



If I had a Hammer I Would Build a Net Zero Energy Home!

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CONTINUING EDUCATION CREDIT INFO

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IF I HAD A HAMMER (I'D BUILD A NET ZERO ENERGY HOME)!

- Part 1: Pathways to High-Performance
 - Programs That Will Get You There
- Part 2: DOE Zero Energy Ready Homes
 - Review Business Case & Requirements
- Part 3: Zero Energy Homes Today
 - Critical Challenges & Keys to Success
- Part 4: Then & Now

A personal reflection on where we have been, where we are, and where we need to go!

OVERARCHING THEMES

- We can and must do better!
 - Challenge ourselves towards better performance
- Existing technology can get us there, but ...
 - We need to reduce the focus on products.
 - We must embrace more robust systems.
 - We need improvement in design & execution.
- For major advances in performance, we will need more robust designs, technologies, and processes.

WHAT IS A HIGH PERFORMANCE HOME?

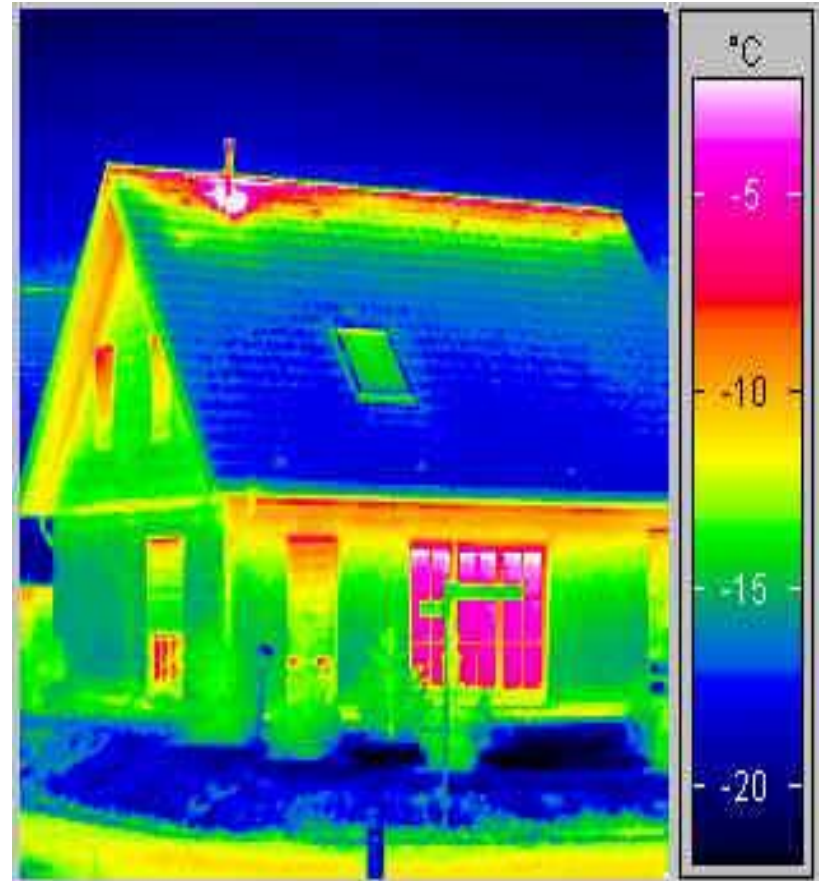
- A deliberate integration of building enclosure, mechanical systems, and controls to provide a
 - comfortable, efficient, durable, and healthy home.
- It demands a “systems approach” to the
 - dynamics of climate, site, and occupants
 - interaction of building enclosure and mechanicals.
- It requires careful planning, teamwork and careful execution in
 - design, construction / installation, and operation.

MAKING THE CASE FOR ROBUST

- We must ensure our high-performance houses meet our expectations today and in the future?
- High-performance houses will push our current approach. Therefore, we must ...
 - design and engineer (not just build) our homes.
 - build forgiveness/tolerance into all systems.
 - build redundancy into critical materials.
 - or make it easy to repair and/or replace key components
 - develop a more predictable delivery system.
 - provide continuous feedback to the occupant.

THE POWER OF ZERO ENERGY HOMES

- Are there buyers who would like to reduce their environmental footprint or have their utility bills go away?



THE POWER OF ZERO ENERGY HOMES

- It is absolutely possible with a couple of caveats!
- Homes will always require energy.
- Can the home produce as much as it uses?
 - Is it site energy or source energy?
 - Is it dollars or carbon?



PART 1. PATHWAYS TO HIGH-PERFORMANCE

- ENERGY STAR (ver 3.1)
 - gets the wheels moving in the right direction.
- DOE Zero Energy Ready Home (ver 6.0)
 - is a more comprehensive, holistic approach.
- Best Current Practices (according to me)
 - fills a couple of key gaps for market/climate.
- Net Zero Energy Now (by Joe Lstiburek)
 - provides a vision for the future.

PATHWAY TO ZERO: METRICS

- Pathway Comparison
 - Enclosure
 - HVAC
 - Domestic Hot Water
 - Indoor Air Quality
 - Renewables

PATH TO ZERO: METRICS

Enclosure (R-values)	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Ceiling	50	50	50	50	60
Walls	20/21	25	25	30	40
Floors	30/38	30/38	30/38	40	--
Foundation	15(10)	15	15	15	20
Slabs					
- Basement	0	0	0	10	10
- On-grade	10	10	10	15-20	20

* From “BSI-081 Zeroing In” by Joseph Lstiburek

PATH TO ZERO: METRICS

Enclosure (U-values)	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Windows	0.32	0.27	0.27	0.25	0.20
Doors	???	0.17-0.30	0.21	0.20	--

Enclosure Airtightness	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE (JL)*
ACH@50Pa	3.0	3.0	2.0	1.0	1.5

PATH TO ZERO: METRICS

HVAC (Equipment)	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Heating					
- AFUE	80%	90%	94%	94%	95%
- HSPF	8.2	8.2	10.0	10.0	--
Cooling (SEER)	13	13	13	15	18
Ventilation					
- Type	Balanced	NR*	Balanced	Balanced	Balanced
- HRV/ERV (Eff)	NR	NR	60%	70%	--
- Distribute	All Rooms	NR*	NR*	All Rooms	All Rooms
Filtration(MERV)	8	8	8	11	--

PATH TO ZERO: METRICS

HVAC (Ductwork)	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Ducts	Sealed S&R	Sealed S&R	Sealed S&R	Sealed S&R	Sealed S&R
Leakage	4cfm/100sf	4cfm/100sf	Condition	Condition	Condition
Insulation	R-8	R-8	NA	NA	NA

