# Evaluating Residential Retrofits
# PhiusCon 2021

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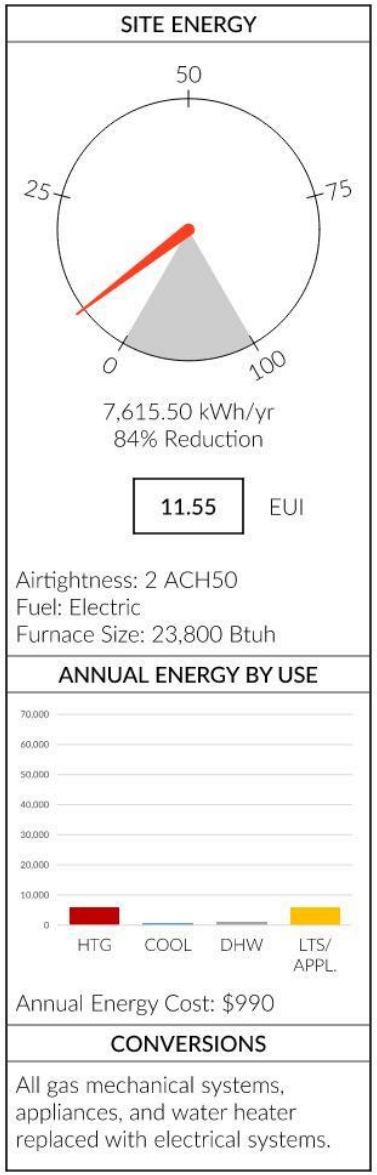


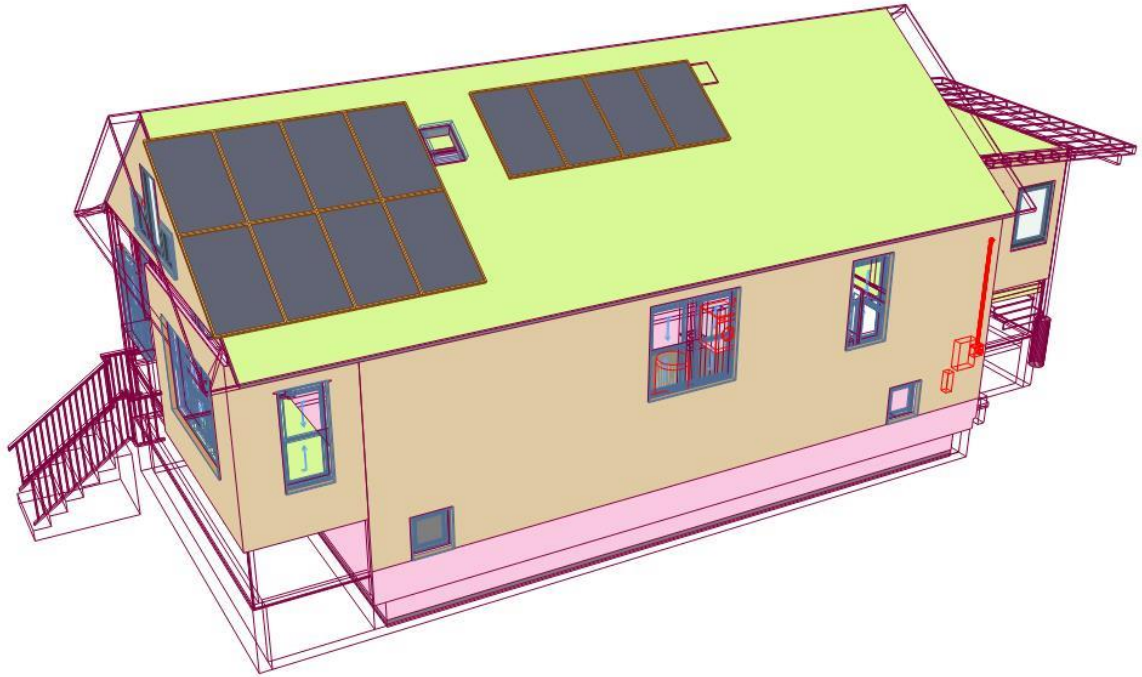

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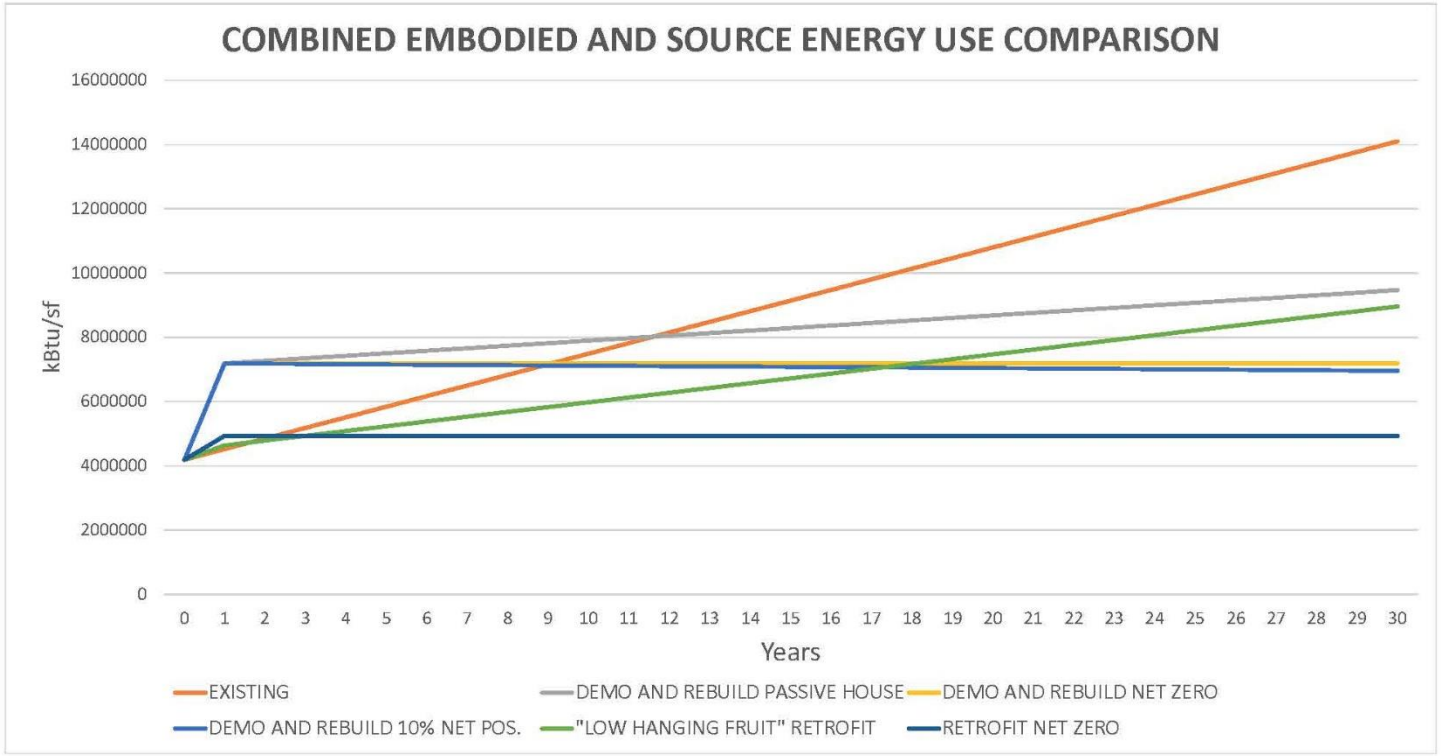
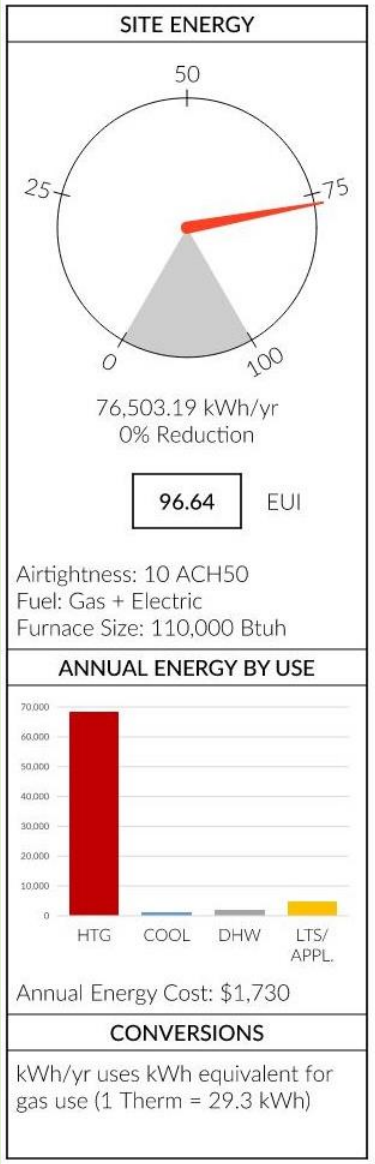
# Retrofits vs New Construction: Embodied Carbon is important

