

Net Zero Energy Homes

High Performance Building Design

Do it Smart, Do it Right



Green Needham

Net Zero Energy Homes and the Real Estate Market

Craig Foley

LAER Realty Partners

Chief Sustainability Officer

craig.rhg@gmail.com



- Craig Foley is a leading national voice on sustainability in the real estate industry. Craig's combination of real estate and energy management skills give him a unique perspective about sustainable energy solutions and subject matter expertise on greening the MLS, high-performance home valuation and marketing, and the impact of climate change on the real estate industry. He is a LEED Green Associate and the chief sustainability officer for LAER Realty Partners. As a real estate broker, he has sold several high-performance projects in and around Greater Boston. He is also the team co-founder of REthink39 Group. REthink39 is devoted to lowering the 39% of U.S. energy consumption attributed to the built environment and believes they can be part of a solution with every transaction closed.

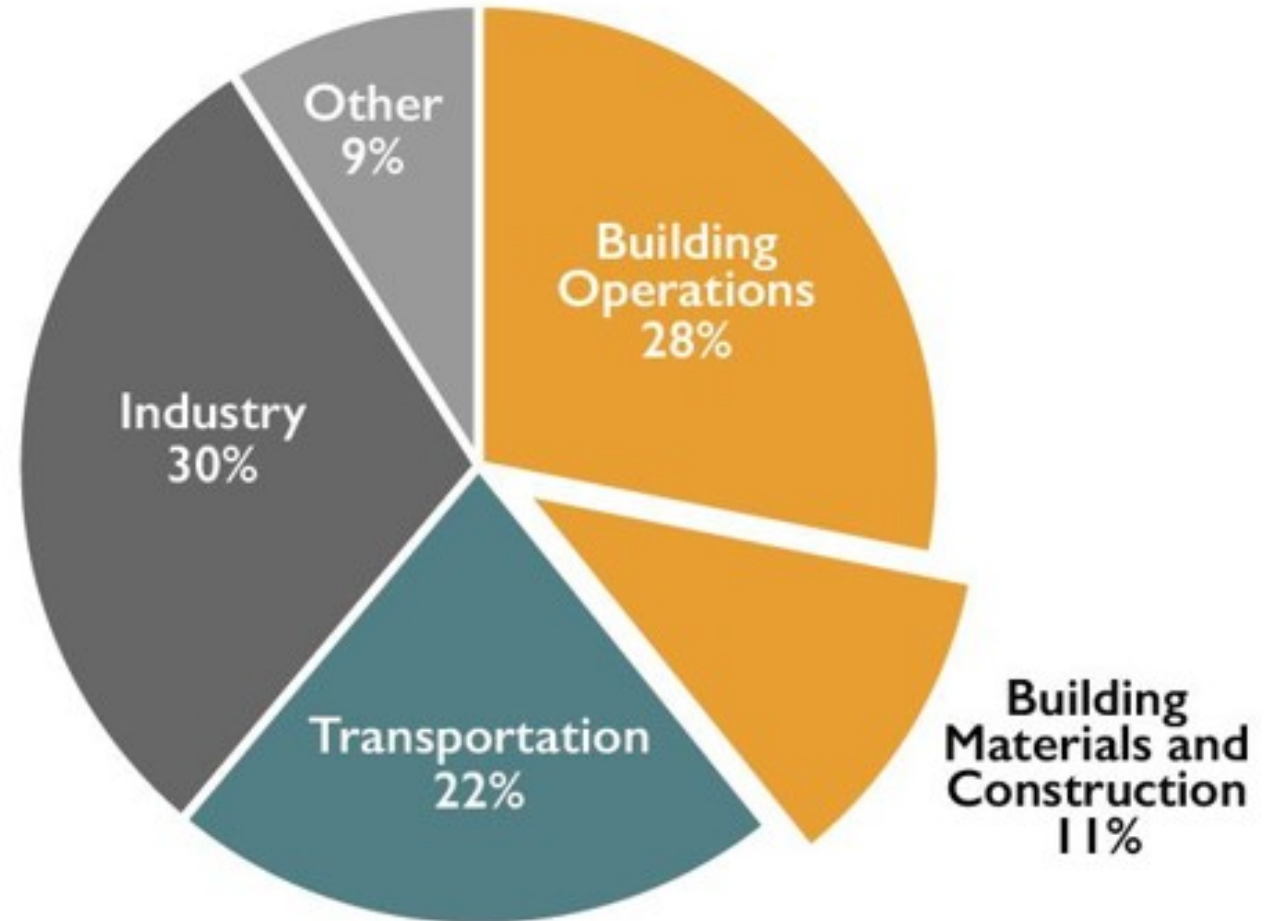


The Two Sides of the Utility Meter



The built environment and GHG emissions

Global CO₂ Emissions by Sector



Source: © 2018 2030, Inc. / Architecture 2030. All Rights Reserved. Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

H3750	An Act authorizing the town of Arlington to adopt and enforce local regulations restricting the use of fossil fuels in certain construction	Rep. Sean Garballey
H3893	An Act authorizing the town of Lexington to adopt and enforce local regulations restricting new fossil fuel infrastructure in certain construction	Rep. Michelle L. Ciccolo
H4117	An Act authorizing the town of Concord to adopt and enforce local regulations restricting new fossil fuel infrastructure in certain construction	Rep. Tami L. Gouveia
H602	An Act to promote energy and economic resilience through clean energy education and job pathway programs	Rep. Thomas A. Golden, Jr.
S1333	An Act to reduce greenhouse gas emissions by permitting local option all-electric buildings and homes ordinances	Sen. James B. Eldridge
S2473	An Act authorizing the town of Brookline to adopt and enforce local regulations restricting new fossil fuel infrastructure in certain construction	Sen. Cynthia Stone Creem
S2515	An Act authorizing the town of Acton to adopt and enforce local regulations restricting new fossil fuel infrastructure in certain construction	Sen. James B. Eldridge

A two-story house with a dark grey roof and white siding. The roof is covered with solar panels. The house has a large sunroom with a wooden frame and large glass windows on the right side. The house is set in a grassy field with trees in the background. The sky is clear and blue.

What is a NZE
home?

What is a NZE home?



1. A home built to high-performance standards (building envelop above code)

What is a NZE home?



- 1. A home built to high-performance standards (building envelope above code)**
- 2. A home that supplies power with renewable energy**

What is a NZE home?



1. A home built to high-performance standards (building envelope above code)
2. A home that supplies power with renewable energy
3. A home that produces as much energy as it uses on an annual basis

Do the
math...

How much \$ did
you spend heating
your home this
last year?
\$_____

Do the
math...

How much \$ did
you spend heating
your home this
last year?
\$ _____

How much \$ did
you spend for
electricity this last
year?
\$ _____

Do the
math...

How much \$ did you spend
heating your home this last
year? \$_____

How much \$ did you spend for
electricity this last year?
\$_____

How much \$ did you spend for
gas for your car this last year
\$_____


Do the
math...

How much \$ did you spend heating your home this last year? \$_____

How much \$ did you spend for electricity this last year? \$_____

How much \$ did you spend for gas for your car this last year \$_____

What does it add up to?
\$_____



What is a NZE home?

- These homeowners spent **\$434 *for the year*** for heating, lighting, hot water, powering all their gadgets and appliances and running one EV

Are these cost savings recognized in the market? You betcha they are, IF



Are these cost savings recognized in the market? You betcha they are, IF



- https://www.buildingenergydigital.com/eneb/0218_full_2018/MobilePagedArticle.action?articleId=1422004#articleId1422004

Are these cost savings recognized in the market? You betcha they are, IF




**Appraisal
Institute®**
*Professionals Providing
Real Estate Solutions*

- <https://ai.appraisalinstitute.org/eweb/Dynamicpage.aspx?webcode=AIPDPSDirectory&key=428cdb90-9814-47e4-9256-a4113c815862>

**Do you have the competency
needed to value green properties?**

Are these cost savings recognized in the market? You betcha they are, IF

 AI Reports® Form 820.03*	Client File #:		Appraisal File #:	
	Residential Green and Energy Efficient Addendum			
	Client:			
	Subject Property:			
	City:		State:	Zip:
Additional resources to aid in the valuation of green properties and the completion of this form can be found at http://www.appraisalinstitute.org/education/green_energy_addendum.aspx				



ENERGY SENSE FINANCE™
EiVALUE® • **PvVALUE®**

<https://www.pvvalue.com/>

It's Time for a War on Climate

Fuel Fights!

SAVE YOUR SHARE

- 1** Keep temperature at 65° F. during day - lower at night.
- 2** Don't heat unused rooms.
- 3** Keep windows closed.
- 4** Draw window shades at night.
- 5** Shut off heat when weather permits.
- 6** Keep heating plant in top condition.
- 7** Use less hot water.

Saving fuel also saves manpower, material, equipment
CONSERVE COAL, OIL, GAS... FOR WAR
Sentinel at www.Yecere.com

Some resources...

The Process of High-Performance Home Valuation, BuildingEnergy Magazine Spring 2018

https://www.buildingenergymagazine-digital.com/eneb/0218_fall_2018/MobilePagedArticle.action?articleId=1422004

Selling the Sun, MA CE class that addresses solar in residential real estate transaction,

<https://ma.keepmecertified.com/selling-the-sun>

Complimentary supporting video for using the PV Value Tool

https://www.youtube.com/watch?v=6FJ1ZDeC_ZM&t=5s

NAR link to letter to request a qualified appraiser, <https://green.realtor/green-resources/guide-appraisals>

Appraisal Institutes Registry of Valuation of Sustainable Buildings appraisers

<https://ai.appraisalinstitute.org/eweb/Dynamicpage.aspx?webcode=AIPDPDirectory&key=428cd b90-9814-47e4-9256-a4113c815862>

