ANATOMY OF A HIGH PERFORMANCE HOME

Tim Yandow

Yandow Green Builders

St. George, Vermont

PROJECT COLLABORATION

YANDOW GREEN BUILDERS
TIM AND THE AWESOME CREW

PILL-MAHARAM ARCHITECTS
DAVID PILL AND KAREN BUSHEY

EFFICIENCY VERMONT
PETER SCHNEIDER, SANDRA MEIDLINGER AND MATT SARGENT

PRIMARY GOAL OF A HP HOME IS TO DISTILL THE BENEFITS OF A PASSIV HAUS WHILE OPTIMIZING COST

GET AS CLOSE TO NET ZERO W/O RENEWABLES

THE REALLY GOOD JUST ENOUGH NOT OVERBOARD HOUSE

REDUCE HEAT/ENERGY LOADS SUFFICIENTLY TO SIGNIFICANTLY DOWNSIZE HEATING/COOLING REQUIREMENTS

(HELPS OFFSET SOME OF THE WINDOW AND INSULATION UPGRADES)

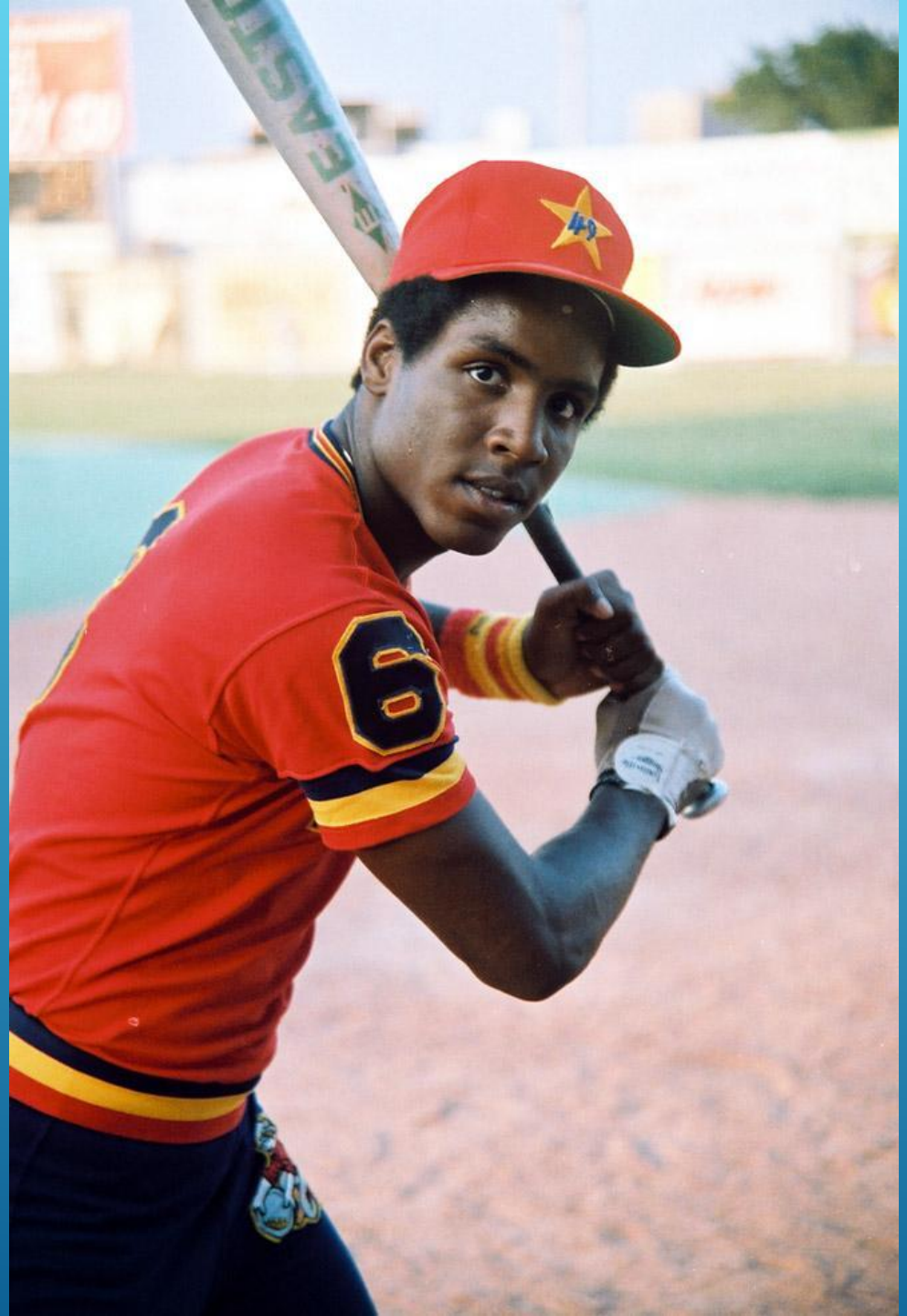
EFFICIENCY VERMONT RESIDENTIAL NEW CONSTRUCTION PROGRAM TIER COMPARISON AND INCENTIVES

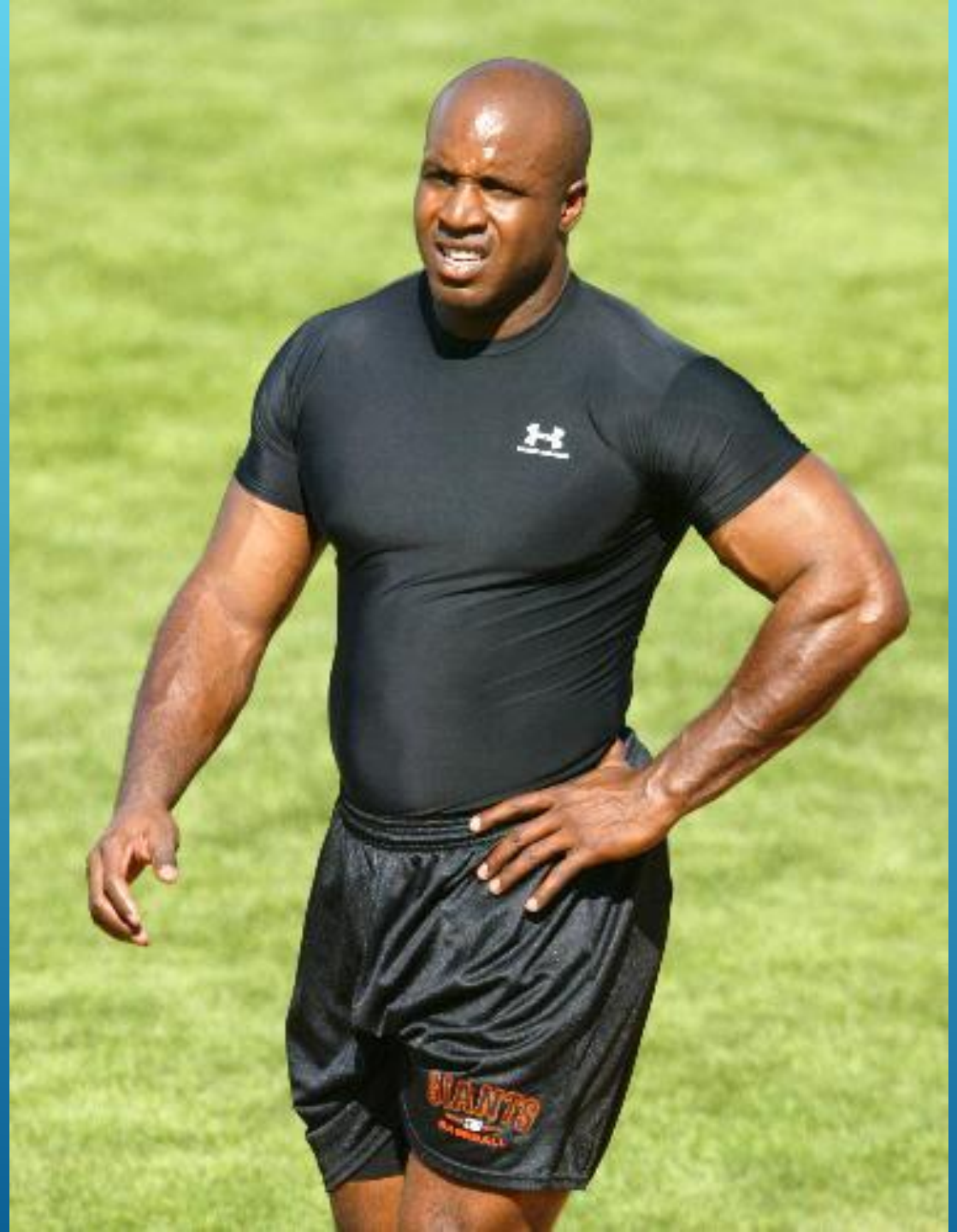
	Reference Standard	Residential New Construction Service Tiers		
Category*	**Residential Building Energy Standards (RBES) – VT Energy Code**	**Energy Code Plus Bronze**	**Vermont ENERGY STAR® Homes Silver**	**High Performance Home Gold**
Windows Maximum Weighted Average NFRC U-Factor	U-0.32	U-0.32	U-0.32	U-0.19
Doors Maximum Weighted Average NFRC U-Factor	U-0.32	U-0.32	U-0.32	U-0.25
Insulation Installation Minimum Installation Quality (using RESNET Grading System)	Per manufacturer's instructions	Grade II	Grade I	Grade I
Ceiling Insulation (flat) Minimum R-Value	R-49 (R-38 is allowed when full, uncompressed R-38 extends over the top plate at the eaves)	R-49 (R-38 is allowed when full, uncompressed R-38 extends over the top plate at the eaves)	R-49 (R-38 is allowed when full, uncompressed R-38 extends over the top plate at the eaves)	R-80
Ceiling Insulation (sloped) Minimum R-Value	R-49 (R-30 is allowed for up to 500 square feet or 20% of the total insulated ceiling area, whichever is less)	R-49 (R-30 is allowed for up to 500 square feet or 20% of the total insulated ceiling area, whichever is less)	R-49 (R-30 is allowed for up to 500 square feet or 20% of the total insulated ceiling area, whichever is less)	R-60
Wall Insulation (above grade & band joist) Minimum R-Value	R-20 or R-13 cavity + R-5 Continuous	R-20 or R-13 cavity + R-5 Continuous	R-20 or R-13 cavity + R-5 Continuous	R-40
Foundation Wall Insulation Minimum R-Value.	R-15 cont./R-20 cavity	R-15 cont./R-20 cavity	R-15 cont./R-20 cavity	R-30
Floor Insulation (exposed)	R-15	R-30	R-30	R-40
Slab Edge Insulation (when within 12" finished grade)	R-15 Must extend 4 ft	R-15 Must extend 4 ft	R-15 Must extend 4 ft	R-30 (Footing:≥R-8)
Insulation Under Heated Slab	R-15	R-15	R-15	R-30 (Unheated as well)
Heating & Cooling Equipment Minimum Efficiency	Meets Federal minimum standard	ENERGY STAR or equivalent	ENERGY STAR or equivalent	ENERGY STAR or equivalent* *Boilers must achieve minimum 94% AFUE
Air Leakage Maximum ACH50	5 ACH50 or pass visual inspection	4 ACH50 and pass Thermal Enclosure System Checklist	3 ACH50 and pass Thermal Enclosure System Checklist	1 ACH50 and pass Thermal Enclosure System Checklist
Heating & Cooling Distribution & Control	Programmable Thermostat – at least one required by RBES Ducts insulated to level of nearest insulated surface Duct Leakage Limits: 6 CFM per 100 sf of CFA Pipe insulation (min. R-3) Required in unconditioned spaces	Meets RBES If ducted system is used, ducts must be inside conditioned space	Meets ENERGY STAR HVAC Checklist Requirements as applicable If ducted system is used, ducts must be inside conditioned space	Custom approach depending on system chosen. discuss with HVAC contractor and EVT Energy Consultant

Category	RBES	Energy Code Bronze	Energy Star Silver	High Performance Gold
Windows U-Factor	0.32	0.32	0.32	0.19
Doors U-Factor	0.32	0.32	0.32	0.25
Insulation Installation Resnet Grading	Per Manufacturer Instructions	Grade II	Grade I	Grade I
Ceiling Insulation (flat) Min R-value	R-49	R-49	R-49	R-80
Ceiling Insulation (sloped)	R-49	R-49	R-49	R-60
Wall Insulation	R-20 or R-13/R-5	R-20 or R-13/R-5	R-20 or R-13/R-5	R-40

Category	RBES	Energy Code Bronze	Energy Star Silver	High Performance Gold
Foundation Wall (min.)	R-15 cont R-20 cavity	R-15 R-20	R-15 R-20	R-30
Exposed Floor Insulation	R-15	R-30	R-30	R-40
Slab Edge Within 12" grade	R-15 (4 ft.)	R-15 (4 ft.)	R-15 (4 ft.)	R-30 Footing min R-8
Insulation Under Heated slab	R-15	R-15	R-15	R-30 Unheated as well
Air Leakage Max ACH50	5 ACH 50 or pass visual inspection	4 ACH 50 and pass thermal bypass insp.	3 ACH 50 and pass thermal bipass	1 ACH 50 and pass thermal bipass
Lighting	50% high eff.	50% Energy Star	80% Energy Star	95% Energy Star
Appliances	N/A	Energy Star	Energy Star	CEE 1-3

Category	RBES	Energy Code Bronze	Energy Star Silver	High Performance Gold
Heating and Cooling	Federal Min Std.	Energy Star or equivalent	Energy Star or equiv.	Energy Star or equiv. (boilers 94% AFUE)
Dist. And Control	RBES	RBES	Energy Star	Custom
Water Heating	Federal Minimum	Federal Minimum	Federal Minimum	Energy Star (rec. drainwater heat recov.)
Ventilation	Whole house per code	RBES	ASHRAE 62.2	ASHRAE 62.2 or Passive House Whole House min. 80% recovery
HERS	75 or less	75 or less	Energy Star	No Threshold +/- 40




GIANTS

OTHER YGB JOBSITE "GREEN" PRACTICES

- Recycle/Reuse jobsite materials and waste. Encourage owner and sub-contractor participation

- Use of renewable resources- cellulose, high recycled content materials,

wood (it's the new green)

Minimal use of high impact materials(on air quality and environment)

foam, PVC/Vinyl, carpet, particle board, high VOC finishes, etc.

