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MAKING A DIFFERENCE IN MINNESOTA: ENVIRONMENT + FOOD & AGRICULTURE + COMMUNITIES + FAMILIES + YOUTH

Zeroing In: The Path to High-Performance May Be Different Than You Think!

EEBA High-Performance Home Summit

October 2, 2019

Denver, CO

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University of Minnesota Extension

ZEROING IN: THE PATH TO HIGH-PERFORMANCE MAY BE DIFFERENT THAN YOU THINK!

- 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
  - A reflection on where we have been, where we are, and where we need to go in the future!

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CONTEXT AND CAUTION

- A focus on general principles that are fairly universal and apply to most climate zones.
- However, some of the specific details are more oriented to locations with cold winters and warm, humid summers.
  - Primarily Climate Zones 5, 6, 7 with green grass
  - They are intended as guidelines only.
  - Your specific designs, performance targets, or market approach may be quite different.

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THE BIGGER SYSTEMS VIEW

- We can and must do better!
  - Must balance efficiency with robust performance.
- Existing technology can get us there!
  - It's not about products; it's about execution.
- New technologies will be important
  - But we must be systematic in their evaluation & application.

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WHAT IS A HIGH PERFORMANCE HOME?

- It is 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.

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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.

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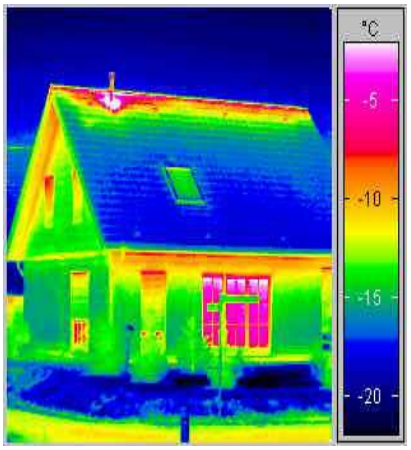
THE POWER OF ZERO ENERGY HOMES

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



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THE POWER OF ZERO ENERGY HOMES

- It is absolutely possible – but 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?

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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.

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PATHWAY TO ZERO: METRICS

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

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PATHWAY TO ZERO: METRICS

Enclosure (R-values)	IECC CZ 5/6/7	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Ceiling	49	49	49	50	60
Walls	20/25/25	20/25/25	20/25/25	30	40
Floors	30/30/38	30/30/38	30/30/38	40	---
Foundation	15	15	15	15-20	20
Slabs					
- Basement	0	0	0	10	10
- On-grade	10	10	10	15-20	20

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

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PATHWAY TO ZERO: METRICS

Enclosure (U-values)	IECC CZ 5/6/7	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	0.17 – 0.30	0.20	---

Enclosure Airtightness	IECC CZ 5/6/7	ENERGY STAR	DOE ZERH	BCP (PH)	NZE (JL)*
ACH@50Pa	3.0	3.0	2.0	1.0	1.5

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PATHWAY TO ZERO: METRICS

HVAC (Equipment)	IECC CZ 5/6/7	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Heating					
- AFUE	80%	90-95%	94%	95%	95%
- HSPF	8.2	9.5	10.0	10.0	---
Cooling (SEER)	13	13	13	15	18
Ventilation					
- Type	NR	NR	Balanced	Balanced	Balanced
- HRV/ERV (Eff)	NR	NR	60%	70%	---
- Distribute	NR	NR	NR	All Rooms	All Rooms
Filtration(MERV)	8	8	8	11	---

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PATHWAY TO ZERO: METRICS

HVAC (Ductwork)	IECC CZ 5/6/7	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	IECC CZ 5/6/7	ENERGY STAR	DOE ZERH	BCP (PH)	NZE (JL)*
Range	NA	NA	Vented	Vent/MUA	Vent/MUA
Dryer	NA	Vented	Vented	Vent/MUA	Vent/MUA
Exhaust Fan	Allowed	Allowed	Allowed	Small/MUA	---

