BetterBuilt[NW]

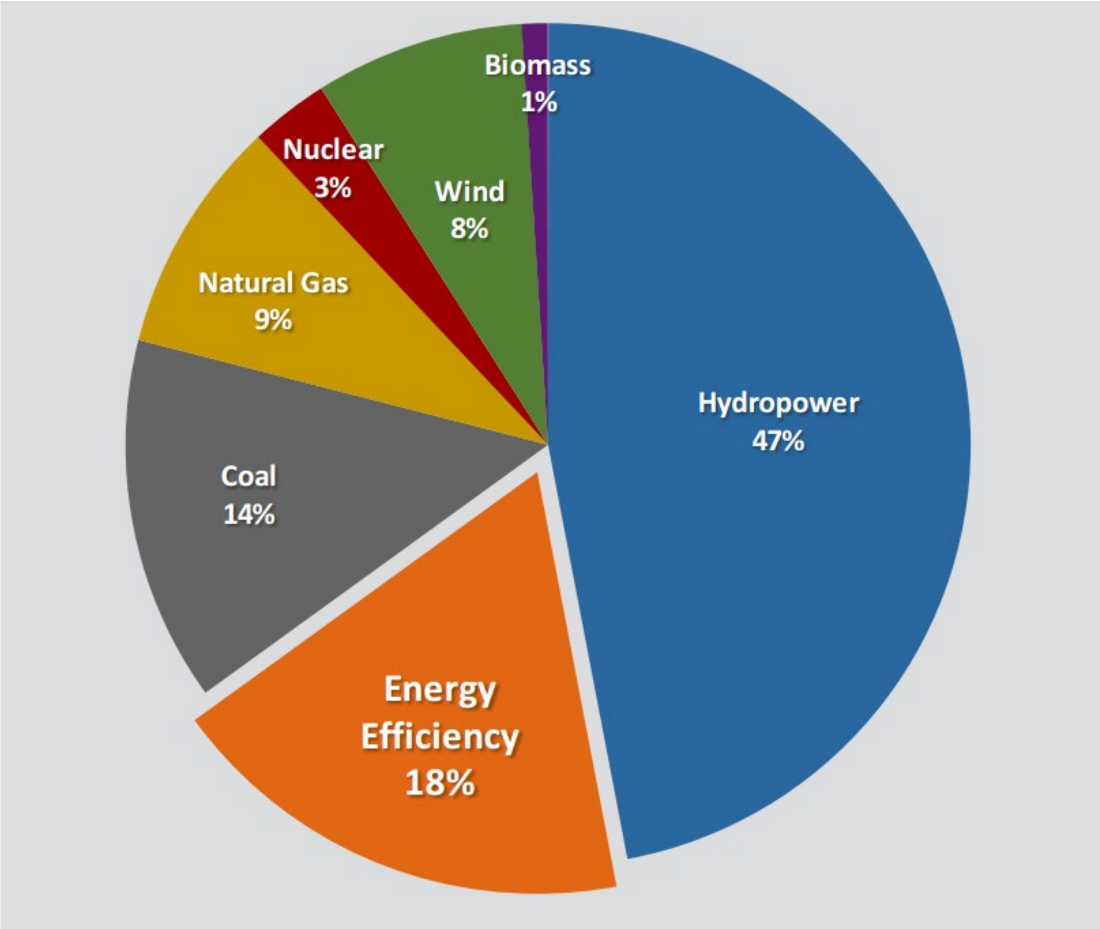
Homes of the Immediate Future

Sensible approaches in use today

October 12, 2018

Introduction and General Design Approach

Understanding Impacts



Since 1978, the region has met over half of its load growth through efficiency resources

$4 billion saved in energy bills

6,000 aMw – enough to power 5 cities the size of Seattle

In 2017, 20% of the overall US energy consumption was from residential buildings

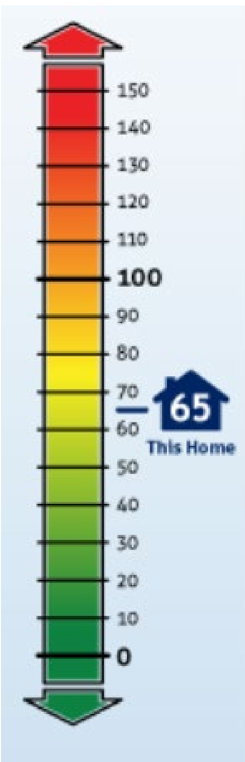
Image and data courtesy of NW Power & Conservation Council

Reducing Energy Use in Residential Structures

- Must be Simple and Cost Conscious
    - Use commonly available materials and transferrable skills
    - Achievable in increments
    - Homeowners need to be able to understand and “run” their house
    - Affordable: having an energy efficient home should be accessible to all prospective homeowners across the market
    - Need to be visually appealing, livable, and durable

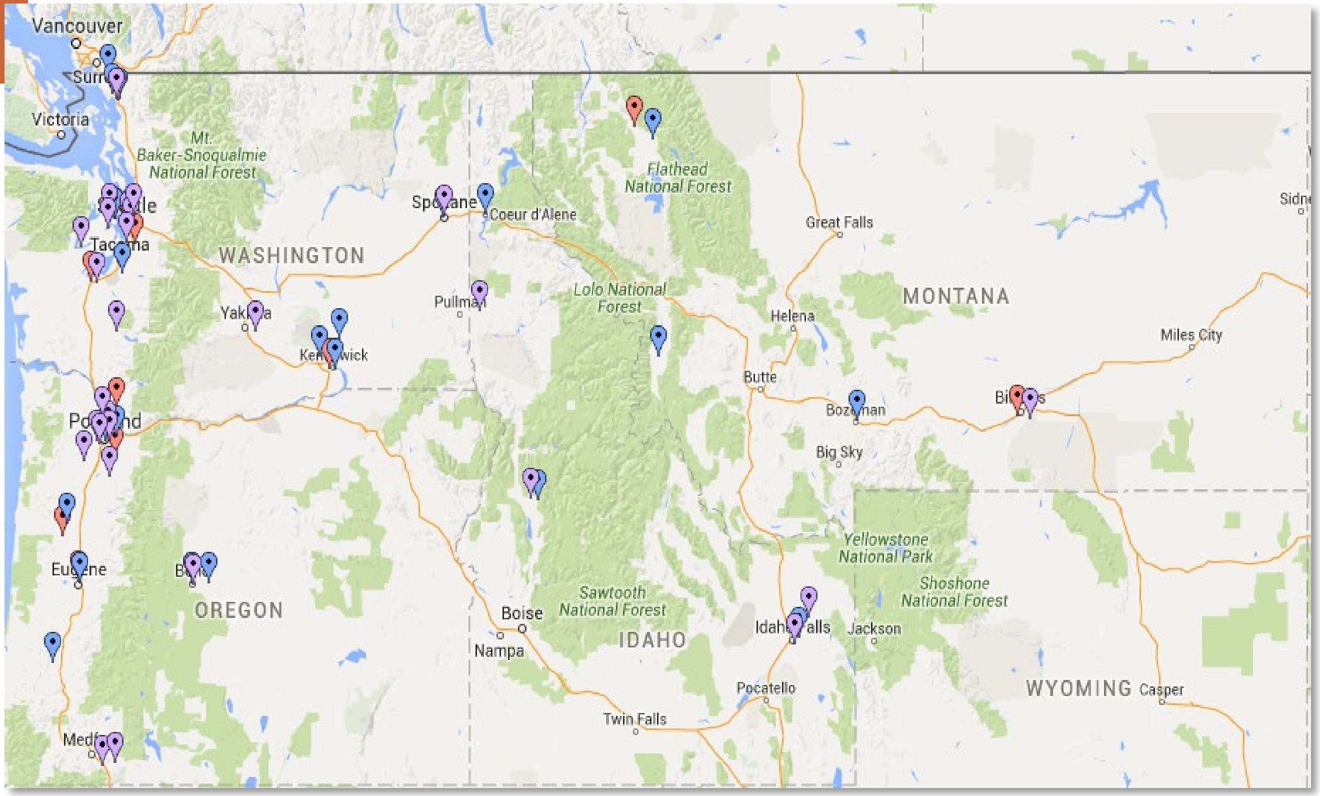
Reducing Energy Use in Residential Structures

- Must produce proven results



  - Look beyond certifications, HERS, energy performance scores, and new homes incentive programs
    - These tools help us quantify potential savings but doesn't always mean the house will perform as designed
    - Chasing the score or incentive target can overshadow real performance
  - A combination of modeling tools, no nonsense/proven techniques, and quality installations all contribute to how the home will perform for years to come

Next Step Home Pilot Program



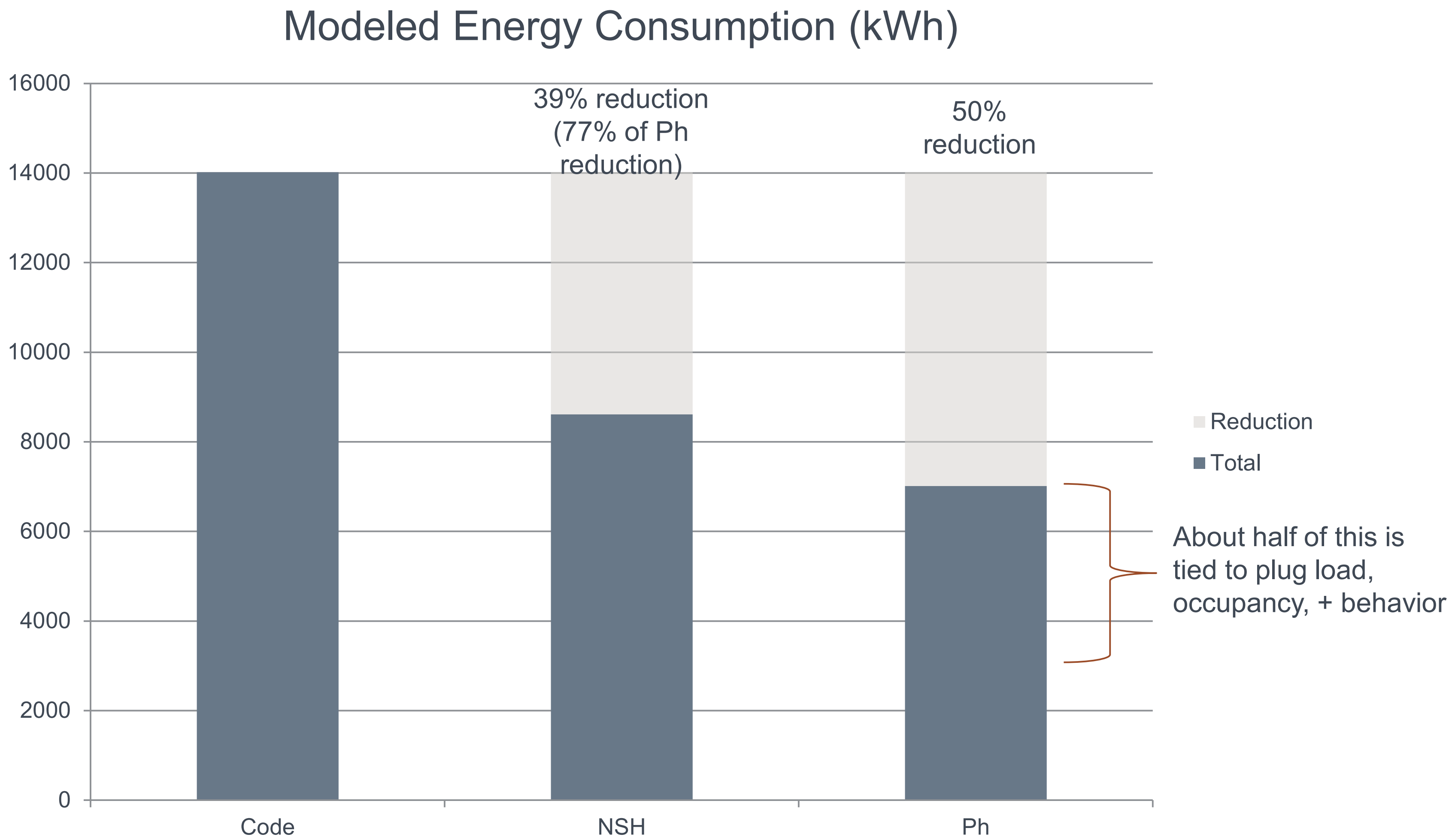
What Does a Typical Pilot Home Look Like?