LAER Sustainability Report, download at <https://www.laerrealty.com/2021LSR>



ARCHITECTURAL SOLUTIONS

PRESENTED BY: STEPHANIE HOROWITZ

E
N
ARCHITECTURE
R
G
Y

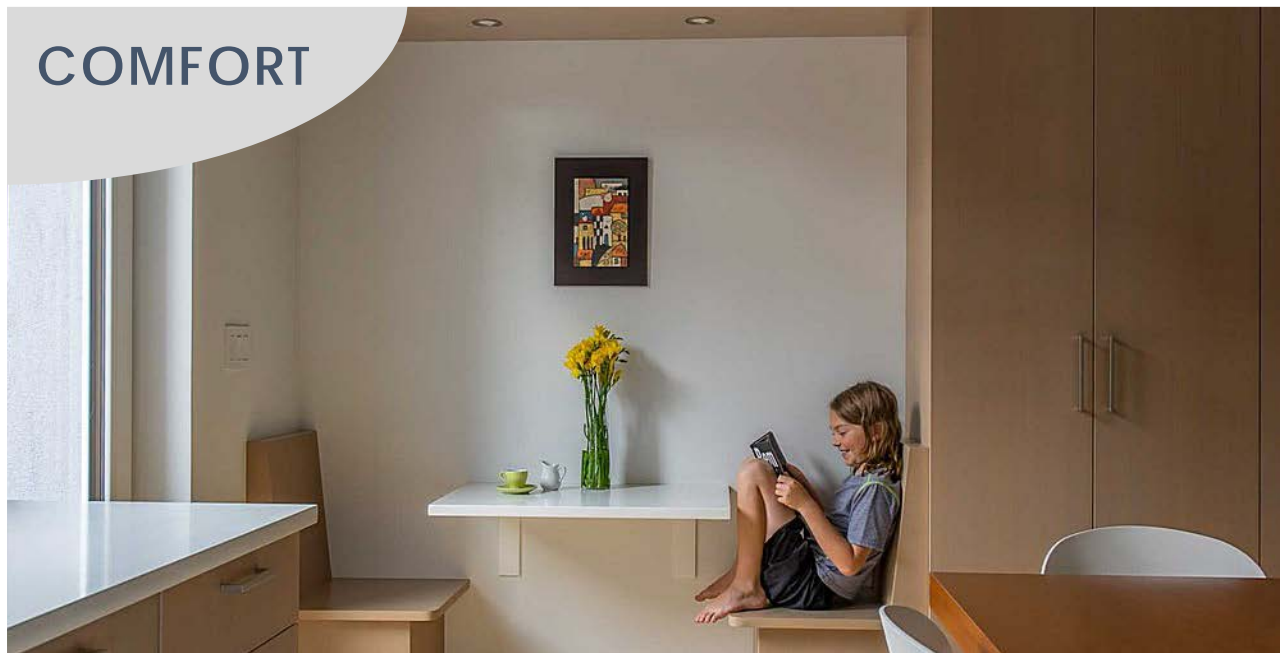


GREAT DESIGN

ENERGY
HEALTH



DURABILITY
COMFORT



CHANGE THE CONVERSATION

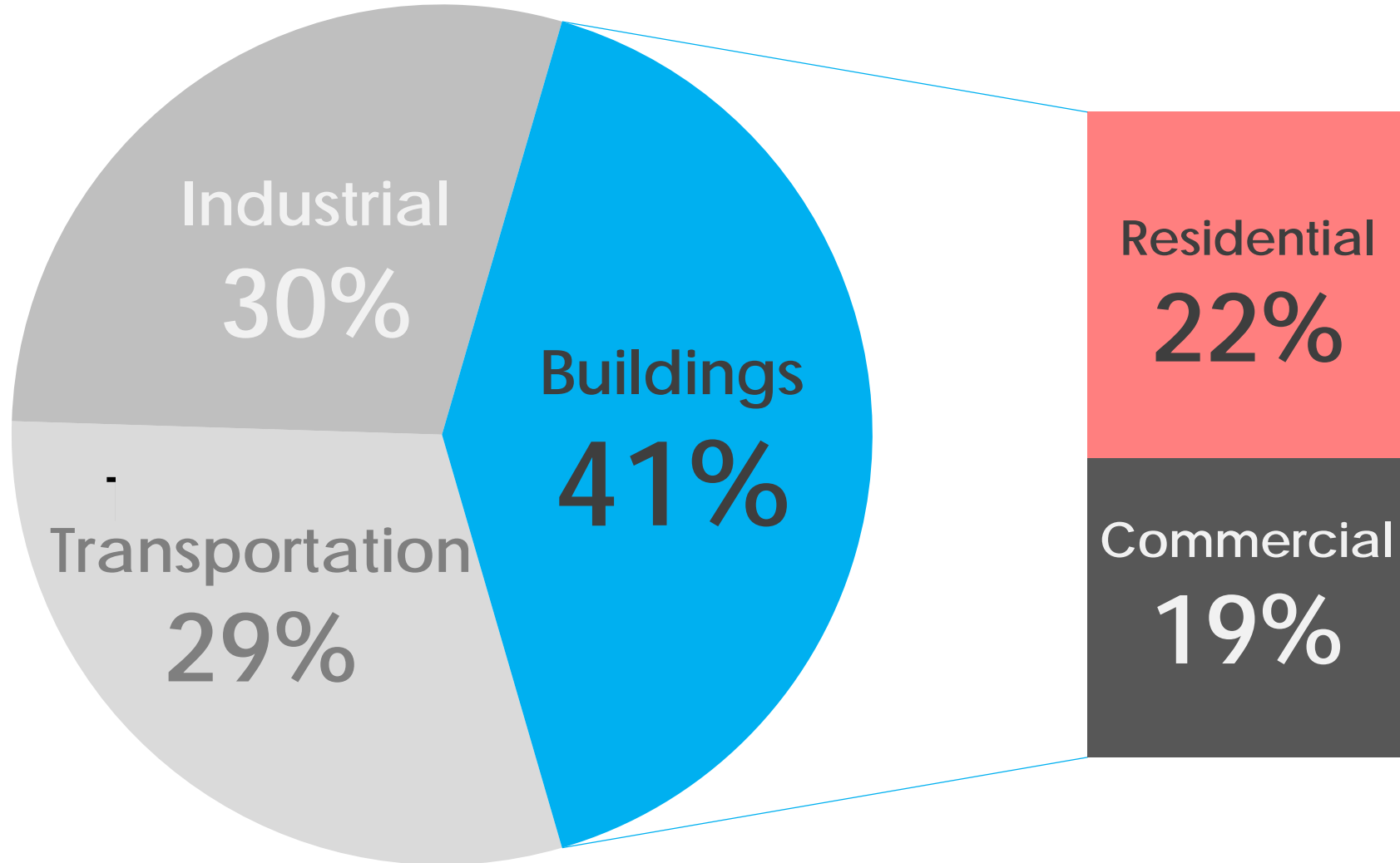
PORTFOLIO | ARCHITECTURE

CHANGE THE CONVERSATION

PORTFOLIO | ARCHITECTURE

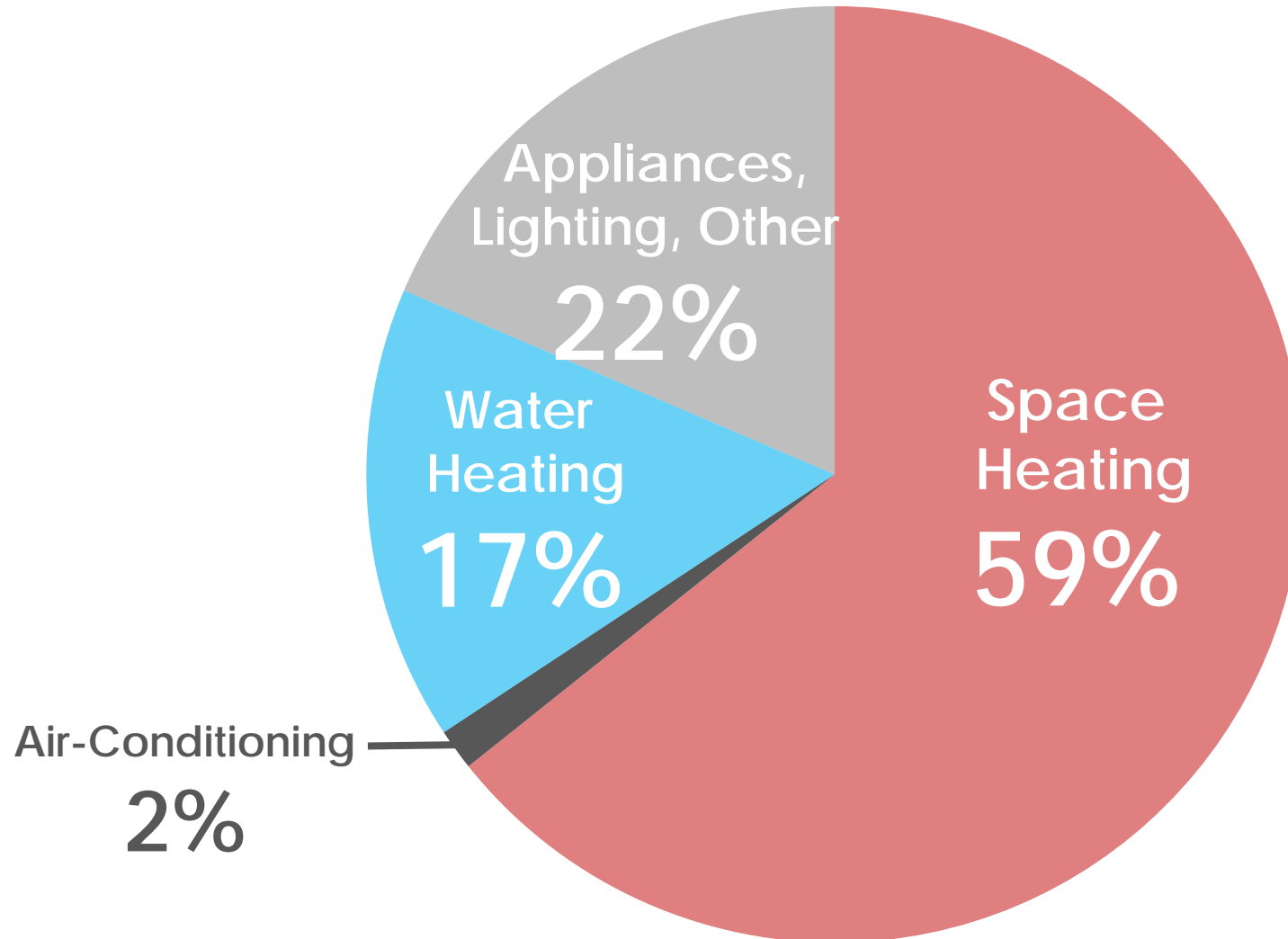
WHERE DOES OUR
ENERGY GO?

US ENERGY USE



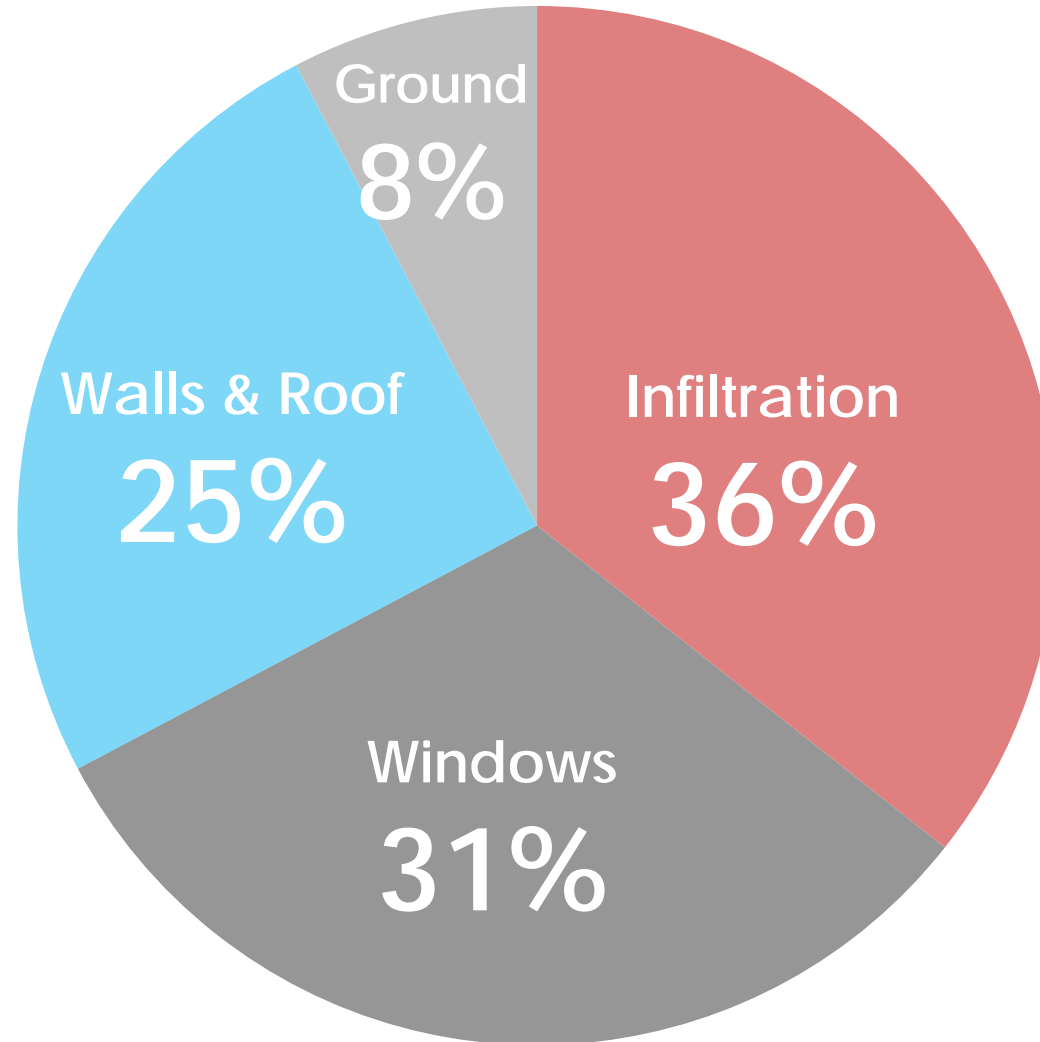
SOURCE: US DEPARTMENT OF ENERGY, 2011

NE ENERGY CONSUMPTION BY END USE

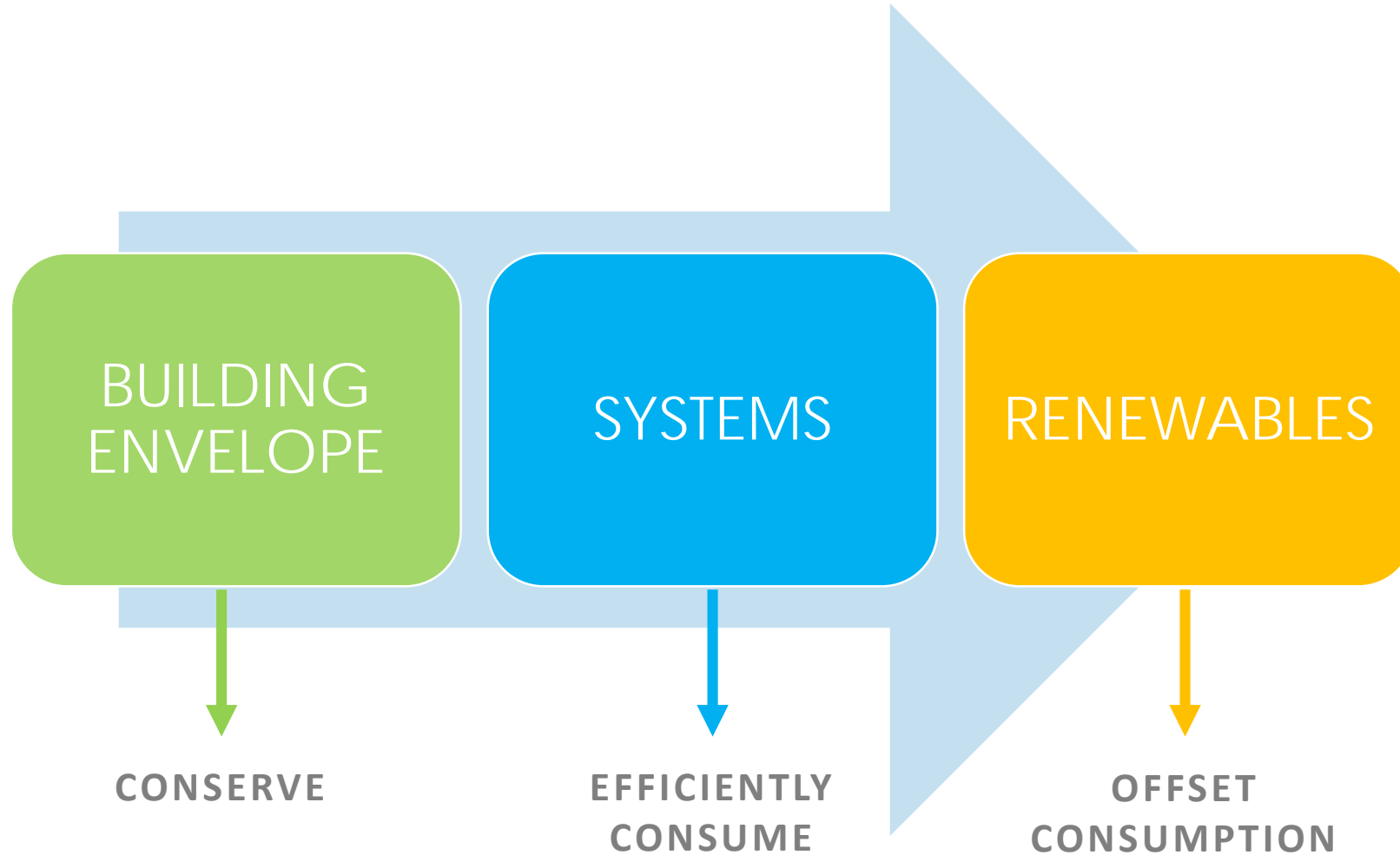


SOURCE: Source: US Energy Information Agency Residential Energy Consumption Survey, 2015

TYPICAL HEAT LOSS BY BUILDING COMPONENTS



DESIGN & FOLLOW THE PATH TO ZERO



BENEFITS

- Increased comfort
- Improved indoor air quality
- Quieter
- Improved durability
- Lower and predictable utility costs
- Smaller carbon footprint



SITE RESPONSIVE DESIGN

LINCOLN FARMHOUSE



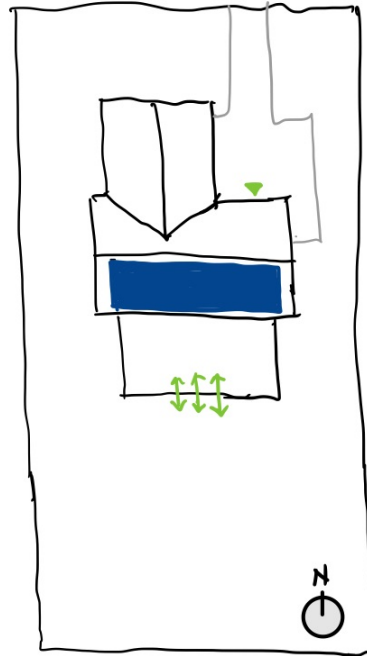
South / Front



North / Rear

SITE RESPONSIVE DESIGN

WELLESLEY GREEN HOME



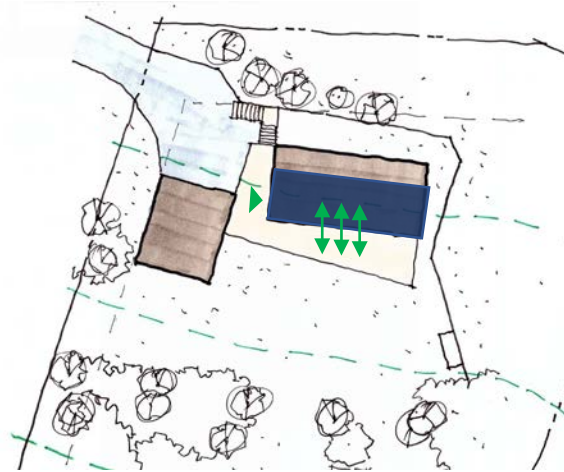
South / Rear



East / Side

SITE RESPONSIVE DESIGN

HINGHAM MARSHFRONT



South / Side



North/Side

BRIGHT LIVING SPACES



STRATEGIES THAT WE LIKE

- Start with design
- Continuous air barriers
- Continuous insulation
- Insulation with low GWP
- Triple-glazed windows
- Air-source heat pumps
- Continuous ventilation w/ energy recovery
- Renewables