Jobsite Air Quality and Safety- Dust, VOC's, Clean and Organized

4 MAIN INTERCONNECTED AREAS OF FOCUS

OPTIMIZE THERMAL RESISTIVITY (R-VALUE)
MINIMIZE THERMAL BREAKS FROM GROUND UP

MINIMIZE AIR INFILTRATION- 1 ACH50 OR LESS
HAVE A CLEAR AIR SEALING PROTOCOL/PENETRATIONS

VENTILATION AND VAPOR CONTROL- WHOLE HOUSE AIR EXCHANGE/HEAT RECOVERY (80% OR BETTER), VAPOR OPEN WALL CAVITY

MINIMIZE ENERGY LOADS- HEATING/COOLING, LIGHTING, APPLIANCES

FOCUS ON THE BUILDING ENVELOPE

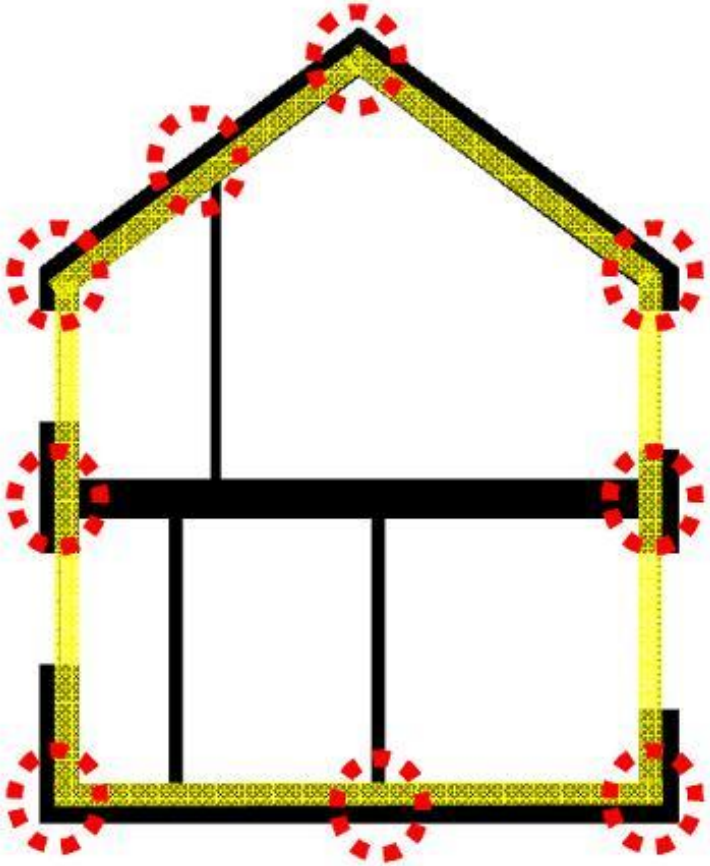
HOUSE SITING

OPTIMIZE SOUTHERN EXPOSURE

THERMAL BRIDGE

A THERMAL BRIDGE, OR COLD BRIDGE, IS A FUNDAMENTAL OF HEAT TRANSFER WHERE A PENETRATION OF THE INSULATION LAYER BY A HIGHLY CONDUCTIVE OR NON-INSULATING MATERIAL TAKES PLACE IN THE SEPARATION BETWEEN THE INTERIOR AND EXTERIOR ENVIRONMENTS OF A BUILDING ASSEMBLY. ...

Where are Thermal Bridges found?



(Window Fitting)

Int Wall - Ceiling

Ridge

Eaves

Floor Junction

Footing

Internal Wall

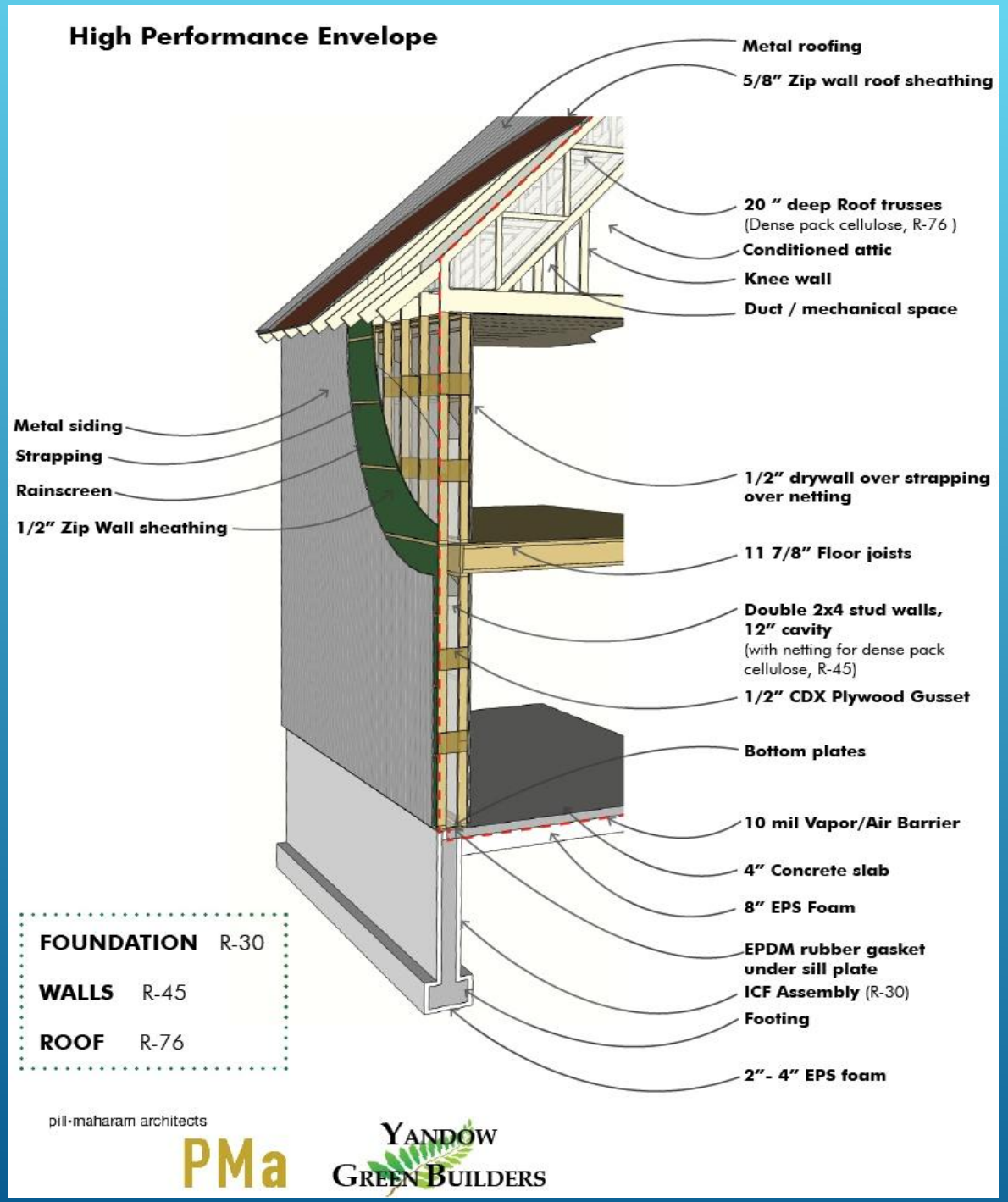
Passive House Academy

WHOLE HOUSE APPROACH

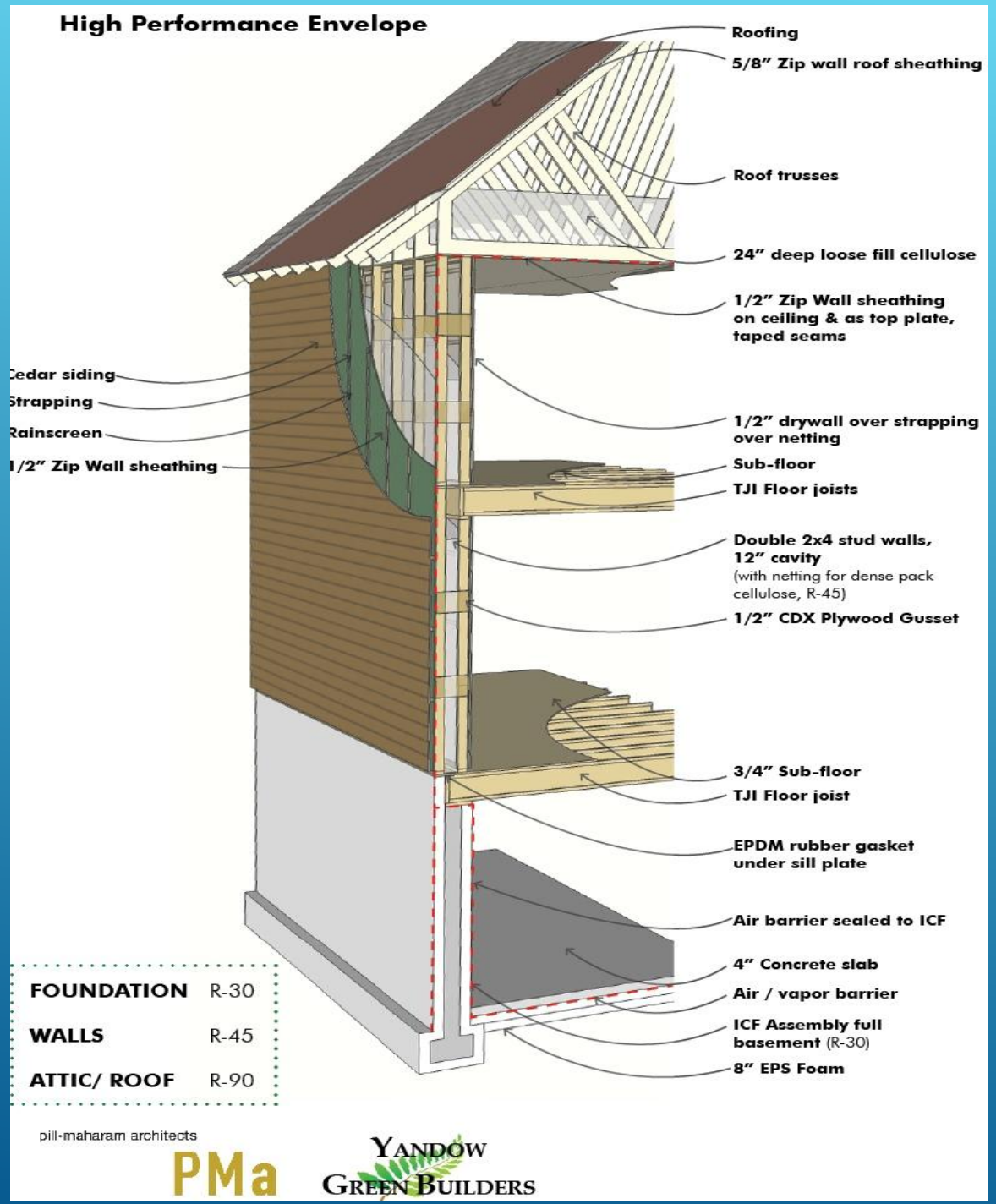
CREATE CONTINUOUS THERMAL BREAK FROM FOOTINGS TO PEAK

AIR BARRIER SHOULD FOLLOW CONTINUOUS LINE OF INSULATION

HAVE CLEAR PROTOCOL/GUIDELINES FOR BUILDERS AND SUB-CONTRACTORS SO BREAK AND BARRIERS ARE NOT COMPROMISED



CONTINUOUS THERMAL BREAK AND AIR BARRIER


High Performance Envelope
Roofing
5/8" Zip wall roof sheathing
Roof trusses
24" deep loose fill cellulose
1/2" Zip Wall sheathing on ceiling & as top plate, taped seams
Cedar siding
Strapping
Rainscreen
1/2" Zip Wall sheathing
1/2" drywall over strapping over netting
Sub-floor
TJI Floor joists
Double 2x4 stud walls, 12" cavity
(with netting for dense pack cellulose, R-45)
1/2" CDX Plywood Gusset
3/4" Sub-floor
TJI Floor joist
EPDM rubber gasket under sill plate
Air barrier sealed to ICF
4" Concrete slab
Air / vapor barrier
ICF Assembly full basement (R-30)
8" EPS Foam
FOUNDATION R-30
WALLS R-45
ATTIC/ ROOF R-90
pill·maharam architects
PMa
YANDOW
GREEN BUILDERS