- Shell
  - Above code wall with reduced thermal bridging
  - Conventional air sealing with attention to detail ~ 2.5 ACH50
  - .25 windows
  - R-60 attic with partial raised heel
  - R-20 stem wall or slab
- Mechanicals
  - High efficiency HRV
  - Mini-split or ducts inside
  - Heat pump water heater or drain waste heat recovery and efficient plumbing layout

What Did We Learn?

- Spec accomplishes savings objective
- Spec is highly buildable
  - Feasible to a wide range of builders including code level builders, affordable housing builders, high volume and custom builders, and owner builders
- Feasible at a reasonable cost
  - Cost-optimized paths achievable at $6,500 -$8,500 cost increase over code build

The Most Bang for the Buck



Efficient Walls

Advanced Walls

- Typical Overall U-value Ranges
    - Optimized 2x6 wall, no rigid: U- .050-.053
    - Optimized 2x6 wall, 1" rigid: U- .041-.045
- Getting U-values under .040 will usually require one of the following
    - Framing changes – double wall, etc.
    - More than 1" of rigid
    - Thicker SIPs or ICFs

Double or Staggered Stud Walls

Wall spec:

- Two 2x4-framed walls with 3½” gap between, blown cellulose insulation
- True conditioned crawlspace with ICF stemwall

Challenges:

- Air barrier framing
- Air sealing details

Success:

- 1.2 ACH50

Double Walls

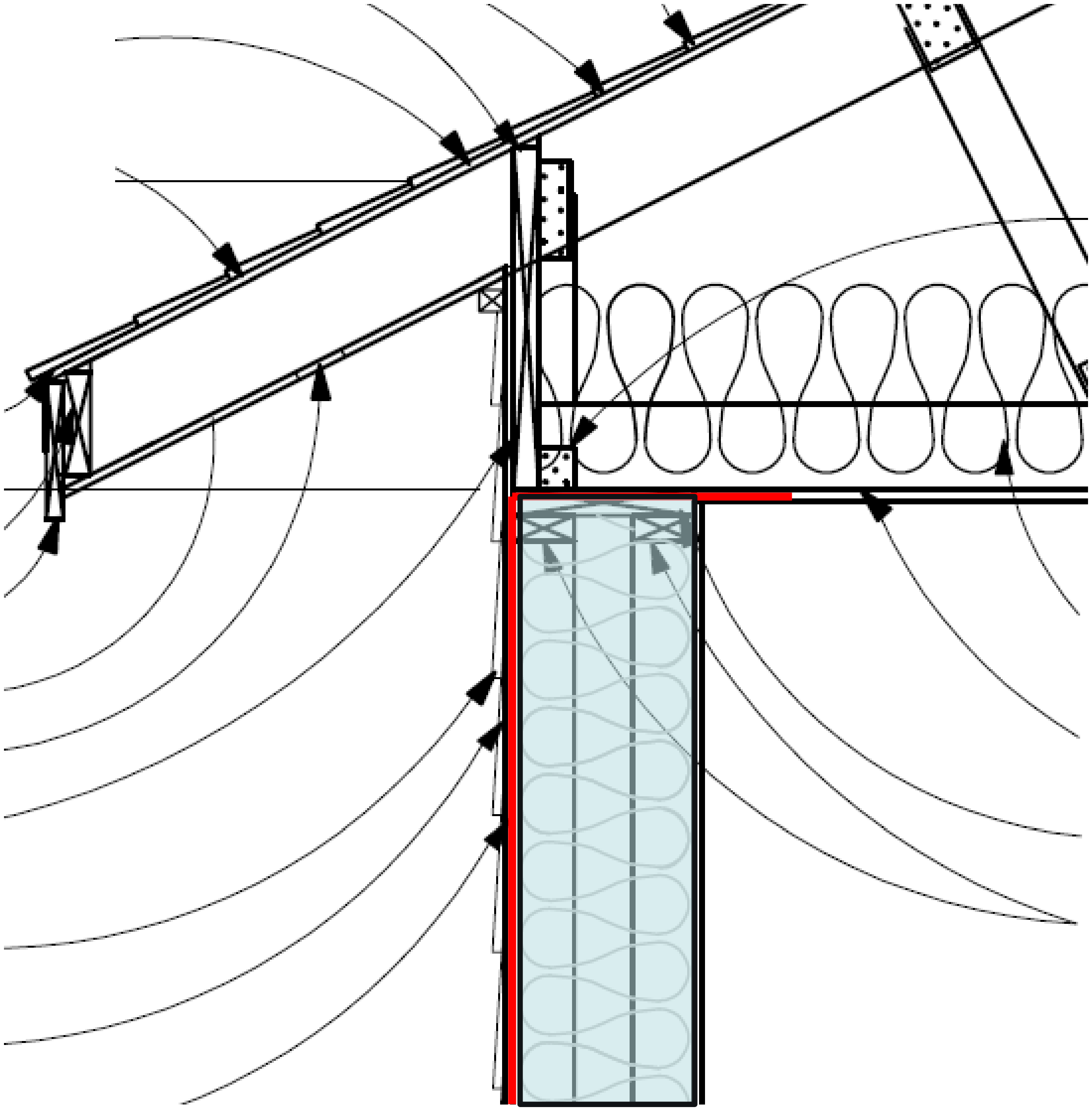
Pros

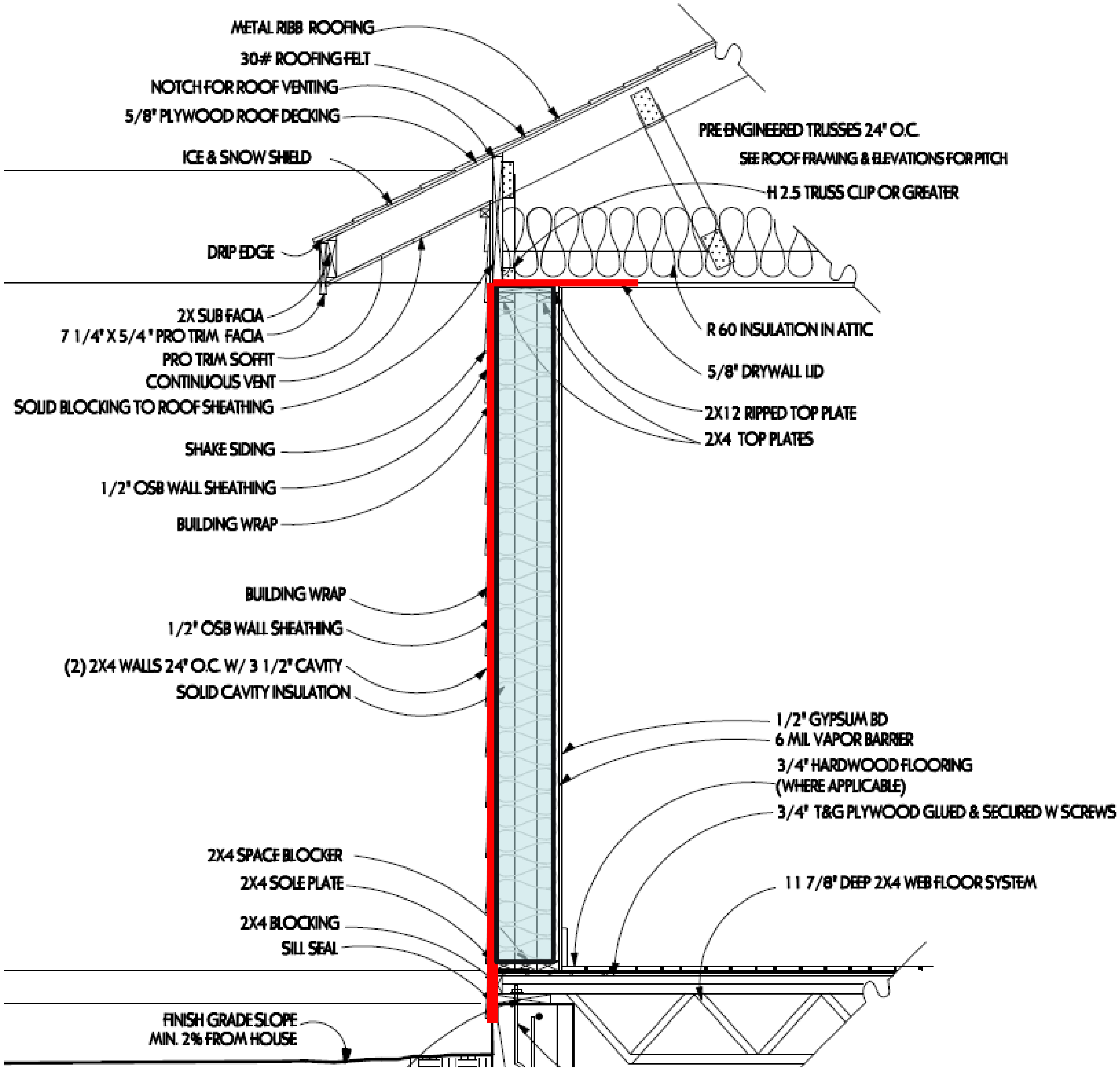
- Minimal learning curve, familiar detailing
- Low cost option
- Acoustics
- True double wall doesn't likely require engineering

Cons

- Reduces interior space
- Adds some complexity
- Dewpoint concerns (more on this later)
- Uses more lumber

True double wall is generally preferable to staggered stud assembly – required engineering, time to dry-in, subcontractor learning curve





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Adding Exterior Insulation

Original wall spec:

- 2x6 intermediate framed wall, 1" rigid foam sheathing, BIB wall cavities
- Needed to add R-value to the wall

Challenges:

- Siding attachment
- Window and doorjamb extensions
- Flashing details

Success:

- Modified all details for higher-performing wall without altering framing system