CONTINUOUS AIR BARRIER



CONTINUOUS INSULATION



LOW GWP INSULATION



Credit: Agepan



Credit: Energia

TRIPLE GLAZED WINDOWS



AIR SOURCE HEAT PUMPS



CONTINUOUS VENTILATION



RENEWABLES



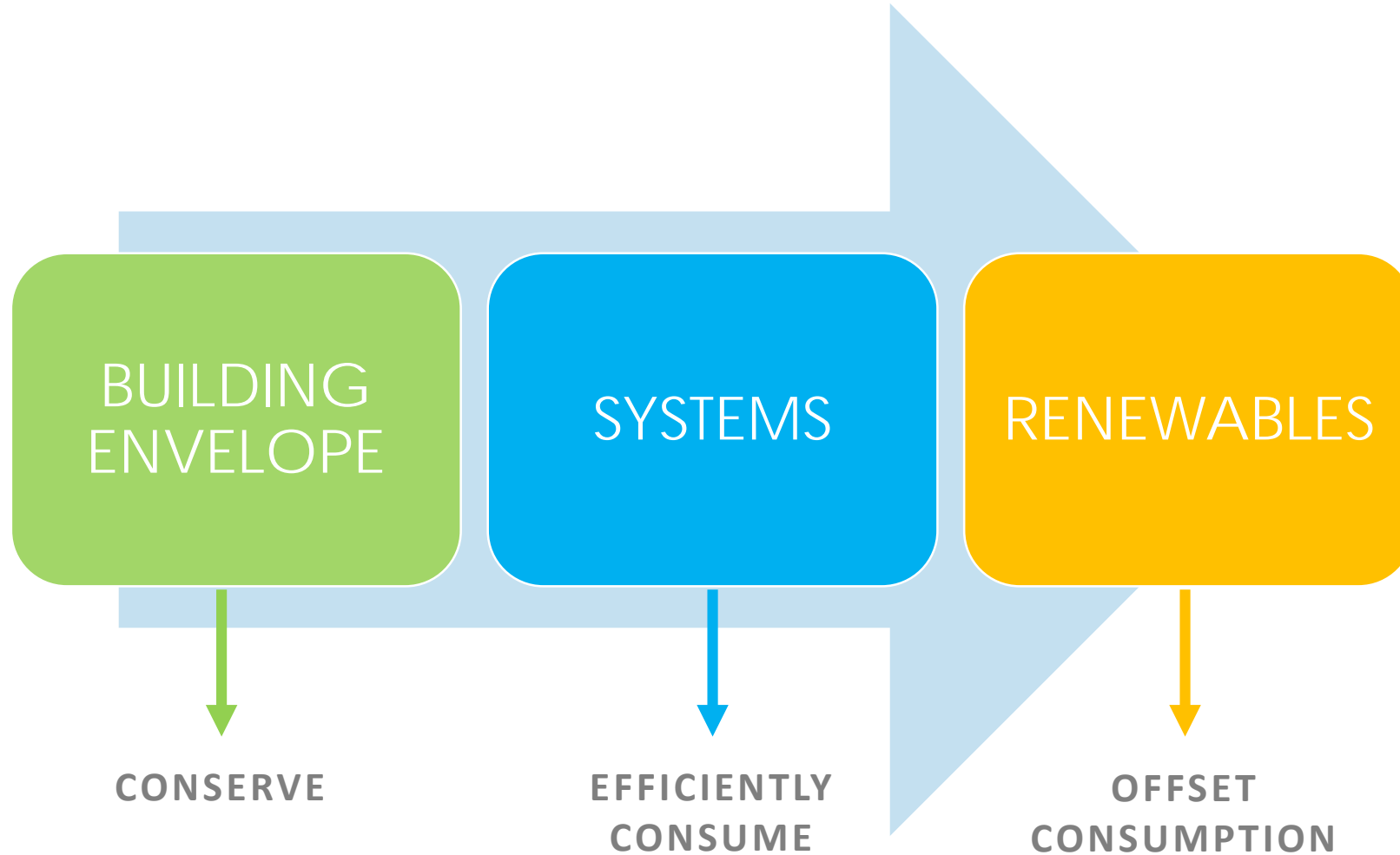
RENEWABLES



RENEWABLES



DESIGN & FOLLOW THE PATH TO ZERO





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Net Zero Energy Homes Builder Experiences

Jonathan Kantar

Sage Builders LLC

Founder / Principal

jonathan@sagebuilders.com





A Solution for the Future

- Provide a functional, attractive, comfortable, affordable, healthy, and durable home that optimizes energy use, embodied carbon, and both investment and operational costs.
- All Electric (remove existing natural gas service)
- “Easy to build”
- Focus on the air barrier: 0.6 ACH50 target

New roofs oriented for solar PV panels





- Demo and protection
- Immediately, establishing the air barrier w/ pressure activated self-adhesive WRB/Air Barrier
- Focus: continuous air, vapor, and thermal barriers: 0.6 ACH50 target;
 - Planning penetrations; sequencing and use of products
 - Tape, tape, and more tape!



- 2" Zip R9 Sheathing, 2x6 @ 16oc (should have done 24"oc) ext. wall
- Performance in a small package –
 - R9 continuous insulation;
 - WRB
 - Air Barrier w/ Zip Tape
 - Compact

- Opportunistic: easy assembly in a process we needed to do anyway
- Constructability
- Readily available





- Focus on CONTINUOUS air sealing:
- Zip system – tape all seams
- Openings: tape zip assembly to framing
- Doors/windows/penetrations: tape/foam units to exterior air barrier and interior air barrier....continuity inside and out
- ROs 1" larger than needed for shimming and spray foam



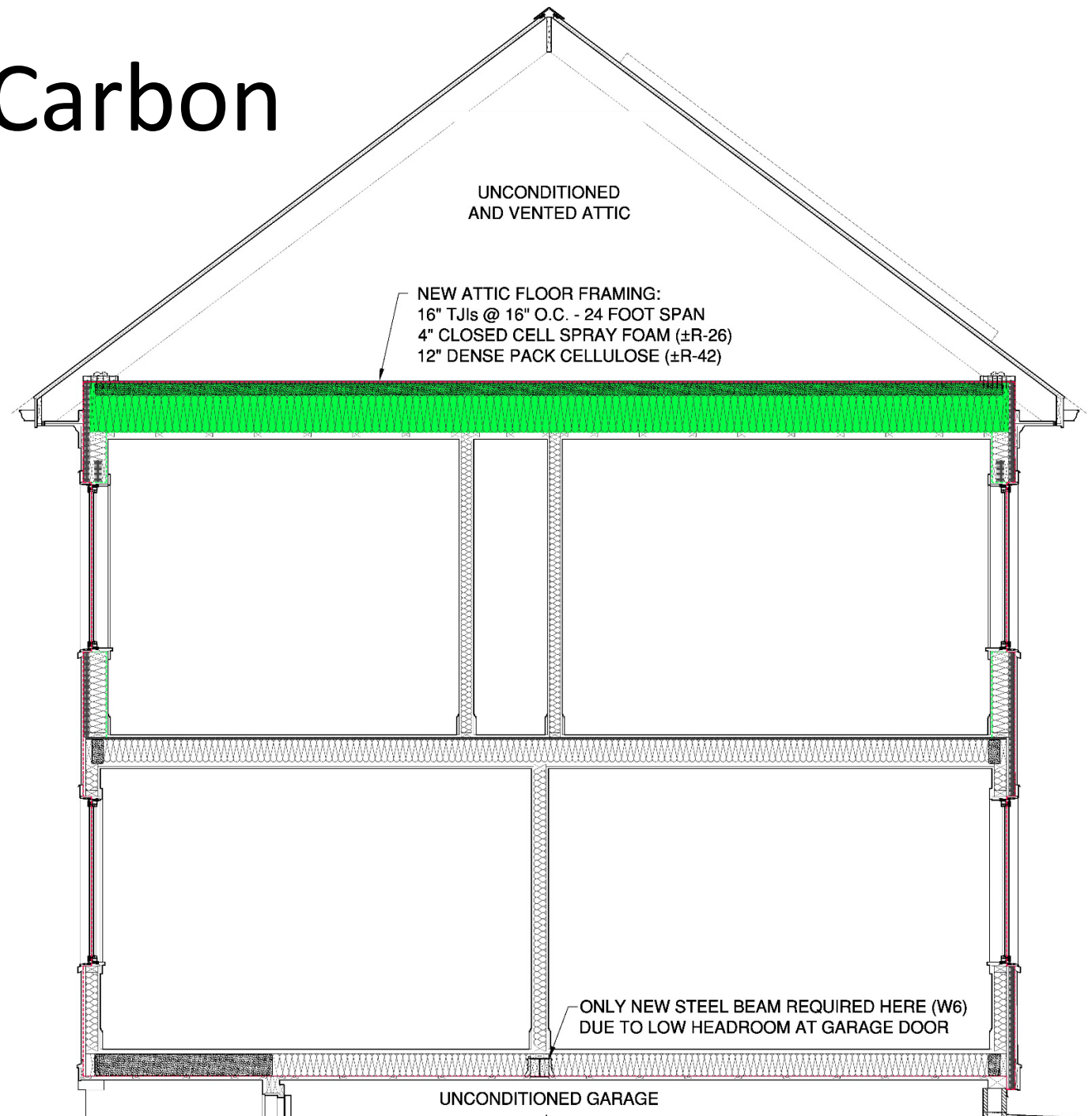
Goal: Reduce Embodied Carbon

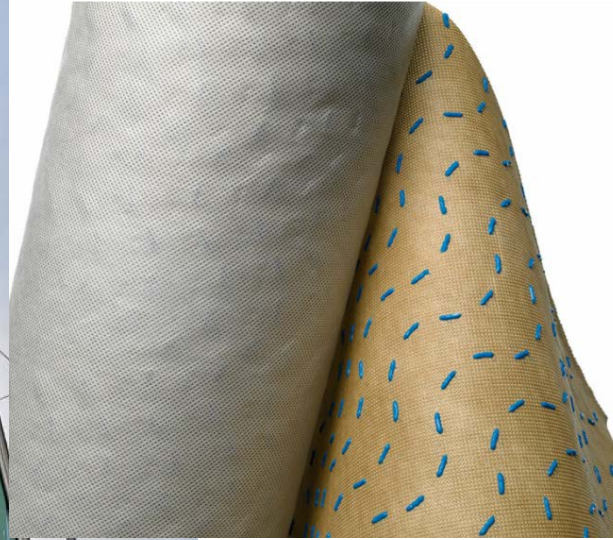
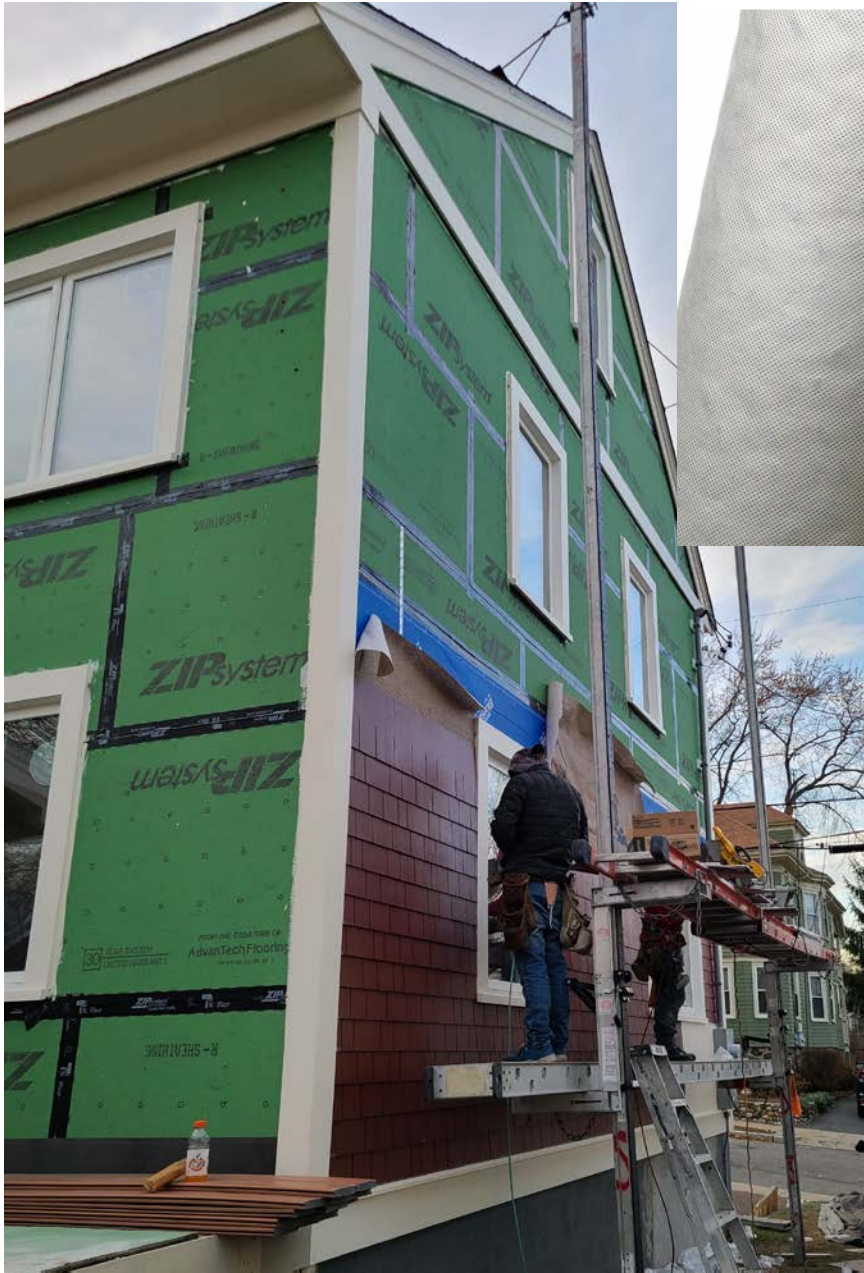
- Reuse much of existing structure
- Minimize new concrete and structural steel (rear addition on piers)
- Minimize use of closed cell spray foam
- Wood framing and dense pack cellulose insulation where feasible
- Boral Exterior Trim (instead of PVC)



Reduce Embodied Carbon

- 16" attic floor joists
- Reduce need for new structural steel
- Extra insulation depth (R-68)
- Compensate for underperforming exterior walls

