On the Road to Net Zero Energy Homes

Energy Design Conference

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CONTINUING EDUCATION CREDIT NOTICE

- In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,
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ON THE ROAD TO NET ZERO HOMES!

- **Part 1: Intro and the Power of Zero**
  - Demand, Incentives, and Stakes are Growing for Net Zero Energy Homes
- **Part 2. Pathways to High-Performance Homes**
  - Moving from Code to ENERGY STAR, ZERH, & NZE
- **Part 3. Building a Strong Foundation with DOE ZERH**
  - Business Case
  - Program Specifications
- **Part 4: Keys to Successful Net Zero Energy Homes**
  - Special Challenges & Strategies

OVERARCHING THEMES

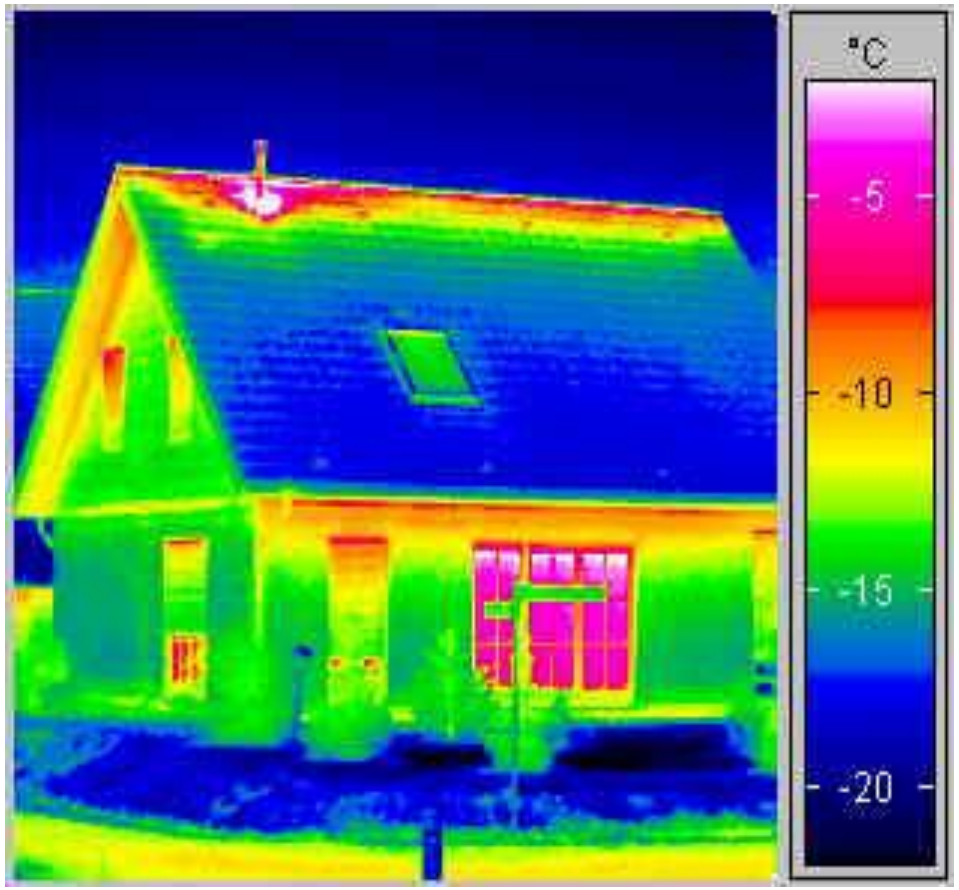
- Today, it has become even more important to challenge ourselves towards better and more robust performance.
  - However, the harder we push the closer we get to the edge!
- Existing technology can get us there, but …
  - We need to reduce the focus on products.
  - We must embrace more robust building & HVAC systems.
  - We need improvements in design & execution.

WHAT IS A HIGH-PERFORMANCE HOME?

- A deliberate and proper integration of building enclosure, mechanical systems, and occupant controls to provide a
  - comfortable, efficient, durable, healthy, and resilient 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 execution in the …
  - design, construction/installation, and operation.

PART 1: THE POWER OF ZERO ENERGY HOMES

- Are there home buyers who would like to make their utility bills go away and/or significantly reduce their environmental footprint?