Adding Exterior Insulation

Pros

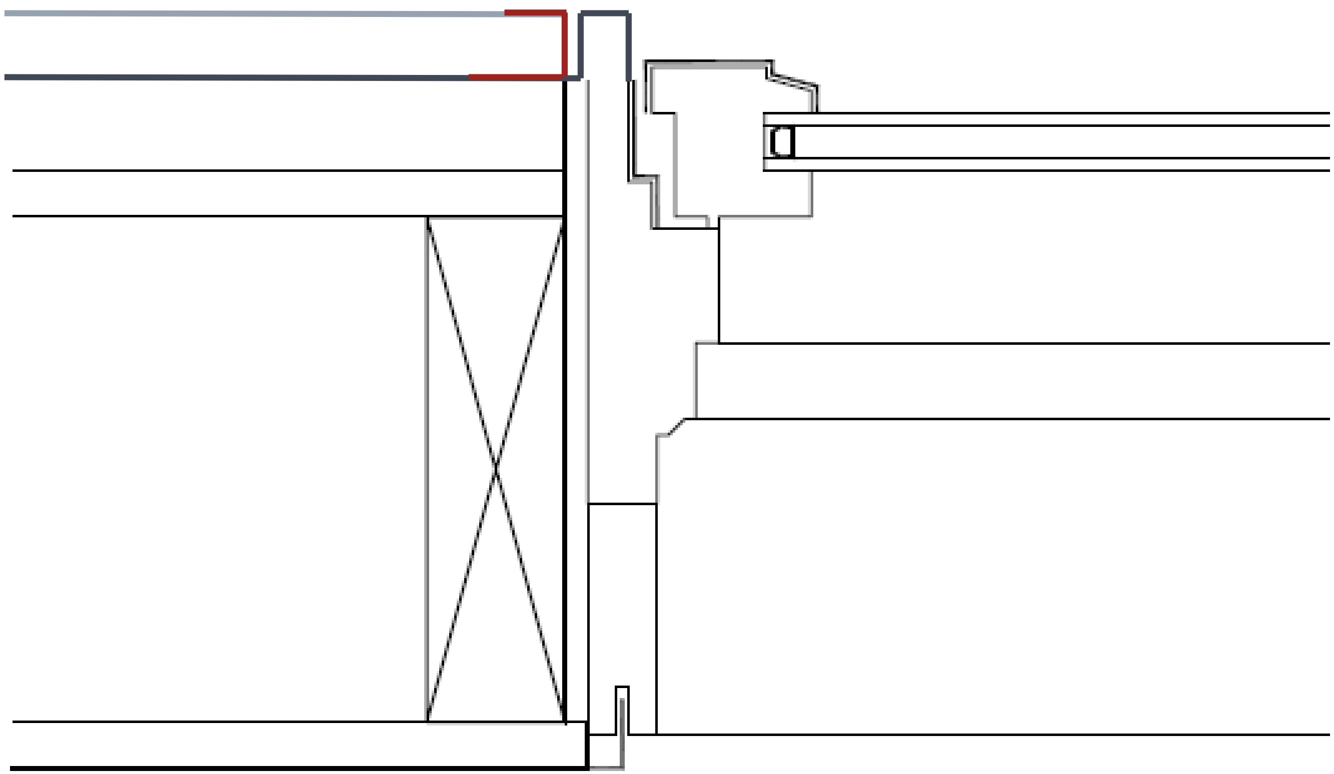
- Protects against condensation
- Redundant air control
- Easy to incorporate rain screens
- Easily replicable after learning curve

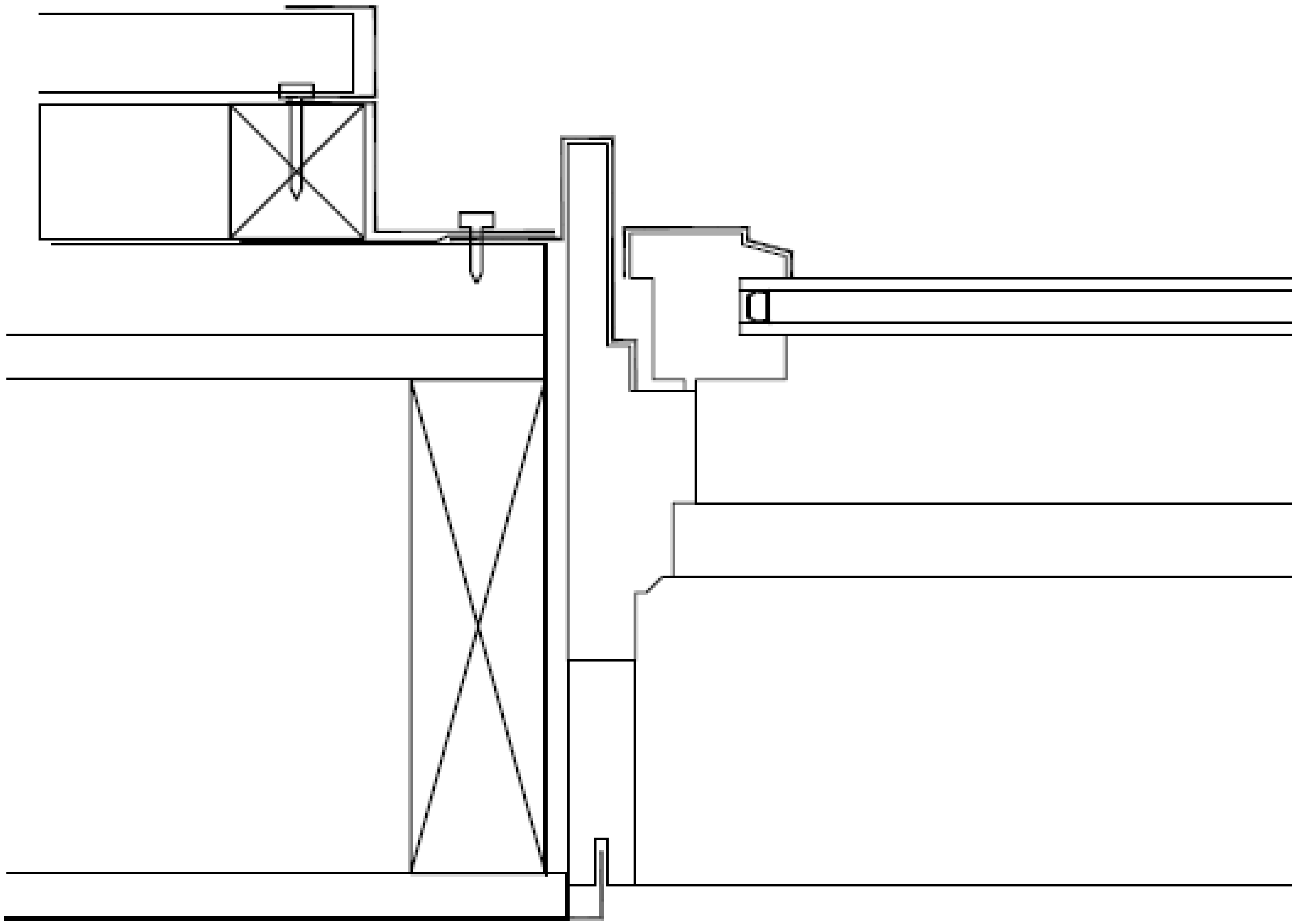
Cons

- Fastener length and siding warranty
- Additional strapping and sheeting steps
- Unfamiliar flashing and WRB details for subs
- Interior vapor barrier issues

Redundant air control – with staggered and taped seams, found homes generally turn out very tight. Details available on our Efficient Walls and Airtightness poster


Styrofoam
SCOREBOARD Insu





SIPs and ICFs

SIPs and ICFs

Pros

- Protects against condensation
- Good air control
- Easily replicable
- Standard exterior finishing processes

Cons

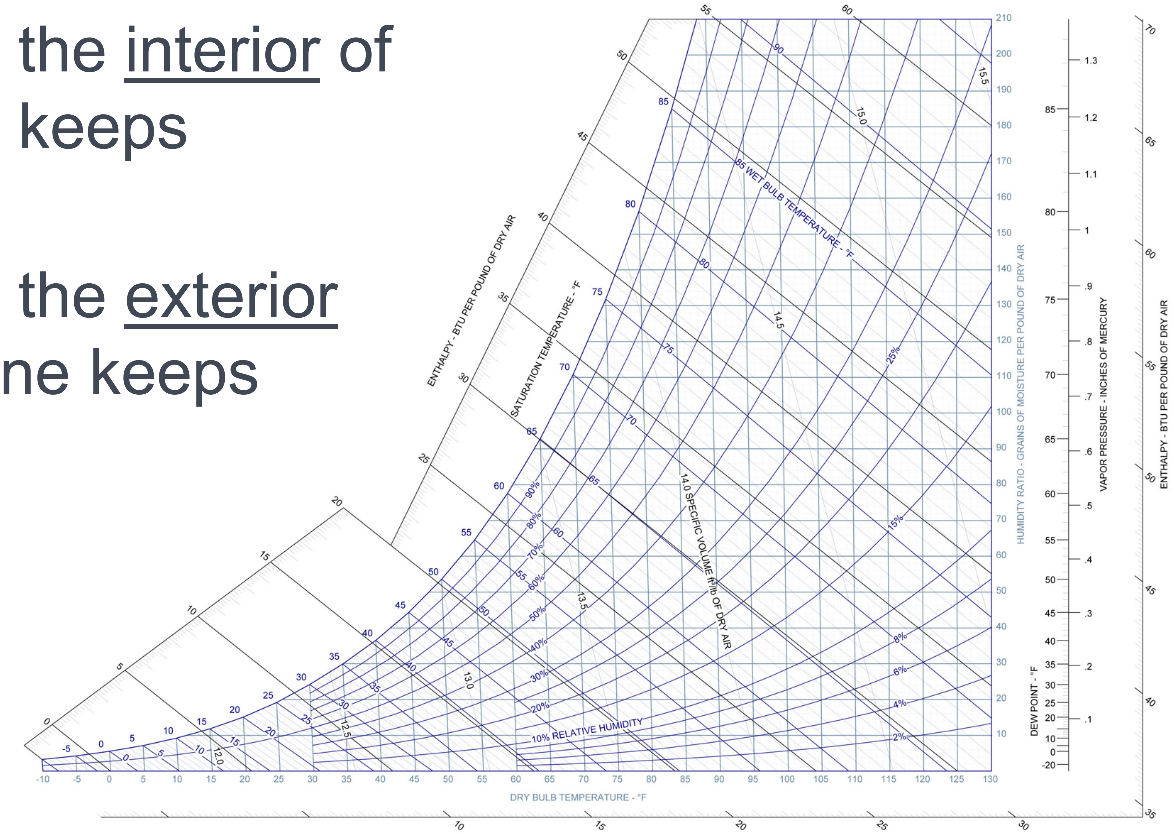
- Generally an "all-in" commitment
- Good detailing is critical for SIP roof