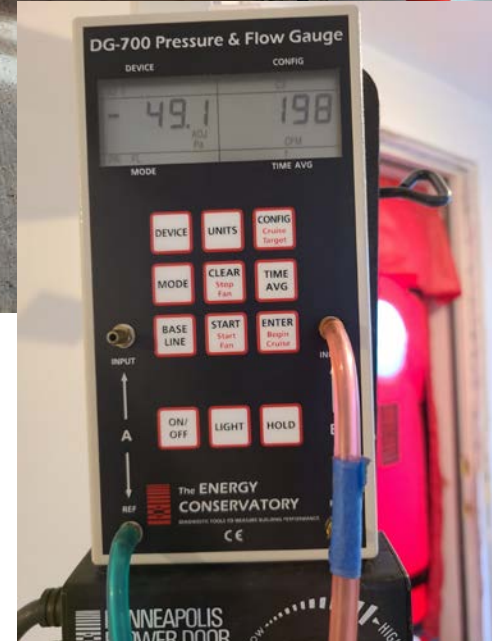
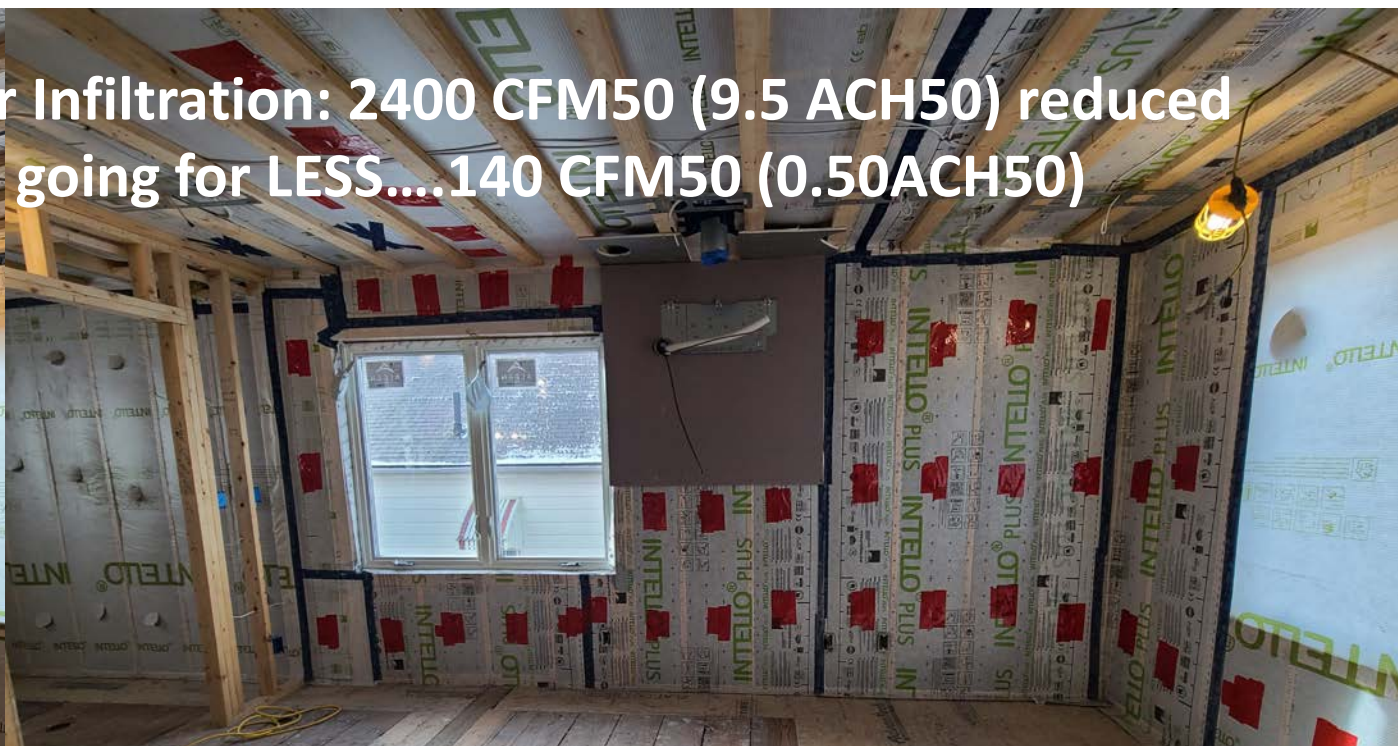
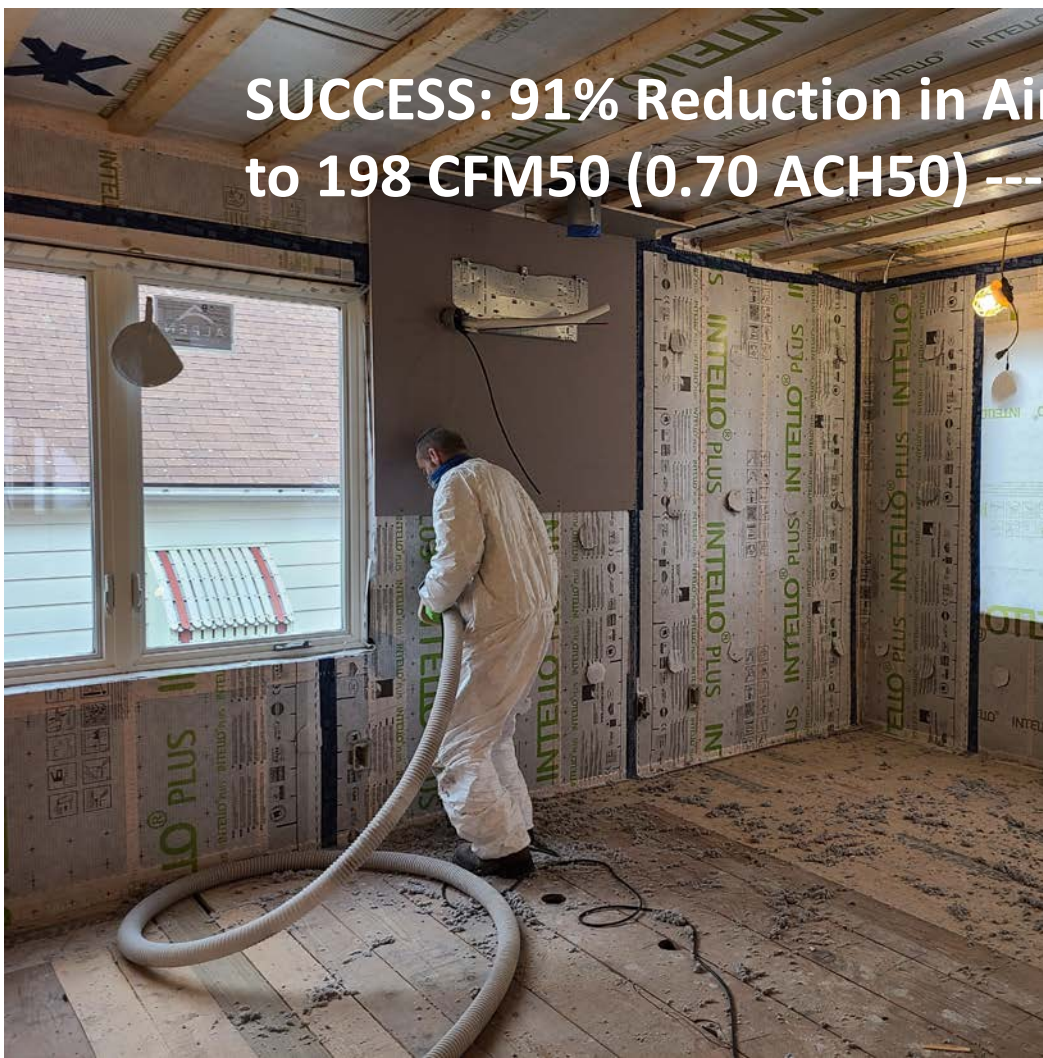




The exterior - looking for durability, efficiency, economy with no compromises: **** R8+ Windows ****

- Boral Exterior Trim for durability and environmentally friendly;
- Trim pre-assembled w/ pocket holes, rabbeted out for window flange
- 3 dimensional WRB for air gap
- Prefinished, cementitious panel shingle siding – quick installation, durable, fire protection, handsome
- Stop the water! Flash head casing, flash horizontal blocks, trim

SUCCESS: 91% Reduction in Air Infiltration: 2400 CFM50 (9.5 ACH50) reduced to 198 CFM50 (0.70 ACH50) --- going for LESS....140 CFM50 (0.50ACH50)

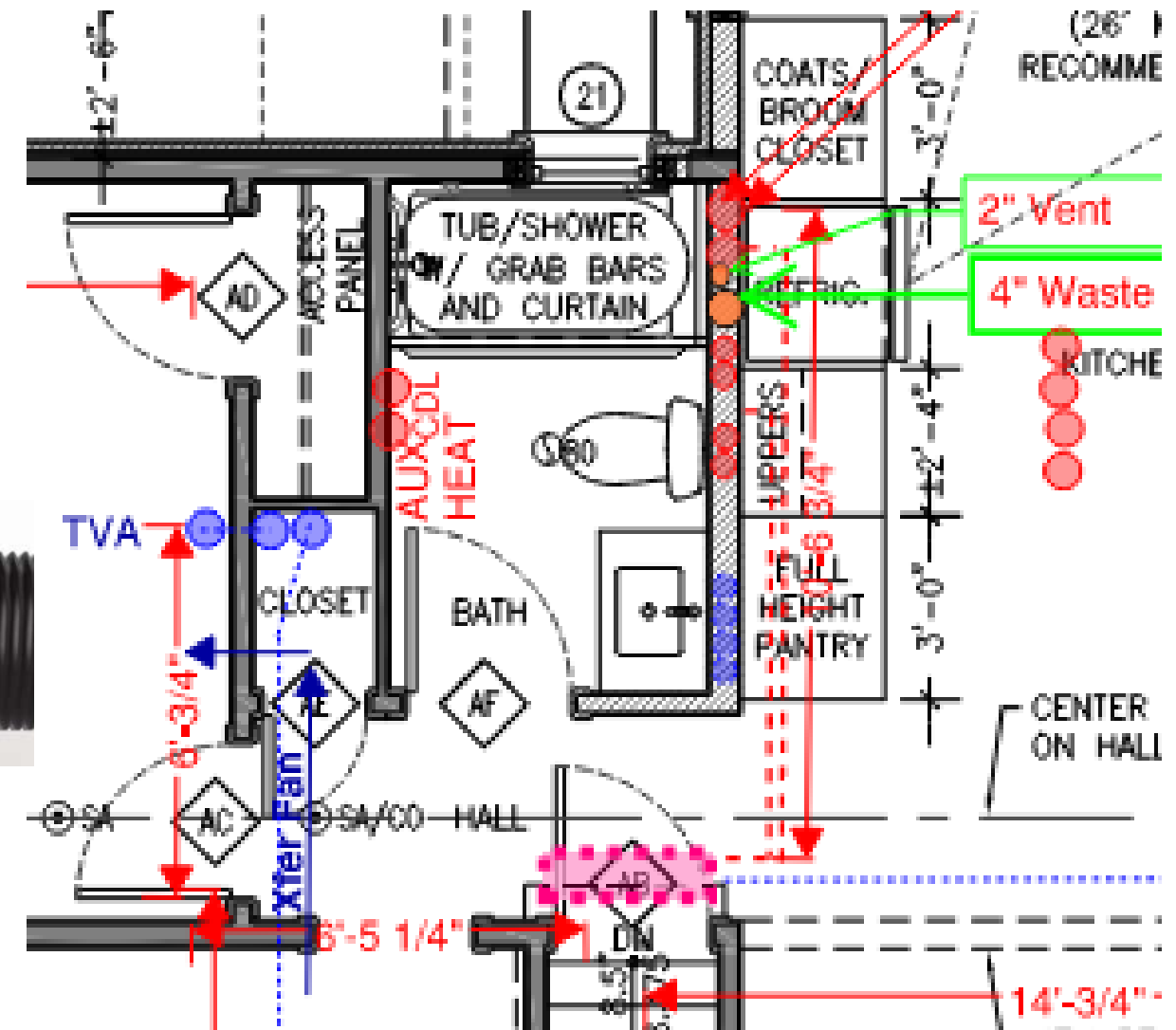


- Dense packed cellulose and TAPING – many hours (\$\$\$\$) and tons of tape (\$\$\$)
- Missed: blower door 1) before interior air barrier, 2) after air barrier, 3) after insulation, 4) after taping.



Heating, A/C and Ventilation

- Critical aspect of the project
- Must do thorough, careful energy modeling
- Consider layout and distribution



- Where to put all the pipes and tubes ??
- Worked w/ vendor to size systems – ended up oversizing both....but still within efficient oper. Ranges
- Air transfer fans for distribution



Net Zero to Boot !!

Boucher Energy Systems, Inc.

World Class HVAC



www.boucherenergy.com

Since 1981

New Air Source Heat Pump Home

- Traditional New England style homes
- 6" spray foam exterior
- Wrapped with foam under sheathing R-10 for no thermal bridge



New Air Source Heat Pump Home

- Large solar array powers most of home's needs
- No flue pipes through side walls or roof
- No fossil fuels



Air Handlers

- Replaces traditional gas hot air furnace
- Can be stacked in tight spaces (since there are no gas lines or flue pipes)



Ceiling recessed unit

- Functions just like the more traditional wall head style units, yet sits flush in a ceiling for a cleaner look
- Can be used in areas where ductwork is impractical OR to reduce costs and create zoning



Fresh Air Ventilation

- Zehnder ERV (energy recovery ventilator)
- Tighter new homes require fresh air ventilation for occupant health and comfort



Condensing Units

- Variable speed enhances efficiency
- Very quiet condenser, reduces noise complaints from own neighbors
- Extremely long line lengths



Geothermal: Unveiling the mystery....