FOUNDATIONS

INSULATE UNDER THE FOOTINGS

INSULATED FOOTING WITH HIGH DENSITY EPS FOAM

INSULATED CONCRETE FORM WALLS

INSULATED FOOTINGS AND GROUND LOOP

Conventional Foundation

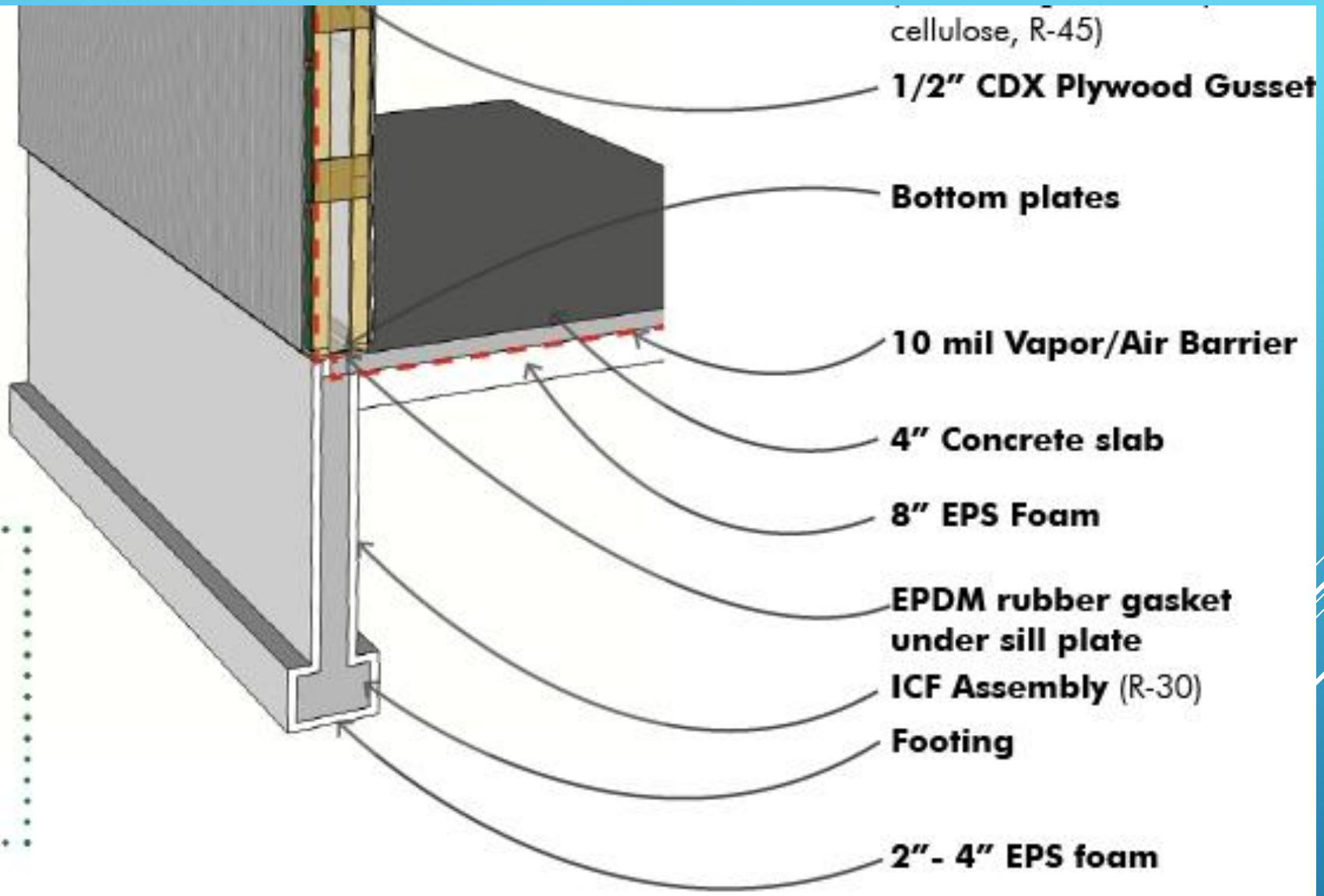
ICF Foundation

ICF/ SLAB INTERFACE AND SLAB EDGE INSULATION

HIGH PERFORMANCE ALTERNATIVES

10 ML AIR BARRIER UNDER SLAB

SEAL SLAB AIR BARRIER TO SHEATHING



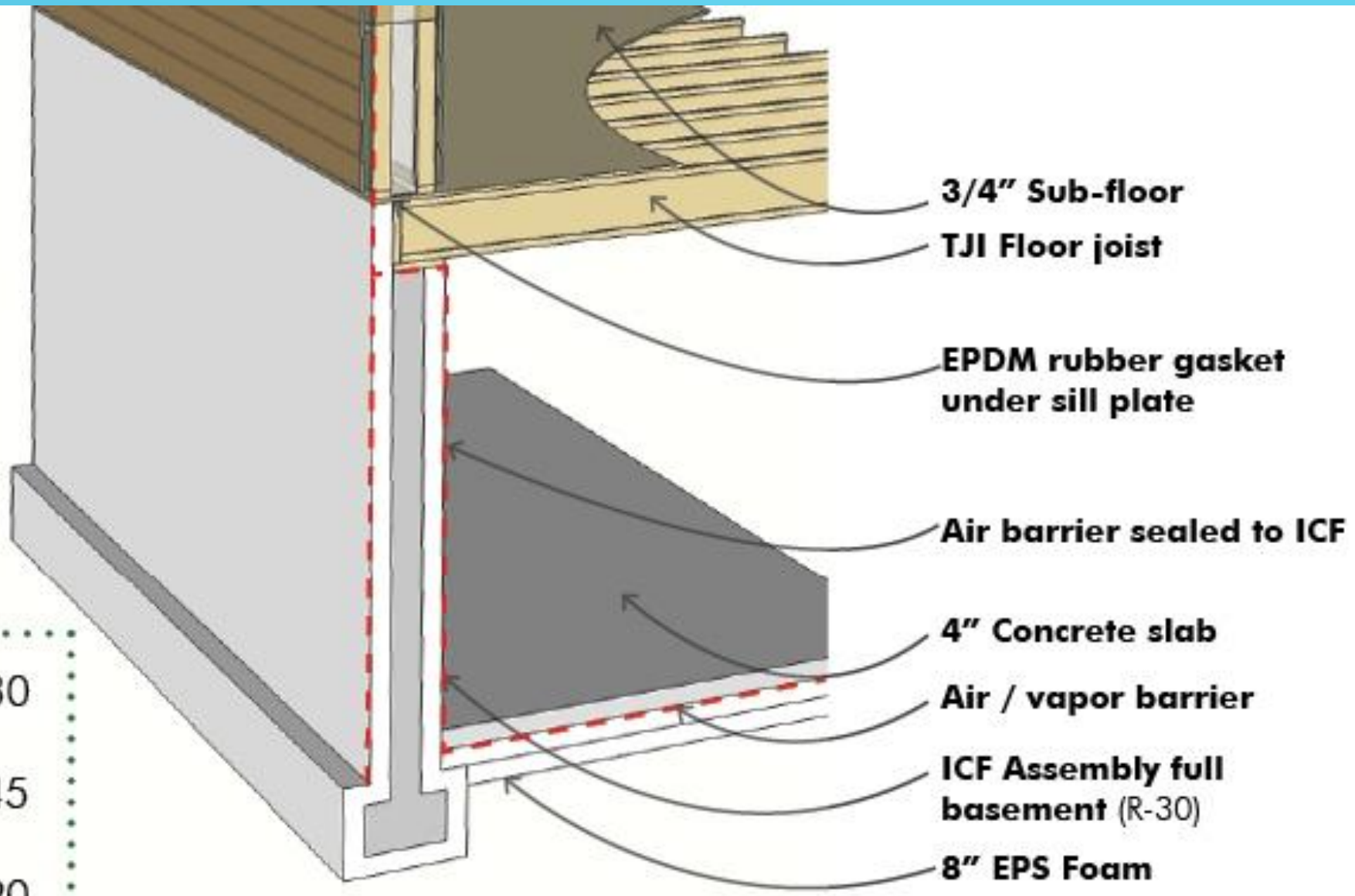
FOUNDATION R-30

WALLS R-45

ROOF R-76

INSULATION AND AIR BARRIER DETAIL IN FULL BASEMENT

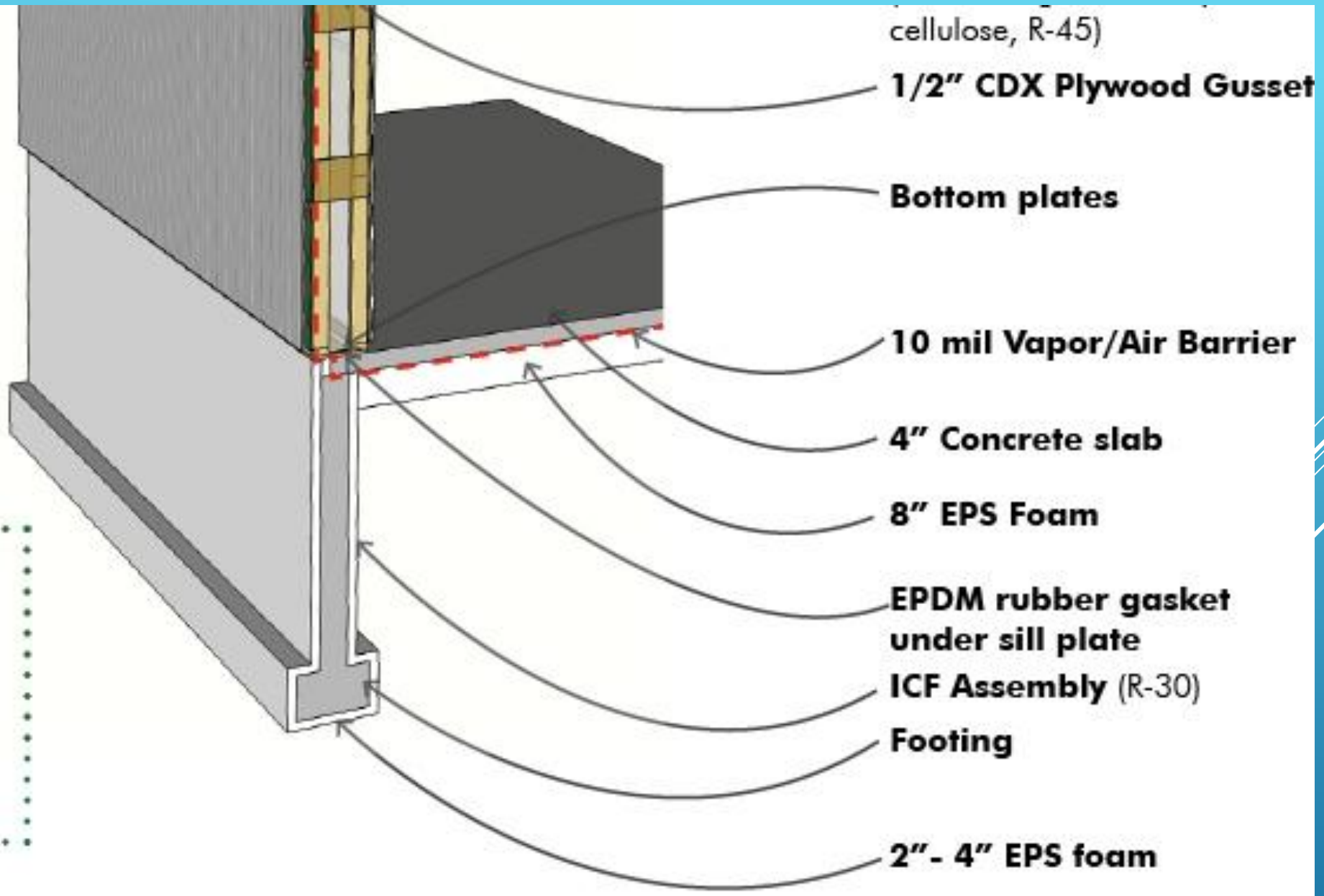
SEAL AIR BARRIER TO BASEMENT WALL



FOUNDATION	R-30
WALLS	R-45
ATTIC/ ROOF	R-90

WATERPROOF MEMBRANE OVER INSULATION

FRAMING

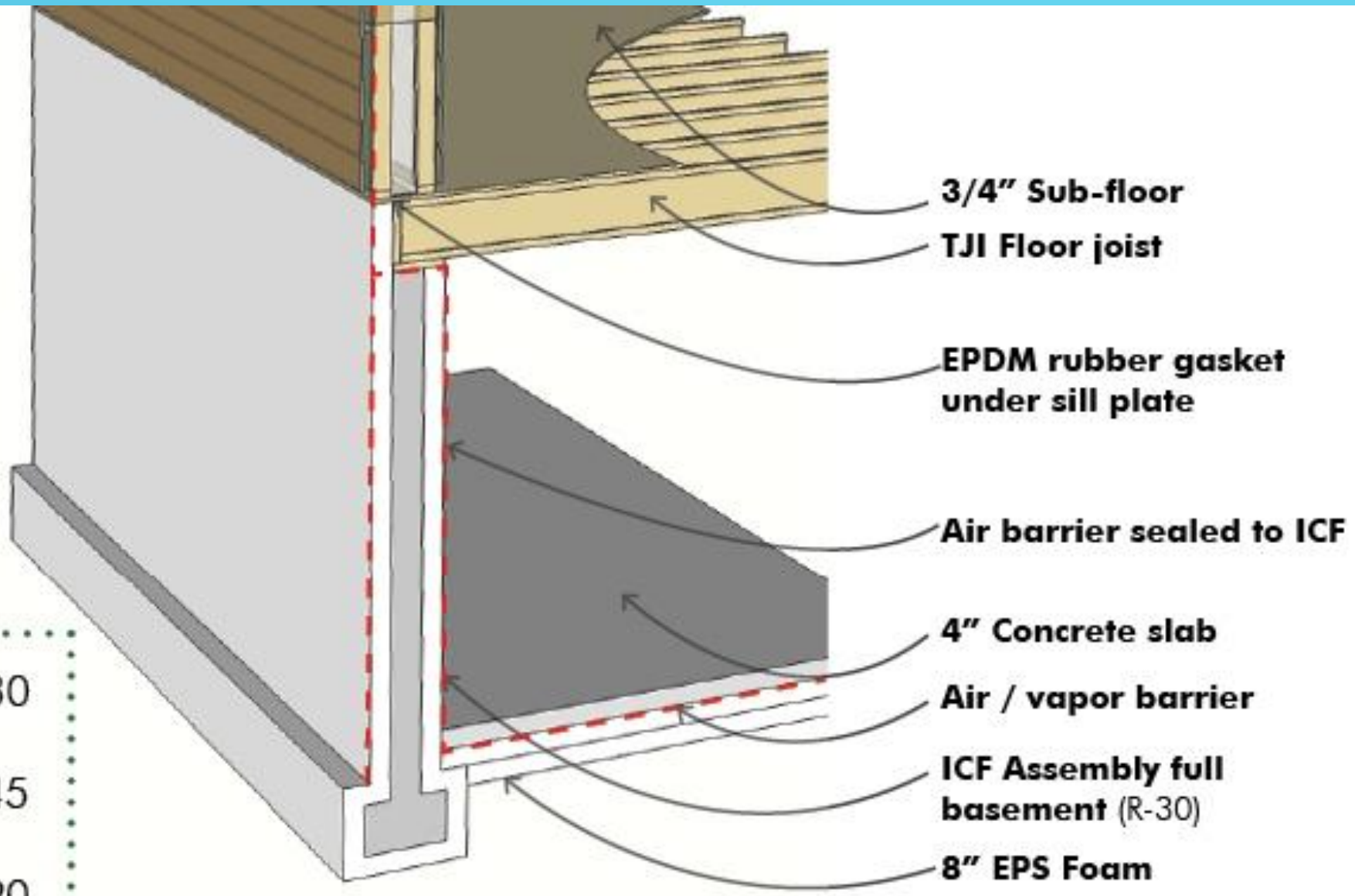


FOUNDATION R-30

WALLS R-45

ROOF R-76

DOUBLE WALL BOTTOM PLATES EPDM GASKET AND SILICONE



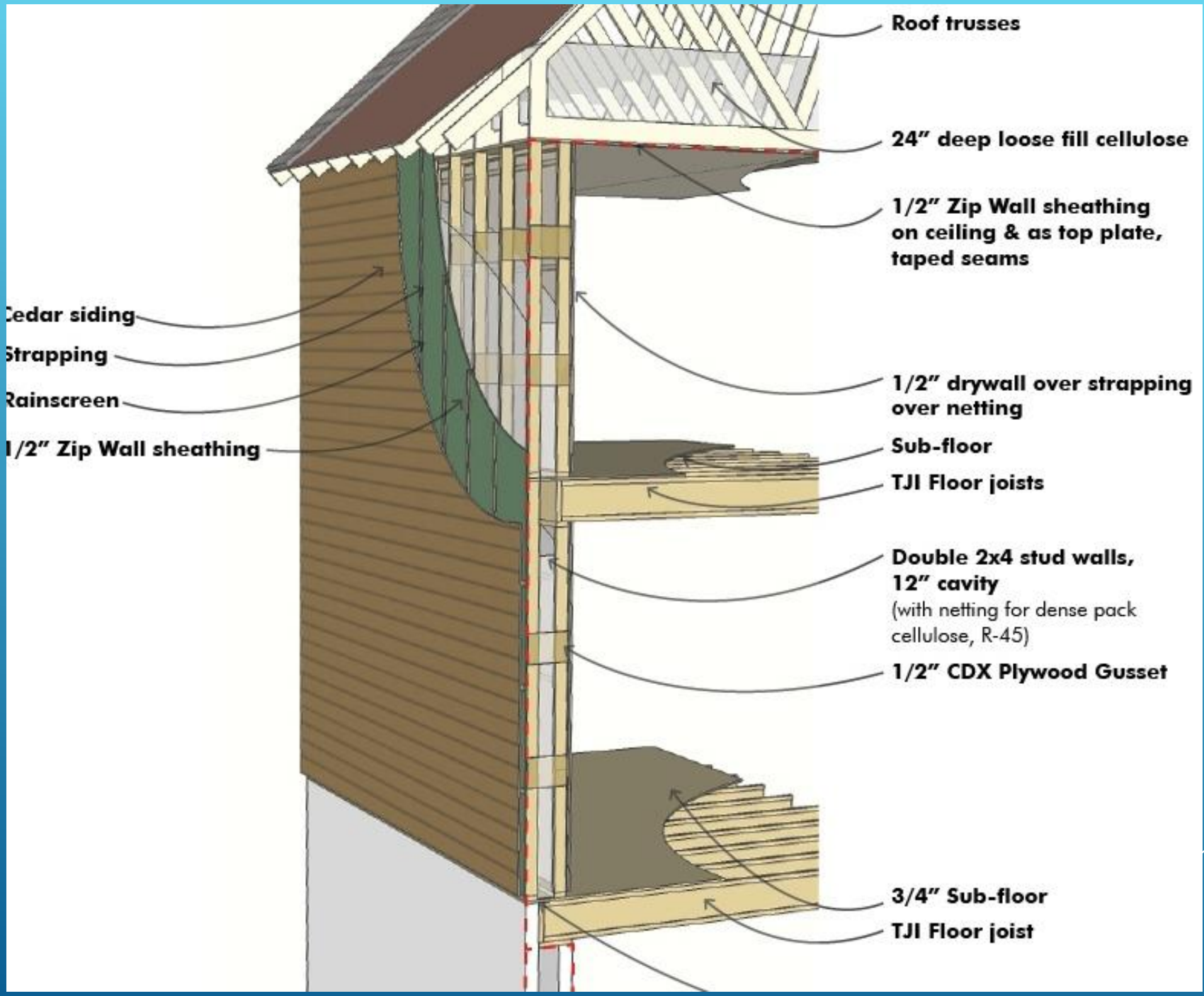
FOUNDATION	R-30
WALLS	R-45
ATTIC/ ROOF	R-90