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PATHWAY TO ZERO: METRICS

Domestic Hot Water	IECC CZ 5/6/7	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Plant (EF)	0.53	0.59 - 0.63	0.67	CSC(combi)	--
Insulation	R-3	R-3	R-5	R-5	--
Distribution	NA	NA	WaterSense	WaterSense	--

Appliances & Lighting	IECC CZ 5/6/7	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

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PATHWAY TO ZERO: METRICS

Indoor Air Quality	IECC CZ 5/6/7	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
IndoorAir+	NA	Partial	Yes	Yes	---
Garage Vent	NA	NA	Yes*	Yes*	---
Radon	NA	Rn Ready	Rn Ready	ASD	---

Renewable Ready	IECC CZ 5/6/7	ENERGY STAR	DOE ZERH	BCP (PH)	NZE (JL)*
Solar Thermal	NA	NA	Optional	Optional	---
Solar PV	NA	NA	Yes*	Yes	Yes

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PART 2: ZERO ENERGY READY HOME

ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

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Building America Strategy

J.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Ultra-High Efficiency

- Enclosure
- Low-Load HVAC
- Components

+

High-Performance

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

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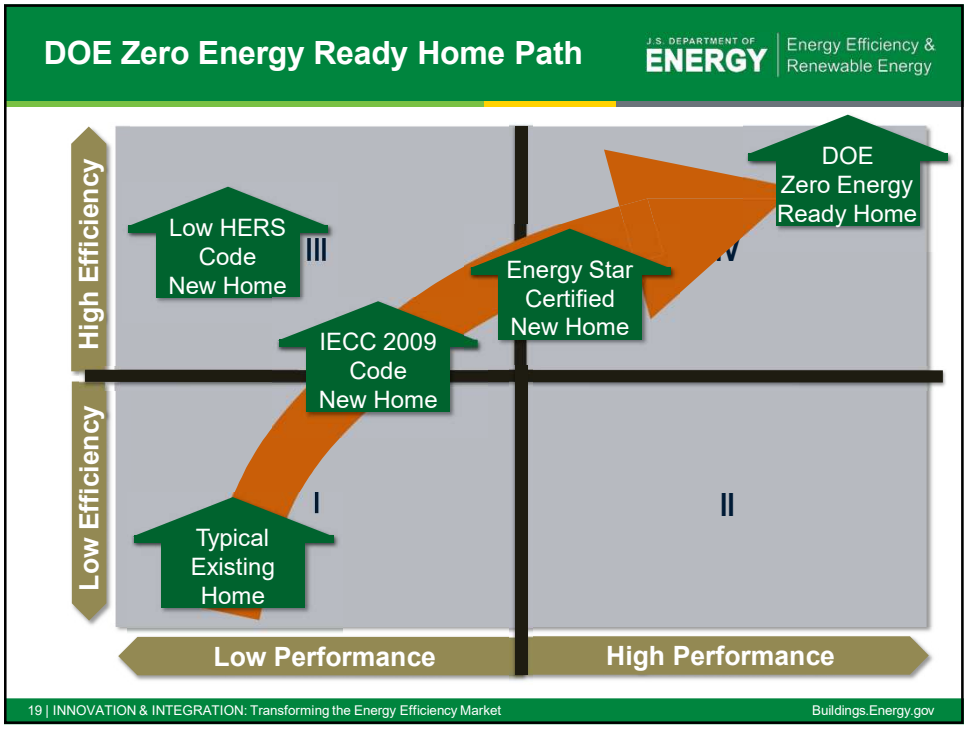