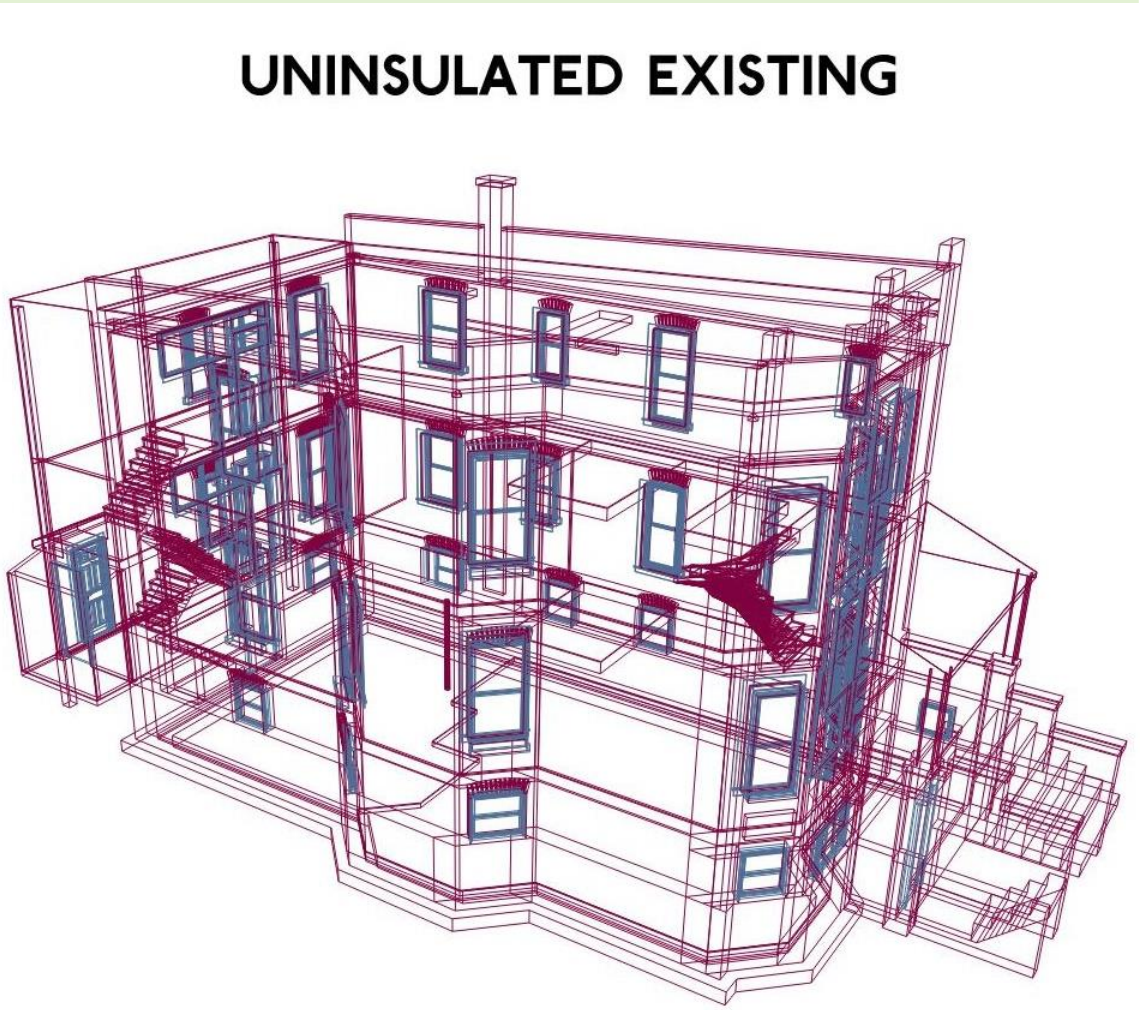
Good retrofits, especially in cold climates, are the answer for carbon reduction, short- and long-term.



# Typical Chicago 2-flat

- Uninsulated
- Leaky
- Inefficient fossil fuel HVAC and appliances
- Most of the energy that arrives here…is wasted.

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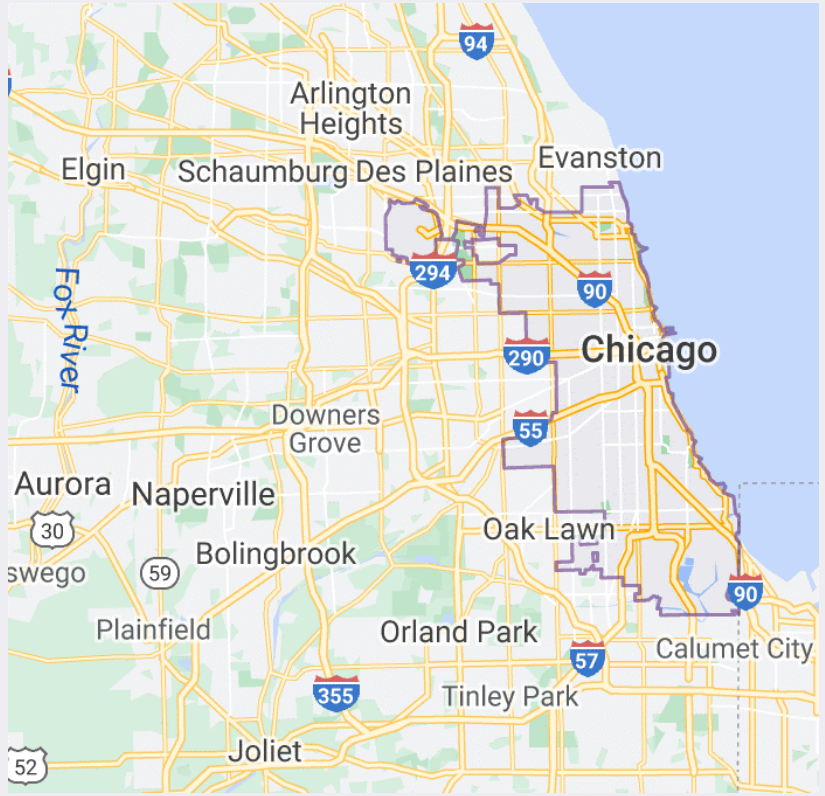
# The scale of the problem-- sobering or exciting numbers:




2010 Chicago residential data:

Total kWh: 4.2B kWh

Total Therms: 695M

Total kWh equivalent: 24.5B

kWh per person: 9,074 kWh

PHIUS Source energy-inspired* target: 3,400 kWh/person

That's a 63% energy reduction per person, as we move to electric cars (shifting auto energy from gas stations to residences).

# Sobering or exciting numbers, cont'd:

Paris Accord: 80% emissions reduction by 2050; zero by 2100

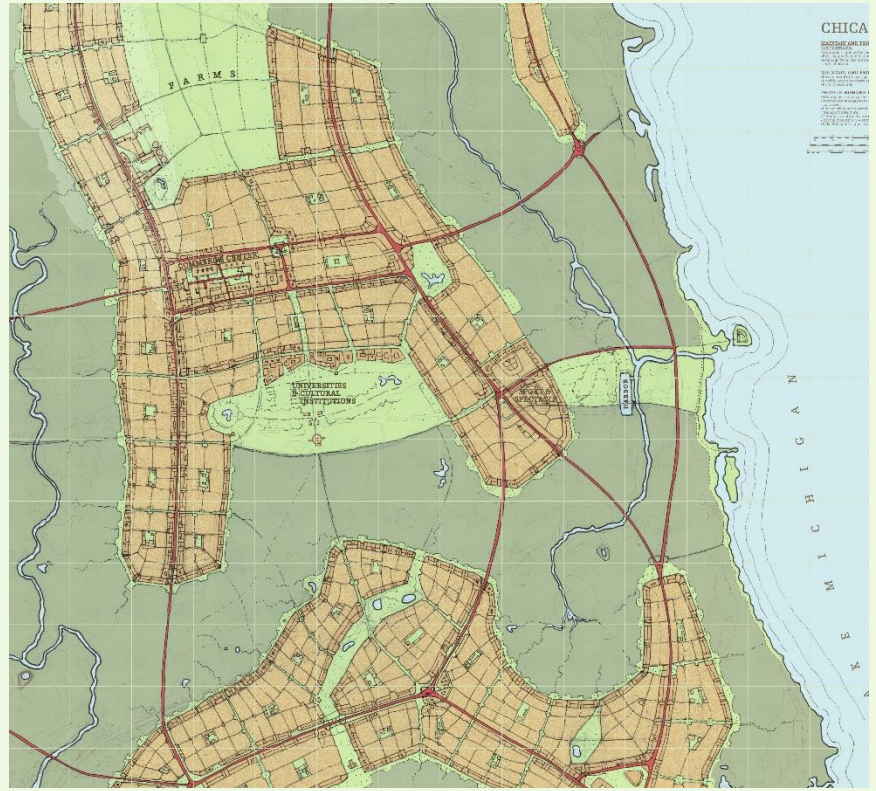
2030 Challenge: zero carbon buildings by 2030 (no fossil fuel GHG emissions to operate); CFC: zero by 2050