12 INCH R-45 WALL CAVITY

DOUBLE STUD WALL ASSEMBLY

RAIN SCREEN AND AIR SEAL AS YOU GO

DOUBLE WALL WINDOW BUCKS


Roof trusses
24" deep loose fill cellulose
1/2" Zip Wall sheathing on ceiling & as top plate, taped seams
Cedar siding
Strapping
Rainscreen
1/2" Zip Wall sheathing
1/2" drywall over strapping over netting
Sub-floor
TJI Floor joists
Double 2x4 stud walls, 12" cavity
(with netting for dense pack cellulose, R-45)
1/2" CDX Plywood Gusset
3/4" Sub-floor
TJI Floor joist

FLOOR SYSTEM FRAMING
ENCLOSE IN THERMAL ENVELOPE

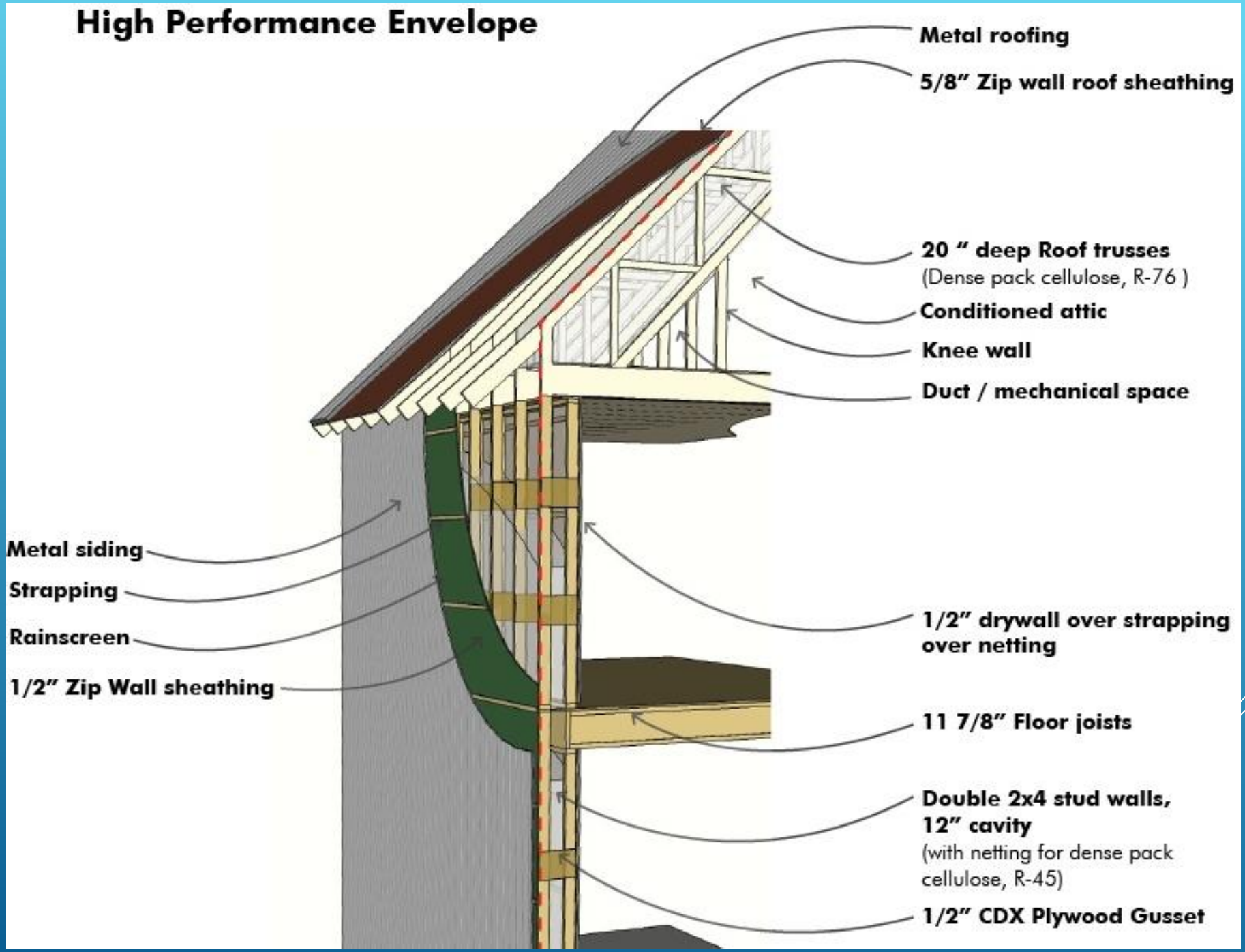
AIR SEAL AROUND WINDOW OPENINGS
CARE FOR YOUR AIR BARRIER

STAY ORGANIZED!

ROOF WITH ATTIC INSIDE ENVELOPE TRUSSES PREPPED FOR INSULATION

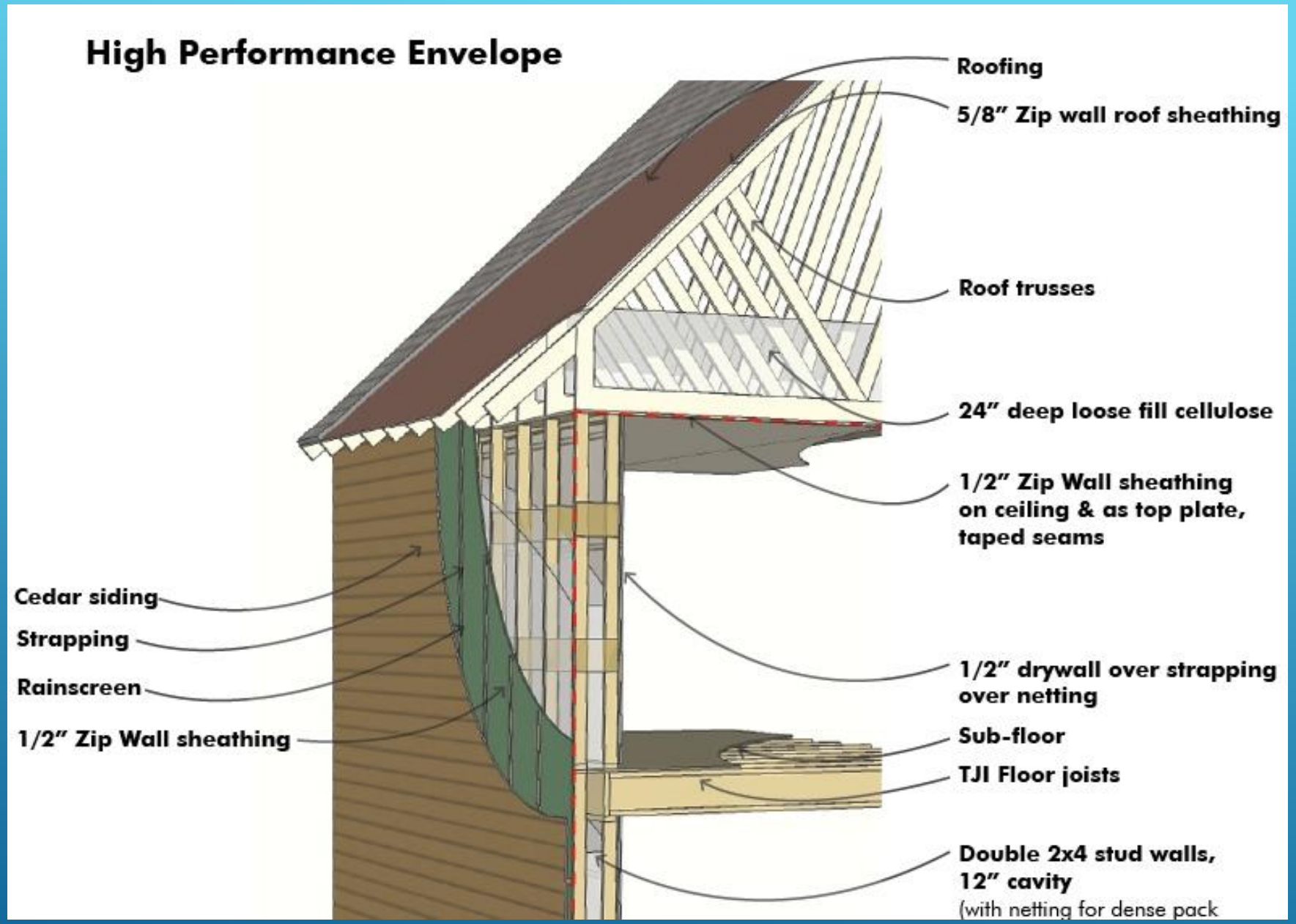
RAISED HEEL TRUSS ELIMINATES BRIDGING AT TOP PLATE

High Performance Envelope



CONDITIONED ATTIC AIR BARRIER GOES TO PEAK

RAFTER/TRUSS AIR SEALING DETAIL TAPE WORKS BETTER THAN FOAM



AIR BARRIER- FLAT CEILING DETAIL

NON-CONDITIONED ATTIC AIR BARRIER AT CEILING UNDER TRUSSES BEFORE PARTITIONS

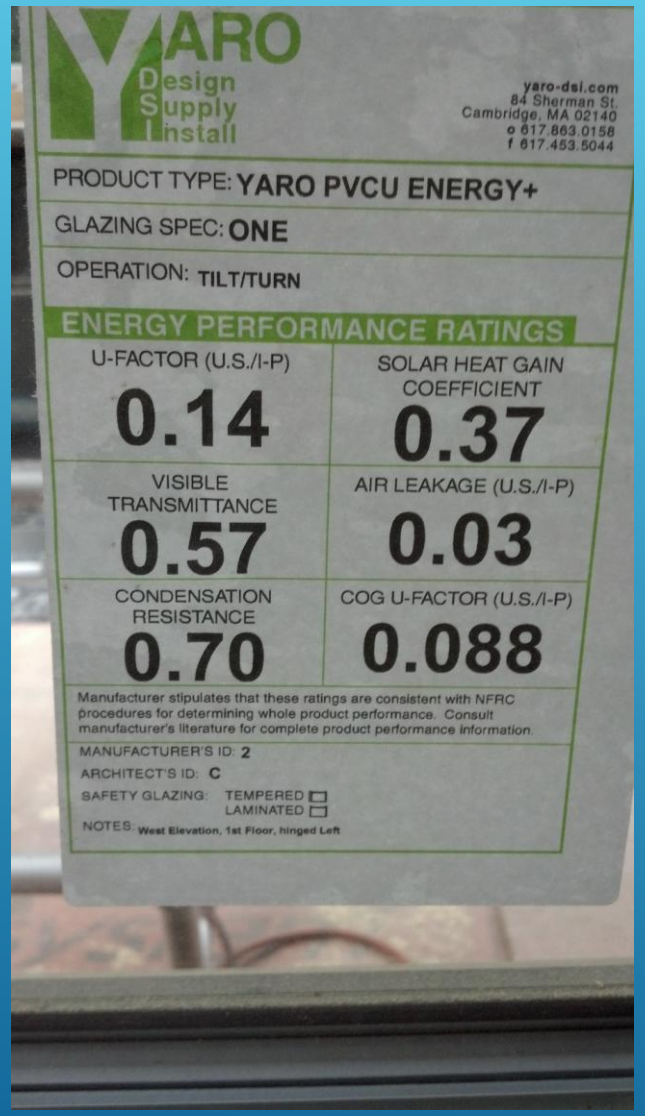
WINDOWS

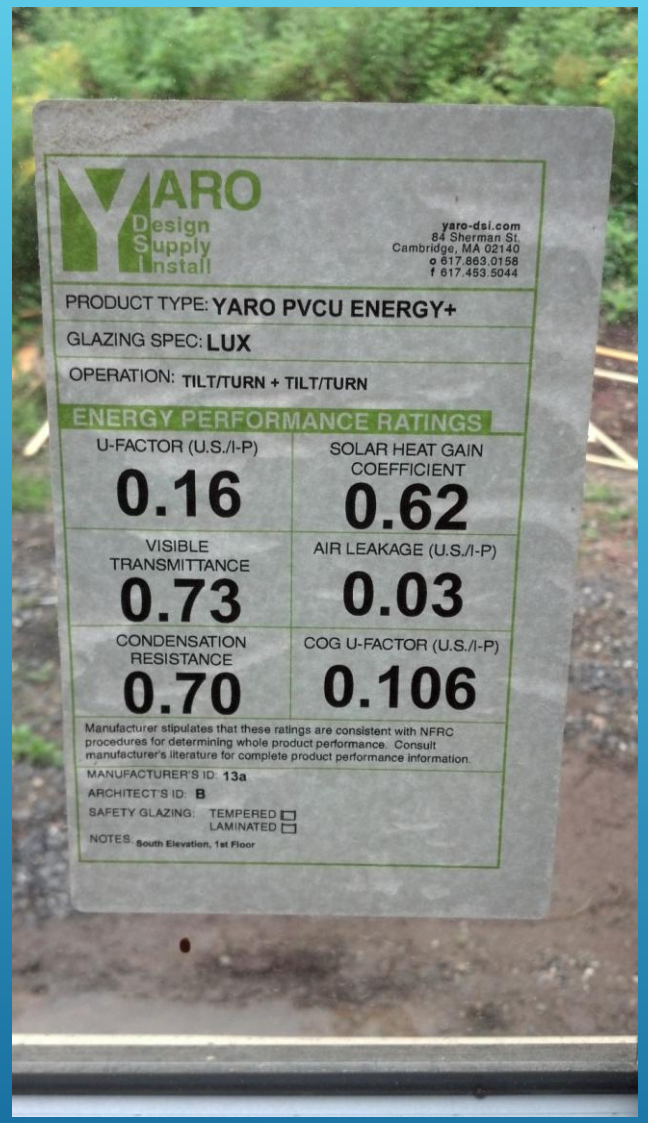

PVCU WINDOW
Energy+
Schuco SI 82
Uf 0.18 Btu/(h·ft²·°F)
SCHÜCO
YARO
windows + doors