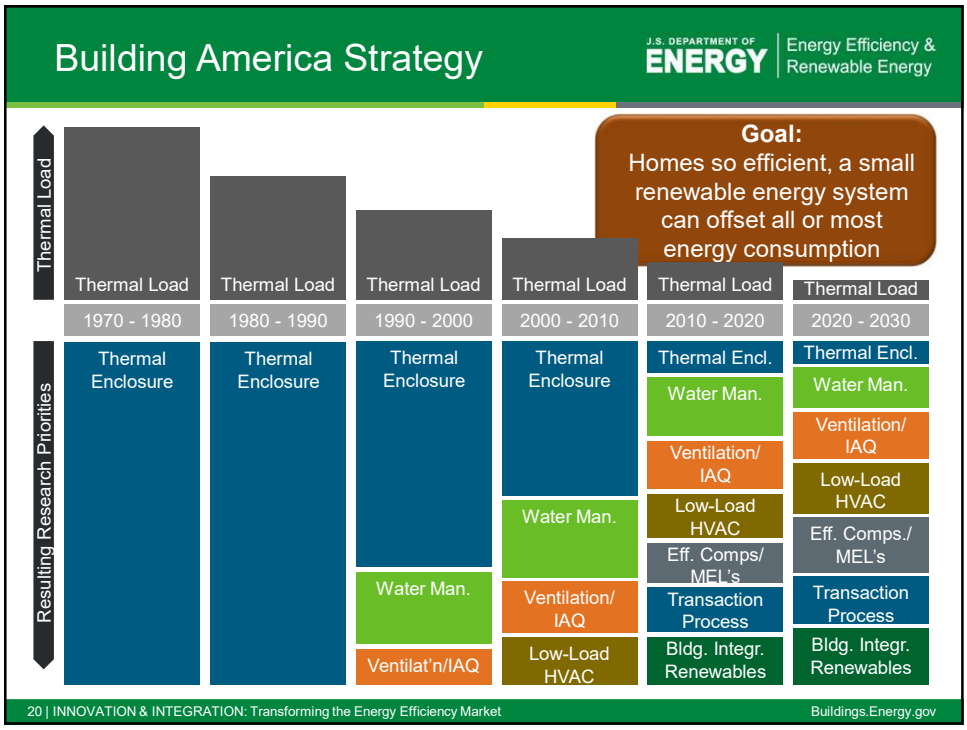

DOE ZERO ENERGY READY HOME

- 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.

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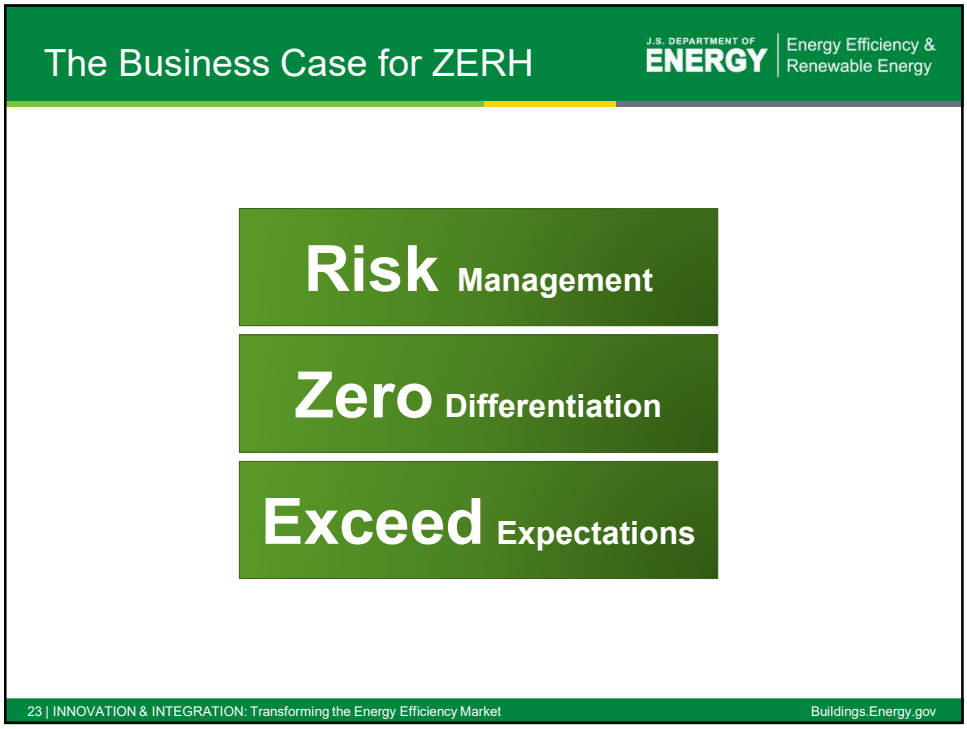

