Materials & Resources Category
Easiest Rehab Credits in LEED-H v4

#4 Low-Emitting Products: Composite Wood

- 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

#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

#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
Suggestion: sign up for free benchmarking today!
IAQ Challenges
Toughest IAQ Challenges for Rehabs

#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

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

- Fireplaces must have doors (OK)
- If fireplace/stove doesn’t have closed combustion or power venting, must be <-5Pa 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

#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 45 cfm 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

#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

#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 re-homed, 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 kitchen + 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 ACH H50

HERS drops from 173 to 59
ACH H50 drops from 25.6 to 3.1
Gas Use: now close to 600 Therms/yr
Electric Use: Predicted exceeds Actual

REM/Rate prediction exceeds Actual Electric Use by 2000 kWh/yr
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

- Median Home
- Efficient Home
- Our Water

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<tr>
<td>2017</td>
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Electric Use: 20% better than “Efficient”

**wegowise Annual Electric Use**

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<th>Year</th>
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<th>Efficient Home</th>
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<tr>
<td>2017</td>
<td>2800</td>
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Gas Use: 2% worse than "Efficient"
Greenhouse Gas: 2% better than Efficient

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wegowise Annual Greenhouse Gas

Cost to purchase 4.5 tons of CO2 offsets: <$80
LEED Favors Rehabs

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

- 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

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!
There is no silver bullet, but there are thoughtful decisions

Look for the option that meets the largest quantity of your objectives. Use multi-attribute analysis.
To live is to learn!

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

• 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…
Thank you!
Any questions?

Maureen Mahle
Director, Sustainable Housing Services
mmahle@swinter.com