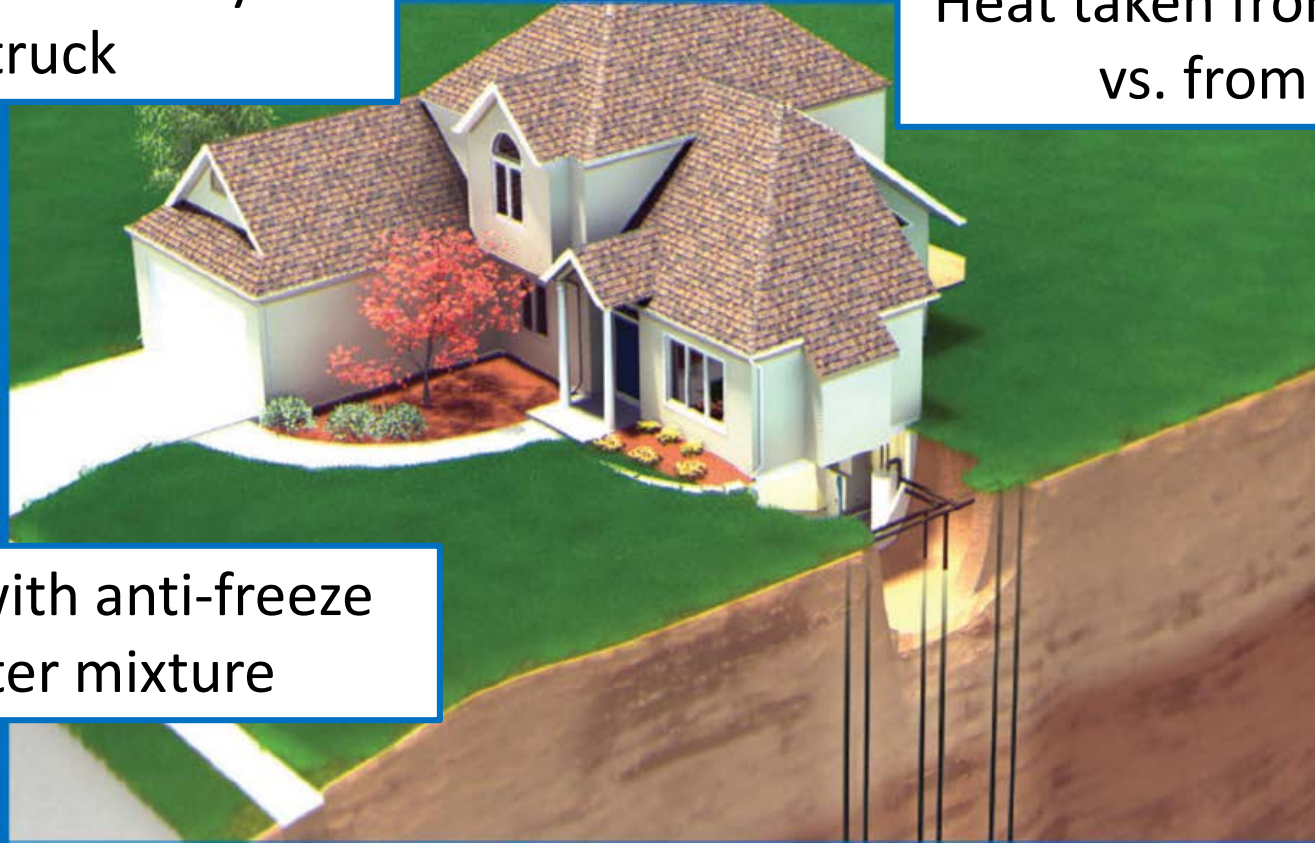
Geothermal: Not a mystery, not magic ☺

Closed-Loop Vertical System

Bore holes drilled by well truck

Heat taken from ground vs. from air

Filled with anti-freeze water mixture



New Geothermal Home (Front)

- Benson Wood post and beam
- Exterior walls 9.5" TGI with high density cellulose
- Factory assembled wall systems, including windows
- Foundation walls insulated to R-15
- Air tightness at >1 ACH50



New Geothermal Home (Back)

- Large open porch areas
- Eliminates A/C condenser clutter on exteriors
- Eliminates noise near outdoor living spaces
- Eliminates wall penetrations, ugly flue pipes



New Geothermal Home (interior)

- No indoor units hanging on walls
- Traditional floor mounted grills like any other system

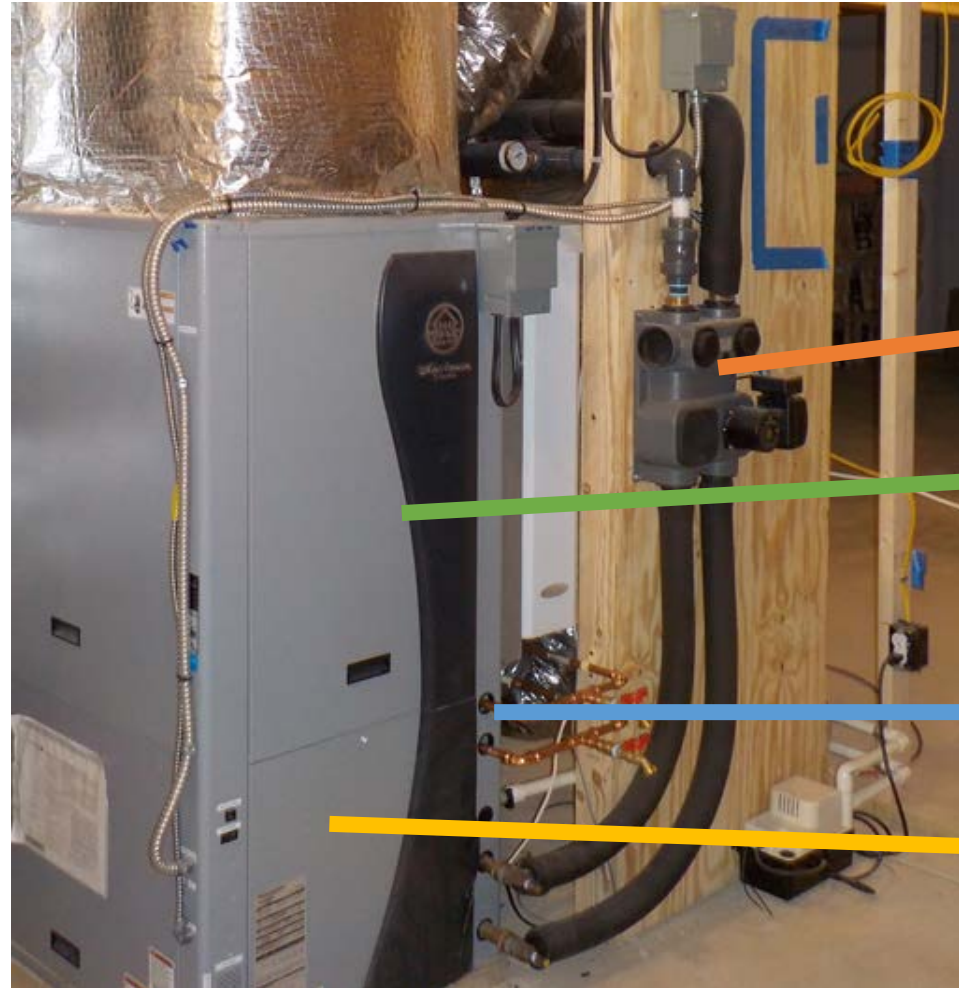


New Geothermal Home (equipment room)

- Two units, one per floor
- 2 in 1 system: an air handler AND condensing unit



New Geothermal Home (components)



Pump Station

Blower section

Desuperheater
(Supplements
water heater)

Condenser section

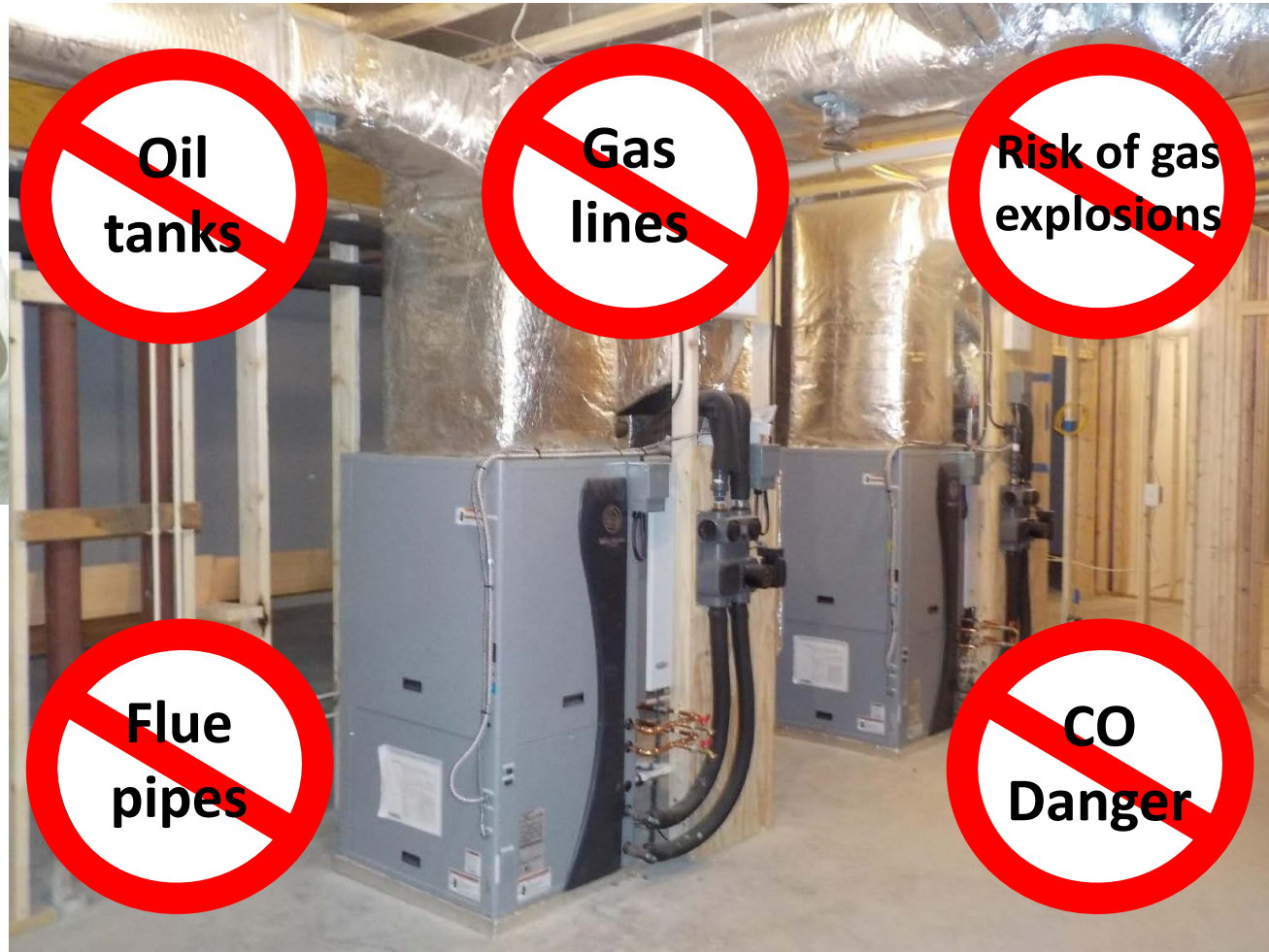
New Geothermal Home (components)



What's
missing?




Look at what you don't need...



New Geothermal Home (duct work)

- Sized larger than traditional hot air ductwork
- Radiused corners for less resistance
- R-8 fiberglass wrap
- Sealed beyond minimum code





Would you drive your car with the
emergency brake on?



One great tip to improve efficiency in
ANY home on ANY HVAC system...



=



Boucher Energy Systems, Inc.

World Class HVAC



www.boucherenergy.com

Since 1981

Thank You

Net Zero Energy Homes Heat Pump Energy Modeling

Ed Quinlan

Green Needham Collaborative

Engineered Solutions Inc.

Founder/Principal/Retired

ed@btuchaser.com



Green Needham

Energy Plus for Building Energy Analysis

Graphical User Interfaces:

- * BEopt
- * Sketch Up
- * Open Studio


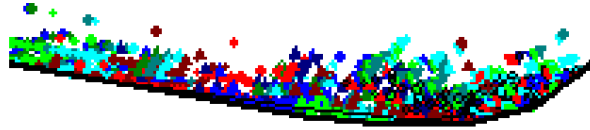


BEopt – Building Energy Optimization

BEopt 2.8.0.0

BEopt

Building Energy Optimization
with Hour-by-Hour Simulations



National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
www.nrel.gov

Project type:

☒ Standard
☐ Building America
☐ California Metrics

Application type:

☒ New Construction
☐ Retrofit

Building type:

☒ Single-Family Detached
☐ Multi-Family

☐ Do not ask again

OK

PV Watts – Solar PV Analysis

PVWatts® Calculator



Get Started: [GO »](#)

[English](#)
[Español](#)

[HELP](#)

[FEEDBACK](#)



NREL's PVWatts® Calculator

Estimates the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems throughout the world. It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations.



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BEopt Energy Input Parameters

BEopt 2.8.0.0 - Energy Options Analysis* [Standard, New Construction, Single-Family Detached]

File Screen Case Run Reports Tools Help

Input: Output: Run:

Geothermal Heat Pump Ducted Heat Pump Super Ins Base - Ducts in vented attic Propane Base - Ducts in Space Propane Geothermal Heat Pump Super Ins Base - Ducts in vented attic (2)

Analysis: Design Reference: My Design

Building

EPW Location: USA_MA_Norwood.Mem.AP.72509

Terrain: Suburban

Natural Gas Hookup: ☒

Economics

Project Analysis Period	30	years
Inflation Rate	3.0	%
Discount Rate (Real)	3.0	%
Efficiency Material Cost Multiplier	1.000	
Efficiency Labor Cost Multiplier	1.000	
PV Material Cost Multiplier	1.000	
PV Labor Cost Multiplier	1.000	

Mortgage

Down Payment	0.0	%
Mortgage Interest Rate	4.0	%
Mortgage Period	30	years
Marginal Income Tax Rate, Federal	28.0	%
Marginal Income Tax Rate, State	0.0	%

Project Info

Building Name:

Street Address:

City:

State:

Zip:

Country:

Notes:

Base Case with Natural Gas

Electricity Natural Gas Oil Propane

Utility Rates

☒ Simple ☐ Detailed

☒ User Specified

Fixed	7.00	\$/month
Marginal	0.2338	\$/kWh
Average	0.2451	\$/kWh

☐ State Average

☐ National Average

Fuel Escalation (Real): 0.00 %/year

PV Compensation

☒ Net Metering ☐ Feed-in Tariff

Annual Excess Sellback Rate

☒ Retail Electricity Cost: 0.23380 \$/kWh

☐ User Specified

Monthly Grid Connection Fee: 0.00 \$/kW

Energy Factors

Source/Site Ratio	3.150
Carbon Factor	0.719 lb/kWh

BEopt – House Geometry

BEopt 2.8.0.0 - Energy Options Analysis* [Standard, New Construction, Single-Family Detached]

File Screen Case Run Reports Tools Graphs Help

Input: Output:

☒ Base - Ducts in vented attic ☒ Base - Ducts in Space ☒ Ducted Heat Pump ☒ Ductless Heat Pump ☒ Geothermal Heat Pump ☒ Ducted Heat Pump Super Ins ☒ Base - Ducts in vented attic Propane ☒

Analysis: Design Reference: My Design

This case contains output associated with these inputs and therefore inputs are disabled. To modify inputs or create a new design, either [clear](#) the existing output or create a [new case](#).

Levels Fnd 1st 2nd 3rd 4th 5th 6th

Spaces

- Living
- Open to Below
- Unfinished Attic
- Finished Attic
- Vaulted Ceiling
- Garage Roof
- Porch Roof (Pitched)
- Flat Roof / Deck
- Erase

	Beds	Baths	Finished (sqft)
Total	5+	3+	4200

Scale: 1 cell = 2 ft

Front

Wall Height 10 ft

No errors.