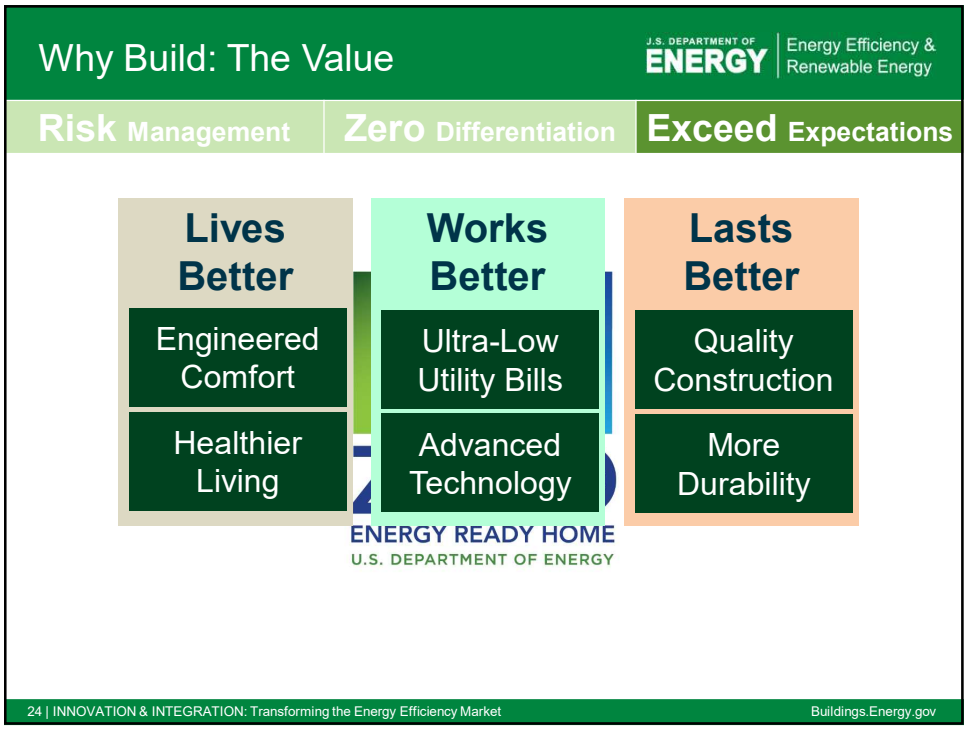

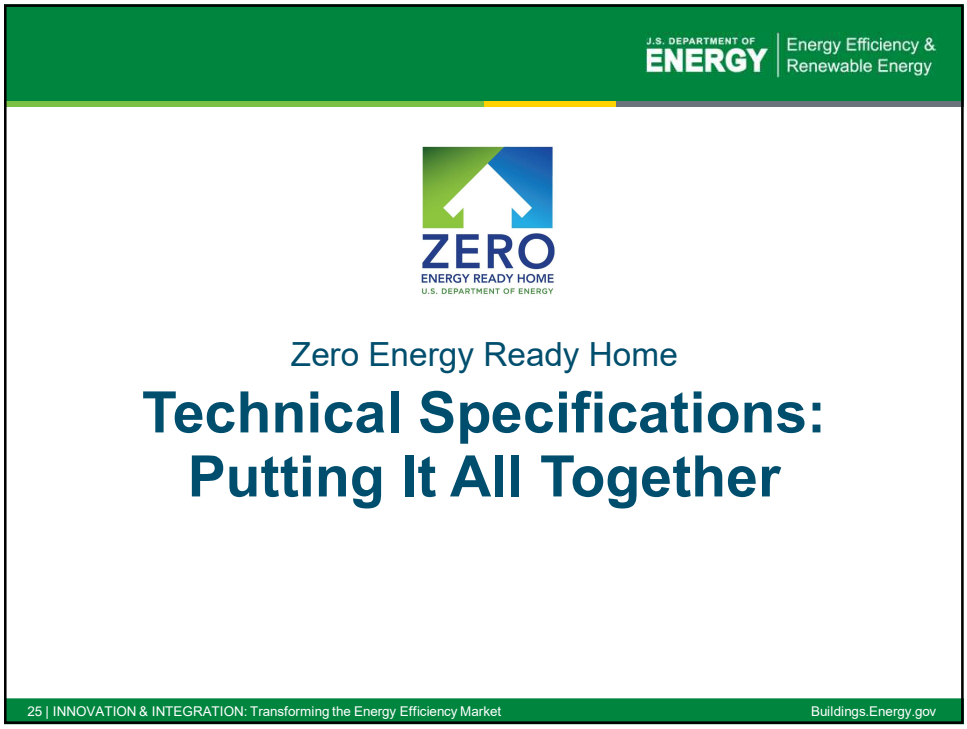

DOE ZERH Framework

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Mandatory Reqts.

Must Comply

'Target Home' Specs

Trade-Off Flexibility

Size Adjust. Factor

Identical to Energy Star

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

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

Exhibit 2: DOE Challenge Home Target Home[3, 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			
• Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standards. • Infiltration[21] (ACH50): 3 in CZs 1-2 | 2.5 in CZs 3-4 | 2 in CZs 5-7 | 1.5 in CZ 8			
Windows[20, 22, 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.[23]			
Water Heater			
ENERGY STAR minimum; for heating oil water heaters use EF = 0.60			

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Exhibit 3: Benchmark Home Size[25]

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

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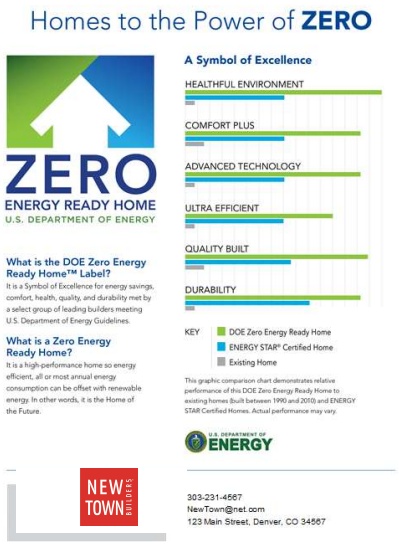
Translating the Value Proposition

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



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PART 3: 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".

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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.