Make-Up Air	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE (JL)*
Range	300 cfm?	NA	Vented	Vent/MUA	Vent/MUA
Dryer	NA	Vented	Vented	Vent/MUA	Vent/MUA
Exhaust Fan	Allowed	Allowed	Allowed	Small/MUA	--

PATH TO ZERO: METRICS

Domestic Hot Water	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Plant (EF)	0.53?	0.67	0.67	CSC(combi)	--
Insulation	R-3	R-3	R-5	R-5	--
Distribution	NA	NA	WaterSense	WaterSense	--

Appliances & Lighting	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE (JL)*
Appliances	NA	E-STAR	E-STAR	E-STAR+	E-STAR+
Lighting	NA	80% E-STAR	80% E-STAR	90% LED	100% LED

PATH TO ZERO: METRICS

Indoor Air Quality	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
IndoorAir+	NA	Partial	Yes	Yes	--
Garage Vent	NA	NA	Yes*	Yes*	--
Radon	Rn Ready	Rn Ready	Rn Ready	ASD	--

Renewable Ready	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE (JL)*
Solar Thermal	NA	NA	Optional	Optional	--
Solar PV	NA	NA	Yes*	Yes	Yes

PATH TO ZERO: COST SUMMARY**

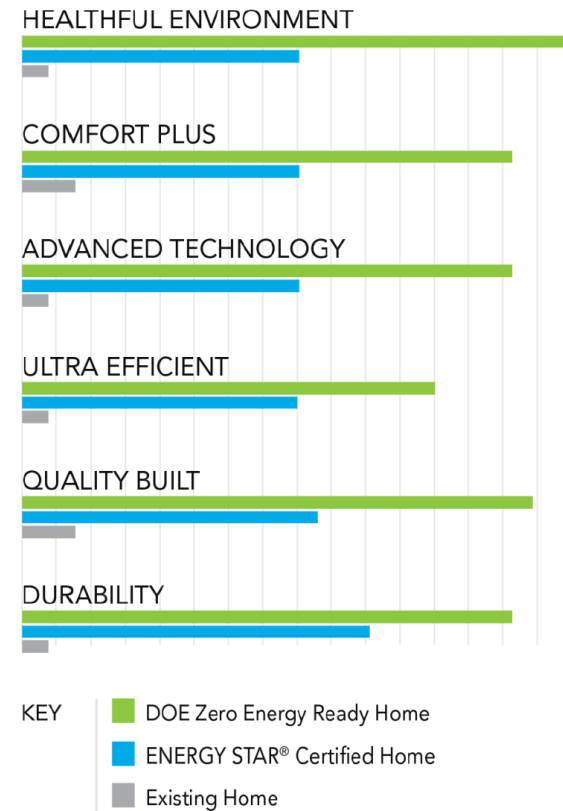
	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Cost Premium	Base	\$5,000	\$9,000	\$12,000	\$16,000
Energy \$/yr	\$2,000	\$1,500	\$1,250	\$1,000	\$750
PV for NZE	20 kW	15 kW	12 kW	10 kW	8 kW
PV System \$	\$60,000	\$45,000	\$36,000	\$30,000	\$24,000
Total Cost	\$60,000	\$50,000	\$45,000	\$42,000	\$40,000

** These are very rough estimates for illustration purposes only!

PART 2: ZERO ENERGY READY HOME



A Symbol of Excellence



Ultra-High Efficiency



High- Performance

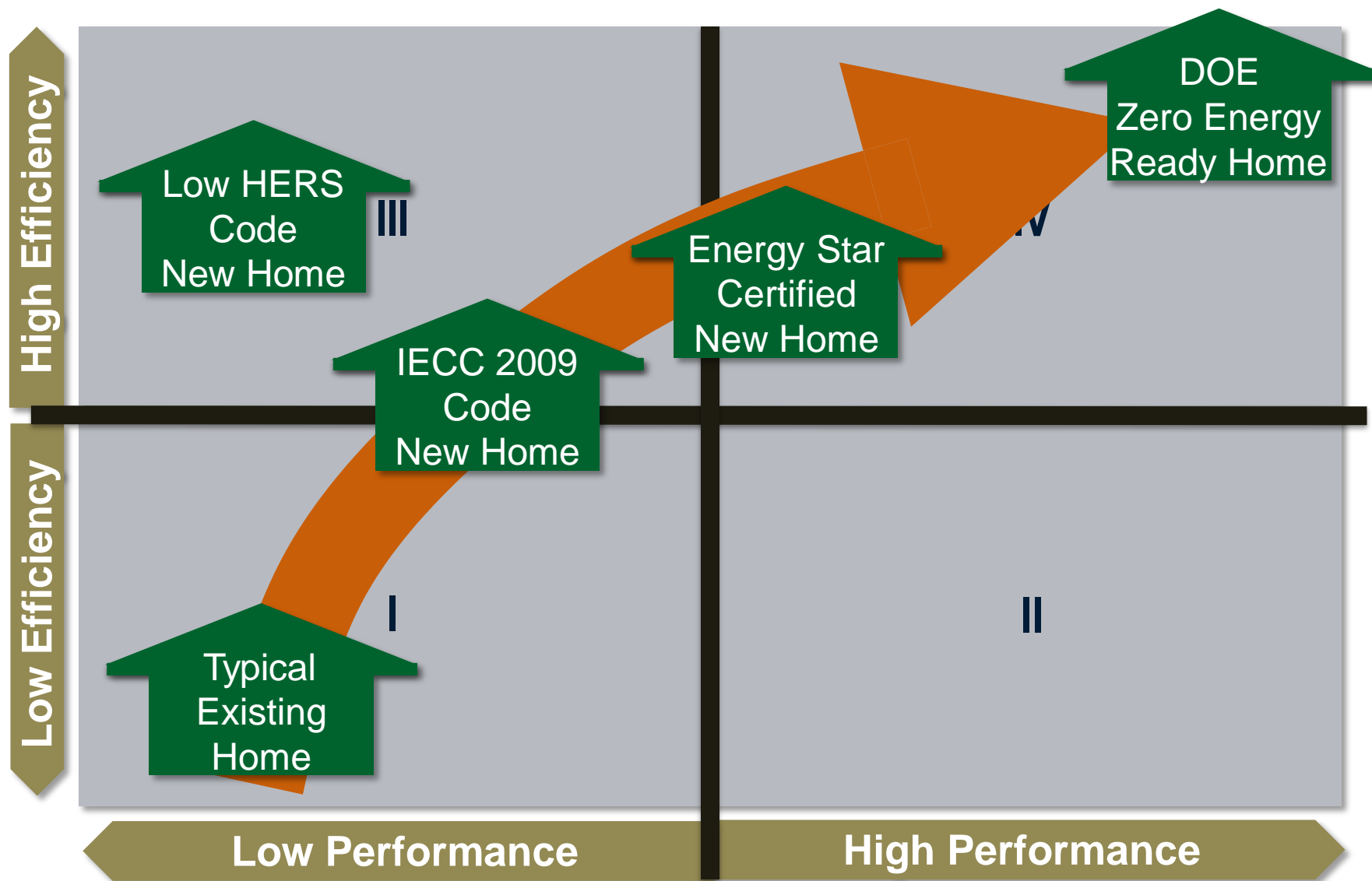
- Enclosure
- Low-Load HVAC
- Components