CMAP: 3.37M housing units in Chicago Metro

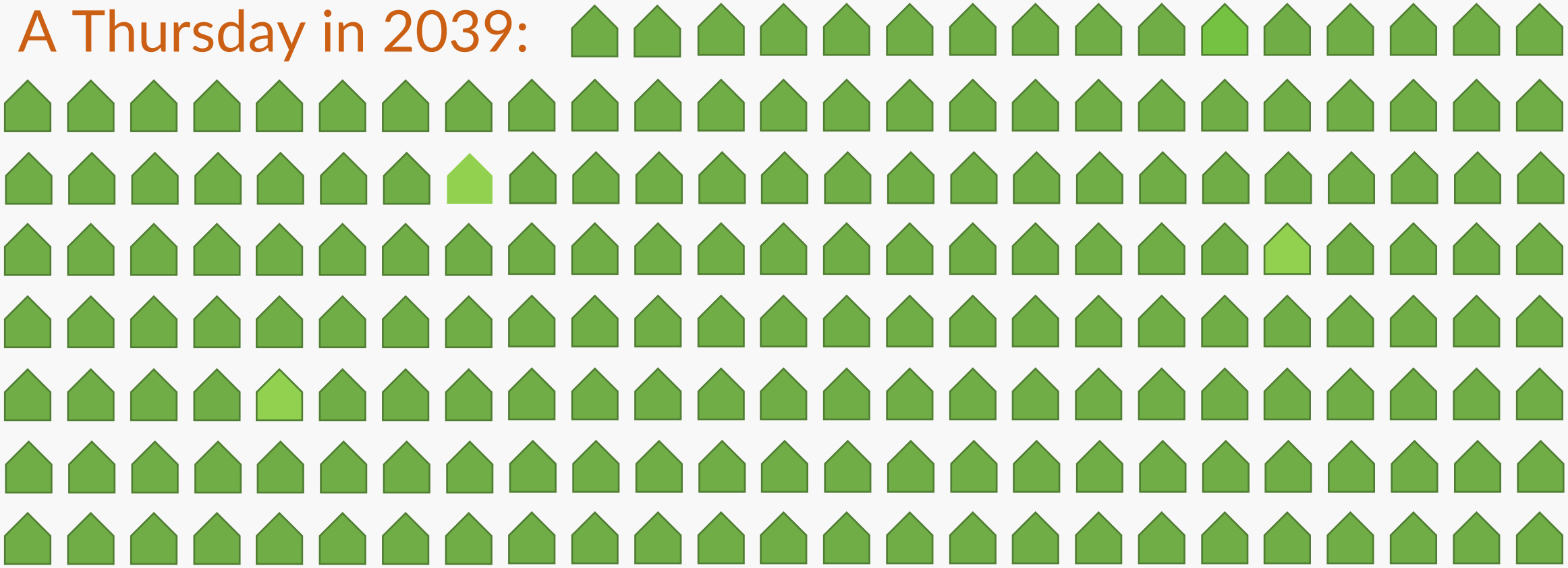
If 1.37M are replaced and we "only" retrofit 2M…well, that's

- 222,000 housing units a year; or
- **609 per day**, or about
- 25 per minute for the next 8.25 years to get to zero carbon by 2030.

**If we give ourselves until 2050, it's "only" 189 per day.**



# A Thursday in 2039:



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# Our Five DER projects
# …and why they don't make Phius+

FLlWright Balch House, 1909

1970's Ranch

Early 1900's Chicago 2-flat

2 clients: NZE request
1 client: just a gut reno
1 client: DIY DER, but no certification
Me: Phius would be nice, Phius Source Energy sufficient

c.2000 Suburban

1919 frame Bungalow

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# Our Five DER projects …and even though they don't make Phius+, all of them:

- Strive for continuous insulation
- Strive for airtightness
- Use heat pumps for space- and water heating, most go all-electric
- Plan for or incorporate solar PV
- Use efficient appliances and lighting

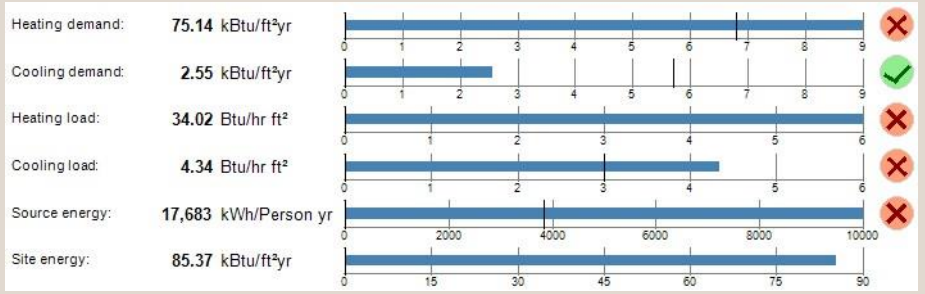
…in other words, employ a Passive approach to the retrofit.

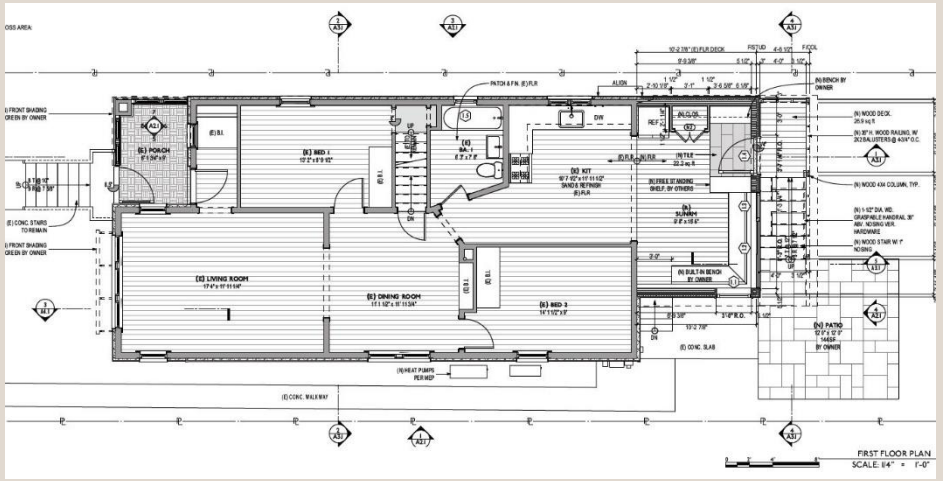
In these project we typically reduced overall energy use by 70-85% from where we found it

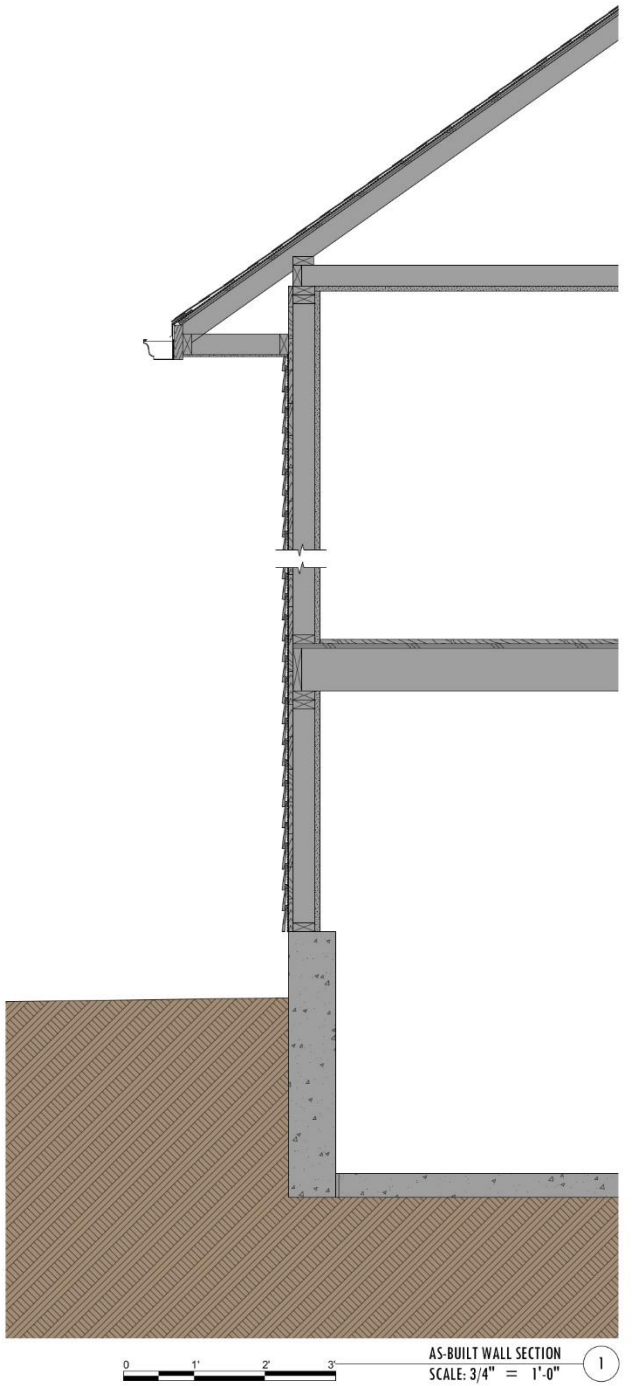

1919 frame Bungalow

# 1919 frame bungalow Before

- Virtually no insulation anywhere
- About 10ACH50
- Old gas furnace and water heater
- Only ventilation is a kitchen hood
- Exterior in disrepair—good candidate for exterior retrofit
- Windows had previously been replaced with double glazed, still in decent shape