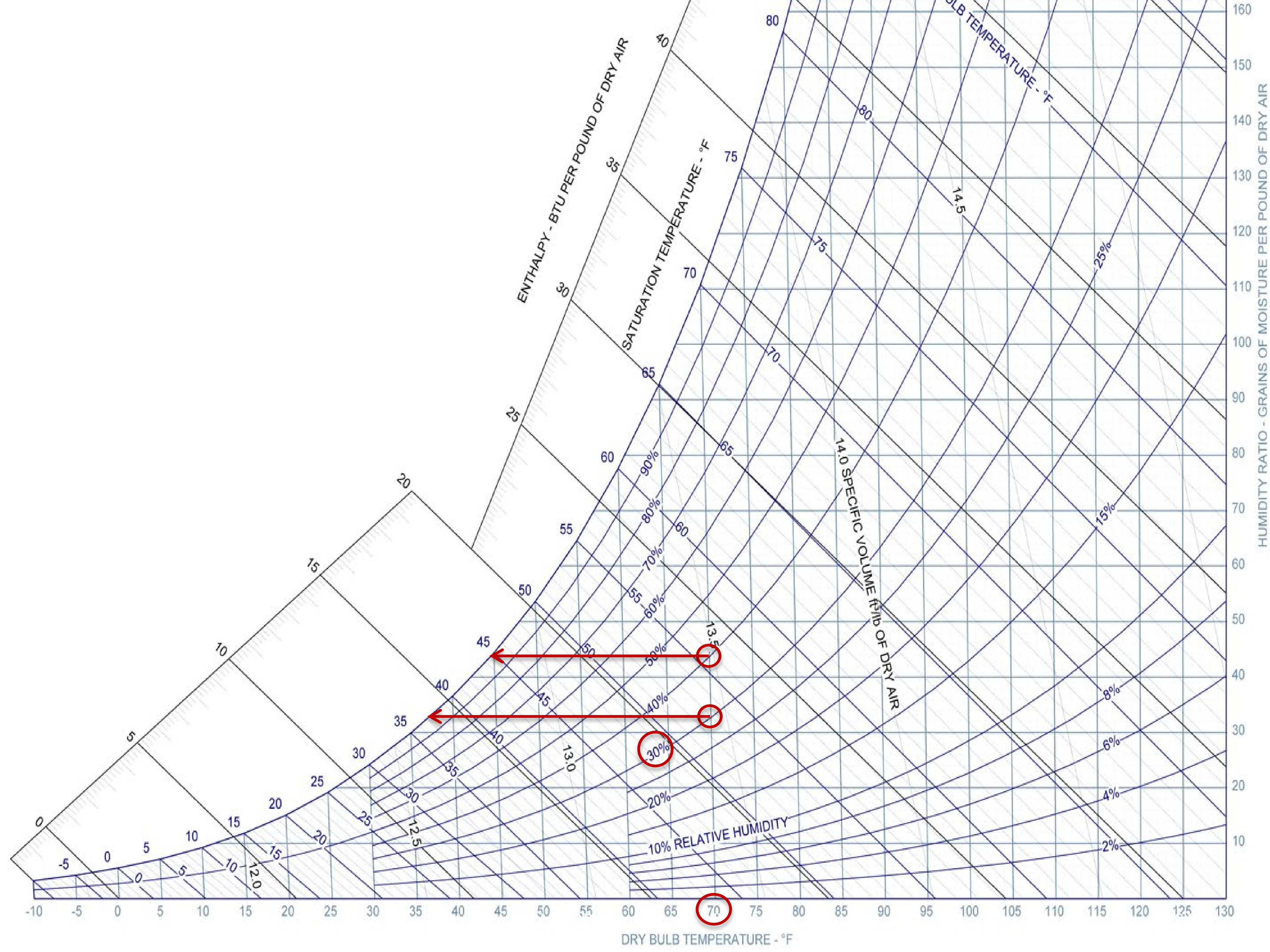
Days of SIP installation/fly-in can be hectic and intense working closely with a SIP contractor is a recommendable introductory step.

Moisture Control

Dewpoint

- Adding insulation to the interior of the sheathing plane keeps sheathing colder
- Adding insulation to the exterior of the sheathing plane keeps sheathing warmer





ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
WET BULB TEMPERATURE - °F
14.0 SPECIFIC VOLUME ft³/lb OF DRY AIR
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
10% RELATIVE HUMIDITY
20%
30%
40%
50%
60%
70%
80%
90%
25%
15%
8%
6%
4%
2%
DRY BULB TEMPERATURE - °F

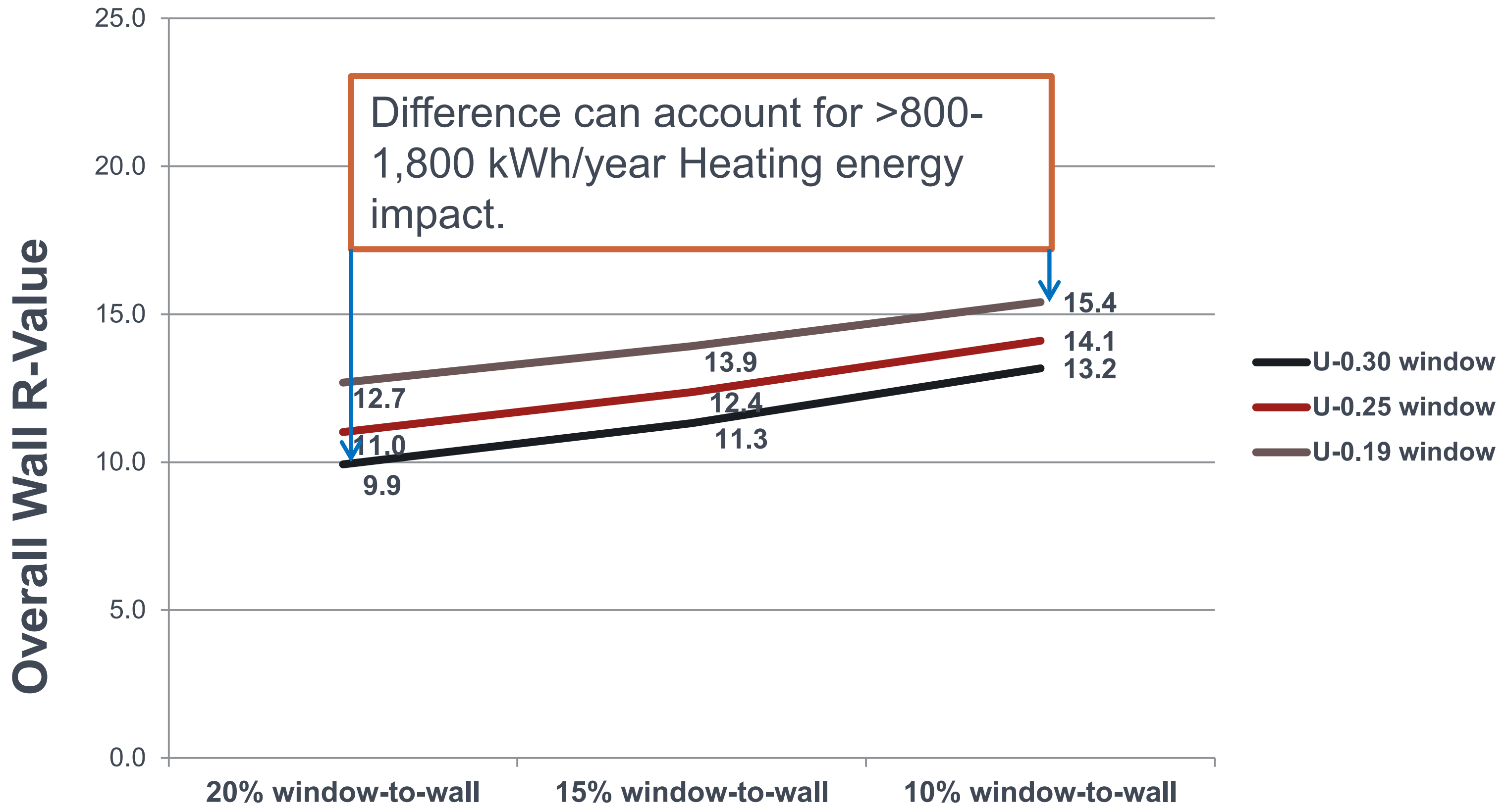
Window – Wall Balance

Better Window or Better Wall?

- Window area and window U-Value can have unexpected impacts to overall wall R-Value
- Understand the interactions when planning a shell upgrade
  - Window upgrades more critical with WTF ratios above 20%
  - Use a calculator: http://www.cascadiawindows.com/tools/r-value-u-value-calculator
  - Quote both wall and window upgrade packages and pick a match that balances savings and investment
  - Premium window lines often have significantly higher incremental upgrade cost than builder grade window lines

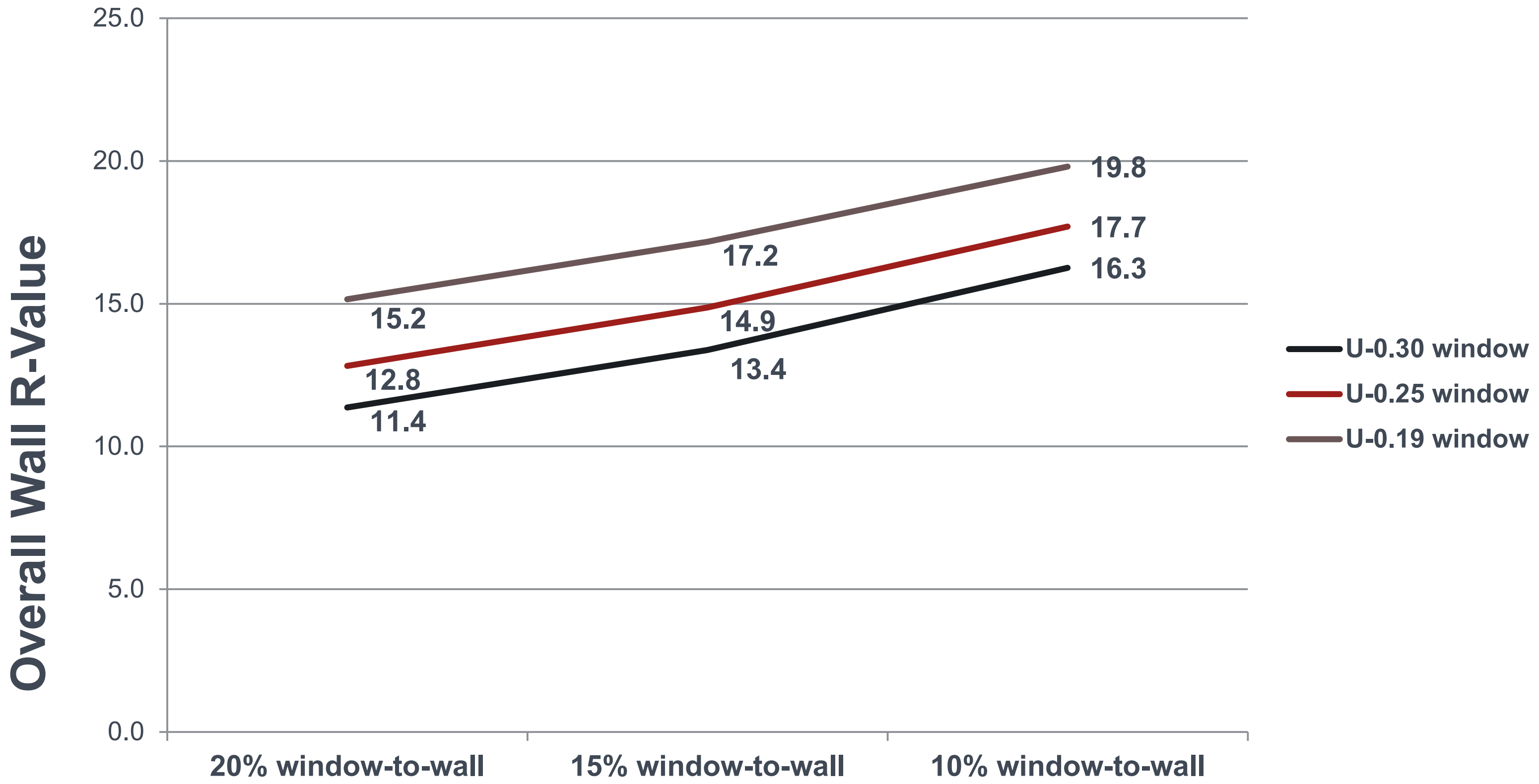
Thermal Control

Impacts of window selection Nominal R-23 wall (U-0.051)