BEopt Input – Wall Construction

BEopt 2.8.0.0 - Energy Options Analysis* [Standard, New Construction, Single-Family Detached]

FileScreenCaseRunReportsToolsHelp

Input:Output:Run:

Geothermal Heat PumpDucted Heat Pump Super InsBase - Ducts in vented attic PropaneBase - Ducts in Space PropaneGeothermal Heat Pump Super InsBase - Ducts in vented attic (2)

Analysis: DesignReference: My Design

My Design

Orientation

Neighbors

Walls

Wood Stud

Double Wood Stud

Steel Stud

CMU

SIP

ICF

Other

Wall Sheathing

Exterior Finish

Ceilings/Roofs

Unfinished Attic

Roof Material

Radiant Barrier

Foundation/Floors

Slab

Carpet

Thermal Mass

Floor Mass

Exterior Wall Mass

Partition Wall Mass

Ceiling Mass

Windows & Doors

Window Areas

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

1 2 3 4 5 6 7 8 9

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

1 2 3 4 5 6 7 8 9

1 2 3 4

1 2 3 4

1 2 3 4 5 6 7 8 9 10 11 12

1 2 3 4 5 6 7 8 9 10 11

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

1 2 3 4 5 6 7 8 9 10 11 12 13

1 2

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

1 2 3 4 5 6

1 2 3

1 2 3 4 5 6 7

1 2 3 4 5 6 7

1 2 3 4 5 6 7

1 2 3 4 5 6 7 8 9 10 11

Option	R-Assembly [h-ft ² -R/Btu]	Cavity Insulation
3) Uninsulated, 2x6, 24 in o.c.	4.1	
4) R-7 Fiberglass Batt, 2x4, 16 in o.c.	9.3	fiberglass
5) R-11 Fiberglass Batt, 2x4, 16 in o.c.	10.9	fiberglass
6) R-13 Fiberglass Batt, 2x4, 16 in o.c.	11.9	fiberglass
7) R-15 Fiberglass Batt, 2x4, 16 in o.c.	12.7	fiberglass
8) R-19 Fiberglass Batt, 2x6, 24 in o.c.	16.0	fiberglass
9) R-21 Fiberglass Batt, 2x6, 24 in o.c.	17.7	fiberglass
10) R-13 Cellulose, 2x4, 16 in o.c.	11.9	cell
11) R-13 Cellulose, 2x4, 16 in o.c., Grade 2	11.4	cell
12) R-13 Cellulose, 2x4, 16 in o.c., Grade 3	10.8	cell
13) R-19 Cellulose, 2x6, 24 in o.c.	16.8	cell
14) R-13 Fiberglass, 2x4, 16 in o.c.	11.9	fiber
15) R-19 Fiberglass, 2x6, 24 in o.c.	16.8	fiber
16) R-23 Closed Cell Spray Foam, 2x4, 16 in o.c.	15.3	closed cell spray
17) R-36 Closed Cell Spray Foam, 2x6, 24 in o.c.	23.0	closed cell spray
18) R-13 Open Cell Spray Foam, 2x4, 16 in o.c.	11.9	open cell spray
19) R-20 Open Cell Spray Foam, 2x6, 24 in o.c.	17.3	open cell spray

Wood stud walls are standard wood stud framed walls with cavity insulation.
When batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5' 2x6 cavity), R-values reflect this effect.

Grade of batt installation quality (1, 2, or 3) is described in RESNET's "2006 Mortgage Industry National Home Energy Rating Systems Standards."

BEopt Input – Window Type

BEopt 2.8.0.0 - Energy Options Analysis* [Standard, New Construction, Single-Family Detached]

File Screen Case Run Reports Tools Help

Input: Output: Run:

Geothermal Heat Pump Ducted Heat Pump Super Ins Base - Ducts in vented attic Propane Base - Ducts in Space Propane Geothermal Heat Pump Super Ins Base - Ducts in vented attic (2)

Analysis: Design Reference: My Design

My Design

- Exterior Wall Mass
- Partition Wall Mass
- Ceiling Mass
- Windows & Doors**
 - Window Areas
 - Windows**
 - Interior Shading
 - Door Area
 - Doors
 - Eaves
 - Overhangs
- Airflow**
 - Air Leakage
 - Mechanical Ventilation
 - Natural Ventilation
- Space Conditioning**
 - Central Air Conditioner
 - Room Air Conditioner
 - Furnace
 - Boiler
 - Electric Baseboard
 - Air Source Heat Pump
 - Mini-Split Heat Pump
 - Ground Source Heat Pump
 - Ducts
 - Ceiling Fan
 - Dehumidifier

Option	SHGC	Frame Material	Fi
7) Low-E, Double, Non-metal, Arg, H-Gain	0.53	non-metal	
8) Low-E, Double, Non-metal, Arg, M-Gain	0.44	non-metal	
9) Low-E, Double, Non-metal, Arg, L-Gain	0.3	non-metal	
10) Low-E, Double, Insulated, Air, H-Gain	0.56	insulated	
11) Low-E, Double, Insulated, Air, M-Gain	0.46	insulated	
12) Low-E, Double, Insulated, Air, L-Gain	0.31	insulated	
13) Low-E, Double, Insulated, Arg, H-Gain	0.56	insulated	
14) Low-E, Double, Insulated, Arg, M-Gain	0.46	insulated	
15) Low-E, Double, Insulated, Arg, L-Gain	0.31	insulated	
16) Low-E, Triple, Non-metal, Air, H-Gain	0.38	non-metal	
17) Low-E, Triple, Non-metal, Air, L-Gain	0.26	non-metal	

BEopt is currently only showing options deemed appropriate and for which costs exist. You can [show additional options](#).

The type of window for each facade on the house. Options can define facade-specific window types or a single window type for the building.

U-values and SHGCs listed here are NFRC ratings for standard-size, single casement windows. Other window types and sizes may be represented using Perimeter/Area Ratio as explained in the Window Area category

3-pane windows may include 2 layers of glass and a suspended film.

Argon-filled windows may not be available at higher altitudes (above approximately 3500 feet), due to issue with atmospheric pressure differences between the installation and manufacturer's locations.

For multifamily buildings, the selected option(s) apply to each unit.

BEopt Input – Mechanical System Options

BEopt 2.8.0.0 - Energy Options Analysis* [Standard, New Construction, Single-Family Detached]

File Screen Case Run Reports Tools Graphs Help

Input: Output: Run:

☒ Base - Ducts in vented attic ☒ Base - Ducts in Space ☒ Ducted Heat Pump ☒ Ductless Heat Pump ☒ Geothermal Heat Pump ☒ Ducted Heat Pump Super Ins ☒ Base - Ducts in vented attic Propane ☒

Analysis: Design Reference: My Design

This case contains output associated with these inputs and therefore inputs are disabled. To modify inputs or create a new design, either [clear](#) the existing output or create a [new case](#).

My Design

- Eaves ☐ 1 ☐ 2 ☒ 3 ☐ 4
- Overhangs ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
- **Airflow**
 - Air Leakage ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☒ 12 ☐ 13 ☐ 14 ☐ 15
 - Mechanical Ventilation ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☒ 11
 - Natural Ventilation ☐ 1 ☐ 2 ☐ 3 ☐ 4
- **Space Conditioning**
 - Central Air Conditioner ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10
 - Room Air Conditioner ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10
 - Furnace ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20 ☐ 21 ☐ 22 ☐ 23
 - Boiler ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20
 - Electric Baseboard ☐ 1 ☐ 2
 - **Air Source Heat Pump** ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☒ 9
 - Mini-Split Heat Pump ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20 ☐ 21
 - Ground Source Heat Pump ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13
 - Ducts ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20 ☐ 21 ☐ 22 ☐ 23 ☐ 24 ☐ 25 ☐ 26 ☐ 2
 - Ceiling Fan ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13
 - Dehumidifier ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11
- **Space Conditioning Schedules**
 - Cooling Set Point ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☒ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18
 - Heating Set Point ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☒ 17
 - Humidity Set Point ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- **Water Heating**
 - Water Heater ☐ 1 ☐ 2 ☐ 3
 - Distribution ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20 ☐ 21 ☒ 22
 - Distribution ☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13

Cooling/Heating Output Capacity: Autosize Supplemental Heating Output Capacity: Auto

Option	Compressor	Cooling Cycling [frac]	Heating Cycling [frac]	Number of Speeds
9) SEER 22, 10 HSPF	Var. Speed	0.25	0.24	4

BEopt is currently only showing options deemed appropriate and for which costs exist. You can [show additional options](#).

Heat pumps provide both heating and cooling in one integrated system. Air source heat pumps, often used in moderate climates, use the difference between outdoor and indoor air temperatures to cool and heat. Air source heat pumps provide heating and cooling through a duct system.

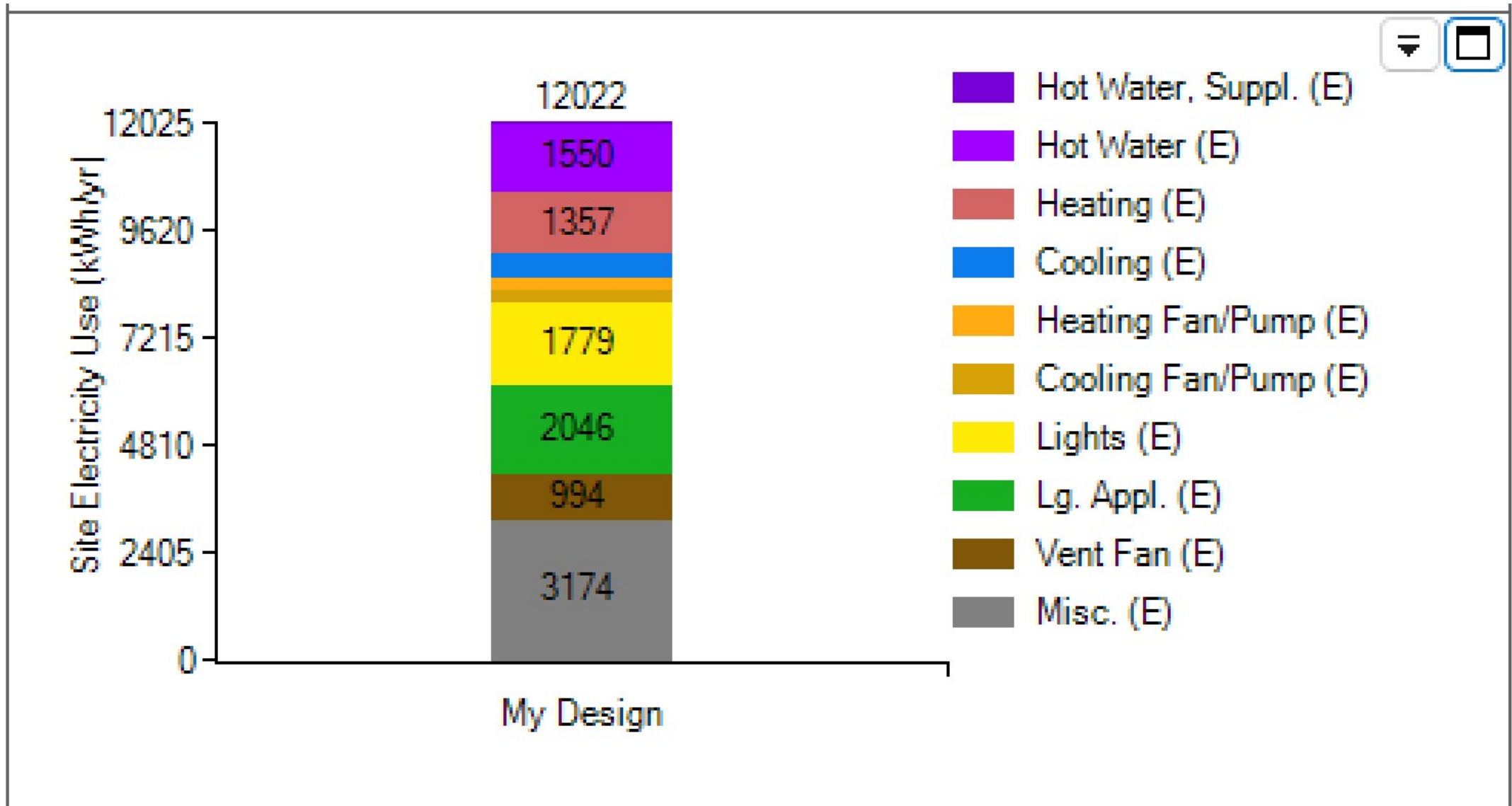
SEER (Seasonal Energy Efficiency Ratio) and HSPF (Heating and Seasonal Performance Factor) are estimates of the efficiency of the heat pump's cooling and heating. SEER and HSPF values shown are nominal rated values; actual performance will vary depending on climate.

For new construction or for autosizing within retrofit analysis, a calculation consistent with ACCA's Manual J 8th Edition is performed to auto-size the equipment for the annual simulation. The auto-sized result is then rounded up to a discrete size for costing purposes. If a unit requires larger than a 5-ton heat pump, multiple heat pumps will be used for costing.

High SEER/HSPF heat pumps tend to decrease in efficiency as the rated capacity increases. This trend has been included for the SEER 18/HSPF 9.3, SEER 19/HSPF 9.5, and SEER 22/HSPF 10.0 options using manufacturer data but can be modified by creating a User-Defined option. EER and COP multipliers are applied to the rated EER for 1.5, 2, 3, 4, and 5 ton heat pumps. The BEopt auto-sized result is used to interpolate between multipliers. For units larger than 5 tons, 2 equally sized units are assumed when adjusting the EER and COP.

For multifamily buildings, the selected option(s) apply to each unit.