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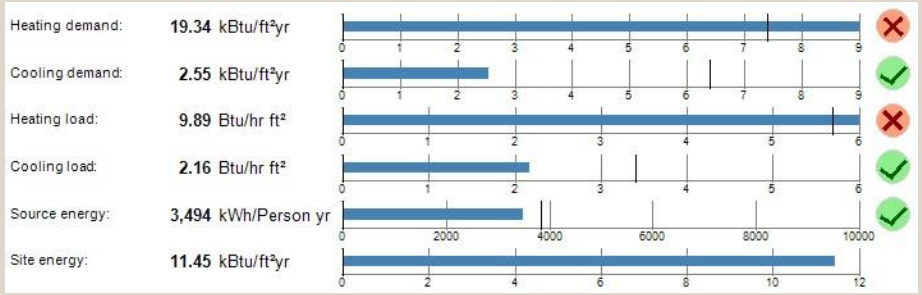
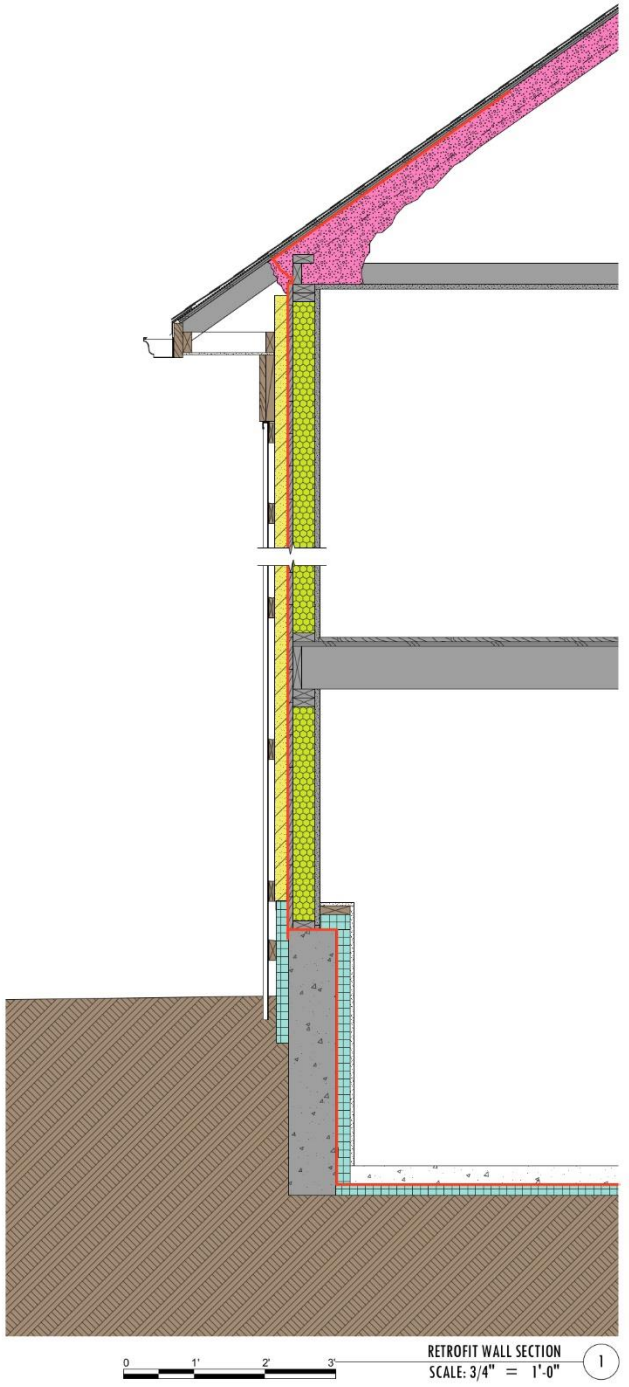
# 1919 frame bungalow After

- Continuous insulation
- About 2ACH50?
- New Heat pump H/AC and DHW
- CERV2 ventilation
- 4kW solar PV




- Achieves Source Energy but nowhere close on heating metrics
- Attic would need to be uninhabitable or roof rebuilt to provide enough insulation
- Can get to Source Zero on roof

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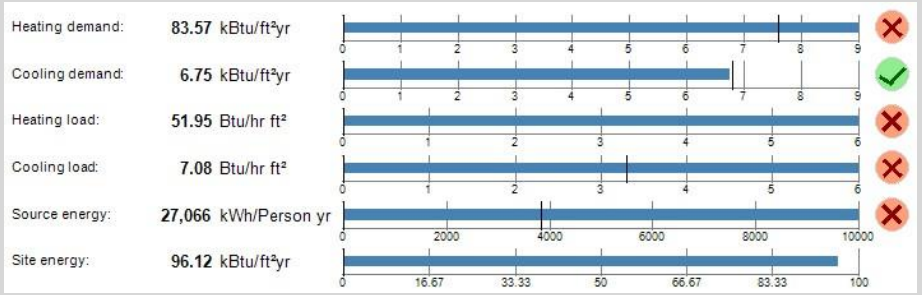
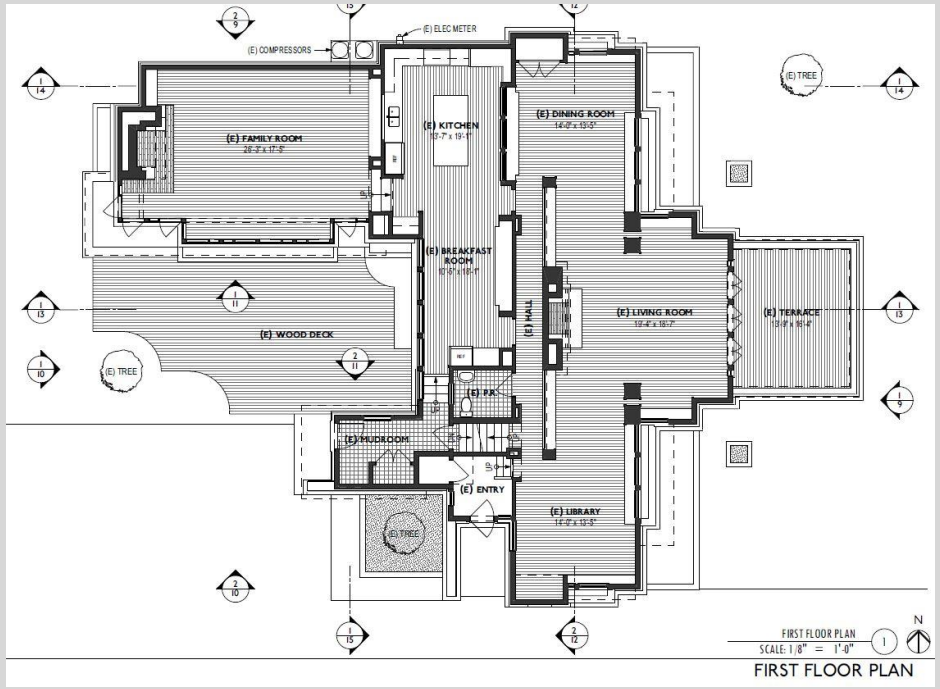
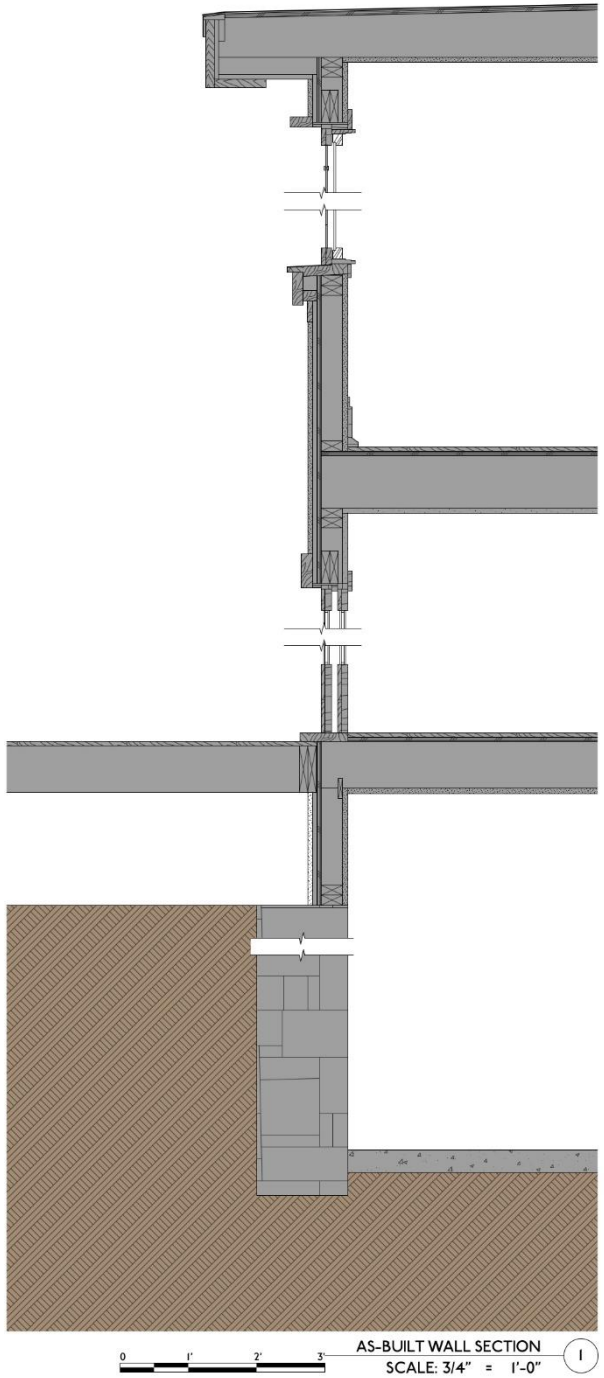
# 1909 FLI Wright Before

- Virtually no insulation
- About 10ACH50
- Gas boiler heat, only maintaining ~50F in -20F weather
- Space-Pak AC in roof joists
- Single glazed windows
- Rubble foundation
- Roof as air exchange mechanism