Thermal Control

Impacts of window selection Nominal R-30 wall (U-0.035)



Ventilate for Good IAQ

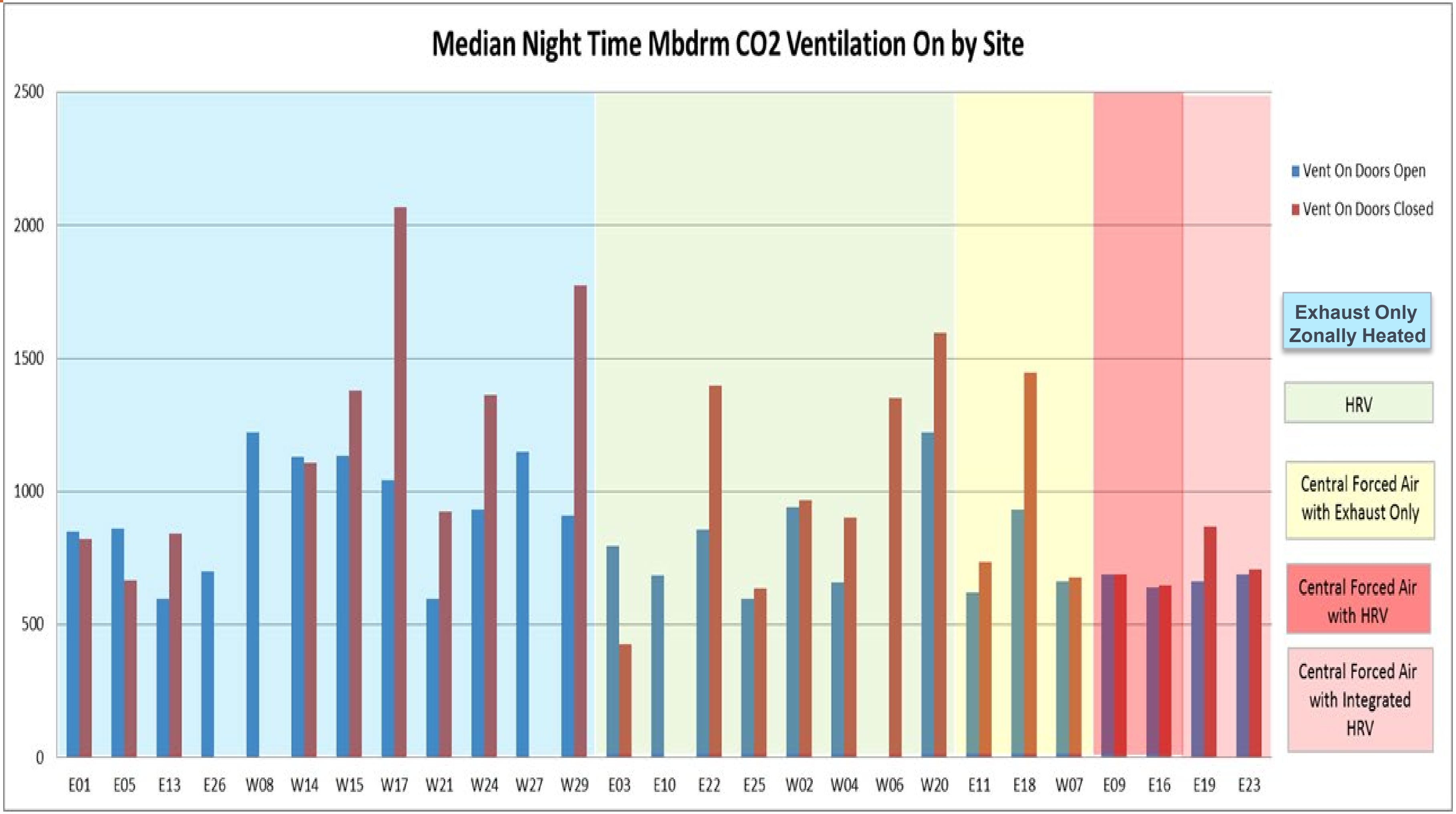
Ventilation Effectiveness Studies

- 2013 NEEA/WSU Ventilation Effectiveness Study
  - 29 homes
  - Multiple ventilation system types
  - System on, system off, doors open, doors closed
  - Monitored CO_2, temperature, and humidity
- NEEA Next Step Home Pilot Phase I and II
  - 40+ homes, all with HRVs
  - 13 months of room by room monitoring including temp, Rh, and VOCs

What was Learned?

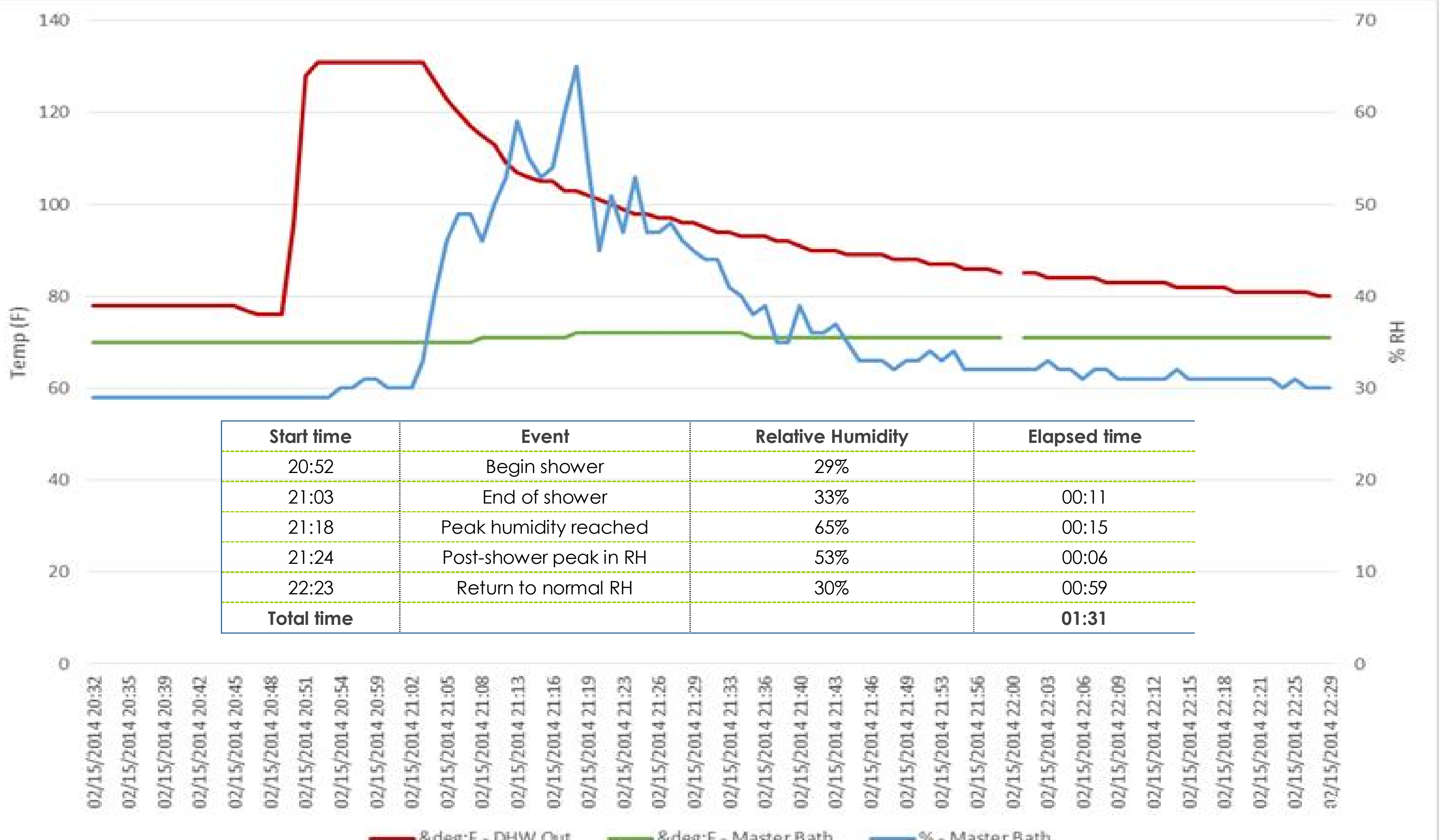
- Without carefully designed ventilation systems, indoor air quality diminishes as homes gets tighter
    - Air quality diminishes further when doors are closed
    - We often focus more on the air tightness than we do the ventilation system
- Plan ventilation strategy at design phase
- Run ventilation continuously
- Ensure a direct supply of fresh air to each room
    - Exhaust only systems suffer when doors are closed especially important in zonal homes
- Approach ventilation as a health and quality of life measure, not an energy efficiency measure.