WINDOWS

TRIPLE PANE U-FACTOR 0.19 OR LESS
OPTIMIZE FOR ASPECT

OPTIMIZE GLAZING FOR ASPECT

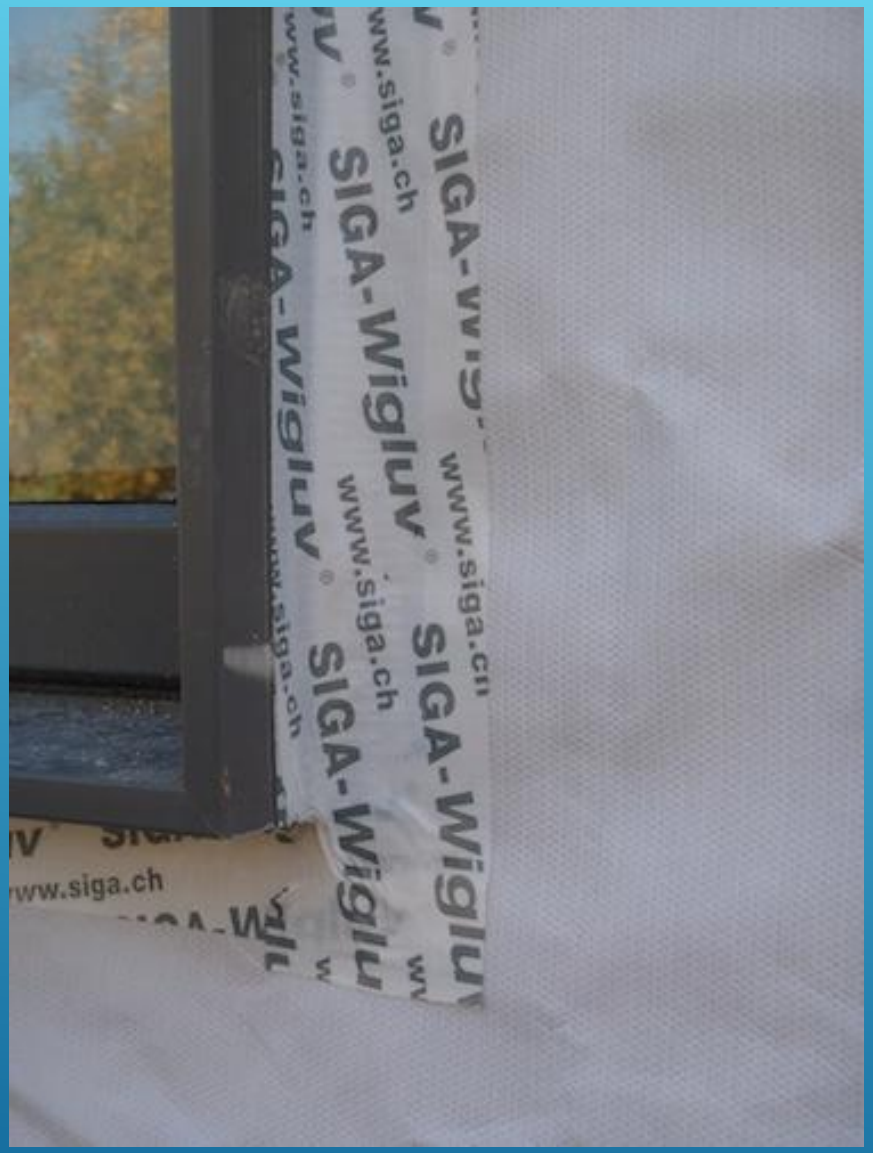




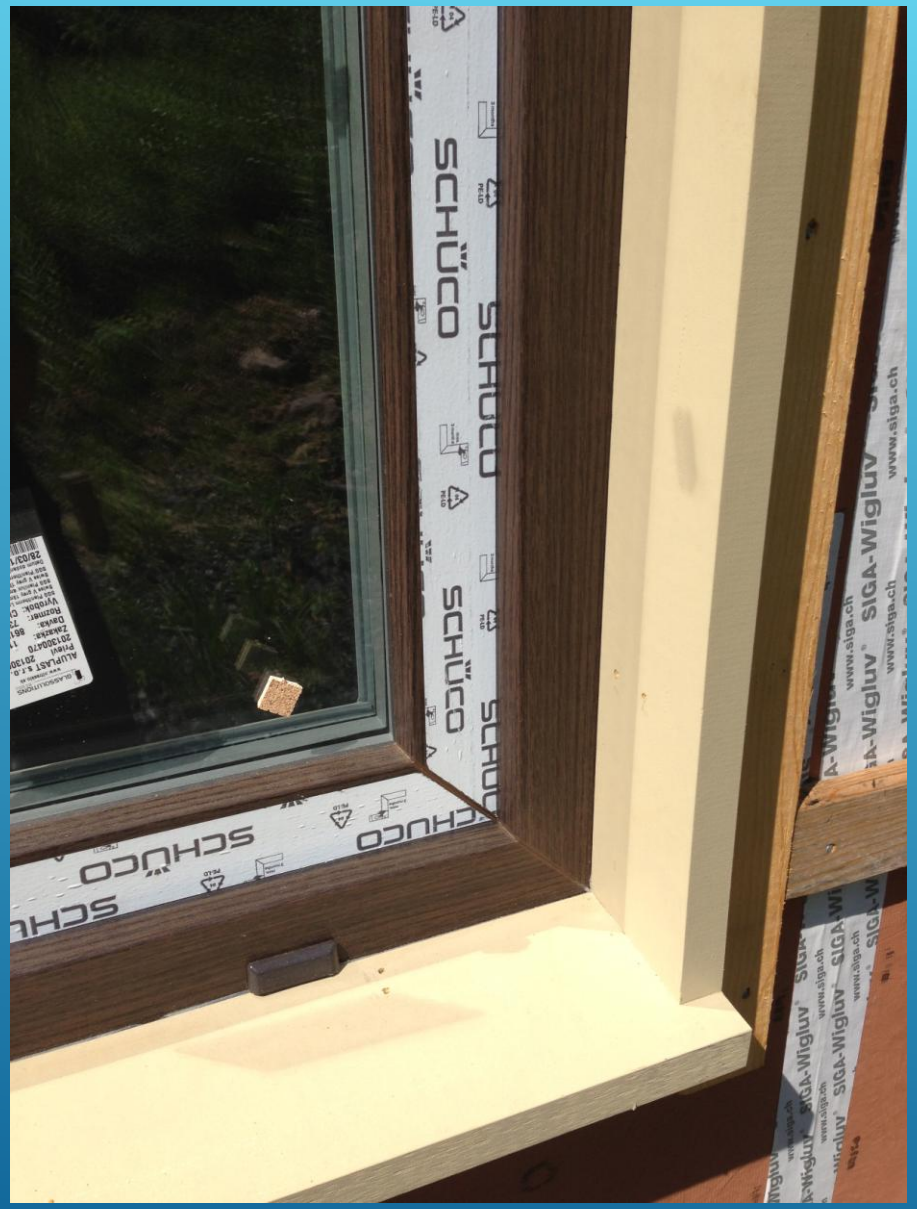
OPTIMIZE FOR ASPECT

FLASH WITH BREATHABLE TAPE

SPRAY FOAM FOR INSULATION



TAPE FOR AIR SEALING WINDOWS



EXTERIOR WINDOW FINISH DETAIL- SLAB HOUSE

INTERIOR WINDOW FINISH DETAIL

EXTERIOR WINDOW FINISH- FULL BASEMENT

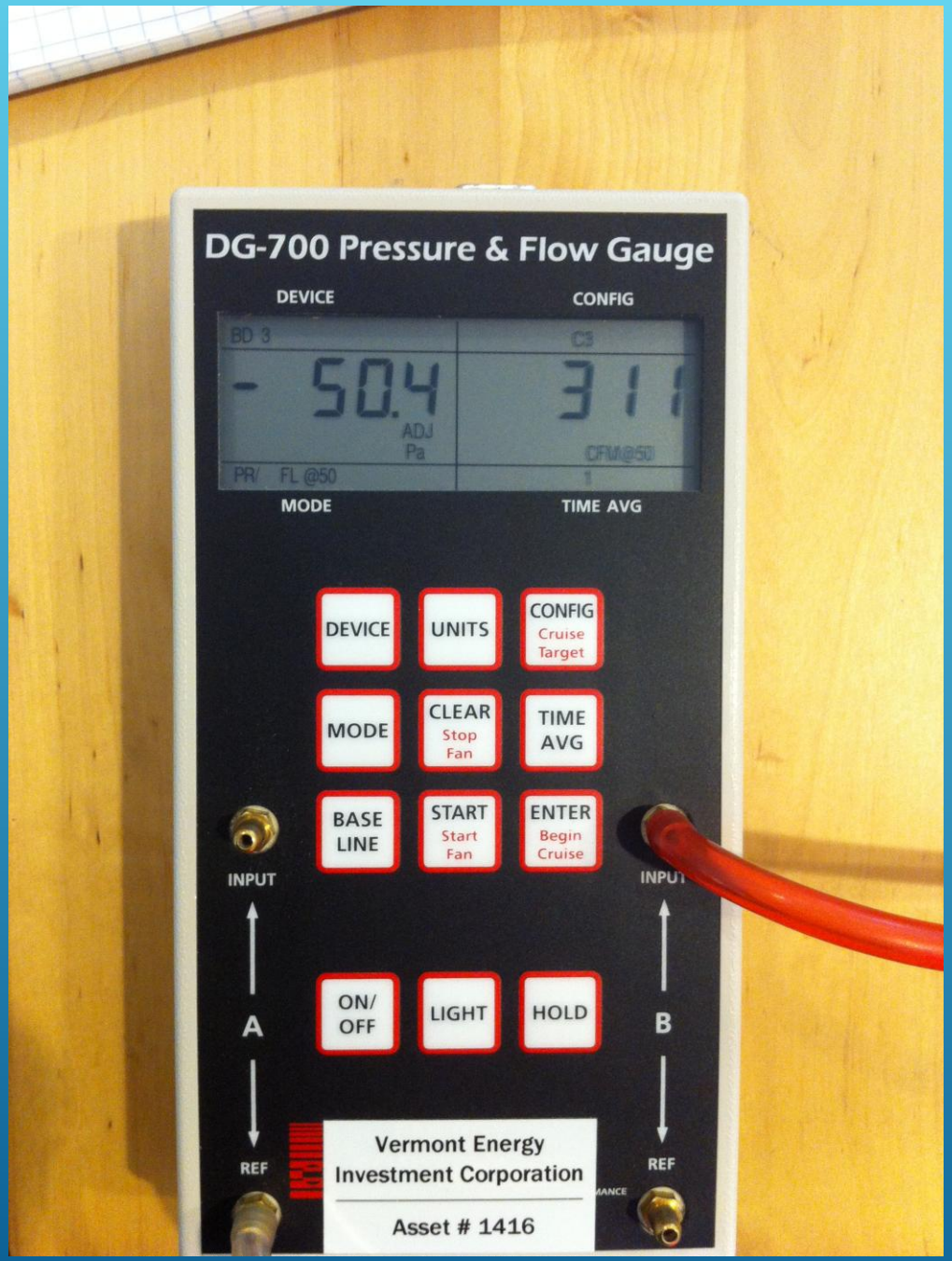
FINISHED WINDOW

ITS ALL IN THE DETAILS

COMPLETED ASSEMBLY-SLAB HOUSE

COMPLETED ASSEMBLY- BASEMENT HOUSE

BLOW AND BLOW OFTEN-HOW LOW CAN YOU GO


DG-700 Pressure & Flow Gauge
DEVICE
CONFIG
BD 3
C3
- 50.4
ADJ
Pa
311
CFM@50
PR/ FL @50
1
MODE
TIME AVG
DEVICE
UNITS
CONFIG
Cruise
Target
MODE
CLEAR
Stop
Fan
TIME
AVG
BASE
LINE
START
Start
Fan
ENTER
Begin
Cruise
INPUT
INPUT
A
B
ON/
OFF
LIGHT
HOLD
REF
REF
Vermont Energy
Investment Corporation
Asset # 1416

INSULATION

R-value of Materials and Depths						
Material	R-value/in	3 1/2"	5 1/4"	10"	12"	15"
Fiberglass blown (attic)	2.20	7.7	11.55	22	26.4	33
Fiberglass blown (wall)	3.20	11.2	16.8	32	38.4	48
Mineral Wool (batt)	3.14	10.99	16.485	31.4	37.68	47.1
Mineral Wool blown (attic)	3.10	10.85	16.275	31	37.2	46.5
Mineral Wool blown (wall)	3.03	10.605	15.9075	30.3	36.36	45.45
Cellulose blown (attic)	3.21	7.455	11.1825	21.3	25.56	31.95
Cellulose blown (wall)	3.70	12.95	19.425	37	44.4	55.5
Open Cell Spray Foam	3.60	12.6	18.9	36	43.2	54
Closed Cell Spray Foam	6.50	22.75	34.125	65	78	97.5

Insulation for 12 inch walls	Pros	Cons
Blown Fiberglass	Fire Resistant, inexpensive, 30-40% recycled, good R-value, non absorbant, mold resistant, durable	Loses R-value with temp. and compression, a bit more exp. than cellulose, fibers health hazard/house dust, Non renewable. Settling
Blown Cellulose	Very green, inexpensive, does not lose R-value with temp. Good air seal when dense packed, fire, mold resistant, moisture buffering, renewable Good R-value, durable	Absorbs moisture, corrosive to metal and brick (borate) Settling if not installed correctly
Rock Wool	Handles heat well, sound absorption, good R-value, high recycled content, durable	Not commonly blown, more expensive
Open Cell Spray Foam	Good initial air seal, low expansion, less expensive than closed cell foam	5-13% shrinkage, R-value similar to cellulose but 2-3x cost, absorbs moisture, nasty chemicals, non renewable, combustible, Low durability

Insulation for 12 Inch Walls	Pros	Cons
Closed Cell Spray Foam	High R-Value Good Air Sealing Will stick to anything	Expensive (3-6x Fiberglass or cellulose) Vapor Closed Cavity Holds in moisture High Expansion Prone to cracking Highly Combustible Pulls away from framing Shrinkage Unpredictable air sealing Difficult to identify and repair air leaks Sensitive to Jobsite conditions

Other Cons of Spray Foam

Degrading thermal insulation values
LTTR's based on only 15 year life cycle- durability questionable
Irredeemable global warming potential
Very Flammable
Non-renewable- Petroleum Based
Dangerous toxic ingredients- Off Gassing

Can Contribute to Sick Building Syndrome

Contains Neurotoxic and Potentially Carcinogenic Flame Retardants which release into environment through it's life cycle and bio-accumulates

OTHER USES FOR SPRAY FOAM

DENSE PACK CELLULOSE WALLS

3.5-4 Pounds per cubic foot avoids settling

Net and strap (or 5/8" drywall)