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NET ZERO ENERGY TODAY

- 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 are be presented as challenges.
  - But don't construe these as negatives,
  - Rather as important precautions necessary to ensure your successful pursuit of NZE homes.

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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 hurt you.
  - Low-load increases need for thermal storage
- But people want windows …
  - So give them window; just use good judgement on orientation, placement, type and treatments.
- Collect the solar energy with PV…
  - Which is needed to satisfy non-thermal loads.

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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 …
    - simply don't do it!

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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.

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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.

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ZEROING IN*

- Perhaps the greatest challenge will be latent load management!
  - In the swing seasons and under part-load conditions humidity 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.

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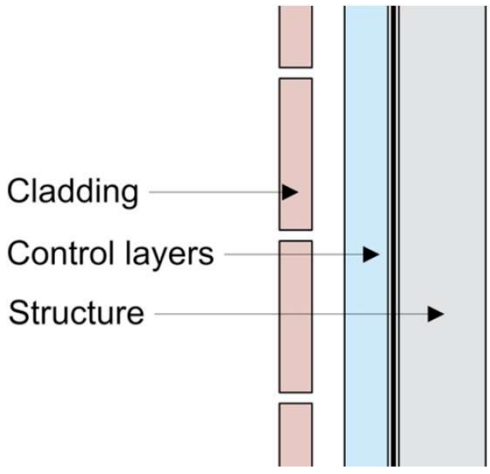
CHALLENGE 1: FORGIVING ENCLOSURE