Nighttime Bedroom CO2 Levels



Bath Ventilation

HRV running continuously in low speed (27W)



Start time	Event	Relative Humidity	Elapsed time
20:52	Begin shower	29%	
21:03	End of shower	33%	00:11
21:18	Peak humidity reached	65%	00:15
21:24	Post-shower peak in RH	53%	00:06
22:23	Return to normal RH	30%	00:59
Total time			**01:31**

Bath Ventilation

HRV running in boost mode with a timer

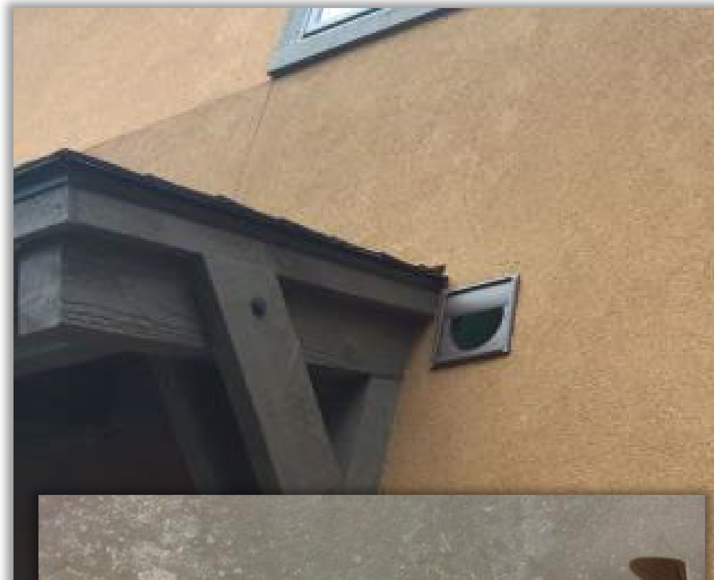
Start time	Event	Relative Humidity	Temperature	Elapsed time
05:44:00	Begin shower	45%	66.0 F	
05:54:00	Peak humidity reached	86%	68.0 F	00:10
06:06:00	End of shower	52%	68.0 F	00:12
06:34:00	Second peak	62%	67.0 F	00:28
10:56:00	Return to normal RH	44%	66.0 F	04:22
Total				**05:12**

Effective Ventilation Strategies

- Fresh air intake on forced air system
  - Watch the fan wattage and commissioning details
  - Intermittent run times reduces effectiveness
- HRV
  - HRV or SUV…..select 80% SRE or higher and .8 watts/cfm or lower
  - Independent ducting, shared ducting, or a combination can all work
  - When sharing ducts:
    - Understand competing pressures
    - Air handler fan wattage is critical, use ECM 2.3 or higher
  - When using independent ducts
    - Duct design and commissioning are critical
    - Keep the ducts inside conditioned space

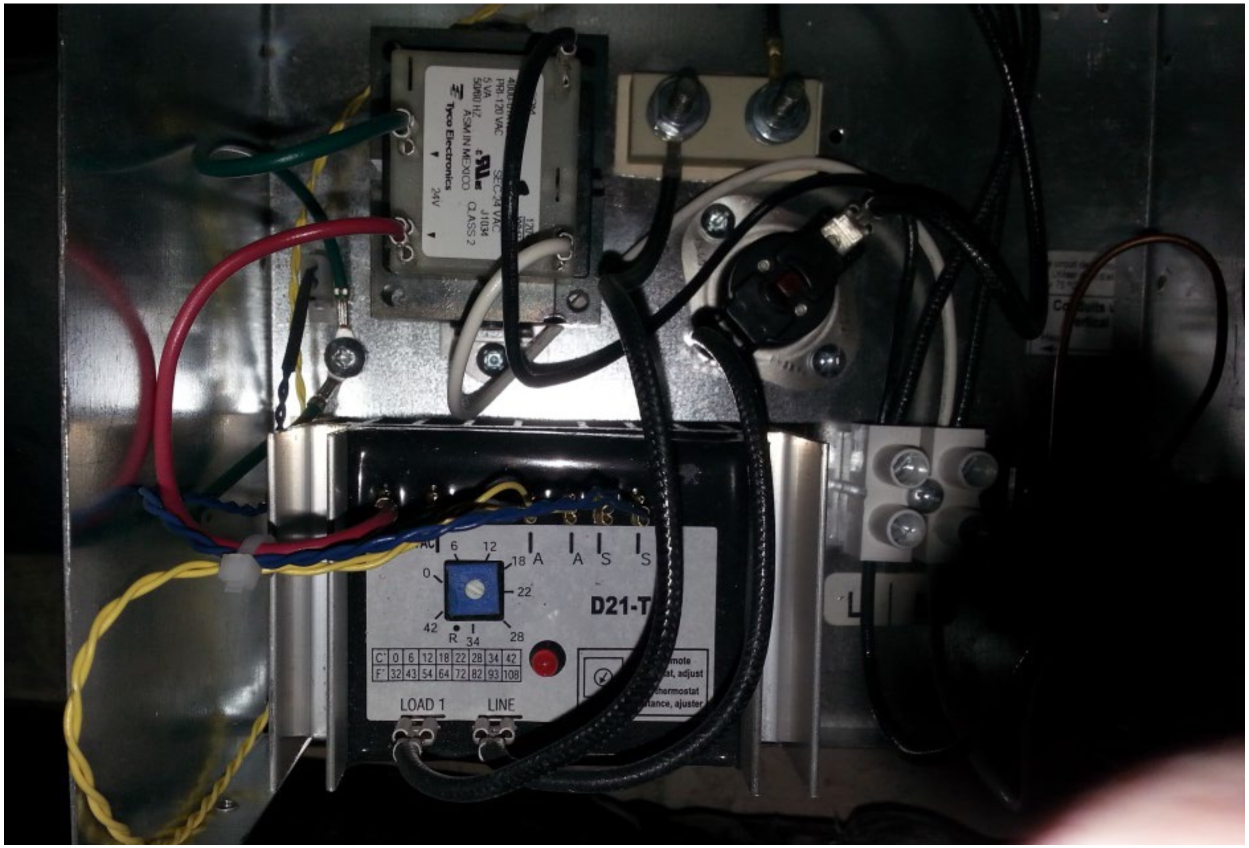
HRV Commissioning is Important

- I have good ventilation since I have an HRV right?
  - An HRV does little for indoor air quality if not commissioned
  - System must be balanced to achieve rated SRE
  - Rooms closest to the HRV likely receive 80% of the airflow when room-by-room balancing is not done
  - Rater can offer commissioning service



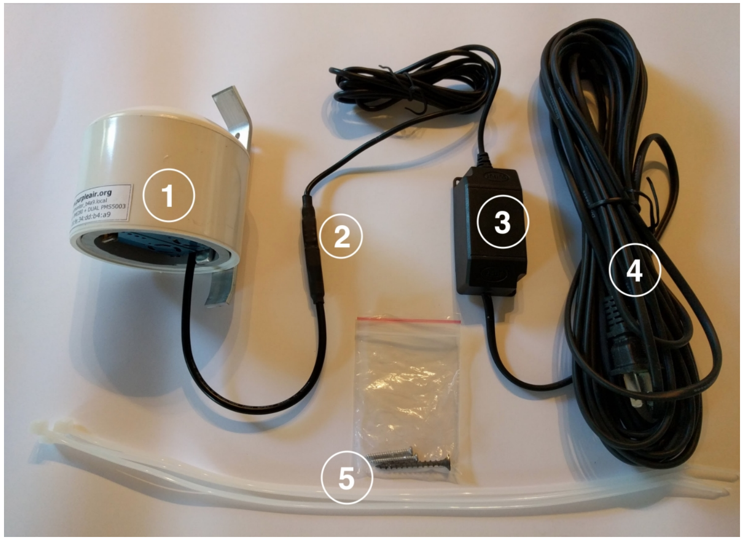

LIFEBREATH

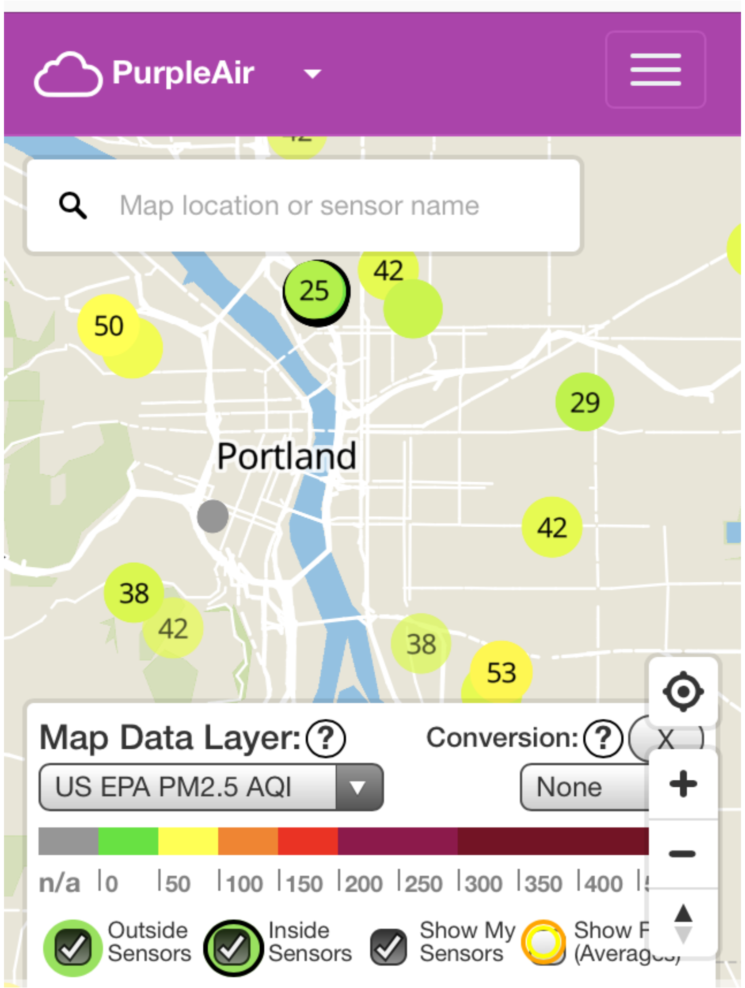
HRV Commissioning



Occupant Interactions

- If occupants are aware of IAQ issues, they are more likely to try and understand their ventilation system





Ditch the Ducts or Bring Them Inside

Ducts Inside

Conductive heat loss: Boise design conditions

Home CFA	Weather location	Design Temp	Duct Type	Surface Area	Duct Location	Duct U-value	Duct Air Temp	Location Design Temp	Delta-T	Design Heat Loss (Btu/hr)
2200	Boise	9	Supply	594	Unvented Crawl	0.125	100	23.8	76.2	5,658
			Return	110	Attic	0.125	70	19	51	701
										6,359

Other Surface	Surface U-value	Equivalent area
Ceiling	0.019	5,487
Wall	0.052	2,005
Window	0.28	372
Floor	0.03	3,475

Ducts Inside

Conductive heat loss: Portland design conditions

Home CFA	Weather location	Design Temp	Duct Type	Surface Area	Duct Location	Duct U-value	Duct Air Temp	Location Design Temp	Delta-T	Design Heat Loss (Btu/hr)
2200	Portland	27	Supply	594	Attic	0.125	100	37	63	4,678
			Return	110	Garage	0.125	70	40	30	413
										5,090