BEopt Output - Energy Consumption by End Use

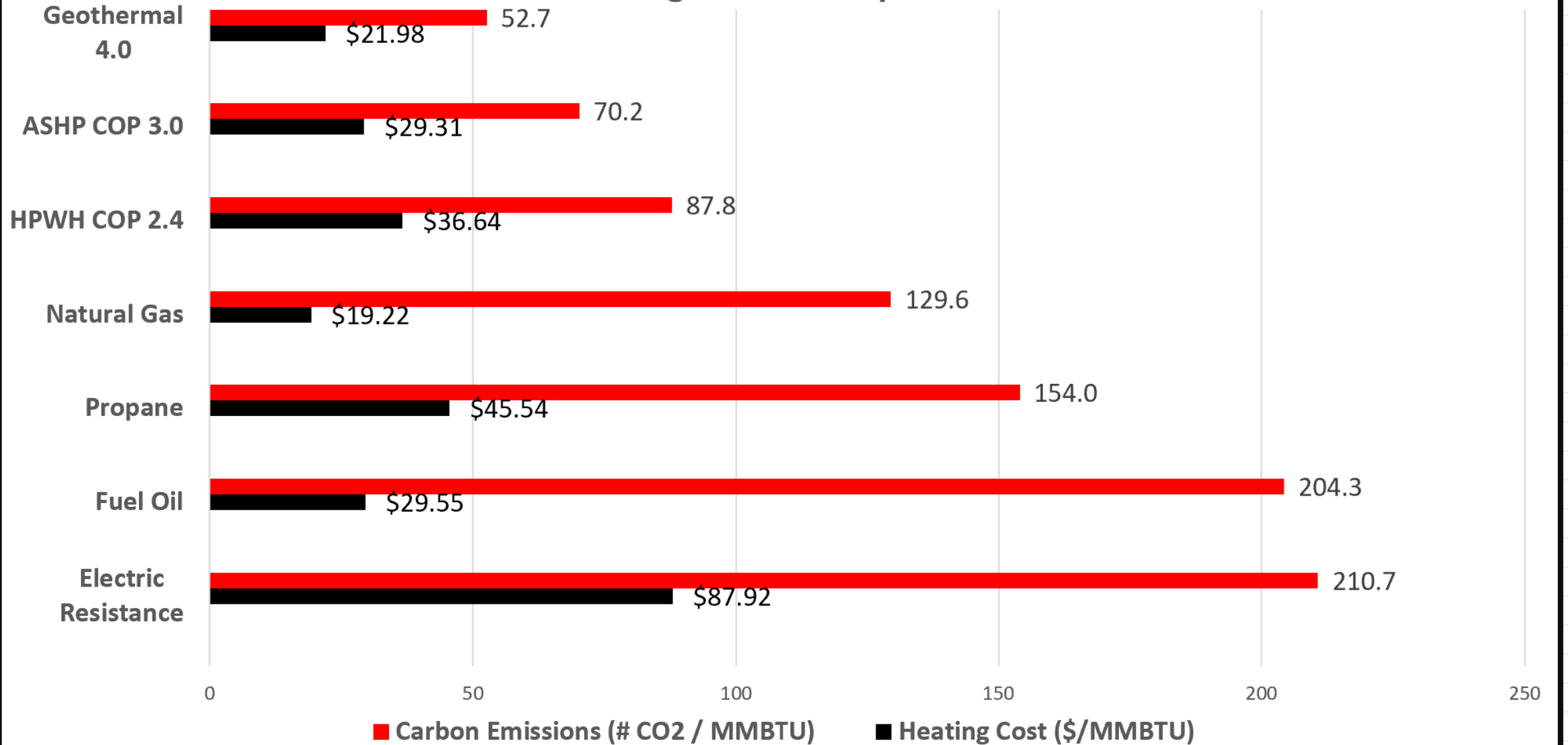


BEopt/Energy Plus Energy Model

House Description: 2 Story Colonial, 5 BdRm, 4 BathRm, 4,200 SF Finished Space

Item Description	Base Case Gas Furnace, Split DX AC	Option 1 Ducted ASHP	Option 2 Ductless ASHP	Option 3 Geo Heat Pump	Option 4 Ducted ASHP w/ Super Ins.	Option 5 Geo Heat Pump w/ Super Insul
Heat Fuel	Gas / Propane	All Electric	All Electric	All Electric	All Electric	All Electric
Orientation	N/S	N/S	N/S	N/S	N/S	N/S
Wall Construction	2x6, 24" o.c., R-19, FiberGlass	Base	Base	Base	2x6, 24" o.c., R-19, Dense Pack Cellulose	2x6, 24" o.c., R-19, Dense Pack Cellulose
Wall Sheathing	1/2" OSB	Base	Base	Base	1/2" OSB, R-10 XPS	1/2" OSB, R-10 XPS
Attic Floor Insulation	R-49 FiberGlass	Base	Base	Base	R-60, Foam/Cellulose	R-60, Foam/Cellulose
Slab	4 Ft Perim R10	Base	Base	Base	100% Slab R-30	100% Slab R-30
Windows Qty	15% N/S/E/W	Base	Base	Base	30% S, 10% N/E/W	30% S, 10% N/E/W
Window U Value	0.30	Base	Base	Base	0.18	0.18
Window SHGF	0.46	Base	Base	Base	0.40	0.40
Infiltration	3 ACH50	Base	Base	Base	1 ACH 50	1 ACH 50
Mech Vent	ERV 70%	Base	Base	Base	Base	Base
AC	SEER 14	SEER 22	SEER 26	EER 20.2	SEER 22	EER 20.2
Heat	Furnace 95% AFUE	10 HSPF	10.7 HSPF	COP 4.2	10 HSPF	COP 4.2
Supplemental Heat	None	Yes, Electric	Yes, Electric	None	Yes, Electric	None
Ductwork	In Conditioned Space	Base	None	Base	Base	Base
Cooling Setpoint	74F	Base	Base	Base	Base	Base
Heating Setpoint	70F / 62F	Base	Base	Base	Base	Base
Water Heater	Gas / Propane, Hi-eff	HPWH	HPWH	HPWH	HPWH	HPWH
Lighting	100% LED	Base	Base	Base	Base	Base
Stove	Gas / Propane	Induction El.	Induction El.	Induction El.	Induction El.	Induction El.
Clothes Dryer	Gas / Propane	Electric	Electric	Electric	Electric	Electric
Plug Loads	National Ave	Base	Base	Base	Base	Base
Heating Equip Capacity	60 MBH	60 MBH	60 MBH	60 MBH	30 MBH	30 MBH
Cooling Equip Capacity	4.5 Tons	4.5 tons	4.5 tons	4.5 tons	3 tons	3 tons
	Yellow Blocks Indicate Options that Vary from Base Case					

Heating Source Comparison



Based on Utility Rates as of Jan 31, 2022 for Eversource Electric and Gas, Default Service

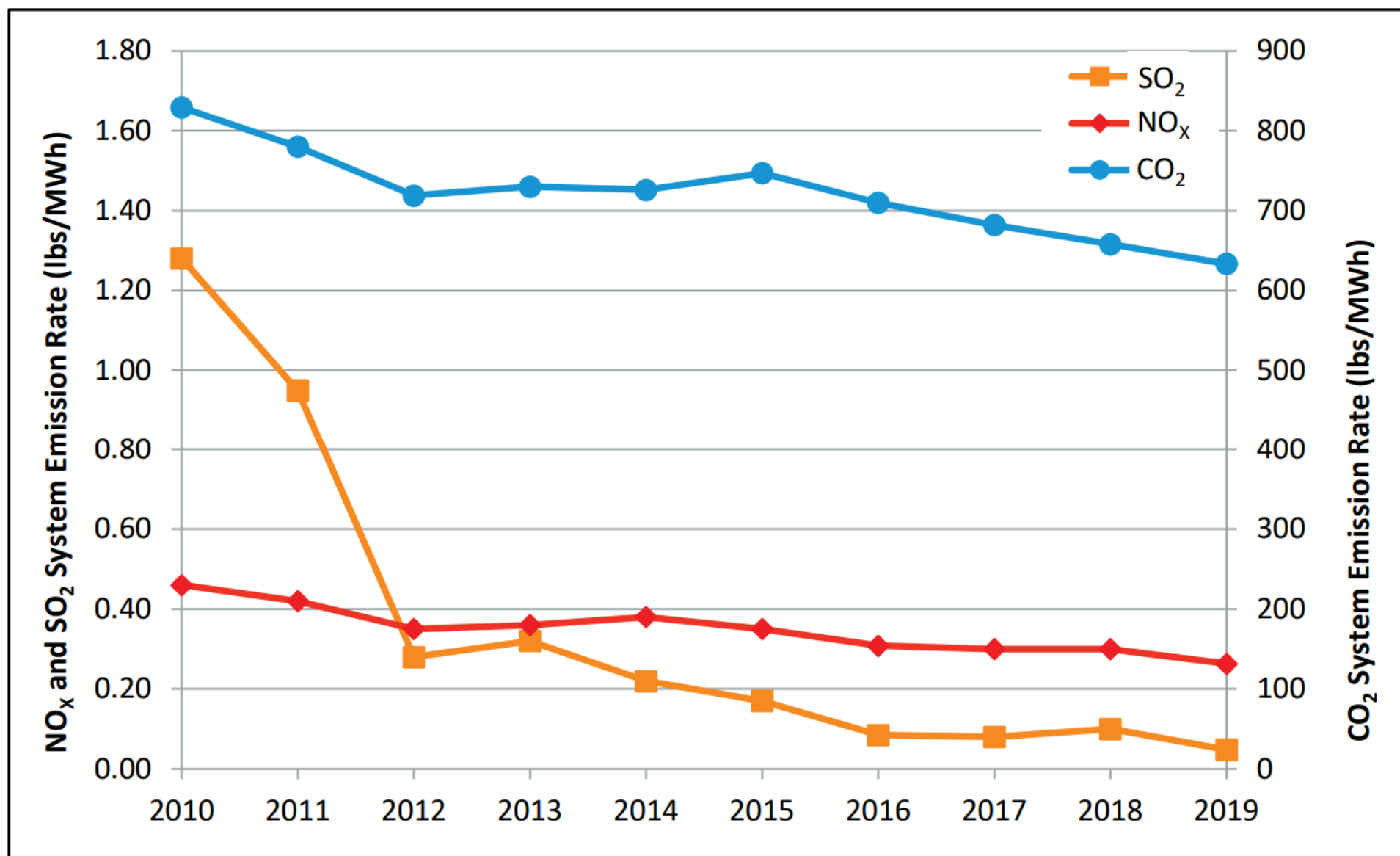
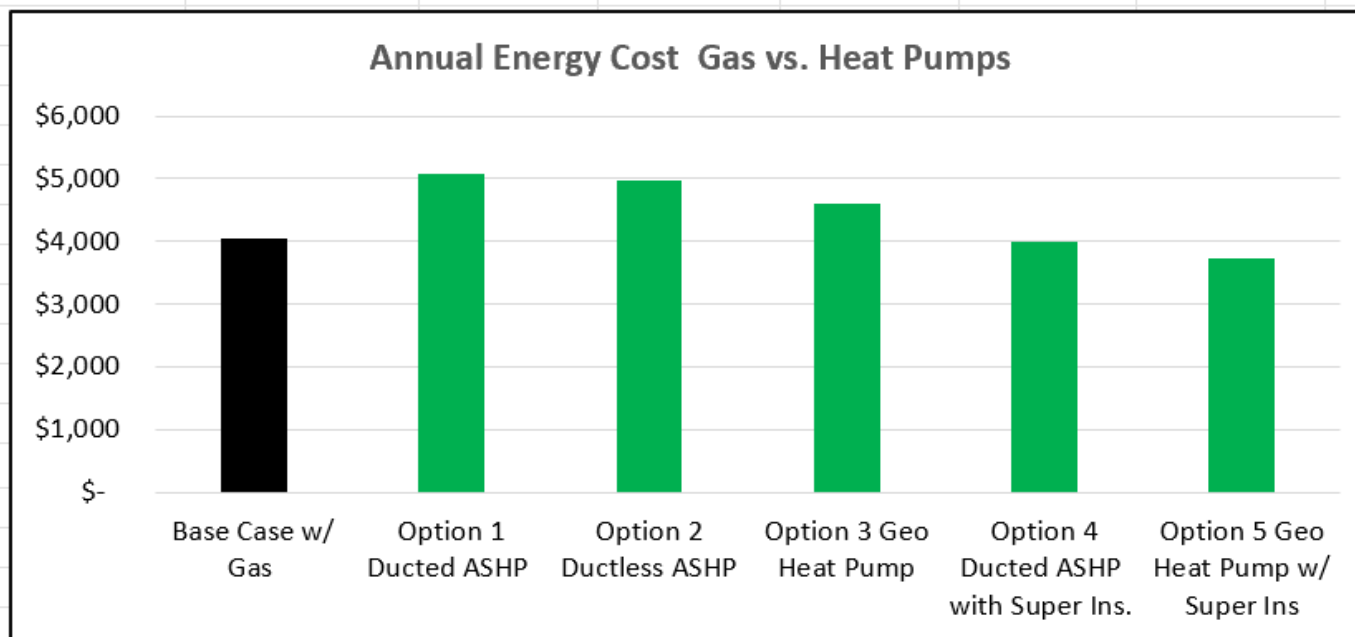


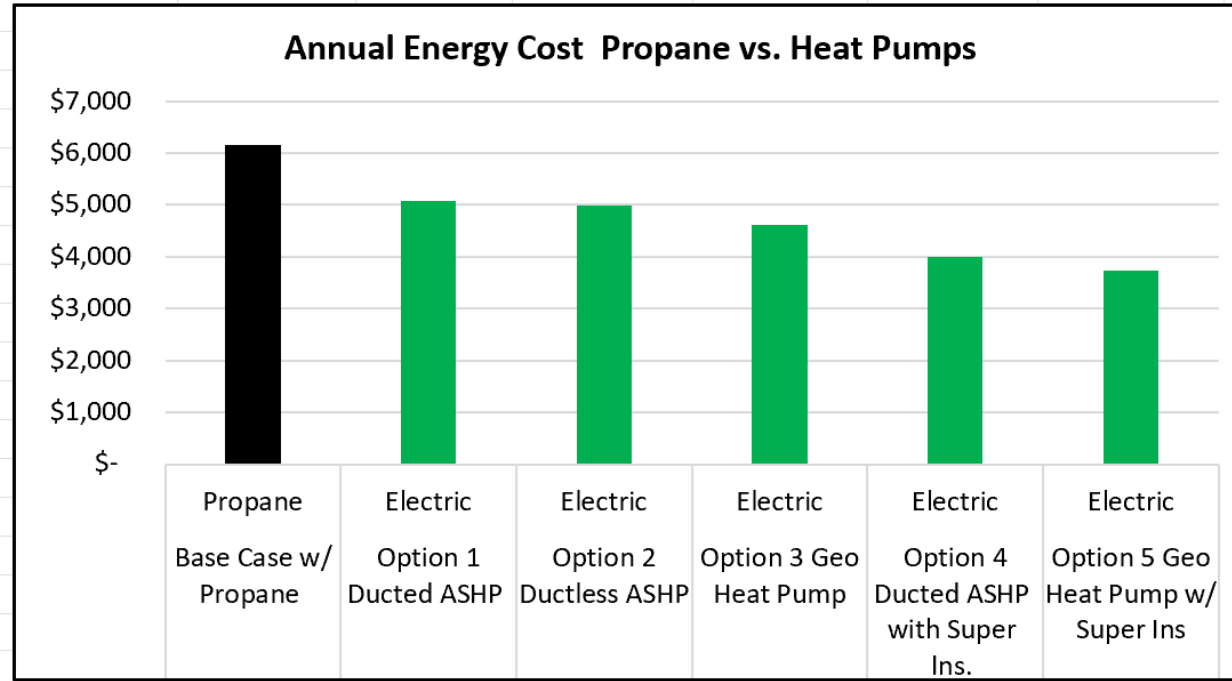
Figure 5-4: ISO New England system annual average generator emission rates, 2010 to 2019 (lbs/MWh).