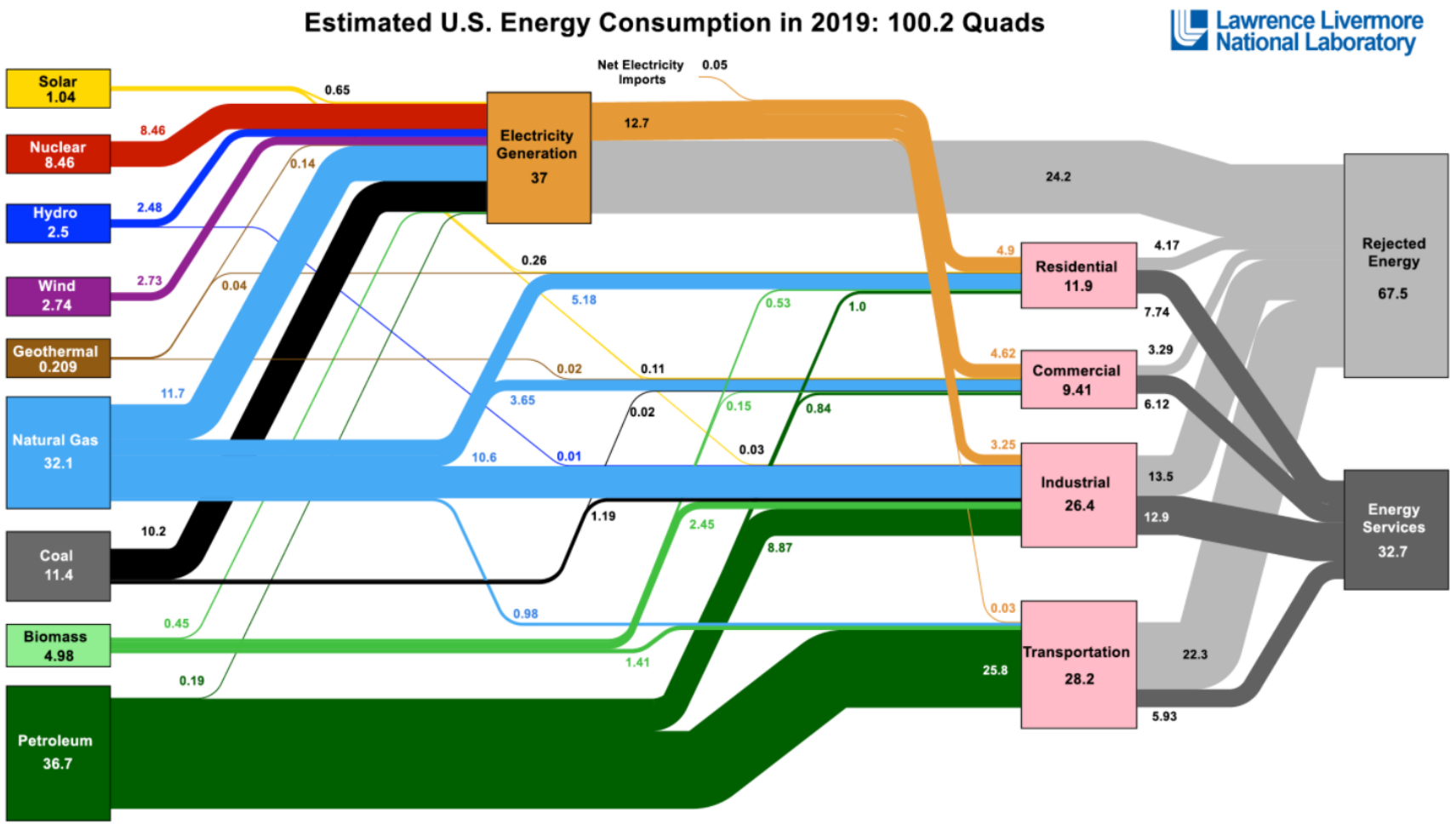


THE POWER OF ZERO ENERGY HOMES

- It is absolutely possible with a couple of caveats.
  - Homes will always require energy.