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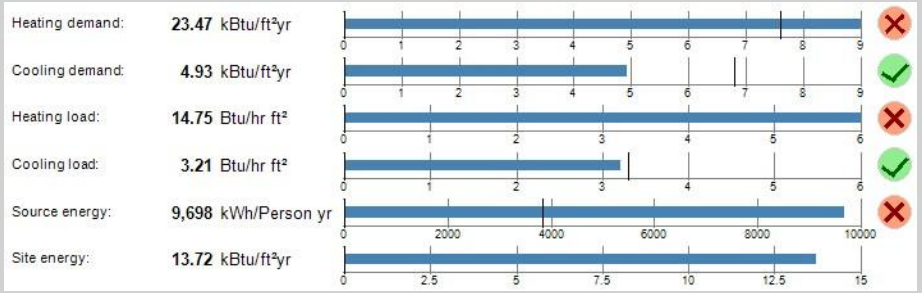
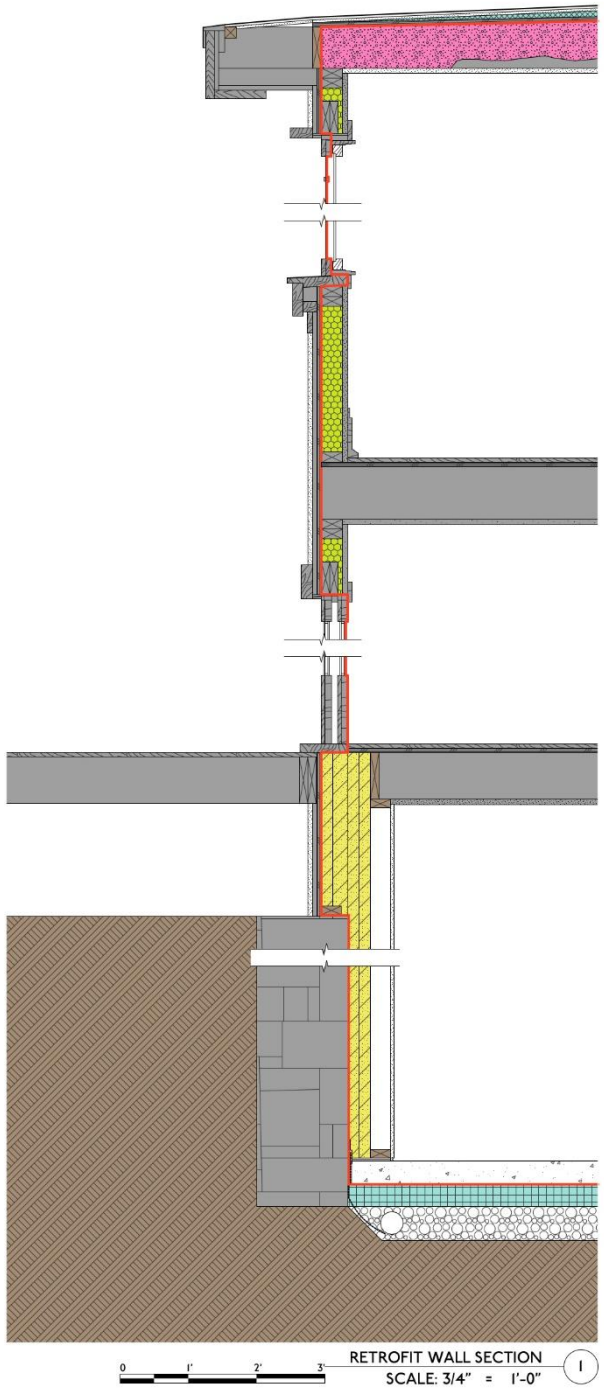
# 1909 FLI Wright After

- Nearly continuous insulation
- About 2ACH50?
- New Ground-Source heat pump H/AC and DHW, with heat to existing radiators and ducts
- New ERV
- Interior storm windows to preserve existing historic windows
- 18kW solar PV designed to achieve Net Zero (on house, garage, not visible from street)




- Achieves Net Zero but nowhere close on heating metrics
- Historic tax credits protect interior and exterior; minimal material removal, limited insulation depths, air barrier discontinuities
- Hella more comfortable
- Can get to Source Zero on roof

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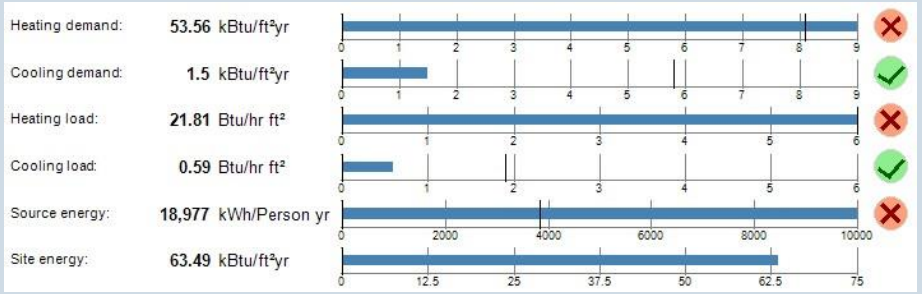
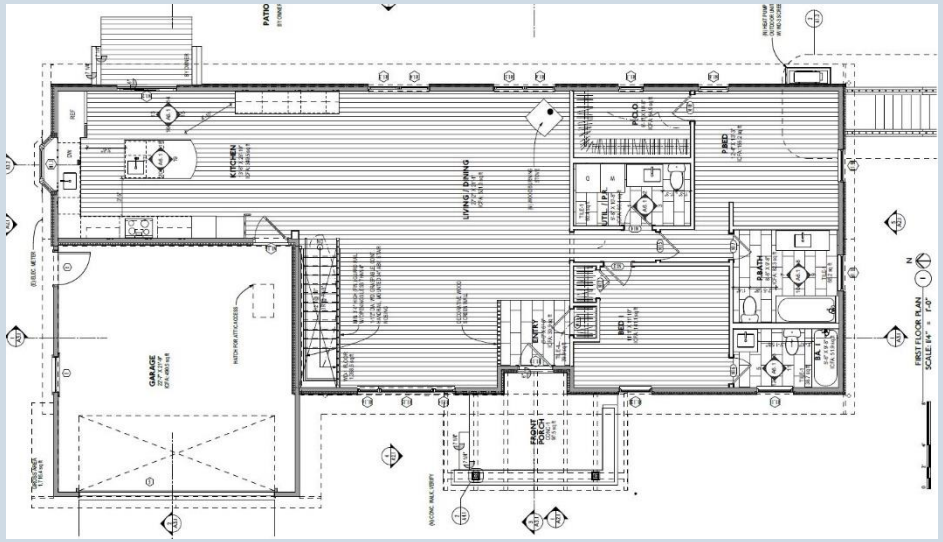
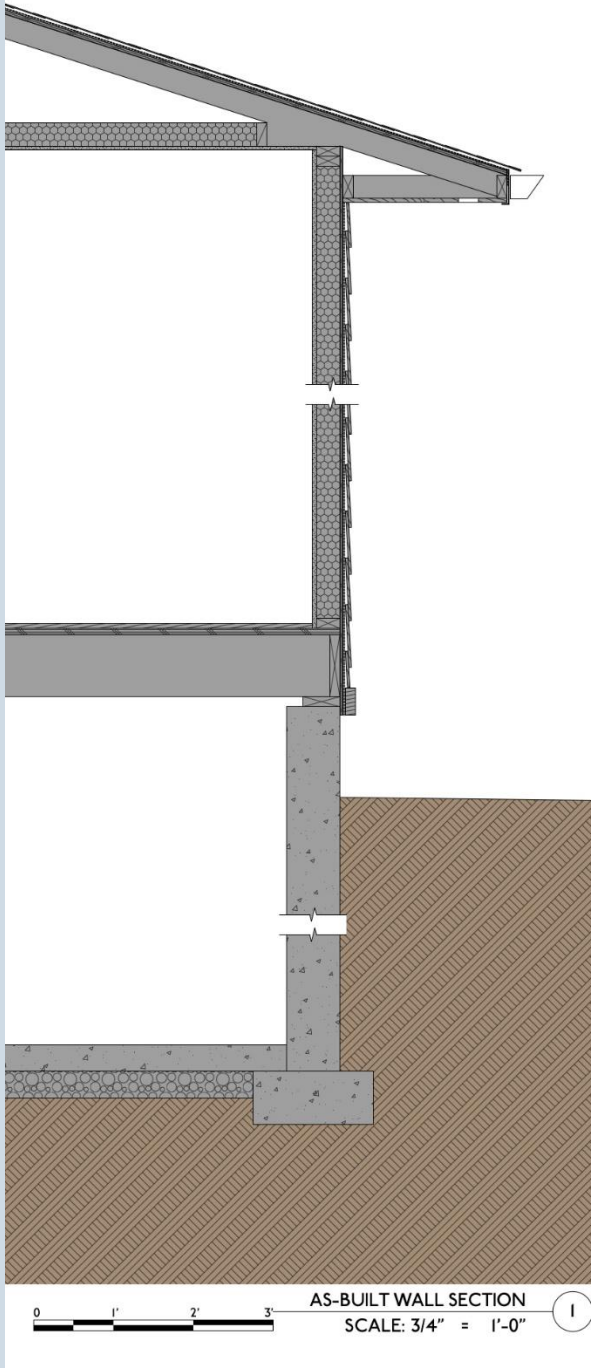
# 1970's Ranch Before

- A little (by PH standards) insulation above grade only
- Old gas furnace and water heater
- Old windows at end of life
- Exhaust-only vent at kitchen and bath