- Affordable
- Comfort
- Health
- Durability
- Renewable Readiness
- Water Conservation
- Disaster Resistance

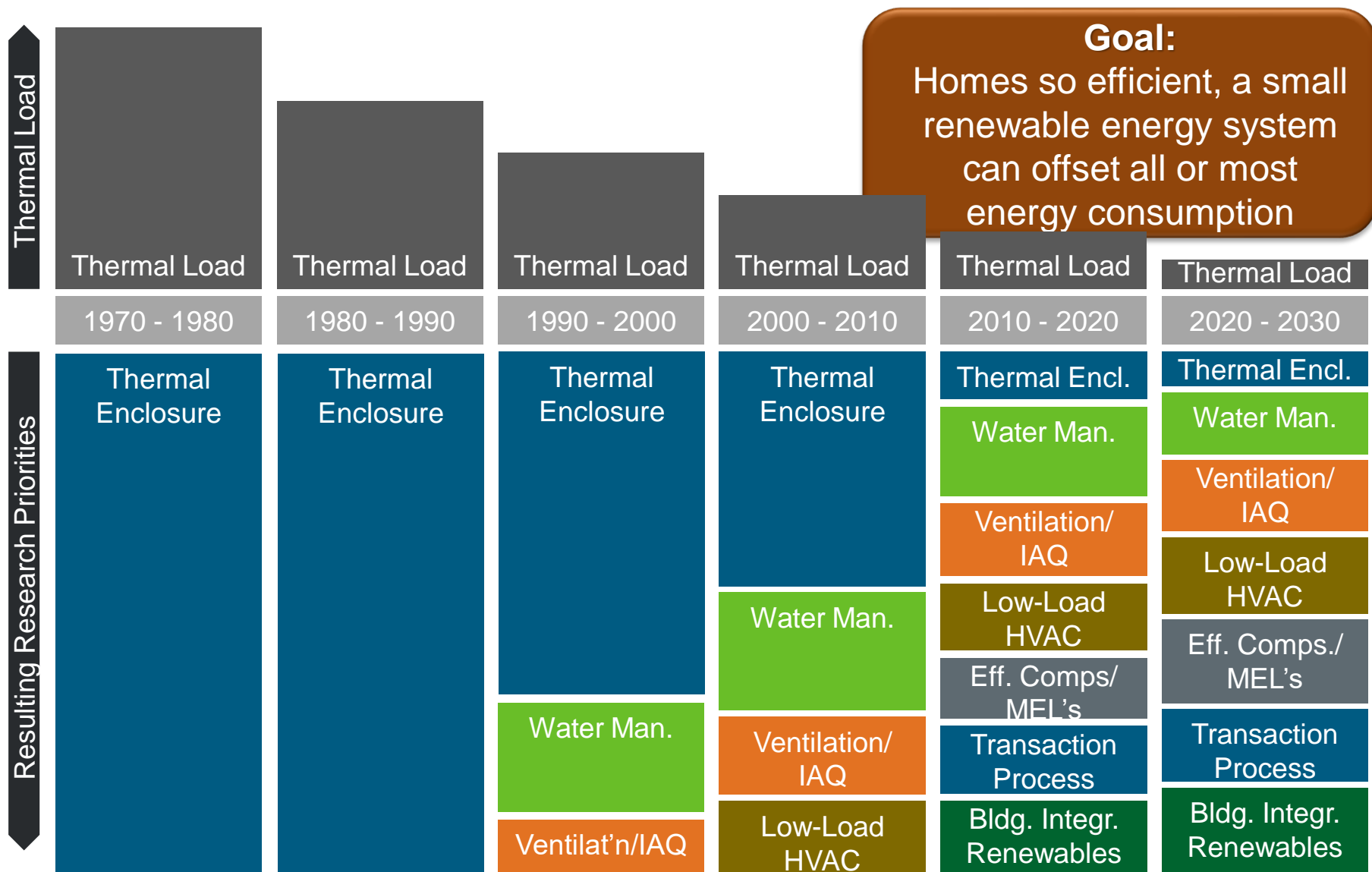
DOE Zero Energy Ready Home Path

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



Building America Strategy



Lots of Recognition Choices...

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



DOE ZERO ENERGY READY HOME

- Provides a solid foundation for high-performance homes!
- In my view, this program is ...
 - Built on a technically sound platform
 - Focused on the right things (not just energy)
 - In the right way (performance-based)
 - At the right level (strategic differentiation)
 - With a delivery process that is credible, but not onerous.

Risk Management

Zero Differentiation

Exceed Expectations

Why Build: The Value

Risk Management

Zero Differentiation

Exceed Expectations

**Lives
Better**

Engineered
Comfort

Healthier
Living

**Works
Better**

Ultra-Low
Utility Bills

Advanced
Technology

**Lasts
Better**

Quality
Construction

More
Durability

ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY



Zero Energy Ready Home

Technical Specifications: Putting It All Together

- ENERGY STAR Certified Homes v3.1
- Advanced Windows
- Air-Tight Construction
- 2012 IECC Insulation
- Energy Efficient Components
- Efficient Hot Water Distribution
- Indoor Air Quality
- Renewable Ready Construction



DOE ZERH Framework

**Mandatory
Reqt.**

Exhibit 1: DOE Challenge Home Mandatory Requirements for All Labeled Homes

Area of Improvement	Mandatory Requirements
1. ENERGY STAR for Homes Baseline	<input type="checkbox"/> Certified under ENERGY STAR Qualified Homes Version 3 ⁵
2. Envelope ⁶	<input type="checkbox"/> Fenestration shall meet or exceed latest ENERGY STAR requirements ^{7, 8} <input type="checkbox"/> Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels ⁹
3. Duct System	<input type="checkbox"/> Ducts located within the home's thermal and air barrier boundary ¹⁰
4. Water Efficiency	<input type="checkbox"/> Hot water delivery systems shall meet efficient design requirements ¹¹
5. Lighting & Appliances ¹²	<input type="checkbox"/> All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. <input type="checkbox"/> 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets <input type="checkbox"/> All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified
6. Indoor Air Quality	<input type="checkbox"/> EPA Indoor airPLUS Verification Checklist and Construction Specifications ¹³
7. Renewable Ready ¹⁴	<input type="checkbox"/> EPA Renewable Energy Ready Home Solar Electric Checklist and Specifications ¹⁵ <input type="checkbox"/> EPA Renewable Energy Ready Home Solar Thermal Checklist and Specifications ¹⁶