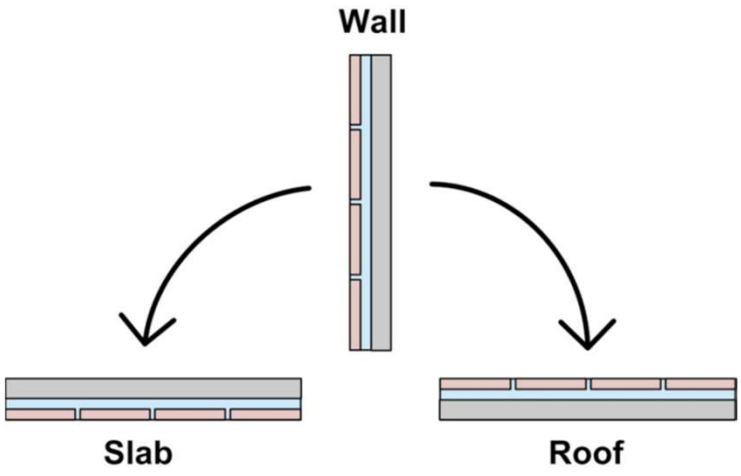
- The "Perfect" Approach
  - Walls
  - Roof
  - Slab
  - Foundation
- Move the structure to the inside and the control layers to the outside …
  - It simply works and works everywhere!!!

THE PERFECT WALL*



* Source: Building Science Corporation

WORKS FOR ROOF & SLAB, TOO!



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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!

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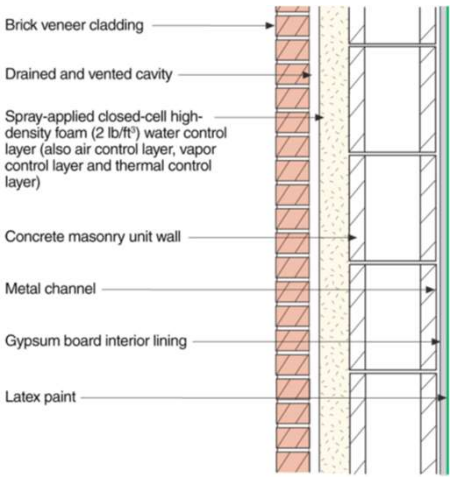
4 IN 1 CONTROL LAYER



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CONTROL LAYERS – PERFECT SLAB

- Dry and Warm Slab w/ RRNC
  - 4" of ¾" and up aggregate; no fines
  - 1 to 3" of extruded polystyrene
  - Poly vapor retarder (optional)
  - 4" high quality slab; all joints and edges sealed
  - Sealed sump basket
  - 3 or 4" passive vent from below slab to the roof
    - with electrical box nearby in attic for fan activation

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CONTROL LAYERS – FOUNDATION

- Dry and Warm Foundation
  - Cast-in-place (or CMU or wood) foundation
    - capillary break between footing and wall
  - Quality exterior waterproofing
  - Exterior drain tile protected by rock & fabric
  - R-15 exterior insulation
    - extruded polystyrene or semi-rigid fiberglass
  - Good vertical drainage
    - with 6" impermeable cap

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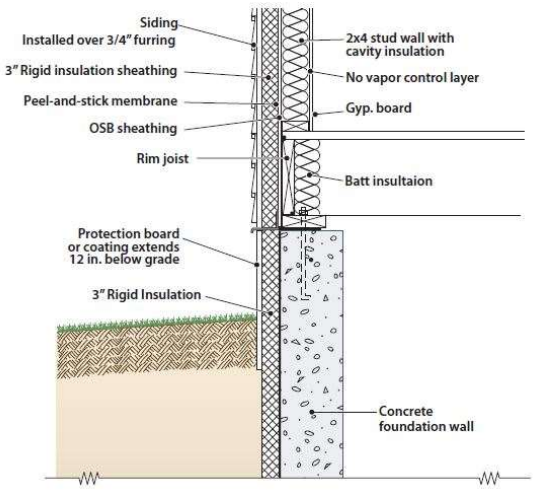
CONTROL LAYERS – HYBRID WALL



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CONTROL LAYERS – FENESTRATION

- Windows Designed for Integration
  - Always use the highest quality, low U-value, warm-edge window you can afford that comes with …
    - a custom fit sill pan,
    - head flashing with end dams, and
    - flanges that are air/water tight with tabs to integrate with flashing and air/water control layers
  - Integrate the window air and water tightness at the air and water control plane.