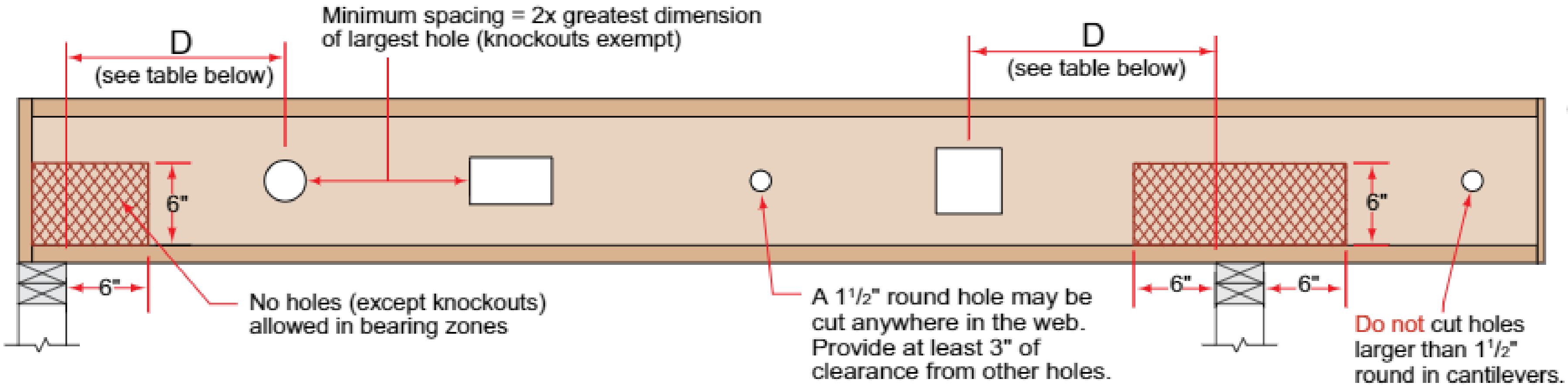
Other Surface	Surface U-value	Equivalent area
Ceiling	0.019	6,230
Wall	0.052	2,276
Window	0.28	423
Floor	0.03	3,946

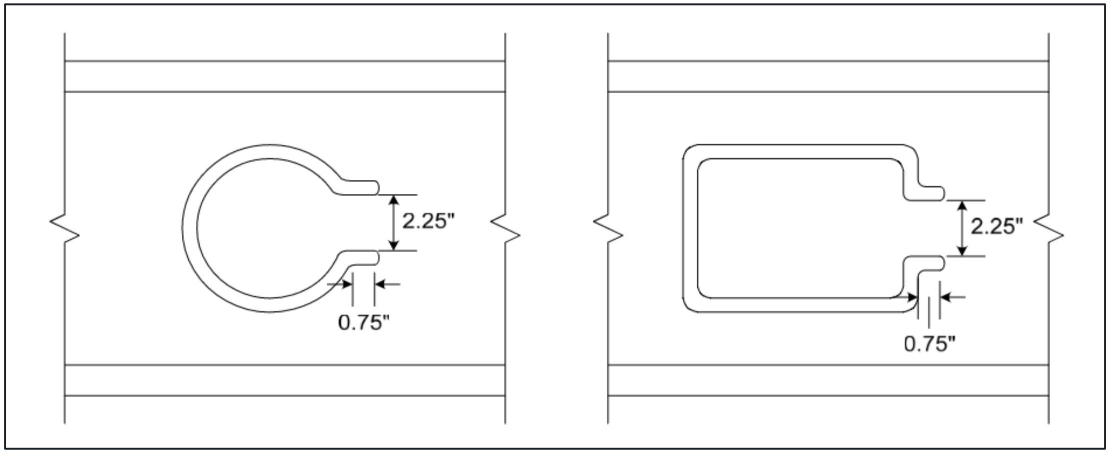
Source data: DOE ASHRAE Std 152 calculator:
https://www.energy.gov/eere/buildings/downloads/ashrae-standard-152-spreadsheet

Ducts Inside – a no brainer

- Putting ducts outside conditioned space is a recipe for waste:
  - The hottest/coldest air and under pressure
  - In the harshest environments
  - With the least amount of thermal protection
- Early design considerations are required
- New options for ducts inside – engineered I joists
- Consider ducted/ductless combination systems

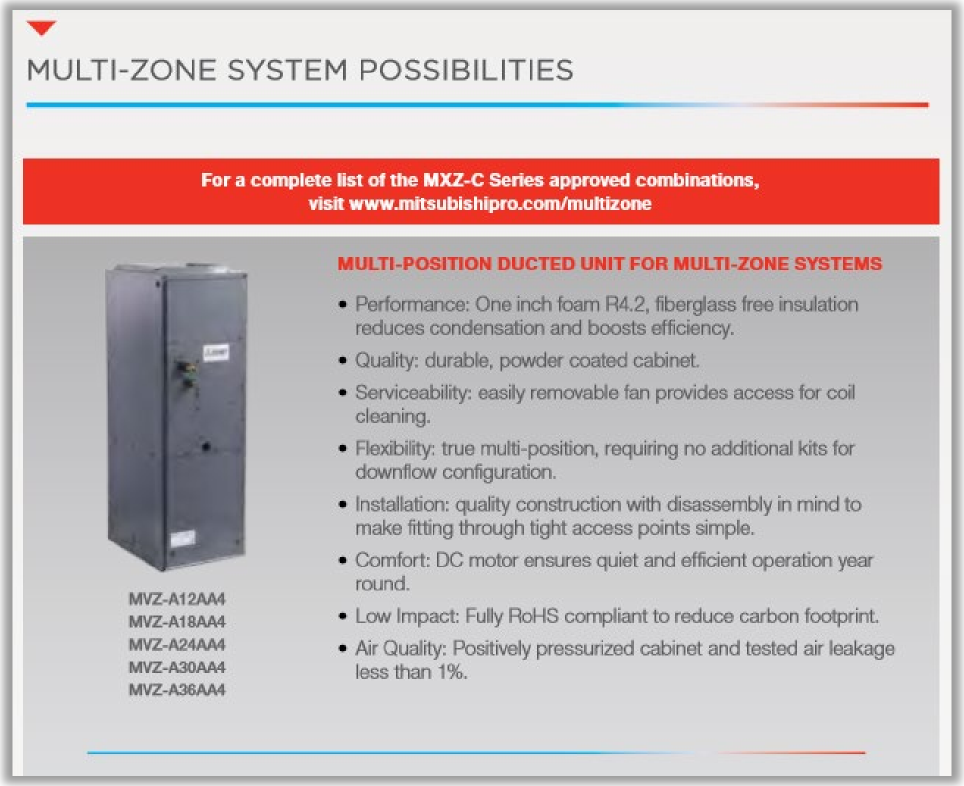
Ducts Inside – new options





Going Ductless

- As a building shell gets better and design loads decrease, zonal and ductless heating strategies begin to make more sense
  - Early design considerations increase success
  - Works well for some homes, not so well for others
  - Floor plan and head location can make or break the installation
  - Reduces overall load
  - Consider a combination of ductless, short-run ducted, or conventional ducted



MULTI-ZONE SYSTEM POSSIBILITIES

For a complete list of the MXZ-C Series approved combinations, visit www.mitsubishipro.com/multizone

MVZ-A12AA4
MVZ-A18AA4
MVZ-A24AA4
MVZ-A30AA4
MVZ-A36AA4

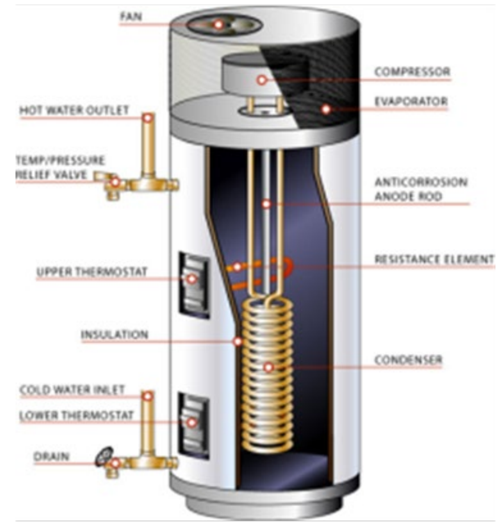
MULTI-POSITION DUCTED UNIT FOR MULTI-ZONE SYSTEMS

- Performance: One inch foam R4.2, fiberglass free insulation reduces condensation and boosts efficiency.
- Quality: durable, powder coated cabinet.
- Serviceability: easily removable fan provides access for coil cleaning.
- Flexibility: true multi-position, requiring no additional kits for downflow configuration.
- Installation: quality construction with disassembly in mind to make fitting through tight access points simple.
- Comfort: DC motor ensures quiet and efficient operation year round.
- Low Impact: Fully RoHS compliant to reduce carbon footprint.
- Air Quality: Positively pressurized cabinet and tested air leakage less than 1%.

Redefining Ducts Outside

Wasted Water and Energy

Wasted Water and Energy



- In a low load home, an electric resistance water heater can equal the heating load
- This is low hanging fruit
- But don't forget about distributions losses…..

End use consumption kWh/yr	Heat Pump	Electric Resistance
Heating	4484	4484
Cooling	879	879
Water Heating	1202	3898
Lights and Appliances	8997	8997

Distribution System Losses

- **20% Distribution Energy Waste**
  - Average 20 percent of energy associated with a hot water delivery system is wasted in distribution losses
- **3,650 Gal. Wasted**
  - Average loss home/yr. waiting for hot water to arrive at the point of use
- **Solutions:**
  - Compact plumbing layout
  - Demand controlled recirculation...or use both

Gallons Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

Flow Rate (GPM)	Time Until Hot Water Arrives (Seconds)															
	1	2	3	4	5	10	15	20	25	30	35	40	45	50	55	60
0.5	0.01	0.02	0.03	0.03	0.04	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50
1	0.02	0.03	0.05	0.07	0.08	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.83	0.92	1.00
1.5	0.03	0.05	0.08	0.10	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25	1.38	1.50
2	0.03	0.07	0.10	0.13	0.17	0.33	0.50	0.67	0.83	1.00	1.17	1.33	1.50	1.67	1.83	2.00
2.5	0.04	0.08	0.13	0.17	0.21	0.42	0.63	0.83	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50
3	0.05	0.10	0.15	0.20	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
3.5	0.06	0.12	0.18	0.23	0.29	0.58	0.88	1.17	1.46	1.75	2.04	2.33	2.63	2.92	3.21	3.50
4	0.07	0.13	0.20	0.27	0.33	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00
4.5	0.08	0.15	0.23	0.30	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	4.50
5	0.08	0.17	0.25	0.33	0.42	0.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00
5.5	0.09	0.18	0.28	0.37	0.46	0.92	1.38	1.83	2.29	2.75	3.21	3.67	4.13	4.58	5.04	5.50
6	0.10	0.20	0.30	0.40	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
6.5	0.11	0.22	0.33	0.43	0.54	1.08	1.63	2.17	2.71	3.25	3.79	4.33	4.88	5.42	5.96	6.50
7	0.12	0.23	0.35	0.47	0.58	1.17	1.75	2.33	2.92	3.50	4.08	4.67	5.25	5.83	6.42	7.00
7.5	0.13	0.25	0.38	0.50	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50
8	0.13	0.27	0.40	0.53	0.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	7.33	8.00
8.5	0.14	0.28	0.43	0.57	0.71	1.42	2.13	2.83	3.54	4.25	4.96	5.67	6.38	7.08	7.79	8.50
9	0.15	0.30	0.45	0.60	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.00
9.5	0.16	0.32	0.48	0.63	0.79	1.58	2.38	3.17	3.96	4.75	5.54	6.33	7.13	7.92	8.71	9.50
10	0.17	0.33	0.50	0.67	0.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.00

1 cup = 8 ounces = 1/16th gallon = 0.0625 gallon

Compact Plumbing Design

- Has the smallest length and smallest "possible" diameter
- The fewest plumbing restrictions to minimize pressure drop and optimize velocity
- Limit longest hot water run to 25'
- Avoid manifold systems
- The time-to-tap < 10 seconds, but < 5 seconds is very buildable

	3/8" ID PEX	**1/2" ID PEX**	**3/4" ID PEX**	**1" ID PEX**
Feet Per Cup	12.09	6.62	3.34	2.02
Cups in 25'	2.12	3.84	7.58	12.51

Recirculate the Smart Way

- Demand control is the only energy efficient option
  - Avoid continuous and timer controlled systems
  - Time and temperature controlled systems are better, but still wasteful
  - Demand control is incorporated with temperature control for the ideal system

The difference in these systems is in the *energy* it takes to keep the trunk line primed with hot water.