**Must
Comply**

**'Target
Home'
Specs**

Exhibit 2: DOE Challenge Home Target Home^{1, 17}

HVAC Equipment ¹⁸			
	Hot Climates (2012 IECC Zones 1,2) ¹⁹	Mixed Climates (2012 IECC Zones 3, 4 except Marine)	Cold Climates (2012 IECC Zones 4 Marine 5,6,7,8)
AFUE	80%	90%	94%
SEER	18	15	13
HSPF	8.2	9	10 ²⁰
Geothermal Heat Pump	ENERGY STAR EER and COP Criteria		
ASHRAE 62.2 Whole-House Mechanical Ventilation System	1.4 cfm/W; no heat exchange	1.4 cfm/W; no heat exchange	1.2 cfm/W; heat exchange with 60% SRE
Insulation and Infiltration			
<ul style="list-style-type: none"> Insulation levels shall meet the 2012 IECC and achieve Grade 1 Installation, per RESNET standards. Infiltration²¹ (ACH50): 3 in CZ's 1-2 2.5 in CZ's 3-4 2 in CZ's 5-7 1.5 in CZ 8 			
Windows^{22, 23, 24}			
	Hot Climates (2012 IECC Zones 1,2)	Mixed Climates (2012 IECC Zones 3, 4 except Marine)	Cold Climates (2012 IECC Zones 4 Marine 5,6,7,8)
SHGC	0.25	0.27	any
U-Value	0.4	0.3	0.27
Homes qualifying through the Prescriptive Path with a total window-to-floor area greater than 15% shall have adjusted U-values or SHGCs. ²⁵			
Water Heater			
ENERGY STAR minimum; for heating oil water heaters use EF = 0.60			

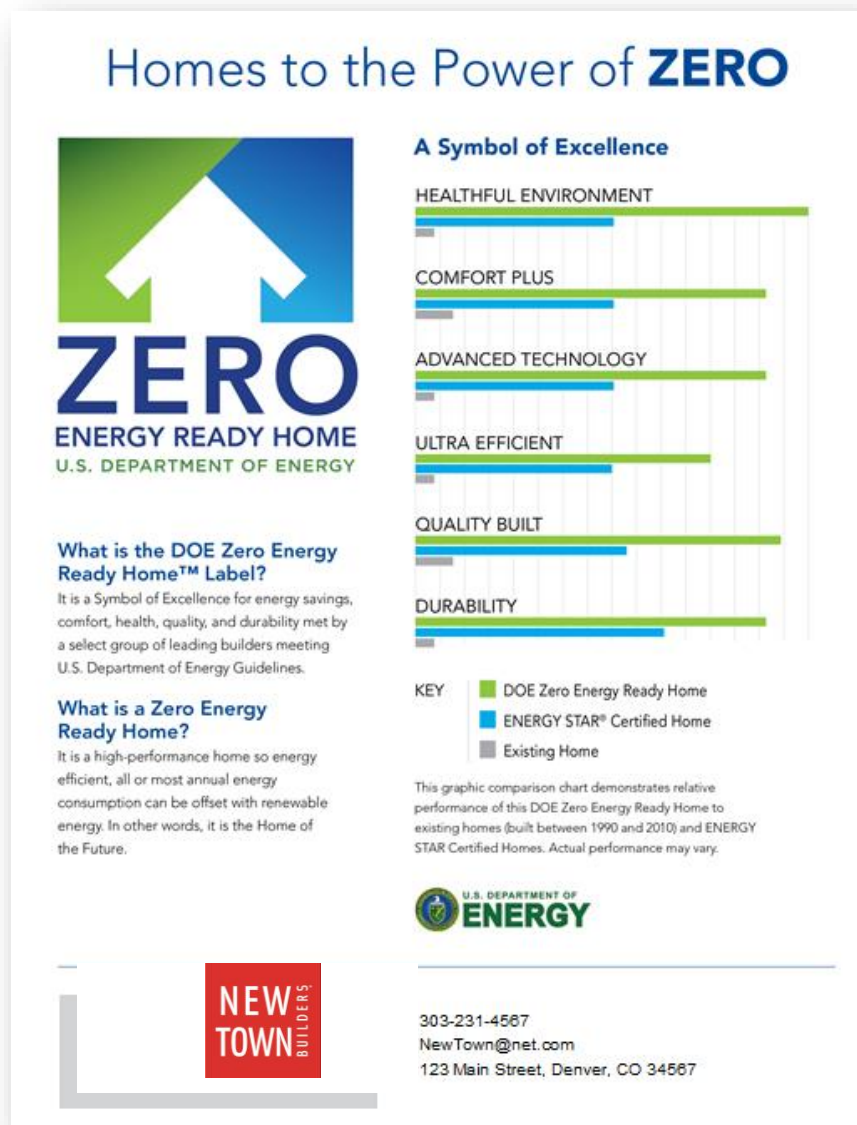
**Trade-Off
Flexibility**

**Size Adjust.
Factor**

Exhibit 3: Benchmark Home Size²⁶

Bedrooms in Home to be Built	1	2	3	4	5	6	7	8
Conditioned Floor Area	1,000	1,600	2,200	2,800	3,400	4,000	4,600	5,200
Benchmark Home								

**Identical to
Energy Star**



PART 4: THE FUTURE IS HERE TODAY!

- The technologies, systems, and best practices are in place for high-performance homes today.
- The “Zero Energy Ready Home” has been proven in the market.
- With solar PV prices falling, a small investment can take your energy bill to “zero”.



NET ZERO ENERGY TODAY

- Definition: the total amount of energy consumed is equal to the total amount of energy generated on-site.
- It can be done ...
 - But must begin with a careful examination of the trade off between the cost of energy reduction and the cost of solar generation.

NET ZERO ENERGY TODAY

- But be prepared – the whole building solution might look a bit different than you imagined.
 - It isn't simple adding more of the same.
 - There are several “new things” that will demand your attention to as you move to Net Zero Energy.
 - From “BSI-081 Zeroing In” by Joseph Lstiburek
- These will be presented as challenges.
 - But don't construe these as negatives,
 - Rather as important precautions necessary to ensure your successful pursuit of NZE homes.

ZEROING IN*

- Don't get carried away with passive solar!
 - The heat gain in the winter may not be needed.
 - The heat gain in the summer will likely hurt you.
- But people want windows –
 - So give them windows; just use good judgement on orientation, placement, type, and treatments.
- Focus on collecting solar energy with PV.
 - Which is needed to satisfy non-thermal loads.