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CONTROL LAYERS – ENHANCED ROOF

- Traditional Vented Attic
  - Ceiling drywall direct to raised heel trusses
    - no poly
  - One pass closed-cell spray foam
    - sealed to the top plate, heel sheathing, and chutes
    - approximately 2” (R-12)
  - Blown-in insulation (R-40 to 50)
    - fiberglass @ 16” to 18”
    - cellulose @ 12” to 15”

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CONTROL LAYERS – HYBRID ROOF

- For Sloped Roof or Conditioned Attic
  - Interior batt (R-21) between rafters or top chords
  - Structural sheathing
  - Peel and stick membrane
  - Exterior foam (R-30 - usually XPS or polyiso)
  - Flat 2x4 furring strips fastened through to frame
    - provides vent space w/ continuous soffit & ridge vents
  - OSB roof deck
  - Building paper and shingles

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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.

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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

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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.

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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

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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.

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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

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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.

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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.

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SPACE DEHUMIDIFCATION

- 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.

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SPACE DEHUMIDIFCATION

- 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.

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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?

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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	+	+

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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

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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?

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

RESOURCES

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

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RESOURCES

- DOE 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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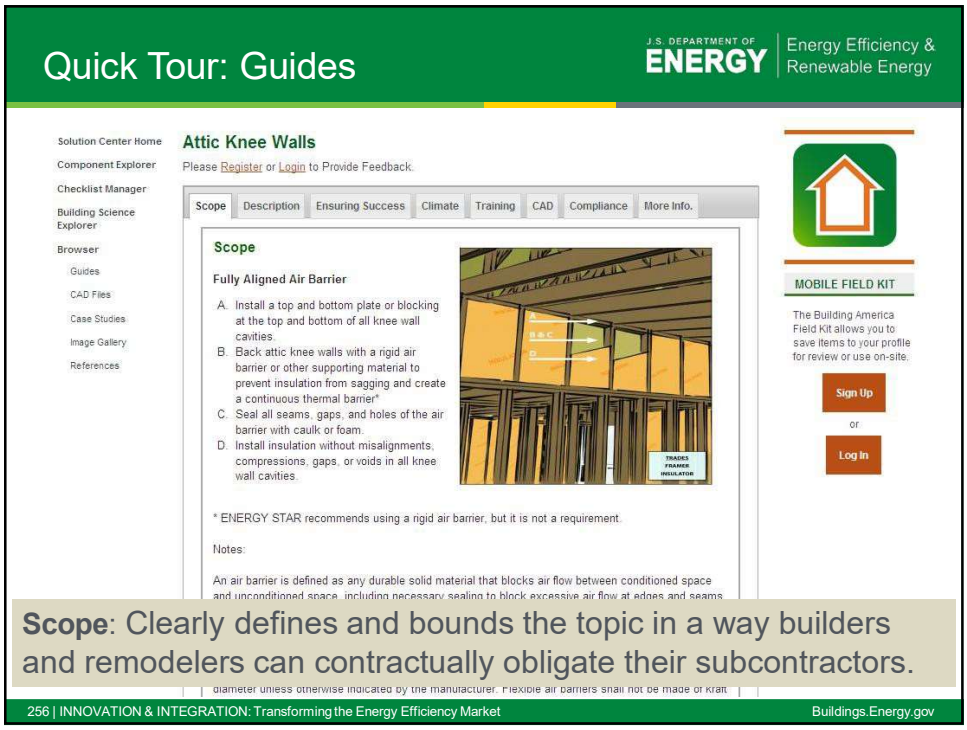

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- High-Performance Enclosures
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- Getting Enclosures Right in ZERH
  - Joe Lsitburek, 2016
  - https://www.energy.gov/eere/buildings/downloads/zerh-webinar-getting-enclosures-right-zero-energy-ready-homes
- BSI-081: Zeroing In
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KEEPING OUR EYE ON THE BALL

- Is it possible that we have over-invested in products and under-invested in good design and proper execution?
- Are we not being realistic about the process?
  - Are we investing in risky designs, systems, and materials and hoping for perfect execution?
  - Are we counting on perfect homeowner operation and maintenance?

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- Discussion & Questions

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