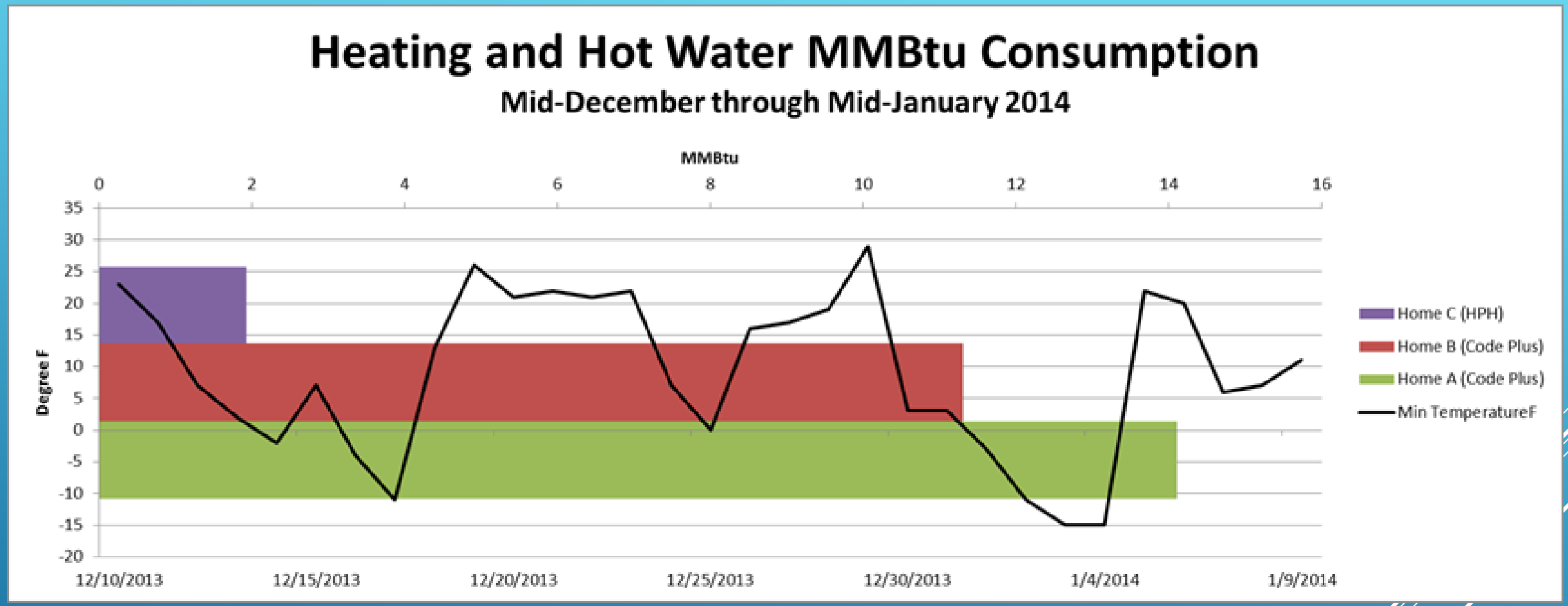
½" drywall- everyone's happy

R-45

DENSE PACKED SLOPES R-76

MECHANICALS

HEAT PUMP HOT WATER HEATER



HPHW HEATER ENERGY USAGE FOR FULL BASEMENT HOUSE

ZEHNDER HRV- CREW INSTALLED
80-85% RECOVERY EFF.
CONTINUOUS FLOW/ LOW ENERGY

ZEHNDER DUCT WORK

ZEHNDER WITH SOIL EXCHANGE LOOP COMFO-FOND

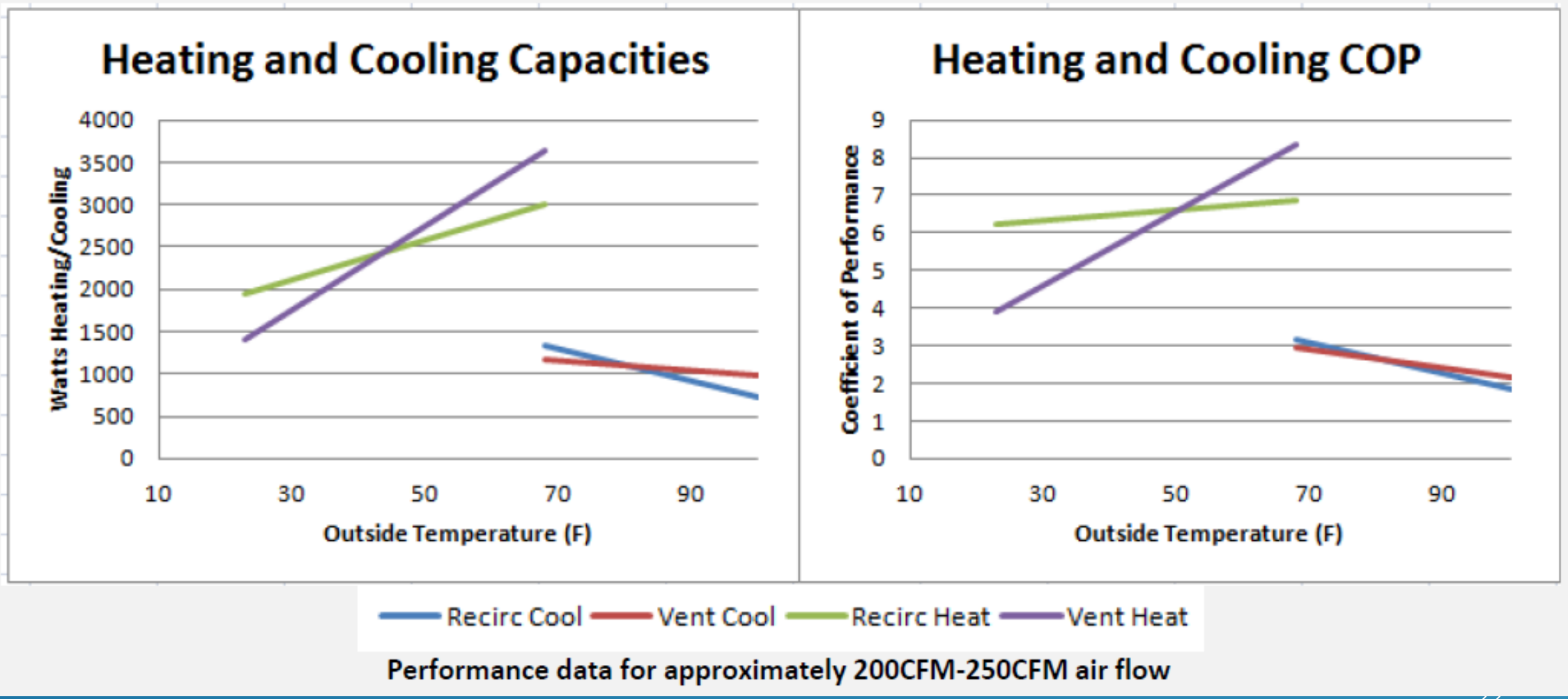
ZEHNDER SUPPLY AND EXHAUST PORTS NO BATHROOM FANS OR VENTED STOVE HOODS

SINGLE POINT MINI-SPLIT
COVERS HEAT LOAD OF HOUSE
21.6KBTU/HR AT 5 DEG TO -13
COOLING 6200-25,200 BTU/HR SEER 20.2

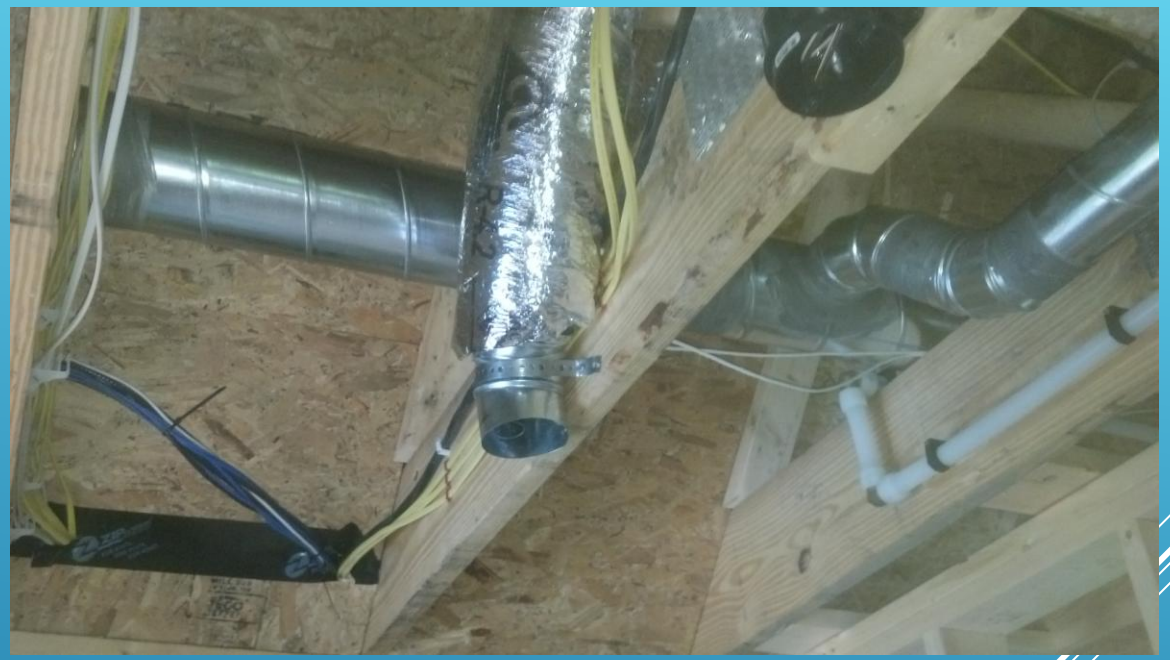
BIOMASS HEATING- 26K BTU

SLAB HOUSE- HPHW HEATER

CONDITIONED ENERGY RECOVERY VENTILATOR- CERV
EXHAUST AIR HEAT PUMP COP 2.5-3.0
COMPLETE DISTRIBUTION OF HEAT AND COOL



CERV- HIGH COP BUT LIMITED HEATING CAPACITY 5500 BTU/HR HEATING 3800 BTU/HR COOLING MONITORS VOC'S AND CO2



CERV ROUGHED IN DUCT WORK
CUSTOM DESIGNED

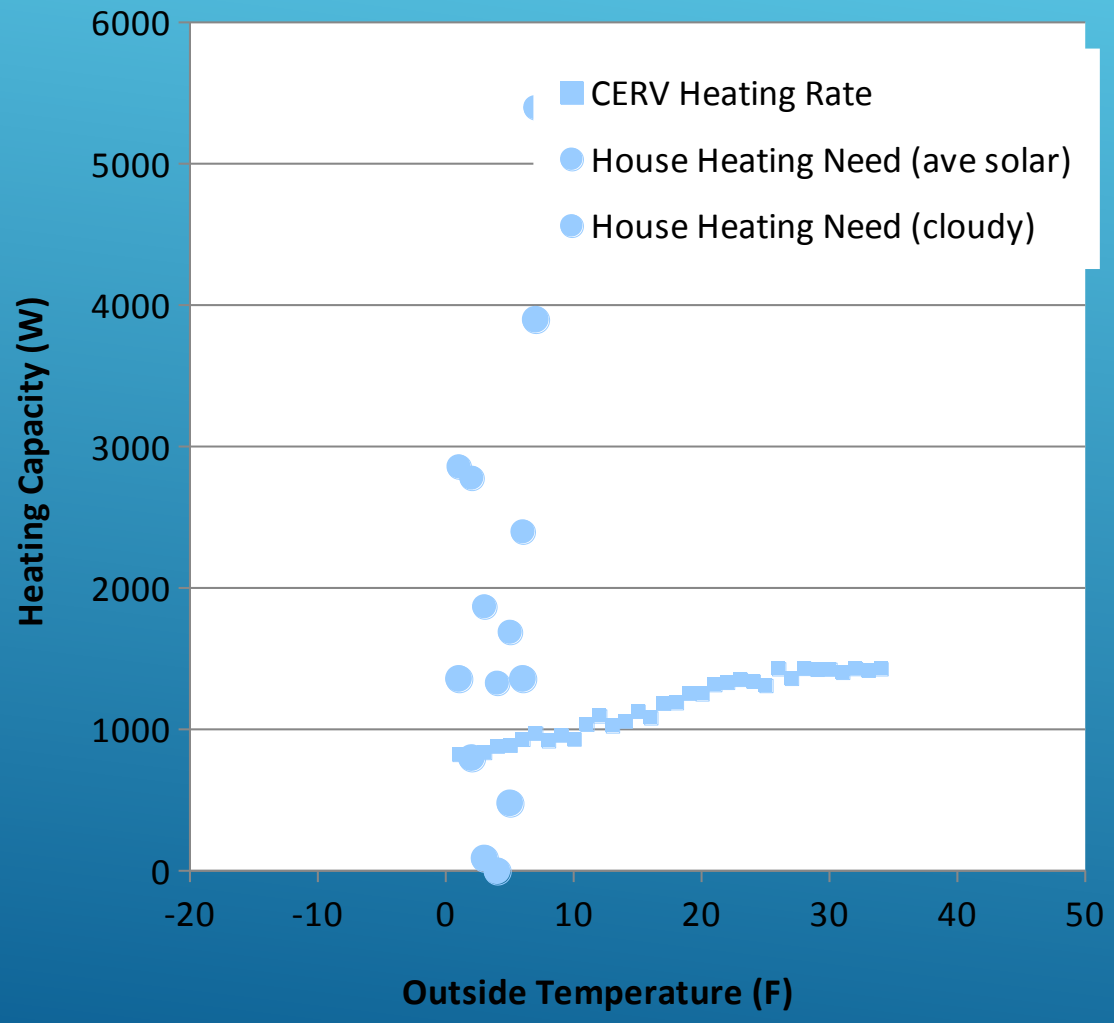
EXHAUST AND SUPPLY DUCTS FOR CERV

EXHAUST AND SUPPLY

CERV WILL DISTRIBUTE BIO-MASS HEATING UNLIKE MOST HRV AND ERV SYSTEMS

Slab Home Heating Needs

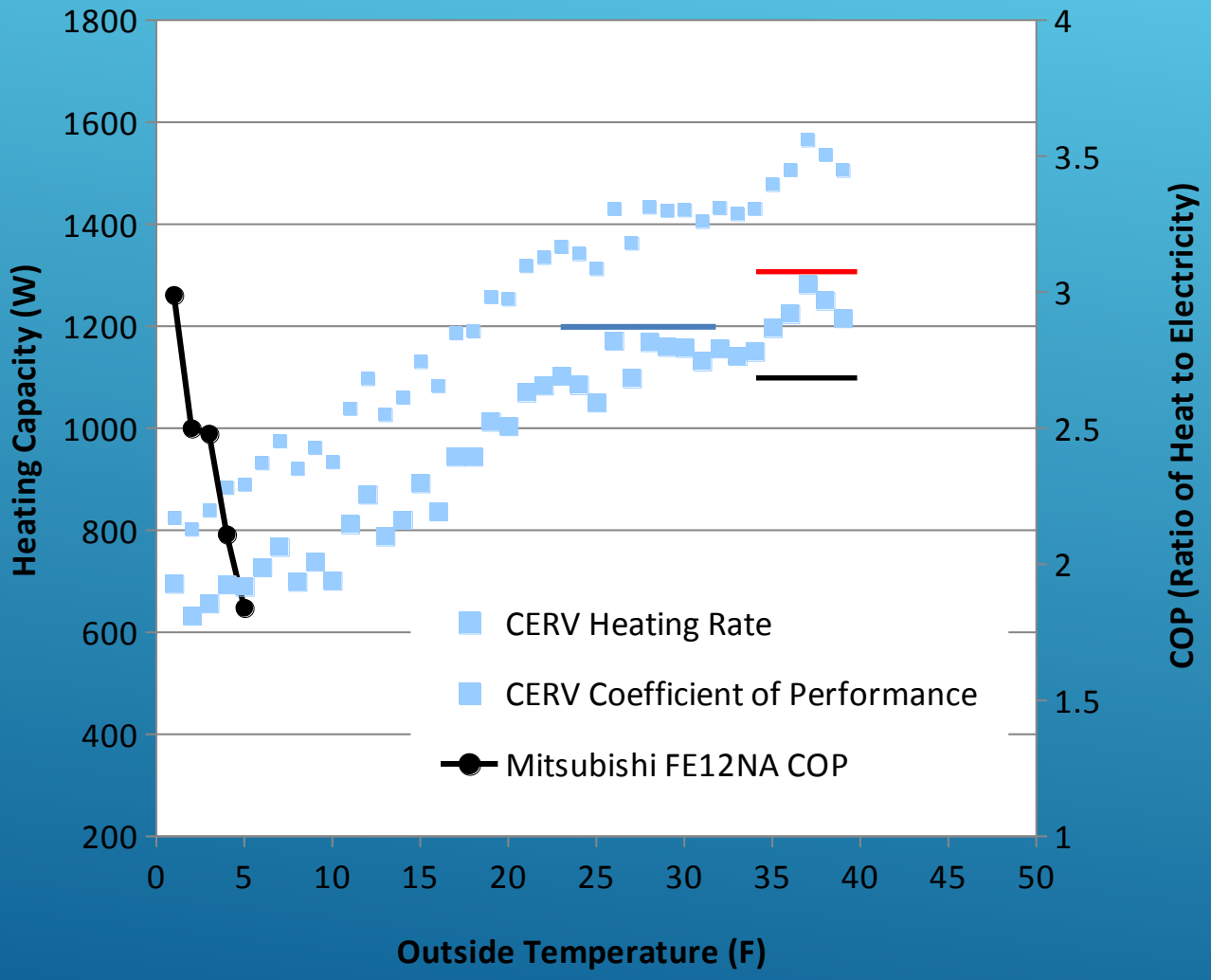
With Average Solar Input and No Solar (Cloudy/Night)