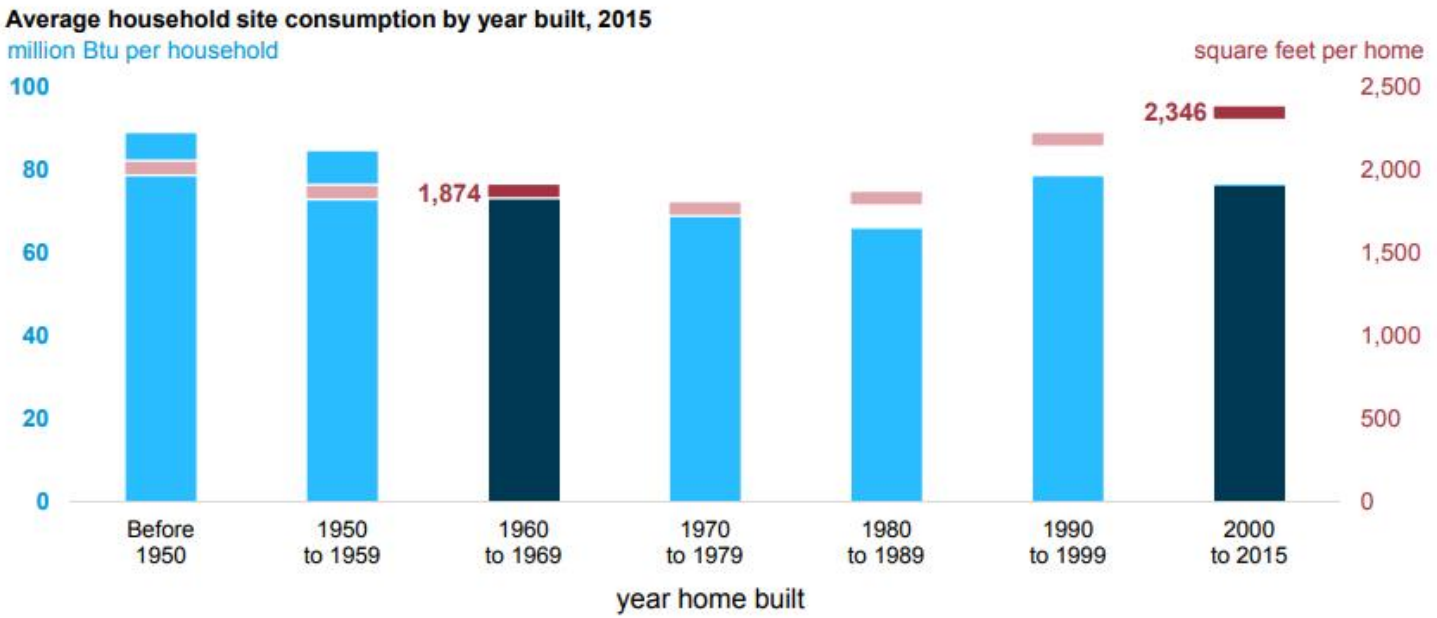
- What are you counting?
  - Can the home produce as much energy as it uses?
  - Is it site energy or source energy; or is it dollars or carbon?

U.S. ENERGY SOURCES & END-USES (2019)