ZEROING IN*

- Ultra-efficiency crushes super-insulated
- Ultra-tight is critical, but it has consequences!
 - Large exhaust devices require a new approach and/or make-up air.
 - clothes dryer: consider a condensing unit
 - range hood: high capture rate with make-up air
 - Interior wood stoves/fireplaces ...
 - just don't do it!

ZEROING IN*

- Ventilation system must be top-drawer!
 - Balance with heat/energy recovery is required.
 - Use the HRV/ERV to satisfy bathroom exhaust requirements to avoid additional exhaust fans.
 - Be certain to provide fresh air to the bedrooms.

ZEROING IN*

- You must have internal air circulation!
 - Air isn't moving bottom to top or side to side.
 - You need mixing for thermal comfort.
 - You must distribute fresh/filtered air for IAQ.
- You can choose to do this with your space conditioning or ventilation system.

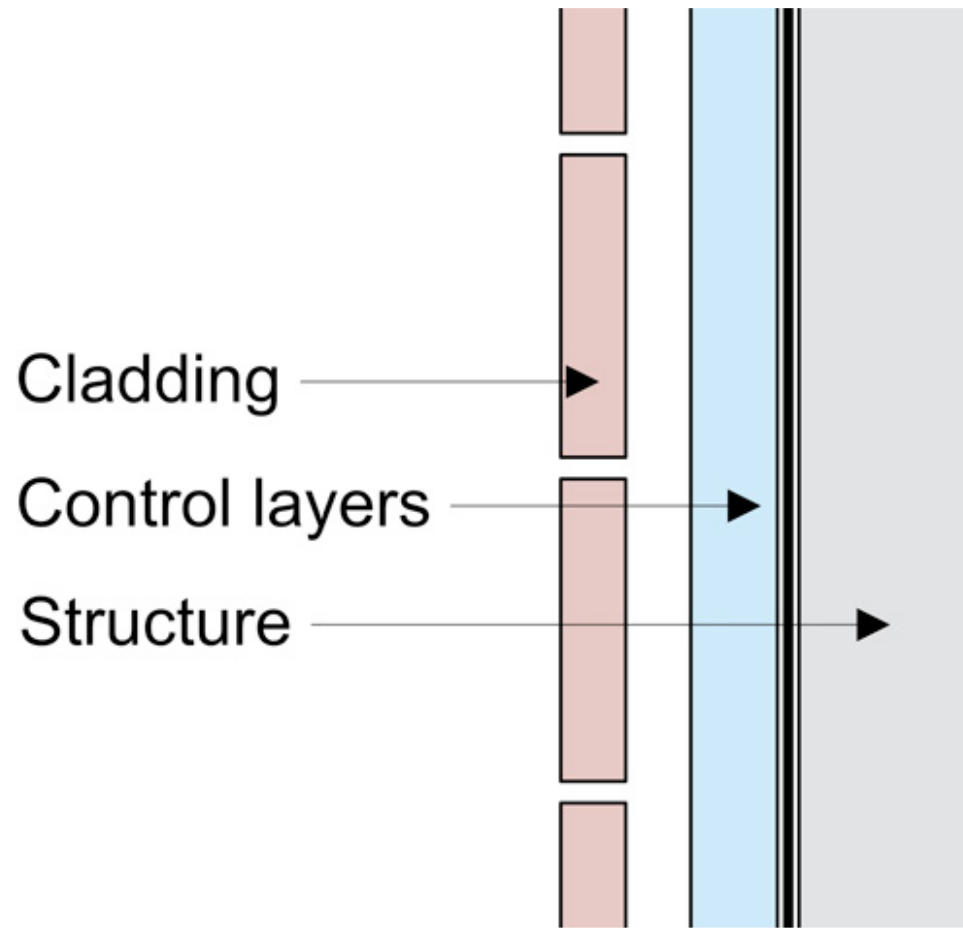
ZEROING IN*

- Perhaps the greatest challenge will be latent load management!
 - In the swing seasons and under part-load conditions moisture can float out of control.
- Do you think you can do this with your space conditioning or ventilation system?
 - It is tougher than it sounds.
 - Dehumidification may need to be an independent system.

CHALLENGE 1: FORGIVING ENCLOSURE

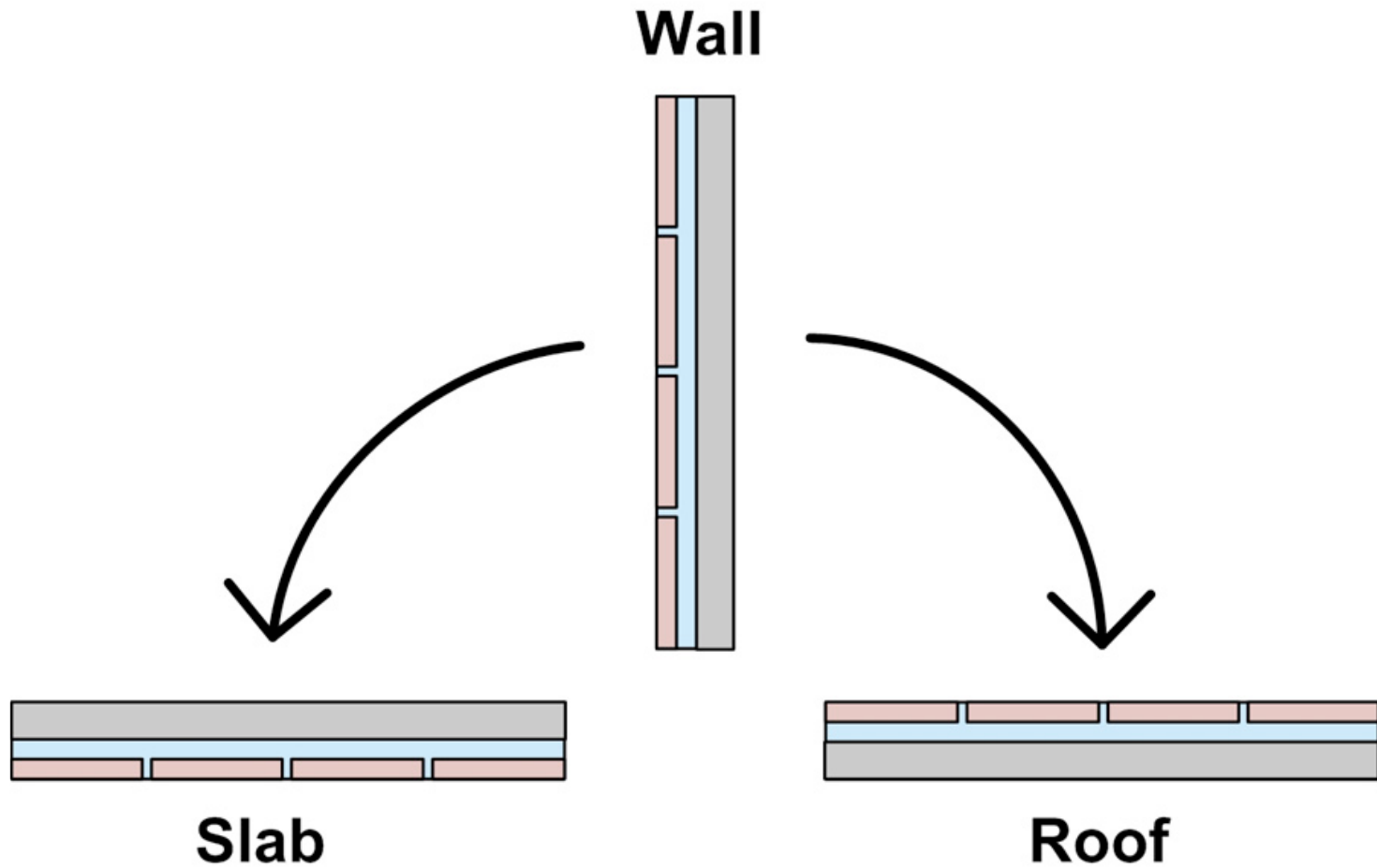
- The “Perfect” Approach
 - Walls
 - Roof
 - Slab
 - Foundation
- Move the structure to the inside and the control layers to the outside ...
 - It simply works and works everywhere!!!