- Average heating needs for October – March
- House heating need is very dependent on solar energy
- Cloudy (and nighttime) heating loads ~1500W greater than average sunny day
- Home heating predictions from ZEROs (Build Equinox home simulation model)

CERV Heating Performance

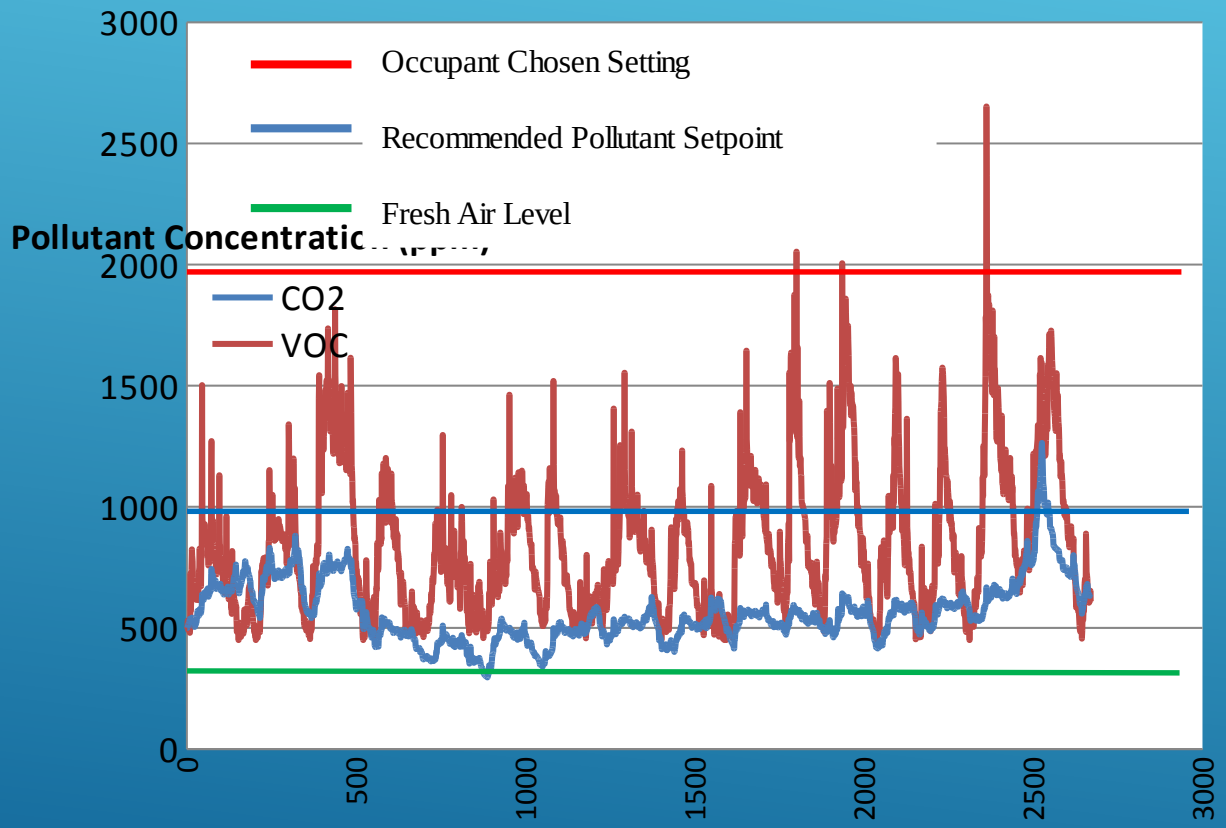
Slab Home (Nov 2013 – Jan 2014)



- CERV is designed to efficiently monitor and manage indoor air quality
  - CERV heating capacity small (1000-2000W)
  - Capacity designed for ventilation air needs
- CERV heating efficiency compares favorably to Mitsubishi FE12N

CERV DCV

(Demand Controlled Ventilation)



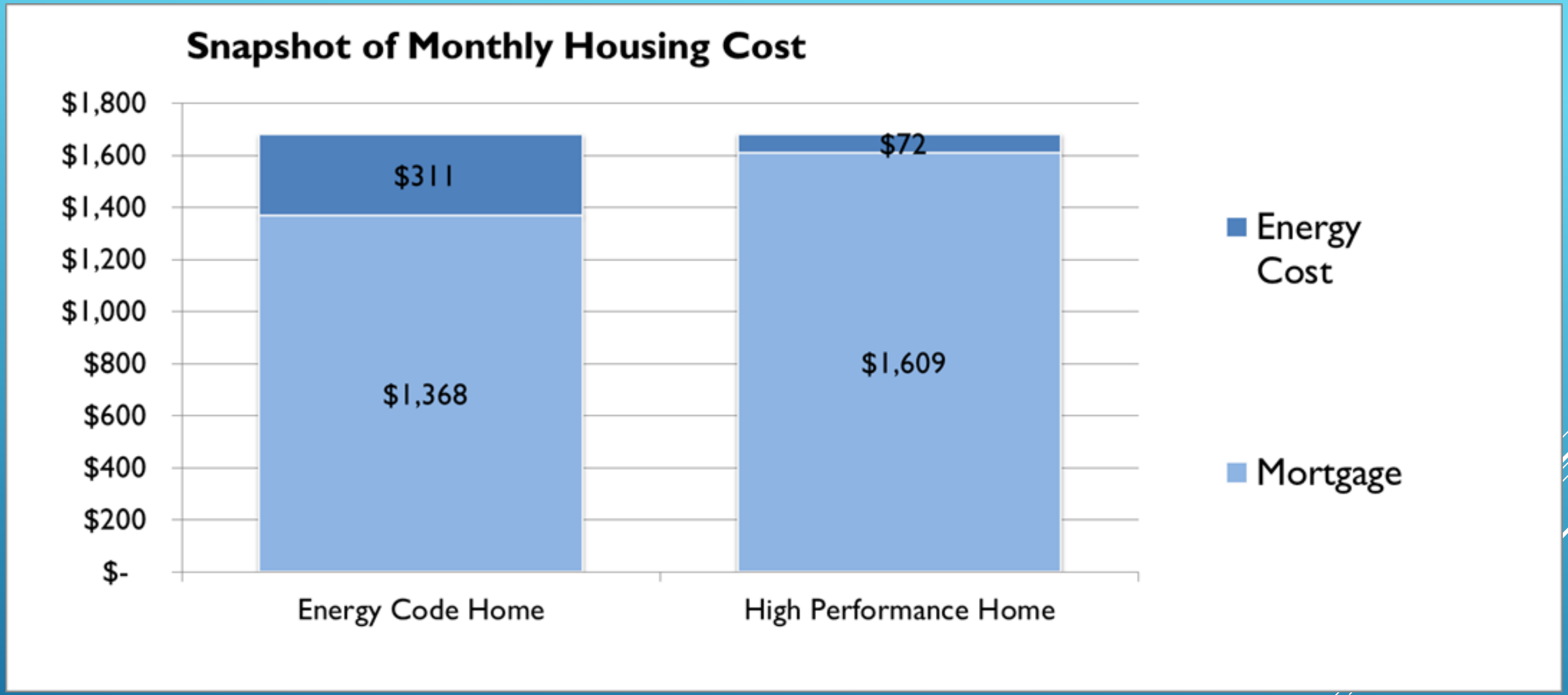
- VOC pollutant levels much higher than CO2 indicating some pollutant source other than human generated pollutants
- Most likely cause due to wood stove
- Occupant chosen pollution setpoint is 2000ppm, allowing high level of indoor air pollution
- Recommended CERV setpoint 900 to 1000ppm (fresh air is 370-400ppm)

HARVESTING THE GOOD STUFF
COSTS AND PERFORMANCE DATA

WHY BUILD THIS WAY?

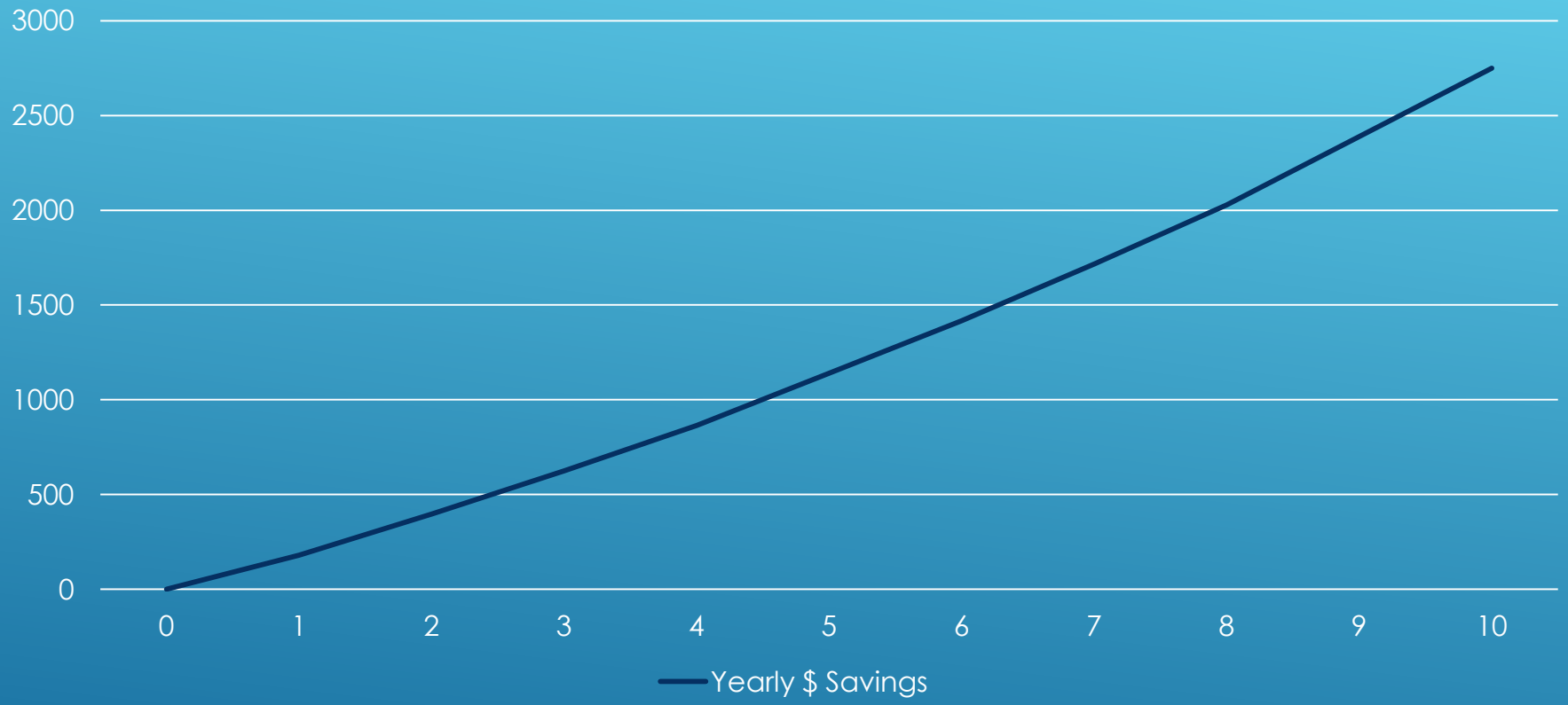
DRAMATIC REDUCTION IN ENERGY USAGE
HERS- AVG. 25-30 (70-75% REDUCTION)
NET ZERO READY
ENERGY SECURITY
INCREASING RETURN ON INVESTMENT
TANGIBLE RESPONSE TO CLIMATE CHANGE

SHOW OFF TO FRIENDS AND FAMILY!