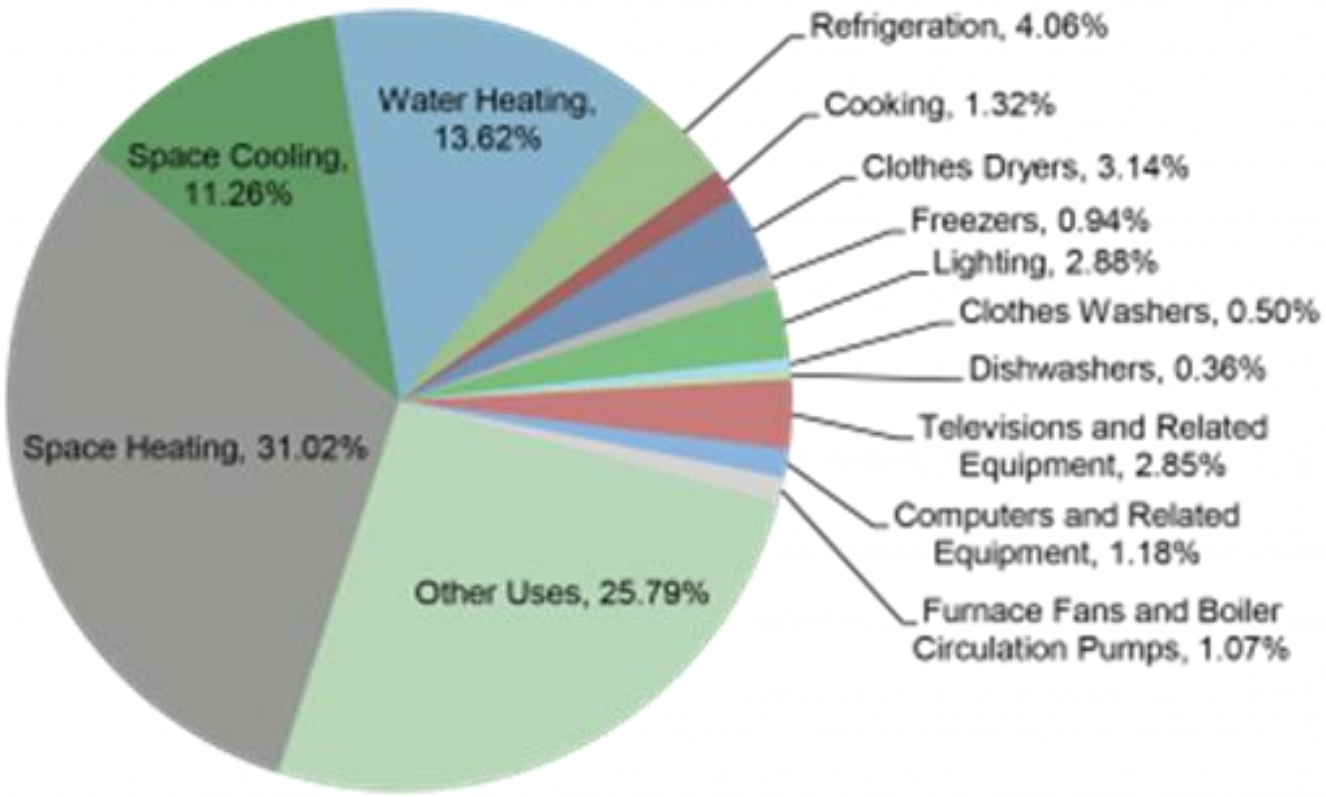
U.S. ENERGY USE BY YEAR BUILT

A home built since 2000 consumed the same amount of energy as one built in the 1960s



Source: EIA, 2015 Residential Energy Consumption Survey

U.S. RESIDENTIAL ENERGY END-USES (EIA 2020)



“NET ZERO BUILDINGS” HAS LEFT THE STATION!*

- According to RESNET more than 300,000 homes were rated in 2021 with an average Hers Index Score of 58.
- Codes have gotten 40% more rigorous since 2009
  - 6 states have announced plans to adopt net zero energy codes
  - Significant changes are ahead in the 2021 IECC
- 18 states have 100% clean energy or renewable energy targets
- As of 2020, nearly 28,000 housing units have met NZE
- IRA locks in a 45L credit of $5000 for SF home certified to ZERH

* Sam Rashkin in Green Builder (11/2/22)

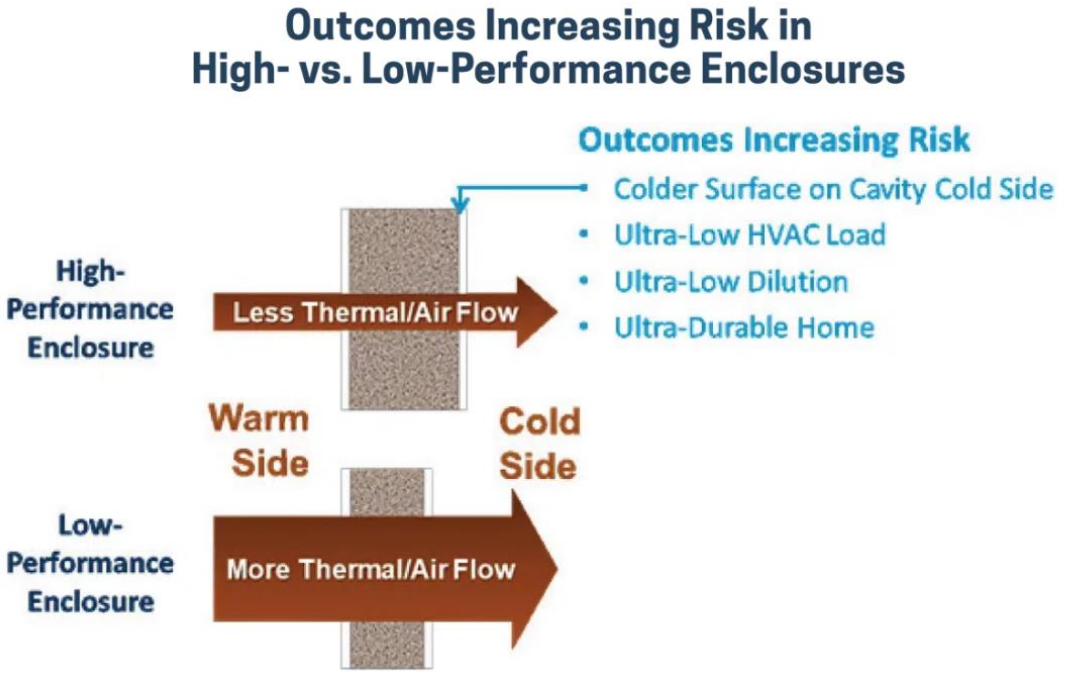
“NET ZERO BUILDINGS” HAS LEFT THE STATION!*