THE PERFECT WALL*



* Source: Building Science Corporation

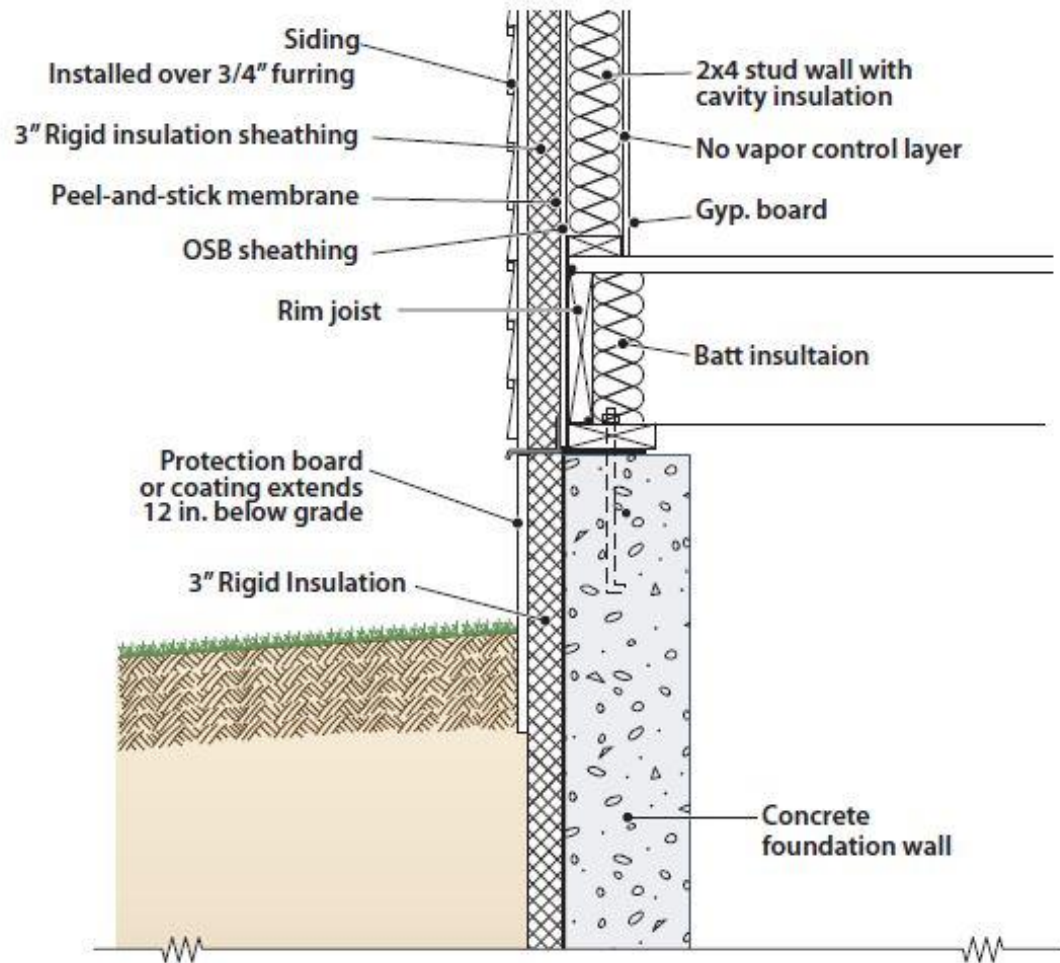
WORKS FOR ROOF & SLAB, TOO!



PUTTING THE LAYERS TOGETHER

- Four Critical Control Layers
 - Water
 - Air
 - Thermal
 - Vapor
- What you use is important, but the where, how, and when (order/sequence) is critical.
 - However, it can be extremely simple!

CONTROL LAYERS – HYBRID WALL



CHALLENGE 2: GREAT VENTILATION

- Good is not good enough!
- You have an incredibly tight enclosure
- Start by managing pollutants (and moisture)
- Humid outdoor air will create some special challenges, especially under part-load conditions.

ALWAYS MANAGE THE POLLUTANT

- Safe pollutant levels
 - Avoid and/or encapsulate for material emissions
 - Use point source control, where possible
 - Then employ general ventilation
- Manage fine particulates
 - Whole house
 - Kitchen range
- Protection against biologicals
 - Humidity control
 - Particle filtration

VENTILATION SUMMARY

- Must be balanced heat recovery ventilation
 - Recommend a source point exhaust strategy
 - In most cases, an ERV is preferable
 - Filtration (MERV 11+) for supply air
 - Distribution to all habitable rooms
 - forced air system
 - separate dedicated duct system
- Spot ventilation can be exhaust-only if small and/or rarely used.

CHALLENGE 3: WHAT ARE WE CHASING?

- Heating isn't the problem any longer!
- Overheating (and cooling) are quickly taking center stage even in colder climates!
 - Internal & solar gains must be carefully managed.
- Natural ventilation/cooling has challenges
 - Cooling when the outside temperature is below the setpoint

SPACE COOLING

- To AC or not to AC?
 - For many reasons, this is changing fast.
 - And for many it isn't an option any longer.
- Natural ventilation can work many days, but not all days for all people.
 - It might present outdoor IAQ issues including pollen, mold spores, and particulates.
 - It can contribute to indoor moisture and mold issues, especially with cooler interior surfaces.