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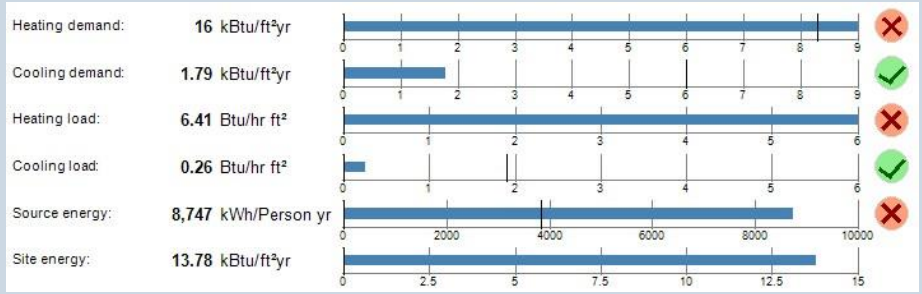
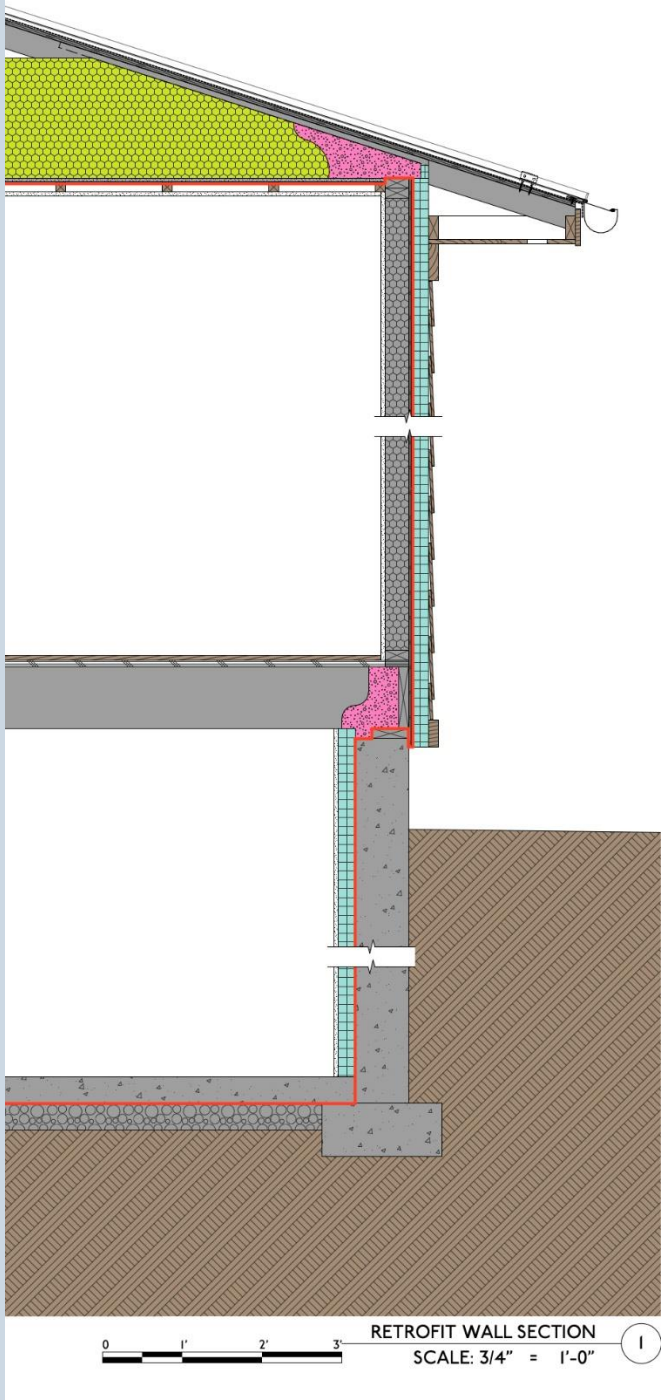
# 1970's Ranch After

- Continuous insulation EXCEPT for slab, which is in good shape and has assumed cap break below
- Foundation wall insulation
- Continuous exterior insulation
- Airtight membrane (Intello) on underside of existing gyp, with new 2x2 furring
- Cellulose attic, vented, with ccspf at eaves
- New Alpen triple-glazed windows
- ASHP space and water heating
- New ERV




- Well below Phius Source Energy with 7kW PV array
- All-electric
- Can get to Source Zero using garage roof
- Couldn't really justify tearing out slab or reducing head height ~7" in basement

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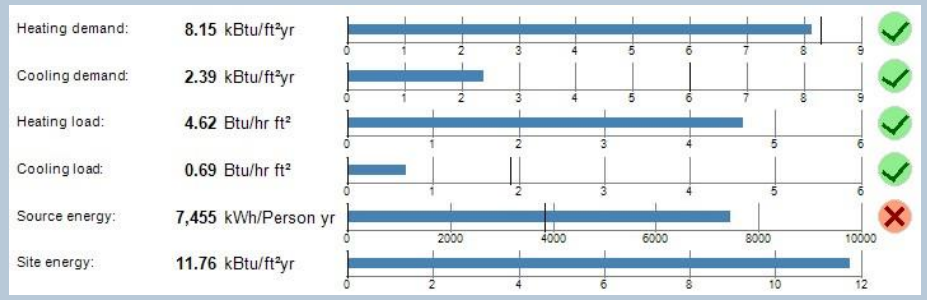
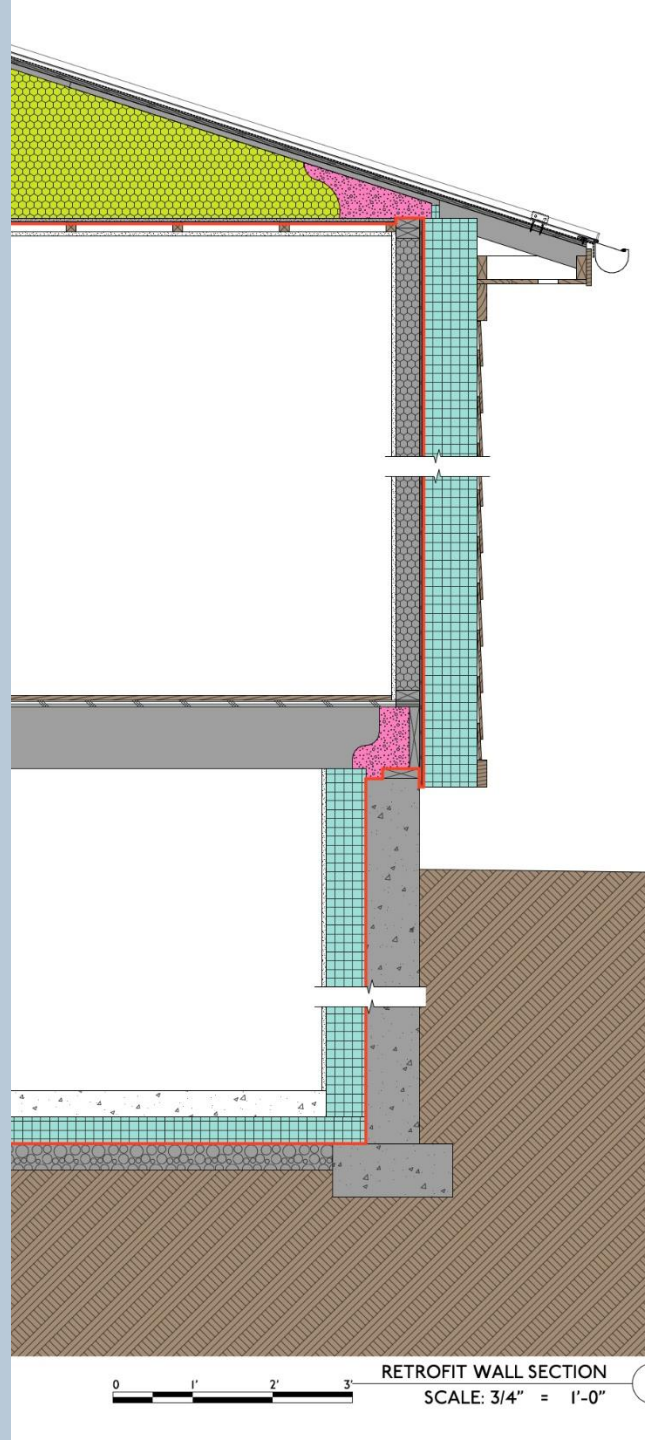
# 1970's Ranch
# If Phius

- 2kW solar PV difference between this and our retrofit, which is ~$7,000 in solar installed cost. The slab work alone would cost at least that much.
- The **shape** and **orientation** of this house just isn't conducive to PH space conditioning metrics.