- But in the end, it will be driven by the user experience
  - no/ultra-low energy bills
  - comfort taken to a new level
  - enhanced convenience
  - low maintenance
  - greater safety
  - healthier living
  - enhanced resilience

* Sam Rashkin in Green Builder (11/2/22)

THE RISKS OF BUILDING NET ZERO ENERGY HOMES*

- Potential Enclosure Risks
  - As you remove heat flow, you must do a much better job of managing moisture flow!
    - better exterior water control
    - better enclosure airtightness
    - better indoor humidity control



* Sam Rashkin in Green Builder (11/2/22)

THE RISKS OF BUILDING NET ZERO ENERGY HOMES*

- Potential HVAC Risks
  - Oversized heating & cooling equipment
  - Poor distribution systems (design, leaky ducts, controls)
  - Poor dehumidification
  - Lack of system commissioning

- Potential IAQ Risks
  - Lack of attention to pollutant source control
  - Poor ventilation and filtration design

* Sam Rashkin in Green Builder (11/2/22)

PART 2. PATHWAYS TO NET ZERO ENERGY HOMES

- ENERGY STAR (Ver3.1:rev12)
  - Gets the wheels moving in the right direction
- DOE Zero Energy Ready Home (Ver1:rev 8.0)
  - Represents a more comprehensive, holistic approach
  - V2 will be coming in 2024
- Net Zero Energy Now (by Joe Lstiburek)
  - Provides a vision for the future

PATHWAY TO ZERO: METRICS

- Pathway Comparison (for Climates Zones 6 & 7)
  - Enclosure
  - HVAC
  - Domestic Hot Water
  - Indoor Air Quality
  - Renewables

PATHWAY TO ZERO: INSULATION

Enclosure (R-values)	Current MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE Now (JL)*
Ceiling	49	49	49	60	60
Walls	20:13+5ci / 21	20+5ci:13+10ci	20+5ci:13+10ci	30:20+5ci:13+10ci	40
Floors	30 / 38	30 / 38	30 / 38	30 / 38	40
Foundation	15ci / (10ci)	19:15ci	19:15ci	19:15ci:13+5	20
Slabs					
- Basement	0	0	0	0	10
- On-grade	10	10ci to 4’	10ci to 4’	10ci to 4’	20

x / x = CZ 6 / CZ 7 : means or

* From “BSI-081 Zeroing In” by Joseph Lstiburek (2014)

WHY CONTINUOUS EXTERIOR INSULATION (CEI)?

- To improve R-value and energy efficiency?
  - Partially, but not the most important aspect
- To reduce thermal bridging and improve energy efficiency?
  - Yes, continuous insulation provides more bang per R-value
- To warm up the first condensing surface in cold climates?
  - Reducing wetting potential is perhaps the most important aspect
- To provide a better drying direction for cavity moisture?
  - Avoid a double vapor retarder and provide a clear drying direction
- To keep the structural components warm, dry, and stable!!!

PATHWAY TO ZERO: FENESTRATION & AIRTIGHTNESS

Enclosure (U-values)	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE Now (JL)*
Windows	0.32	0.27	0.27	0.30	0.20
Doors	???	0.17-0.30	0.21	???	--

Enclosure Airtightness	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE (JL)*
ACH@50Pa	3.0	3.0	2.0	3.0	1.5

PATHWAY TO ZERO: HVAC EQUIPMENT

HVAC (Equipment)	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE Now (JL)*
Heating					
- AFUE	80%	95%	94%	80%	95%
- HSPF or COP	8.2	9.5	10.0	8.2	--
Cooling (SEER)	13	17.1	13	15	18
Ventilation					
- Type	Balanced	NR*	Balanced	NR	Balanced
- HRV/ERV (% SRE)	NR	NR	60%@1.2 cfm/W	65%	--
- Distribute	All Rooms	NR*	NR*	NR	All Rooms
Filtration(MERV)	8	8	8	11	--