NET ZERO ENCLOSURE FLIPS THE LOADS

- Heating balance points are very low
 - 40 to 45 degrees
- Space cooling is very different
 - Loads may look lower
 - But cooling demand will be longer
 - And load diversity/ratios between spaces will be much higher

WHAT TO DO IN THE MIDDLE?

- Highly-insulative, airtight enclosures with unmanaged solar and internal gains can easily overheat when outdoor temperatures are below your setpoint.
 - If natural ventilation works for you this is pretty easy.
 - but it must be based on enthalpy, not temperature.
 - If not, you need an economizer cycle
 - Your ERV/HRV could be working against you.

CHALLENGE 4: HUMIDITY MANAGEMENT

- This is critical in low-load homes, as typical air-conditioning doesn't work.
 - Many times you have high latent loads when there is no significant sensible load.
 - Frequently you need more moisture removal under part-load conditions.

SPACE DEHUMIDIFICATION

- It takes 10 to 15 minutes to wet the coil to the point that condensate is being removed.
 - About the same to re-evaporate, though much shorter if the fan runs continuously.
- It might be possible to downsize the AC and consider reheat to force longer run times.
 - Two-stage or variable capacity AC can help!
- But for best summer humidity control, consider a whole house dehumidifier.

SPACE DEHUMIDIFICATION

- Whole House Dehumidification
 - Since ventilation does not equal humidity control, it is critical to provide systematic dehumidification.
 - Independent control for indoor humidity to control condensation, mold, and dust mites.
 - Huge aid for summer comfort.

CHALLENGE 5: PRESSURE MANAGEMENT

- This becomes increasingly harder with tighter enclosures and larger exhaust devices.
 - Very large negative pressures are very real
- Furthermore, what pressure do we want?

BUILDING ENCLOSURE: PRESSURE

■ Optimal Pressures (house wrt outdoors)

	Winter	Summer
– Building Enclosure	-	+
– Garage Gases	+ (or =)	= (or +)
– Radon (Soil Gases)	+	= (or +)
– Combustion Safety	+ (or =)	+
– Exterior Pollutants	+	+
– Thermal Comfort	+	+

MAKE-UP AIR

- How much negative pressure for how long?
- Key equipment concerns
 - Ventilation impact can be minimized by using a balanced ventilation strategy for both continuous and intermittent ventilation.
 - Kitchen range must be carefully managed.
 - designed for improved capture at lower flow rates
 - Clothes dryer is critical because of the flow rate and potential for extended run times.
 - ventless heat pump dryer

MAKE-UP AIR

- Key Strategies
 - All closed, sealed-combustion equipment
 - Minimize exhaust flows
 - Passive make-up air
 - Is limited in size, is not tempered, and will be plugged
 - Blended make-up air
 - Mixes indoor air with outdoor air to increase the temperature of the air delivered to the house.
 - Tempered Make-up Air
 - Outdoor air is tempered (temperature & humidity)

SUPPLY AIR SYSTEMS

- We need to rethink how we can embrace new supply air strategies to actively manage house pressure.
 - Dedicated outdoor air units
 - Economizers,
 - ???
- How do we condition that air simply and economically?

PART 4. THEN & NOW

- Pat's First New Home
1994



- Pat's Next New Home
Hypothetically 2020



PART 4. THEN & NOW

- Pat's first new home
 - custom design
 - contracted with a respected builder
 - took on items beyond their normal processes
- Primary theme
 - best readily available & affordable technologies for an efficient, durable, and healthy home
- Pat's next new home
 - custom design
 - contract with a respected high-performance builder
 - explicit performance goals w/ QA/QC oversight
- Primary theme
 - smart, practical, and resilient high-performance net zero energy home on a budget

THEN & NOW: GENERAL DESIGN

- 2-story
 - walkout basement
 - Back-facing south
 - Perfect square
 - wrap around garage and porches on west, north, and east
 - Low-pitch hip roof
 - vented attic
 - long overhangs
- 1-1/2 story
 - lookout basement
 - Back-facing south
 - Rectangle
 - garage and entry to protect west and north
 - porch on east
 - Steep gable roof (E-W)
 - vented hybrid roof
 - modest overhangs

THEN & NOW: ENERGY DESIGN

- Optimized enclosure
 - balanced R-values
 - focus on airtightness
- High-efficiency HVAC
- Sun-tempered with some thermal storage
- Natural ventilation
 - corner windows
 - central stairwell
 - whole house fan
- Beefed up enclosure
 - increase insulation levels
 - minimize thermal bridging
 - very airtight
- Step up the efficiency
 - integrated HVAC+DHW
 - more focus on LAMELs
- Reduce passive solar and natural ventilation
- Add solar PV

THEN & NOW: SLAB

- Large washed rock
 - 2" to 3" XPS
 - 2 layers staggered
 - Cross-laminated poly
 - 4" slab
 - sealed edges & joints
 - Sealed sump basket
 - interior drain tile
 - passive radon pipe
- Large washed rock
 - 3" (maybe 4") XPS
 - 2 layers staggered
 - Cross-laminated poly (?)
 - 4" slab
 - sealed edges & joints
 - Sealed sump basket
 - interior drain tile
 - passive radon pipe

THEN & NOW: FOUNDATION

- Cast-in-place concrete
 - Waterproofing
 - Exterior insulation
 - 2" XPS
 - 1" XPS Therm-Dri (BG)
 - 1" XPS rock-panel (AG)
 - Exterior drain tile
 - washed aggregate bed wrapped in filter fabric
 - to daylight
- Cast-in-place concrete
 - Waterproofing
 - Exterior insulation
 - 2" XPS
 - 2" semi-rigid fiberglass
 - fiber-cement panel
 - Exterior drain tile
 - washed aggregate bed wrapped in filter fabric
 - to daylight

THEN & NOW: WALLS

- 2x6 frame wall
 - advanced framing
 - fiberboard sheathing
- Cavity insulation
 - R-22 blown-in-blanket
 - airtight poly with sealed electrical boxes
- Integrated house wrap
 - spun-bonded polyolefin
- Cedar and vinyl siding
- 2x4 frame hybrid wall
 - regular framing
 - 1-1/8 OSB sheathing
- Fully-adhered water, air, vapor control membrane
- 3 to 4” rigid insulation
 - 2 layers XPS/gEPS/PIC
 - 1” mineral wool (?)
 - 1x4 furring strips
- Fiber-cement siding