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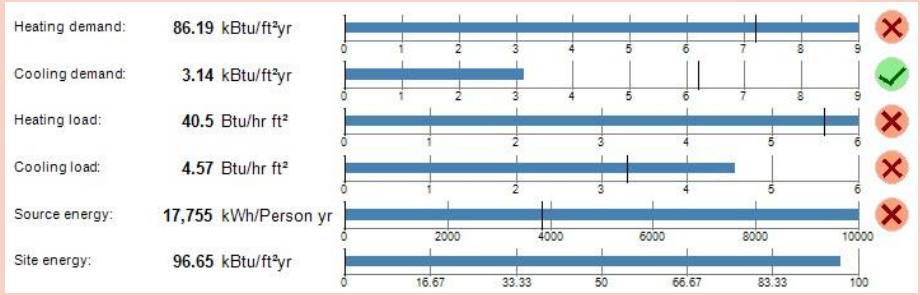
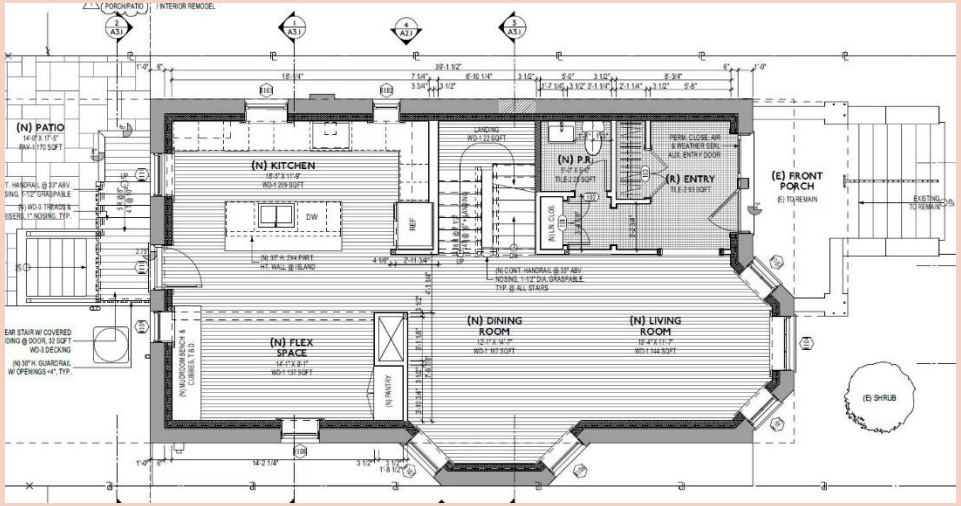
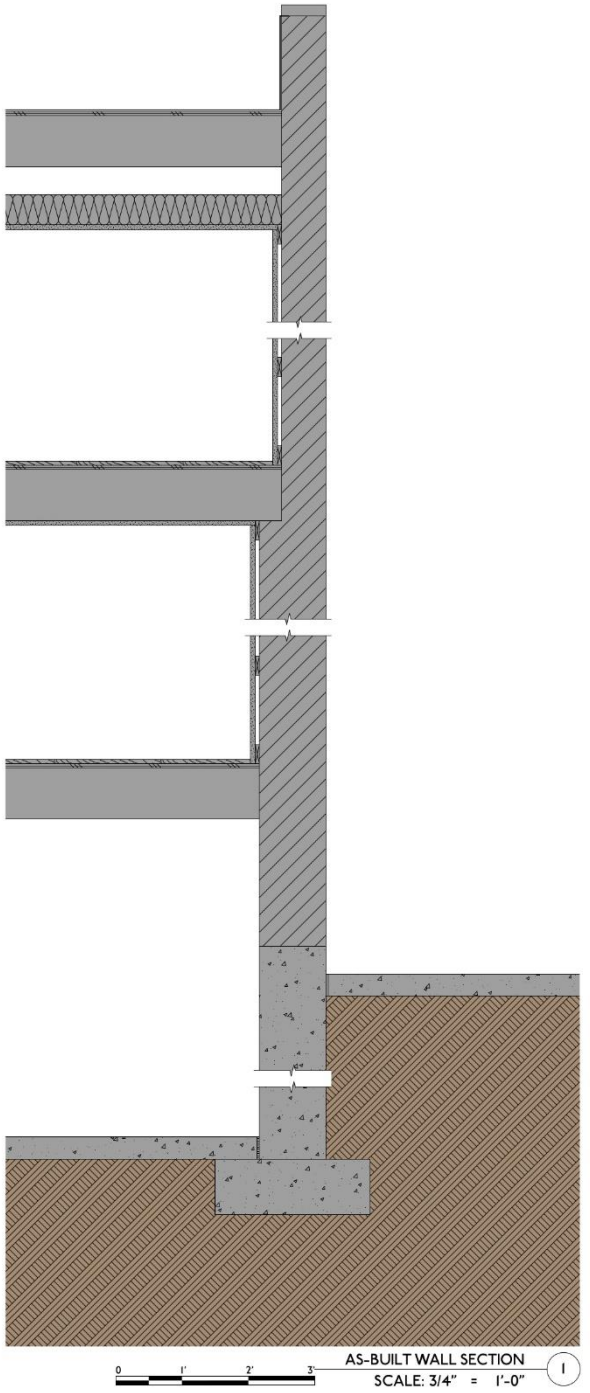
# Early 20th c. 2-flat Before

- Minimal insulation in attic, poorly installed
- Old gas boiler and water heater
- Old windows at end of life
- Exhaust-only vent at kitchen and bath

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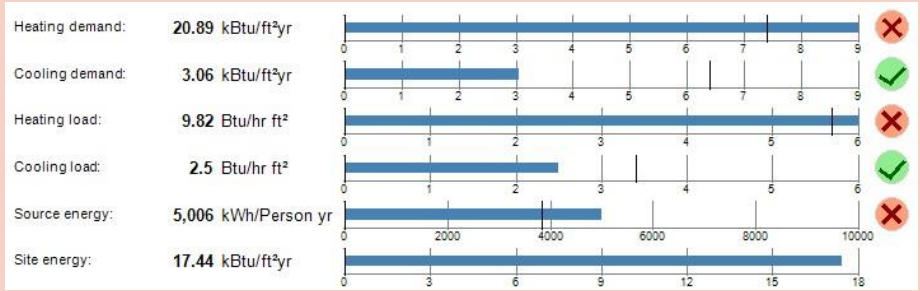
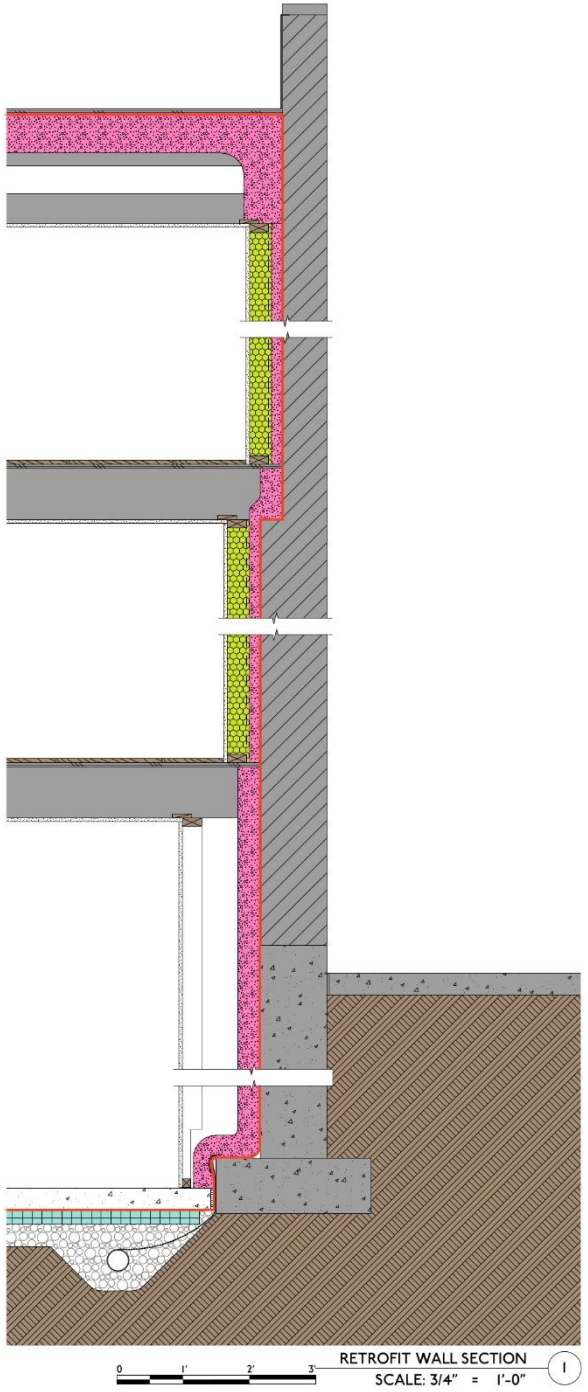
# Early 20th c. 2-flat After

- CCSPF to interior of brick and roof
- New ASHP space and water heating
- New windows, only double-glazed
- New ERV
- Easily achieve Source Energy limit with a modest PV array