New Construction Base Case = Gas Heat



Add Heat Pump	Cooling Capacity (Tons)	4.5	4.5	4.5	4.5	3	3
	Heating Capacity (MBH)	60	60	60	60	30	30
	Annual Energy Cost w/o Solar (\$/Yr)	\$ 4,039	\$ 5,067	\$ 4,977	\$ 4,613	\$ 3,995	\$ 3,740
	Annual Energy Savings w/o solar (\$/Yr)	NA	\$ (1,028)	\$ (938)	\$ (574)	\$ 44	\$ 299
	Construction Cost Change (\$)	NA	\$ -	\$ (5,000)	\$ 15,000	\$ 35,000	\$ 50,000
	Carbon Reduction w/o solar (%)	0%	25%	27%	32%	42%	45%
Add Solar	Solar System Capacity (KW)	5.9	13.0	12.8	11.8	10.2	9.6
	Solar Array Area (SF) 1200 SF Available	295	651	639	592	511	478
	Solar Installed Cost (after Incentives)	\$ 14,299	\$ 32,716	\$ 32,102	\$ 29,644	\$ 25,452	\$ 23,735
	Total Net Project Costs (Solar + Heat Pump)	\$ 14,299	\$ 32,716	\$ 27,102	\$ 44,644	\$ 60,452	\$ 73,735
	Annual Energy Cost (\$/Yr)	\$ 1,473	\$ -	\$ -	\$ -	\$ -	\$ -
	Annual Energy Savings (\$/Yr)	\$ 2,566	\$ 4,039	\$ 4,039	\$ 4,039	\$ 4,039	\$ 4,039
	Carbon Reduction with solar (%)	34%	100%	100%	100%	100%	100%

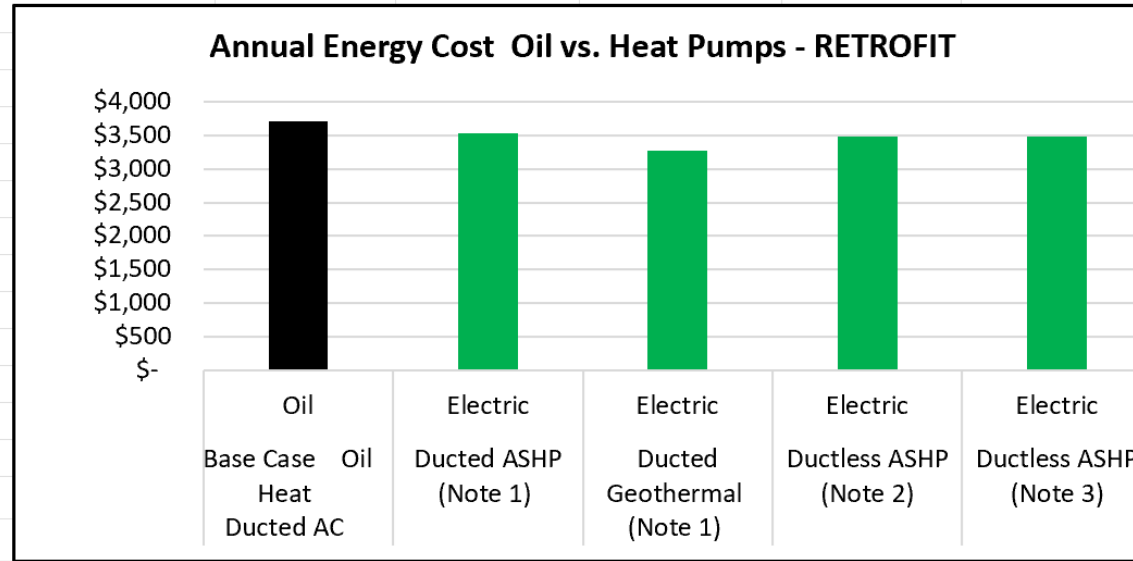
New Construction Base Case = Propane Heat



Add Heat Pump	Cooling Capacity (Tons)	4.5	4.5	4.5	4.5	3	3
	Heating Capacity (MBH)	60	60	60	60	30	30
	Annual Energy Cost w/o Solar (\$/Yr)	\$ 6,146	\$ 5,067	\$ 4,977	\$ 4,613	\$ 3,995	\$ 3,740
	Annual Energy Savings w/o solar (\$/Yr)	NA	\$ 1,079	\$ 1,169	\$ 1,533	\$ 2,151	\$ 2,406
	Construction Cost Change (\$)	NA	\$ -	\$ (5,000)	\$ 15,000	\$ 35,000	\$ 50,000
	MASS Save Incentive (\$)	\$ -	\$ 10,000	\$ 10,000	\$ 15,000	\$ 10,000	\$ 15,000
	Net Construction Cost (\$)	NA	\$ (10,000)	\$ (15,000)	\$ -	\$ 25,000	\$ 35,000
	Carbon Reduction w/o solar (%)	0%	34%	35%	40%	48%	52%
Add Solar	Solar System Capacity (KW)	5.9	13.0	12.8	11.8	10.2	9.6
	Solar Array Area (SF) 1200 SF Available	294	651	639	592	511	478
	Solar Installed Cost (after Rebate)	\$ 14,239	\$ 32,716	\$ 32,102	\$ 29,644	\$ 25,452	\$ 23,735
	Total Net Project Costs	\$ 14,239	\$ 22,716	\$ 17,102	\$ 29,644	\$ 50,452	\$ 58,735
	Annual Energy Cost (\$/Yr)	\$ 3,581	\$ -	\$ -	\$ -	\$ -	\$ -
	Annual Energy Savings	\$ 2,565	\$ 6,146	\$ 6,146	\$ 6,146	\$ 6,146	\$ 6,146
	Carbon Reduction with solar (%)	30%	100%	100%	100%	100%	100%

Retrofit

Base Case =
Oil Heat



Add Heat Pump	Cooling Capacity (Tons)	3 tons	3 tons	3 tons	3 tons
	Heating Capacity (MBH)	45.0	45.0	45.0	45.0
	Annual Energy Cost w/o Solar (\$/Yr)	\$ 3,711	\$ 3,538	\$ 3,270	\$ 3,493
	Annual Energy Savings w/o solar (\$/Yr)	NA	\$ 173	\$ 441	\$ 218
	Added Construction Cost (\$)	NA	\$ 5,000	\$ 20,000	\$ 5,000
	MASS Save Incentive (\$)	\$ -	\$ 10,000	\$ 15,000	\$ 10,000
	Net Construction Cost (\$)	-	\$ (5,000)	\$ 5,000	\$ (5,000)
	Carbon Reduction w/o solar (%)	\$ -	54%	57%	54%
Add Solar	Solar System Capacity (KW)	4.0	9.0	8.3	8.9
	Solar Array Area (SF) 1000 SF Available	201	451	416	445
	Solar Installed Cost (after Rebate)	\$ 9,428	\$ 22,362	\$ 20,553	\$ 22,053
	Total Net Project Costs	\$ 9,428	\$ 17,362	\$ 25,553	\$ 17,053
	Annual Energy Savings	\$ 1,760	\$ 3,711	\$ 3,711	\$ 3,711
	Carbon Reduction with solar (%)	21%	100%	100%	100%

Note 1: Construction cost assumes ducted AC system needs to be replaced so Cost is the incremental cost of Heat Pump vs Split DX AC

Note 2: Construction cost for ductless Heat Pump option assumes house had no AC and Owner was going to install ductless AC (not heat pump)

Note 3: Same as Note 1, plus credit for cost of boiler replacement avoided

Summary Table 1 - Stretch Code Compliant house. Heat Pump & Solar in lieu of fossil fuel heat

	Item	Compared to Gas	Compared to Propane	Comment
Add Heat Pump	Annual House Total Energy Cost with ASHP	25% Higher	18% Lower	Approx \$1,028/Yr higher compared to gas, and approximately \$1,079/Yr lower compared to propane
	Cost of Construction for ASHP	~ Same or Less than Gas	~ At Least \$10,000 Less than Propane	Higher cost of high efficiency heat pumps is offset by elimination of gas furnace, all gas piping, combustion and flue piping. See Note 1 Below
	Carbon Emissions (Before adding solar)	25% Reduction	34% Reduction	If site is not compatible for Solar, House will benefit from lower carbon emissions over time as electric grid provides more renewable power
Add Solar PV	Solar PV Capacity	13 KW		No Shading, +/- 30 Deg due South, 100% of annual energy needed
	Roof Area Req'd	651 SF		1,200 SF Available in Modeled House
	Solar PV System Cost	\$32,716	\$32,716	\$3.50/Watt, Includes Tax Credits
	Net Cost Heat Pump & Solar PV	\$32,716	\$32,716	Net Project Cost includes all incentives/credits available
	Annual House Total Energy Savings	\$4,039	\$6,146	Savings based on Base Case energy cost avoided
	Carbon Emissions	100% Reduction		House achieves Net Zero Energy target

Note 1: MASS Save Incentive of \$10,000/\$15,000 available for Installation of Air Source Heat Pump/Geothermal Heat Pump in Lieu of Propane

Summary Table 2 - Super-Insulated house. Heat Pump & Solar in lieu of fossil fuel heat

	Item	Compared to Gas	Compared to Propane	Comment
Add Heat Pump	Annual House Total Energy Cost with ASHP	2% Lower	35% Lower	Approx \$44 Lower compared to gas, and approximately \$2,151 lower compared to propane
	Added Cost of Higher Efficiency Envelope	\$35,000 Higher (est.)	\$25,000 Higher (est)	See Slide with Table showing insulation changes. Includes savings for smaller HVAC equipment capacity and \$10,000 Incentive for Heat Pump (propane only)
	Carbon Emissions (Before adding solar)	42% Reduction	48% Reduction	If site is not compatible for Solar, House will benefit from lower carbon emissions over time as electric grid provides more renewable power
Add Solar PV	Solar PV Capacity	10.2 KW		No Shading, +/- 30 Deg due South, 100% of annual energy needed
	Roof Area Req'd	511 SF		1,200 SF Available in Modeled House
	Solar PV System Cost	\$25,452		\$3.50/Watt, Includes Tax Credits
	Net Cost Heat Pump & Solar PV	\$60,452	\$50,452	Net Project Cost includes all incentives/credits available
	Annual Energy Savings	\$4,039	\$6,146	Savings based on Base Case energy cost avoided
	Carbon Emissions	100% Reduction		House achieves Net Zero Energy target

Note 1: MASS Save Incentive of \$10,000/\$15,000 available for Installation of Air Source Heat Pump/Geothermal Heat Pump in Lieu of Propane

Note 2: Additional savings available for house designs that can meet a lower HERS rating. Review this with your HERS consultant

Summary Table 3 - Super-Insulated house. Geothermal Heat Pump in lieu of fossil fuel heat

	Item	Compared to Gas	Compared to Propane	Comment
Add Heat Pump	Annual House Energy Cost with Geothermal	8% Lower	40% Lower	Approx \$660 Lower compared to gas, and approximately \$2,800 lower compared to propane
	Added Cost of Higher Efficiency Envelope & Geothermal System	\$50,000	\$35,000	See Slide with Table showing insulation changes. Includes savings for smaller HVAC equipment capacity. Includes MASS Save Incentive for Geo HP. Federal Tax Credit for Geothermal systems includes cost of entire HVAC system (propane only)
	Carbon Emissions (Before adding solar)	45% Reduction	52% Reduction	If site is not compatible for Solar, House will benefit from lower carbon emissions over time as electric grid provides more renewable power
Add Solar PV	Solar PV Capacity	9.6 KW		No Shading, +/- 30 Deg due South, 100% of annual energy needed
	Roof Area Req'd	478		1,200 SF Available in Modeled House
	Solar PV System Cost	\$23,735		\$3.50/Watt, Includes Tax Credits
	Net Cost Heat Pump & Solar PV	\$73,735	\$58,735	Net Project Cost includes all incentives/credits available
	Annual Energy Savings	\$4,039	\$6,146	Savings based on Base Case energy cost avoided
	Carbon Emissions	100% Reduction		House achieves Net Zero Energy target

Note 1: MASS Save Incentive of \$10,000/\$15,000 available for Installation of Air Source Heat Pump/Geothermal Heat Pump in Lieu of Propane

Note 2: Additional savings available for house designs with HERS rating <35.

Summary Table 4 - Retrofit 2,600 SF Existing House with Oil Heat to Heat Pump

(After Mass Save Weatherization)

	Item	Convert to Ducted ASHP (Note 1)	Convert to Ducted or Ductless ASHP (Note 2)	Comment
Add Heat Pump	Annual House Energy Cost with ASHP	4% Lower	13% Lower	Approx \$150 Lower with Ducted ASHP, \$400 lower cwith Ductless ASHP
	Net Cost of Conversion including incentives and avoided cost	(\$5,000)	(\$18,000)	Red Values are negative costs. Includes Incentives and avoided costs (see notes 1,2 below)
	Carbon Emissions (Before adding solar)	54% Reduction	54% Reduction	If site is not compatible for Solar, House will benefit from lower carbon emissions over time as electric grid provides more renewable power
Add Solar PV	Solar PV Capacity	9 KW		No Shading, +/- 30 Deg due South, 100% of annual energy needed
	Roof Area Req'd	451 SF		1,000 SF Available in Modeled House
	Solar PV System Cost	\$22,362		\$3.50/Watt, Includes Tax Credits
	Net Cost Heat Pump & Solar PV	\$17,362	\$4,362	Cost of Solar + Net Cost of HVAC Upgrade
	Annual Energy Savings	\$3,711		Savings based on fuel cost avoided
	Carbon Emissions	100% Reduction		House achieves Net Zero Energy target

Note 1: Cost of conversion assumes AC system needs to be replaced, so the Cost is the incremental cost of Heat Pump system vs Split DX

Note 2: Same as Note 1, plus the Boiler needs to be replaced, so the Cost is the incremental cost of Heat Pump system vs Split DX and new boiler

Summary

- If you are building a new home, build with a cold-climate electric heat pump system for your heating/cooling.
- This is not the “old” heat pump technology of 20+ years ago. It is built to be efficient in a New England environment
- Install an air-source heat pump for Domestic HW and an induction stove for cooking
- The construction cost is less than or equal to a conventional fossil fuel house.
- In many cases, this will also reduce your monthly utility bills.
- You will improve the comfort and indoor air quality of your home
- Work with your architect and HERS rater to explore options for increasing the efficiency of your new home with enhanced insulation levels and air tightness beyond the code requirement.
- Add solar PV to your roof if you have a good exposure.
- Make sure your roof lines are designed to accommodate the installation of the solar PV array.
- With electric heat pumps and solar PV, you can make your new house a “Net Zero Energy” (NZE) home without radically changing the look of the house
- Even if your house doesn’t lend itself to a solar PV system, with heat pumps you will be building with the future in mind, where our electric grid is becoming more carbon neutral with renewable energy sources.
- An all-electric home (especially a NZE home) will have increasing re-sale value over similar sized fossil-fueled homes.
- Check for Federal, State, and Utility Company credits and incentives to lower the cost of your clean energy investments.
- When you build a home, you are building something that will be around for 50-100 years.
- Do it Smart, Do it Right.....now is the opportunity.



High Performance Building Design

Do it Smart, Do it Right

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