THEN & NOW: ROOF ASSEMBLY

- Traditional truss
 - 12" raised heel w/ baffle & chutes
 - flat ceiling
 - fully vented attic
- Airtight poly
- R-50 blown-in insulation w/ adhesive
- Sheathing, paper, & shingles
- Modified scissor truss
 - 1-1/8" OSB sheathing
 - R-21 batt in top chord
- Fully-adhered water, air, vapor control membrane
- 6" rigid insulation R-30+
 - 2 (or 3) layers staggered
 - XPS/gEPS/PIC
 - 2x4 furring strips flat
- Sheathing, paper &

THEN & NOW: AIRTIGHTNESS

- Airtight poly air/vapor barrier
 - walls & ceiling
- Airtight electrical boxes
- No upper ceiling fixtures
- Perfect wall & roof
- Regular electrical boxes and ceiling fixtures
 - wherever my wife wants them
- Glued & screwed drywall

THEN & NOW: FENESTRATION

- Triple-glazed
 - low-E coating
 - argon gas-filled
 - warm-edge spacer
 - airtight awning operator
- Integrated to house wrap
 - minimal pan flashing
 - rough openings are foam/insulation/foam
- Triple glazed
 - double low-E²
 - krypton gas-filled
 - warm-edge spacer
 - awning operator
- Alternate w/ storm
 - double glazed low-E²
 - argon gas-filled
 - casement operator

THEN & NOW: HEATING

- Forced air system
 - ECM fan coil
 - Storage water heater
 - sealed combustion
 - condensing
 - 92% CAE
- Forced air system
 - ECM fan coil
 - ASHP
 - 11 HSPF
 - Sized for cooling
 - Storage water heater
 - sealed combustion
 - condensing; modulating
 - 94% CAE
 - Spot hot water radiant

THEN & NOW: COOLING

- Conventional AC
 - 13 SEER
 - slightly undersized
 - reduced flow for dehumidification
- Dehumidification
 - Stand alone high capacity DH
- ASHP
 - 18 SEER / 11 HSPF
 - Sized for cooling
- Dehumidification
 - use hot water coil for reheat, if needed

THEN & NOW: FILTRATION

- Forced air system
 - 4” pleated media
 - MERV 10
 - Ventilation air
 - standard ERV filter
- Forced air system
 - 4” pleated media
 - MERV 13
 - Ventilation air
 - Upgraded ERV filter
 - Make-up air
 - MERV 8+

THEN & NOW: VENTILATION

- High quality HRV
 - Fully-ducted source-point exhaust
 - bathrooms (no bath fans)
 - kitchen (w/ range hood)
 - laundry
 - Supply air to FA return
 - Medium continuous
 - Button boost for high
 - Later change to ERV
- High quality ERV
 - Fully-ducted source point exhaust
 - Bathrooms (no bath fans)
 - Kitchen (w/ range hood)
 - laundry
 - Supply air to FA return

THEN & NOW: CONTROLS

- Heating & Cooling
 - programmable thermostat
 - circulation control
 - Ventilation
 - low/med continuous
 - push-button to high
- Heating & Cooling
 - programmable thermostat
 - circulation control
 - Ventilation
 - low/med continuous
 - push-button to high
 - air-cycler for distribution
 - Make-up air
 - manual on–off switches
 - automatic auxilliary heat

THEN & NOW: DHW

- High-efficiency DHW
 - sealed combustion
 - condensing tank-type
 - 92% CAE
- Standard piping layout
- Some pipe insulation
- High-efficiency DHW
 - sealed combustion
 - condensing tank-type
 - modulating
 - 94% CAE
- Structured plumbing
 - designed plumbing core
 - recirculation pump
 - end-use switches
- Insulate all pipes

THEN & NOW: OTHER

- Range Hood
 - 160 cfm
 - standard design
 - Clothes Dryer
 - standard w/ short vent
 - ventilation pick-up
 - Wood stove
- Range Hood
 - 150 to 200 cfm
 - extended front w/ side panels
 - Clothes Dryer
 - condensing
 - ventilation pick-up
 - Wood stove (probably)
 - w/ make-up switch

THEN & NOW: MAKE-UP AIR

- Essentially None
 - Cross your fingers
 - Open the window
- Make-Up Air Unit
 - 150 - 200 cfm
 - multi-speed
 - tempering
 - blended w/ house air
 - electric resistance
- Also used for
 - supply air ventilation
 - summer economizer

THEN & NOW: SOLAR

- Passive design
 - southern-orientation
 - limited thermal mass
 - some shading design
- Passive design
 - strategic glazing
 - use existing mass
- Solar PV
 - roof mounted
 - micro-inverter
 - battery storage (?)
- Vehicle charging station

FINAL NOTES & CAUTIONS

- Net Zero Energy Homes will require new enclosure strategies and systems:
 - Higher insulation levels
 - Improved integrity of the water, air, and vapor control layers
 - Better drying strategies
 - More robust delivery systems

FINAL NOTES & CAUTIONS

- Net Zero Energy enclosures will demand a new approach to the mechanical systems:
 - Integrated systems approach to low-load HVAC+DHW
 - Sharp focus on humidity management
 - Increased attention to indoor air quality
 - source control
 - filtration
 - ventilation & distribution
 - Improved make-up air solutions

KEY PARTNERS AND RESOURCES

- Your New Partners
 - Home Energy Raters
 - Home Performance Consultants
 - Utility Providers & Programs
- Other Resources
 - ENERGY STAR
 - Building America

DOE RESOURCES

- Building America Resources
 - General Energy Information (EERE)
 - DOE Zero Energy Ready Home (ZERH)
 - Tour of Zero
 - Top Innovations “Hall of Fame”
 - Building America Solution Center
 - Building Science Advisor

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Attic Knee Walls

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Scope

Description

Ensuring Success

Climate

Training

CAD

Compliance

More Info.

Scope

Fully Aligned Air Barrier

- A. Install a top and bottom plate or blocking at the top and bottom of all knee wall cavities.
- B. Back attic knee walls with a rigid air barrier or other supporting material to prevent insulation from sagging and create a continuous thermal barrier*.
- C. Seal all seams, gaps, and holes of the air barrier with caulk or foam.
- D. Install insulation without misalignments, compressions, gaps, or voids in all knee wall cavities.



* ENERGY STAR recommends using a rigid air barrier, but it is not a requirement.

Notes:

An air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams.



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Scope: Clearly defines and bounds the topic in a way builders and remodelers can contractually obligate their subcontractors.

diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft

KEY RESOURCES

- BSI-081: Zeroing In [Handouts]
 - Joseph Lstiburek
- High-Performance Enclosures
 - John Straube, 2012
- Getting Enclosures Right in ZERH
 - Joe Lsitburek, 2016
 - <https://www.energy.gov/eere/buildings/downloads/zerh-webinar-getting-enclosures-right-zero-energy-ready-homes>
- EEBA Ventilation Guide
 - Armin Rudd, 2011



- Discussion & Questions

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