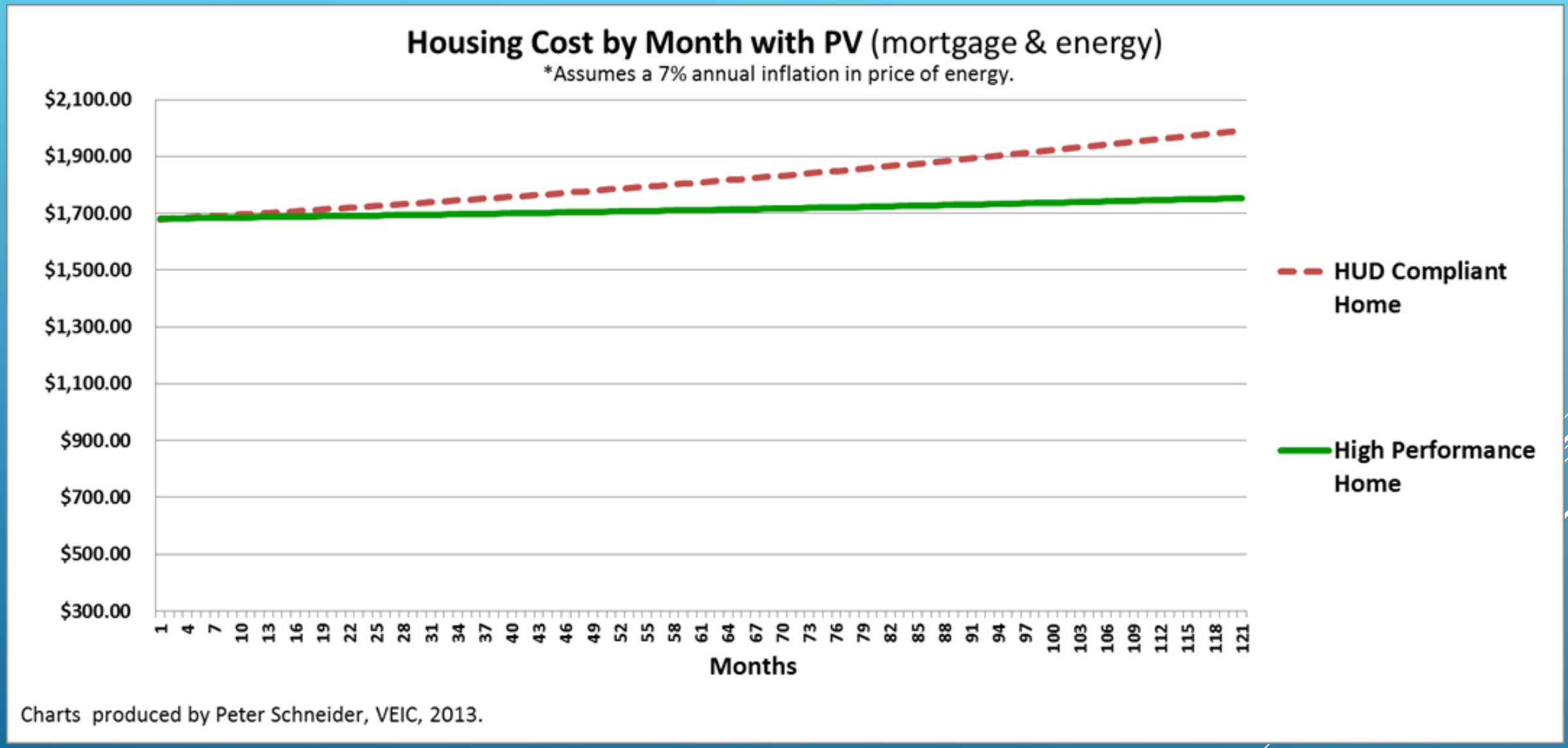


BUILDING COST $180/SQ FT.
ENERGY CODE HOME $157/SQ FT. OR 15%

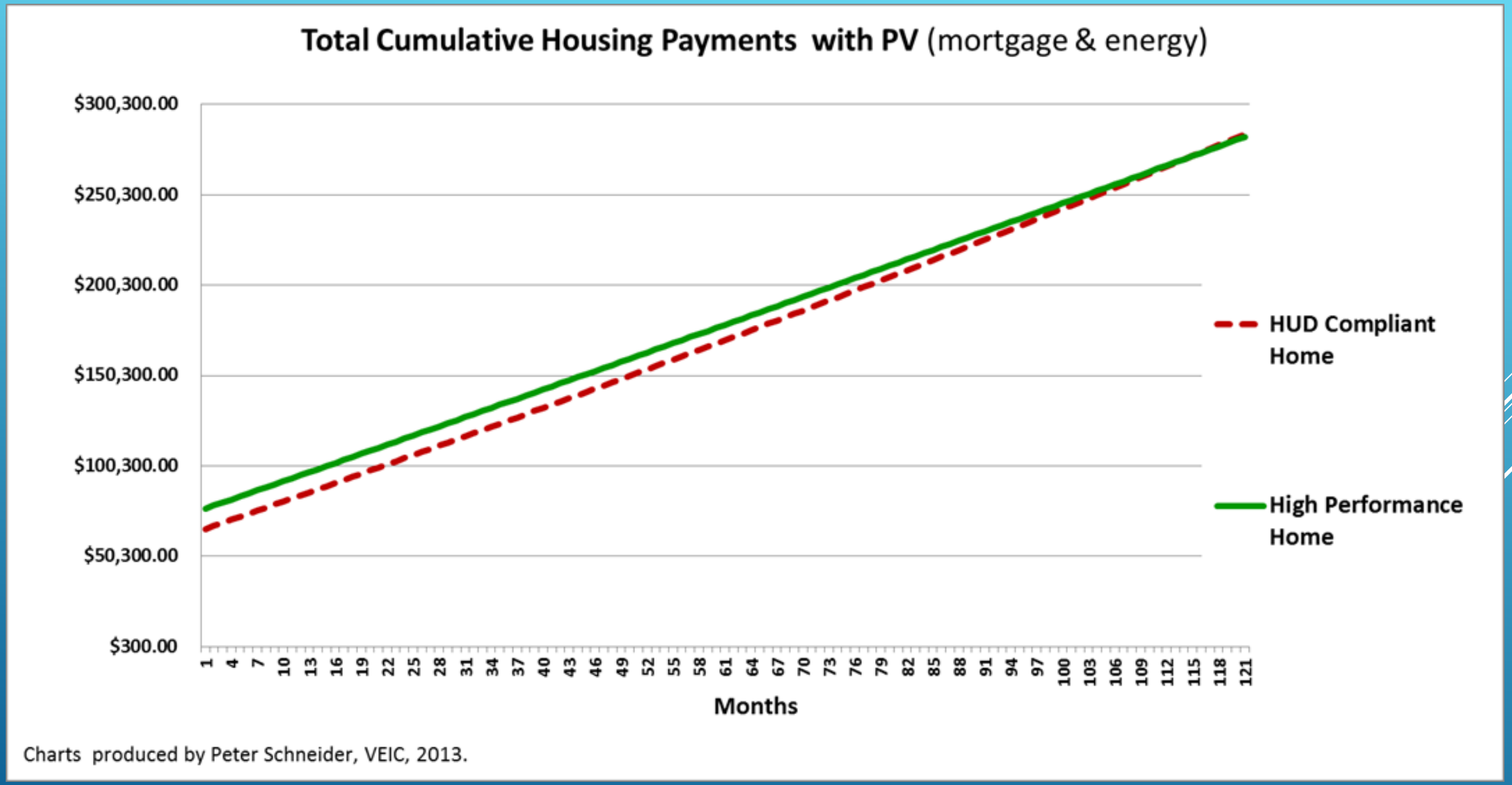
Yearly Savings for HP vs. Code Home



YEARLY SAVINGS OVER 10 YEARS- MORTGAGE + ENERGY
NO RENEWABLES
7% ANNUAL ENERGY COST INFLATION



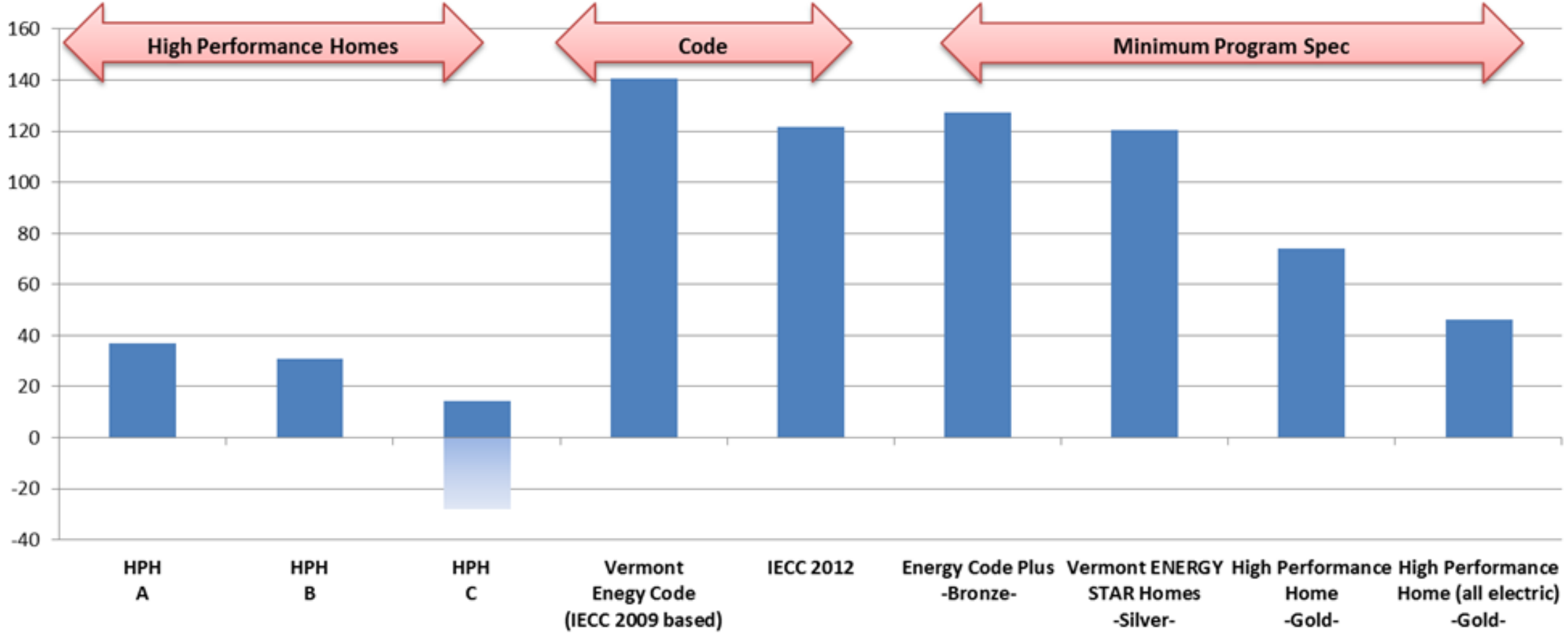
Charts produced by Peter Schneider, VEIC, 2013.



Charts produced by Peter Schneider, VEIC, 2013.

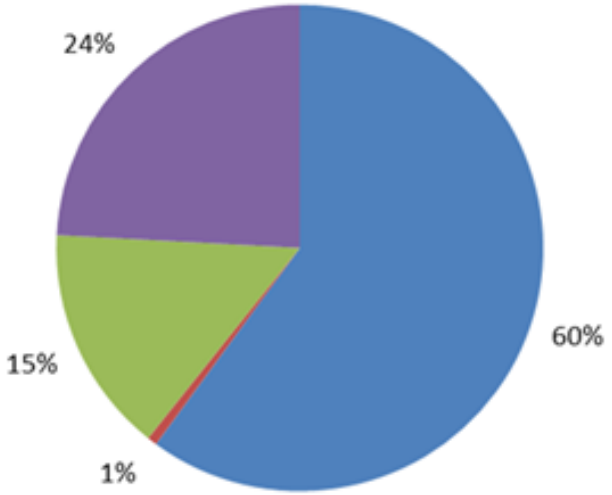
Total Annual MMBtu Consumption

Three VT High Performance Homes vs. Minimum Code and Efficiency Vermont Program Specifications



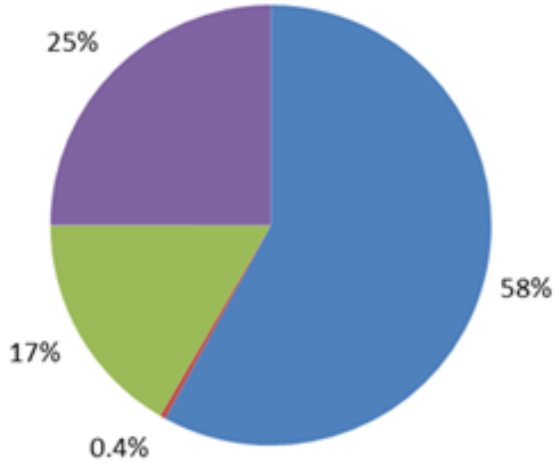
Average Energy Consumption by End Use

EIA RECS 2009, New England



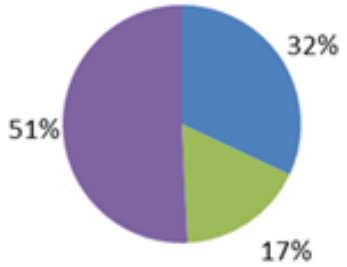
113 Annual MMbtu

Vermont ENERGY STAR Homes 2012



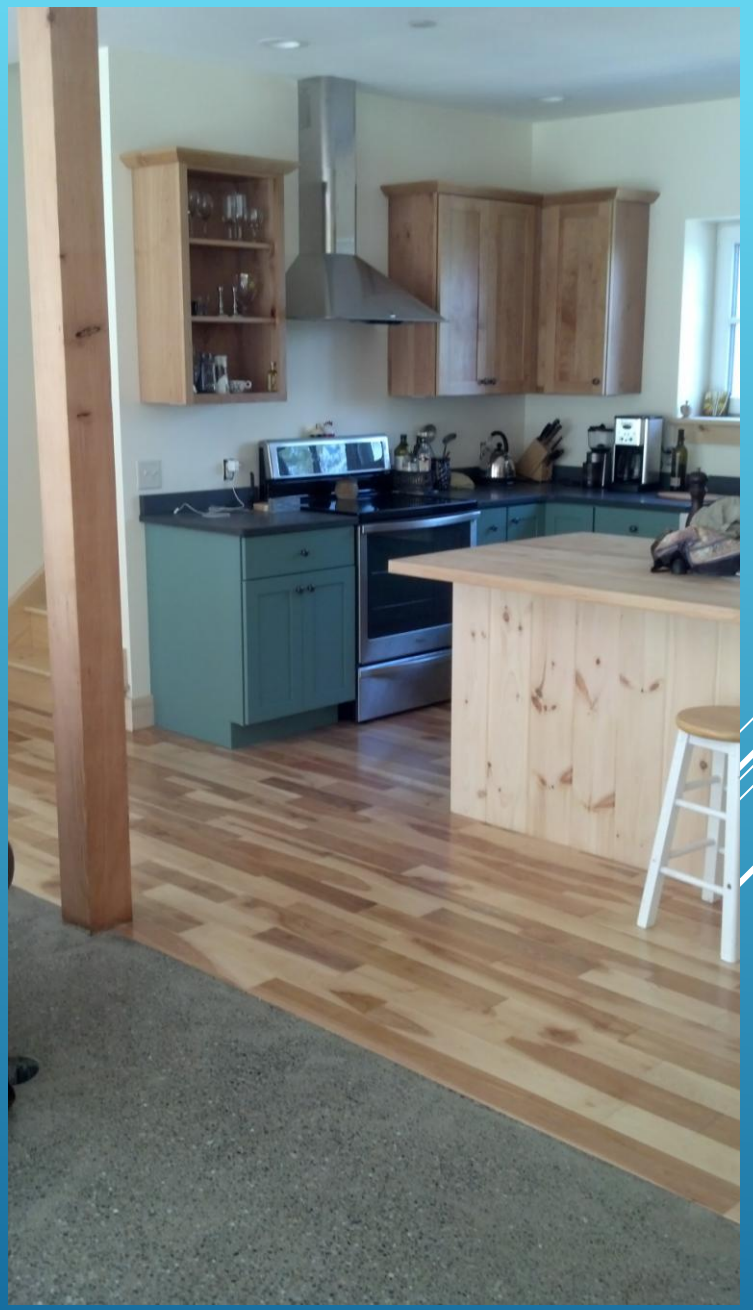
94 Annual MMbtu

Vermont High Performance Homes



34 Annual MMbtu

*End use 'Heating' for High Performance Homes is Heating and Cooling combined



NET ZERO ICF HOME- FULL PV RADIANT SLAB- ELECTRIC WATER WOOD STOVE

HP HOME IN LINCOLN
ZEHNDER/MITSUBISHI SYSTEMS
SOLAR HOT WATER

SUPER INSULATED HOME WITH MASONRY STOVE
FULL PV- NET ZERO
SOLAR HOT WATER

ULTIMATE HP HOME!

CHANGE HAPPENS

I LOVE THIS PLACE