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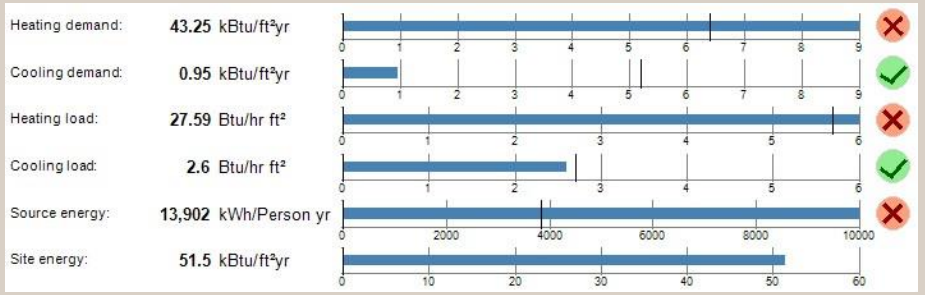
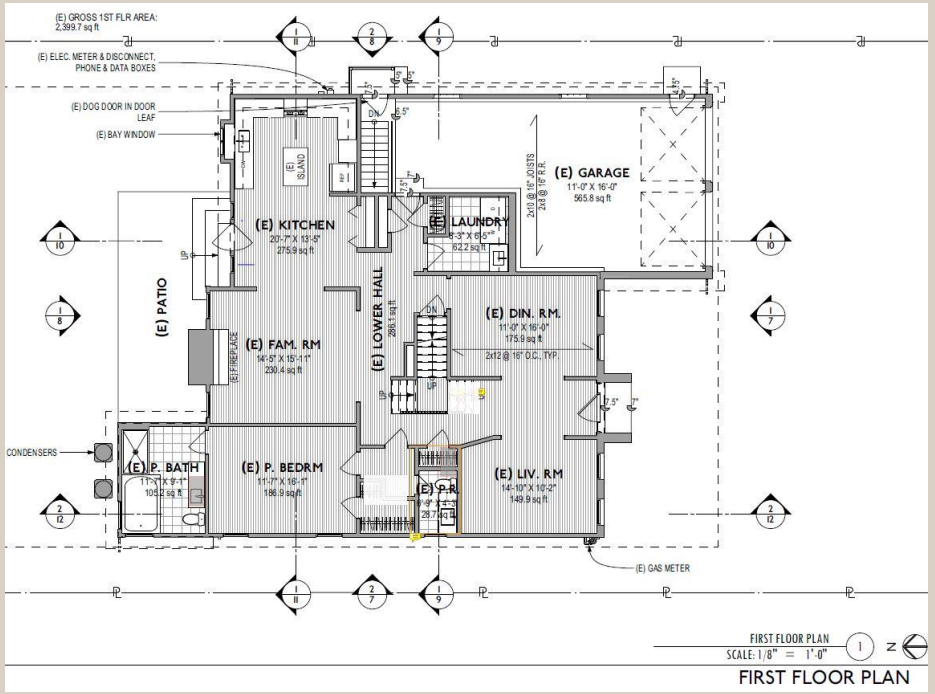
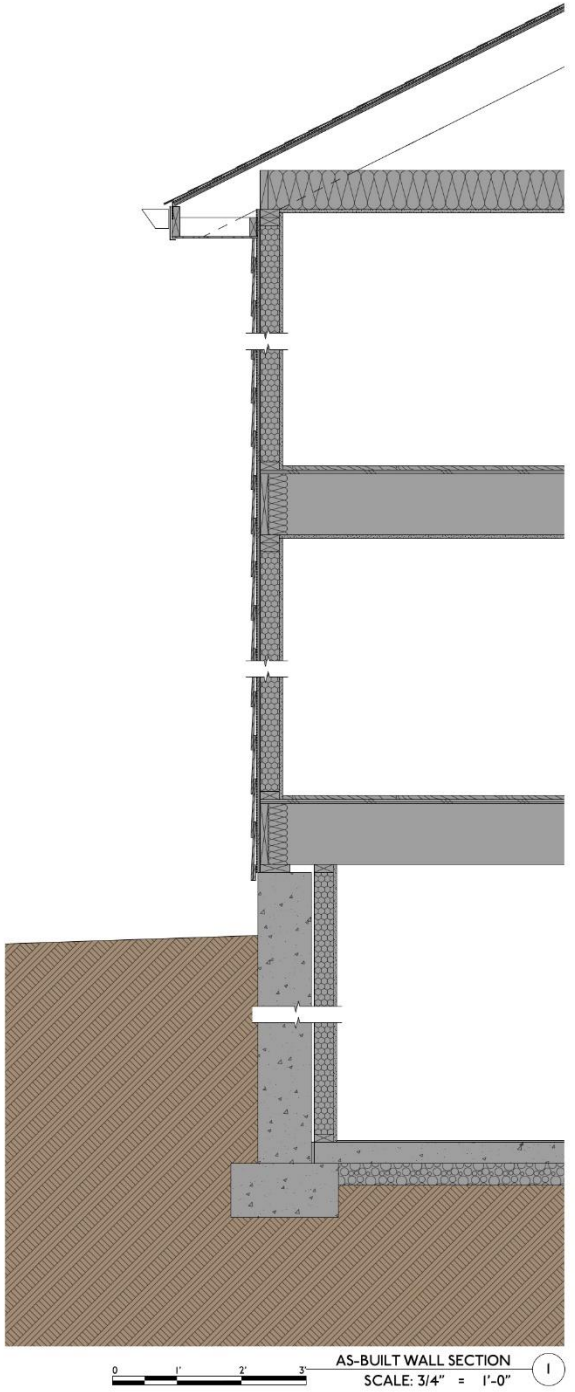
# c. 2000 suburban Before

- Code-minimum insulation
- 5.3ACH50
- 21 year old gas furnace and water heater
- 21 year old windows
- Siding needing replacement (woodpeckers)
- Exhaust-only vent at kitchen and bath

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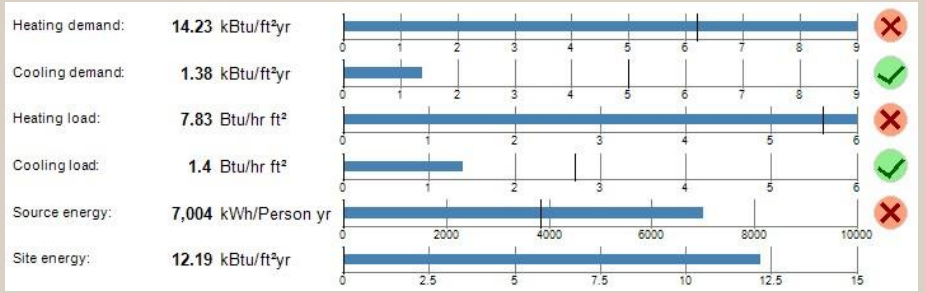
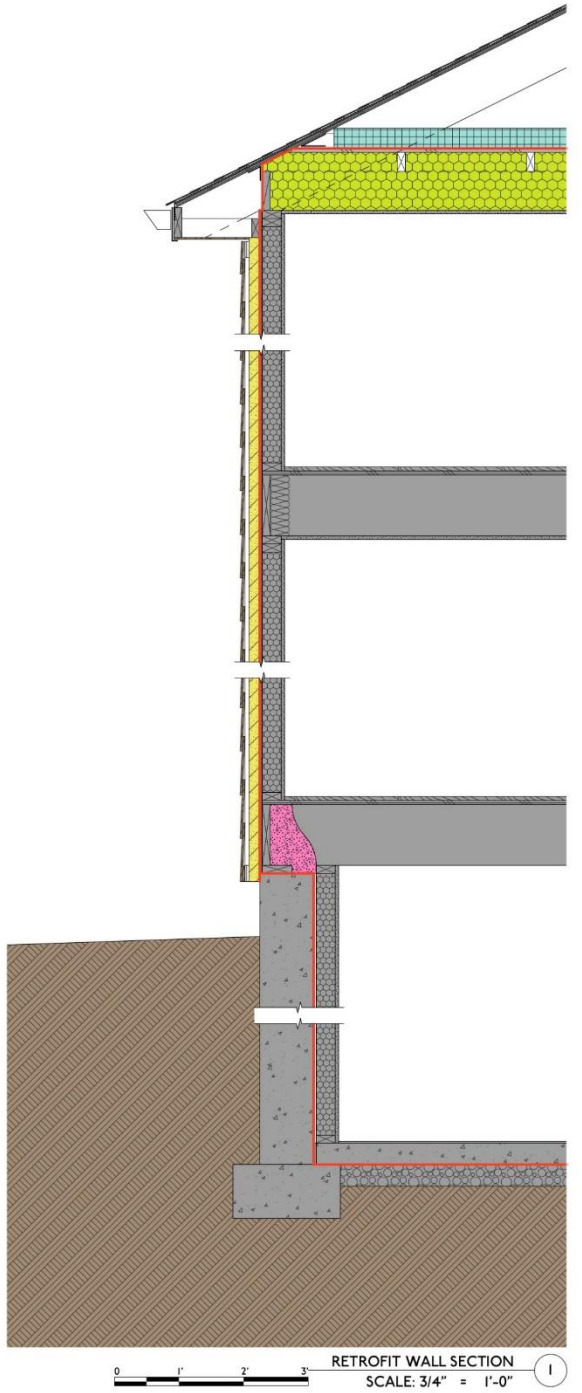
# Early 20th c. 2-flat After

- New exterior wood fiberboard (diffusion open) over air barrier
- New ASHP space conditioning and water heater
- New triple-glazed windows
- New ERV




- Owner's goal: Net Zero. Achievable through this retrofit and filling the roof with PV
- Couldn't really justify tearing out slab or reducing head height ~7" in basement
- Similarly hard to justify tearing out finished basement walls to replace R-13 foundation wall insulation

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# Themes:

- These clients aren't motivated by financial payback. They're on a mission.
- Life cycle of equipment and surfaces informs the plan.
- Therefore phasing can often make sense (there's the rub…).
- Single layer continuous is easy, multiple layers is harder.
- Strive for airtightness, install ERV
- If we're aligning with NZE, it's easier and cheaper to get there by only going partway toward Phius space conditioning metrics.

| | ICFA sqft | PROJECT ROOF TILT | PROJECT ROOF ORIENTAT'n | (1) 330W PANEL OUTPUT kWh/yr | EXISTING kWh/yr | RETROFIT kWh/yr | TOT. ENERGY REDUCTION | PHIUS+ 2018 RETROFIT | EXISTING PANELS REQUIRED | RETROFIT PANELS REQUIRED | PHIUS PANELS REQUIRED |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1042 HIGHLAND | 2,250.0 | 35.31 | 180 | 440 | 56,239.91 | 12,282.82 | 78% | - | 128 | 28 | - |
| HAWK | 2,700.8 | 2.39 | 270 | 371 | 76,503.19 | 13,805.33 | 82% | - | 207 | 38 | - |
| LOTTI | 5,304.9 | 2.39 | 180 | 380 | 149,437.66 | 21,336.13 | 86% | - | 394 | 57 | - |
| HUCKER | 3,101.5 | 18.43 | 90 | 354 | 57,712.73 | 13,163.20 | 77% | 10,685.52 | 164 | 38 | 31 |
| JAVERIA | 4,214.7 | 26.57 | 270/90 | 353 | 63,607.57 | 15,057.61 | 76% | - | 181 | 43 | - |

# Summary Thoughts and Questions:

- Should Phius adapt its retrofit standard to make more room for these kinds of projects?
- What would the advantages be?
  - For homeowners, 3rd party review of retrofit plan
  - Access to incentive funding?
  - For designers and builders, a rigorous certification
- What would prerequisites be?
  - Airtightness
  - Case-by case insulation plan?
  - Efficiency of mechanicals
  - Embodied carbon limit?
- Could phasing be accommodated?