90 percent of the cost is from heat loss in the loop, 10 percent is from the pump operation.

The Cost of Recirculation

	Recirculation						Demand Controlled Priming
	Daily Hours of Operation						
	24	12	8	6	4	2	0.25
Loop Heat Losses							
Natural Gas (therms)	292	146	97	73	49	24	3
Electric (kWh)	6,388	3,194	2,129	1,597	1,065	532	67
Pump Energy(kWh)	438	219	146	110	73	37	8

Loop is assumed to be 100 feet long.

50 feet supply, 50 feet return

Recirculation:

Flow rate is 1 gpm

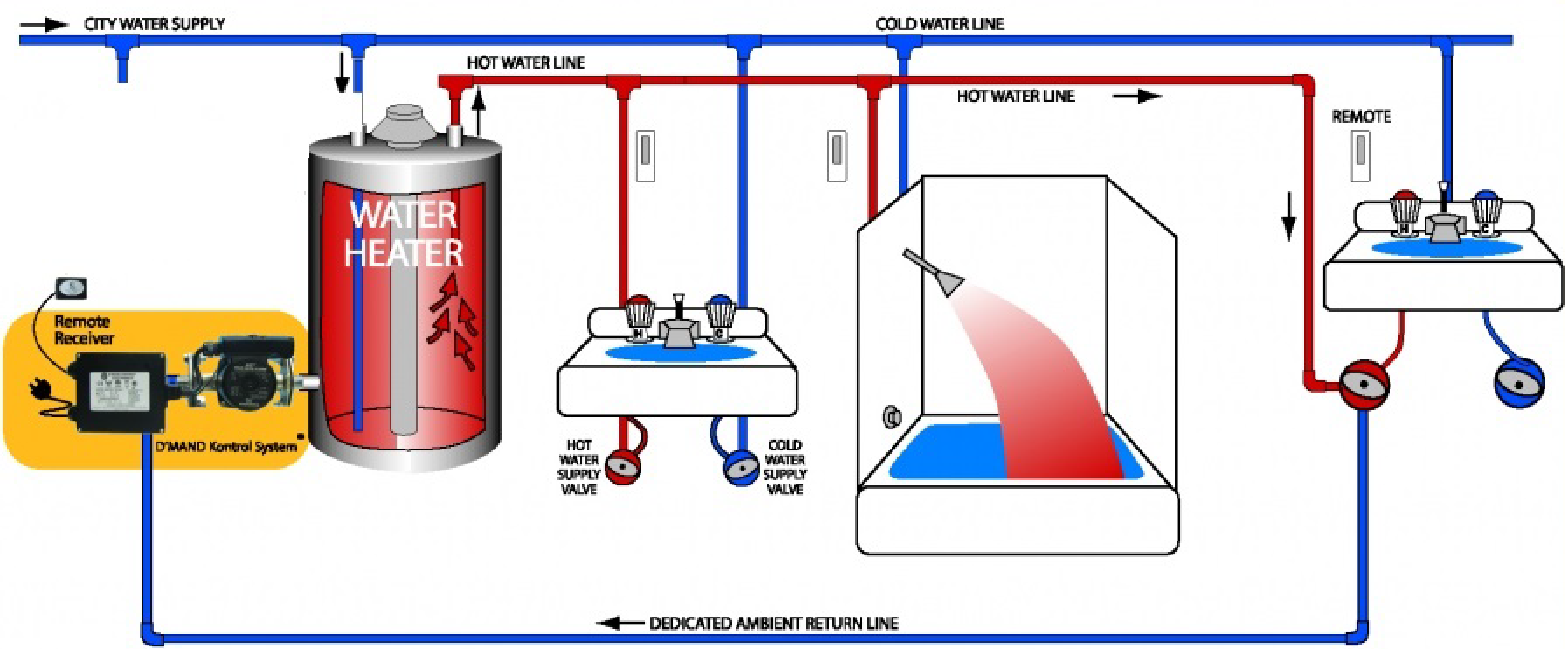
Temperature drop is 5F

50 watt pump

Demand Controlled Priming:

85 watt pump

Recirculation Systems

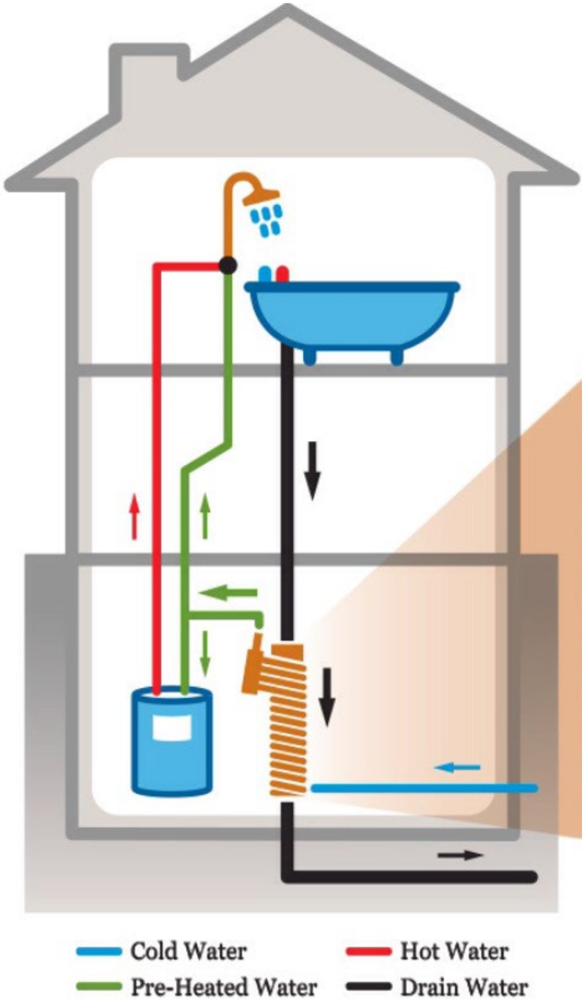



Controls a single (X1) load or pump
model TLC-X1-115
WWW.REDYTEMP.COM

Drain Waste Heat Recovery

- Good addition to electric resistance
  - Install configuration is very important, sweat the details here
  - Not an option on all homes
  - Easy to install and no maintenance
- Can pre-heat water entering water heater or shower by 25 F
- Potential 500 kWh/yr savings

Drain Waste Heat Recovery

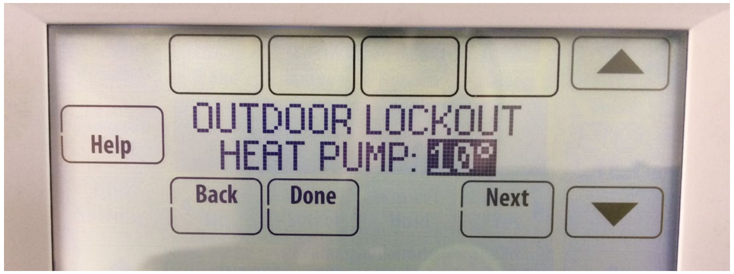


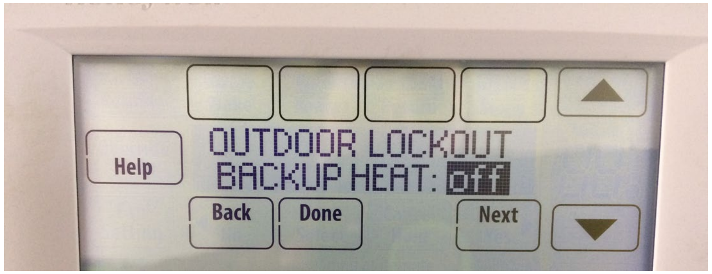
Avoid the Plug-and-play mentality

Plug-and-Play

- Just because we install an energy saving widget in a home doesn't mean it saves energy
- The devil is in the details
- Often doesn't show up in modeling
- Mechanicals usually suffer the most
- The homeowner ultimately suffers

Heat Pump Commissioning

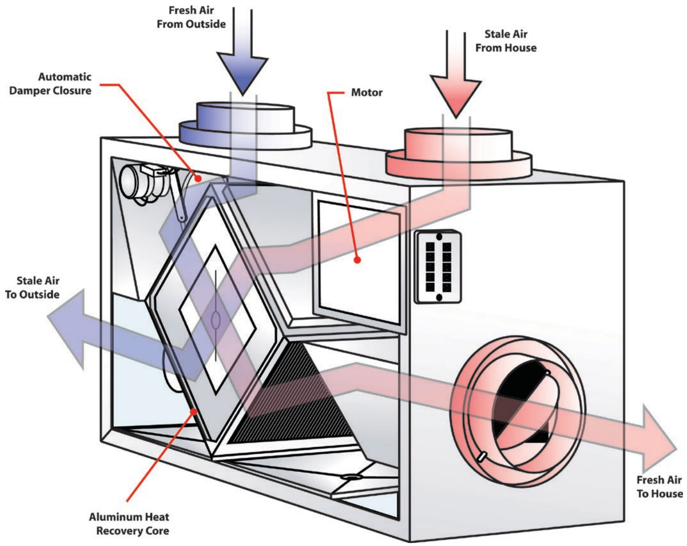




- Get that rated efficiency by:
  - Proper evacuation and charging practices
  - Measure and set optimal CFM/ton
  - Aux heat controls
  - Right sized system
  - Smart duct design

“This Thing Has a Filter?”

- Homeowner education important to ensure proper function and maintenance

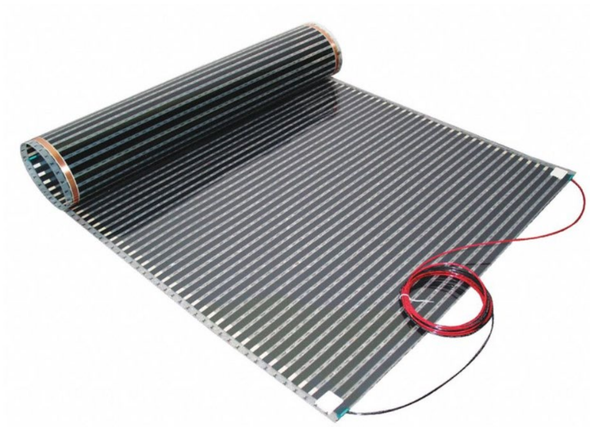


Control Overload


- The best systems in the world do nothing if they aren't used properly
- Homeowners must be educated on the operation of systems in their homes.

Runaway Hidden Loads

- Elec radiant floor heat in bathrooms
  - Difficult to accurately model
  - Often stays on all year
  - Warm feet are worth it right?!



- Loads you can't control
  - Large plug loads
  - Hot tubs, grow operations

THANK YOU!

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