PATHWAY TO ZERO: DUCTWORK & MAKE-UP AIR

HVAC (Ductwork)	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	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	4cfm/100sf	Condition
Insulation	R-8	R-8	NA	R-8	NA

Make-Up Air	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE (JL)*
Range	300 cfm?	NA	Vented	???	Vent/MUA
Dryer	NA	Vented	Vented	???	Vent/MUA
Exhaust Fan	Allowed	Allowed	Allowed	???	--

PATHWAY TO ZERO: DHW & APPLIANCES/LIGHTING

Domestic Hot Water	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE Now (JL)*
Plant (EF)	0.53?	0.53 to 0.67	0.67 / 2.0	0.53?	--
Insulation	R-3	R-3	R-5	R-3	--
Distribution	NA	NA	WaterSense	NA	--

Appliances & Lighting	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE (JL)*
Appliances	NA	E-STAR	E-STAR	NA	E-STAR+
Lighting	NA	80% E-STAR	80% E-STAR	NA	100% LED

PATHWAY TO ZERO: IAQ & RENEWABLES

Indoor Air Quality	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE Now (JL)*
IndoorAir+	NA	Partial	Yes	NA	--
Garage Vent	NA	NA	Yes*	NA	--
Radon	Rn Ready	Rn Ready	Rn Ready	Rn Ready	--

Renewable Ready	MN Code	ENERGY STAR (v3.1 rev 12)	DOE ZERH (rev 8.0)	2021 IECC	NZE (JL)*
Solar Thermal	NA	NA	Optional	NA	--
Solar PV	NA	NA	Yes*	NA	Yes

PATHWAY TO ZERO: COST OPTIMIZATION

- The bottom line is pretty straightforward!

- It is all about optimizing for performance, quality, and cost.
  - Start by optimizing the building enclosure components
    - for both insulation and airtightness levels
  - Next, optimize the mechanical, electrical, and plumbing systems
    - to match the enclosure and occupant loads
  - Last, optimize the renewable energy system to fit the chosen building enclosure and MEP systems.

TIME FOR A QUICK PAUSE

- Questions
- Thoughts
- Reflections
- Discussion

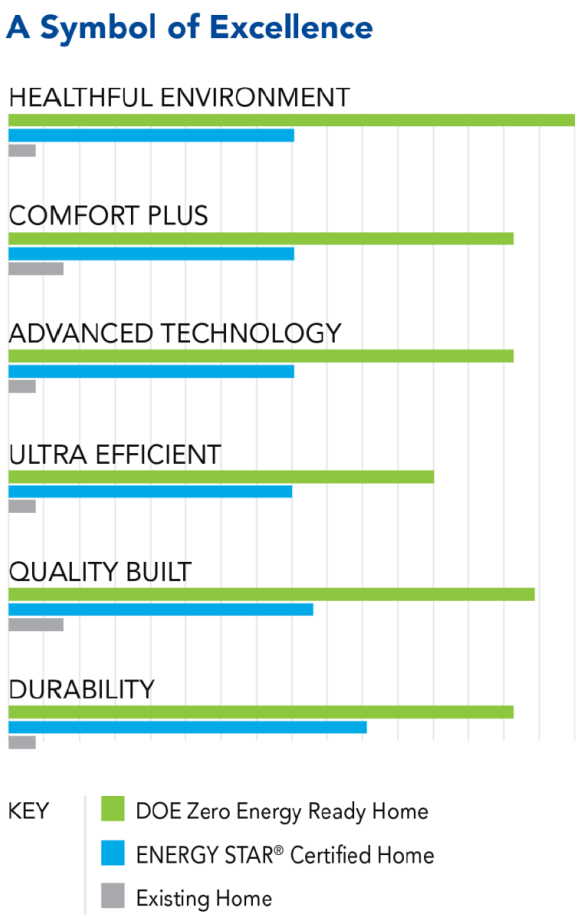
PART 3. DOE ZERO ENERGY READY HOME (ZERH)

- Provides a solid foundation and incremental road to pursue high-performance net zero energy homes!

- In my view, the program is …
  - Built on a technically sound platform
  - Focused on performance (not just energy)
  - At the right level (strategic differentiation)
  - With a delivery process that is credible, but not onerous.

ZERO ENERGY READY HOME (ZERH)

ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY



Ultra-High Efficiency

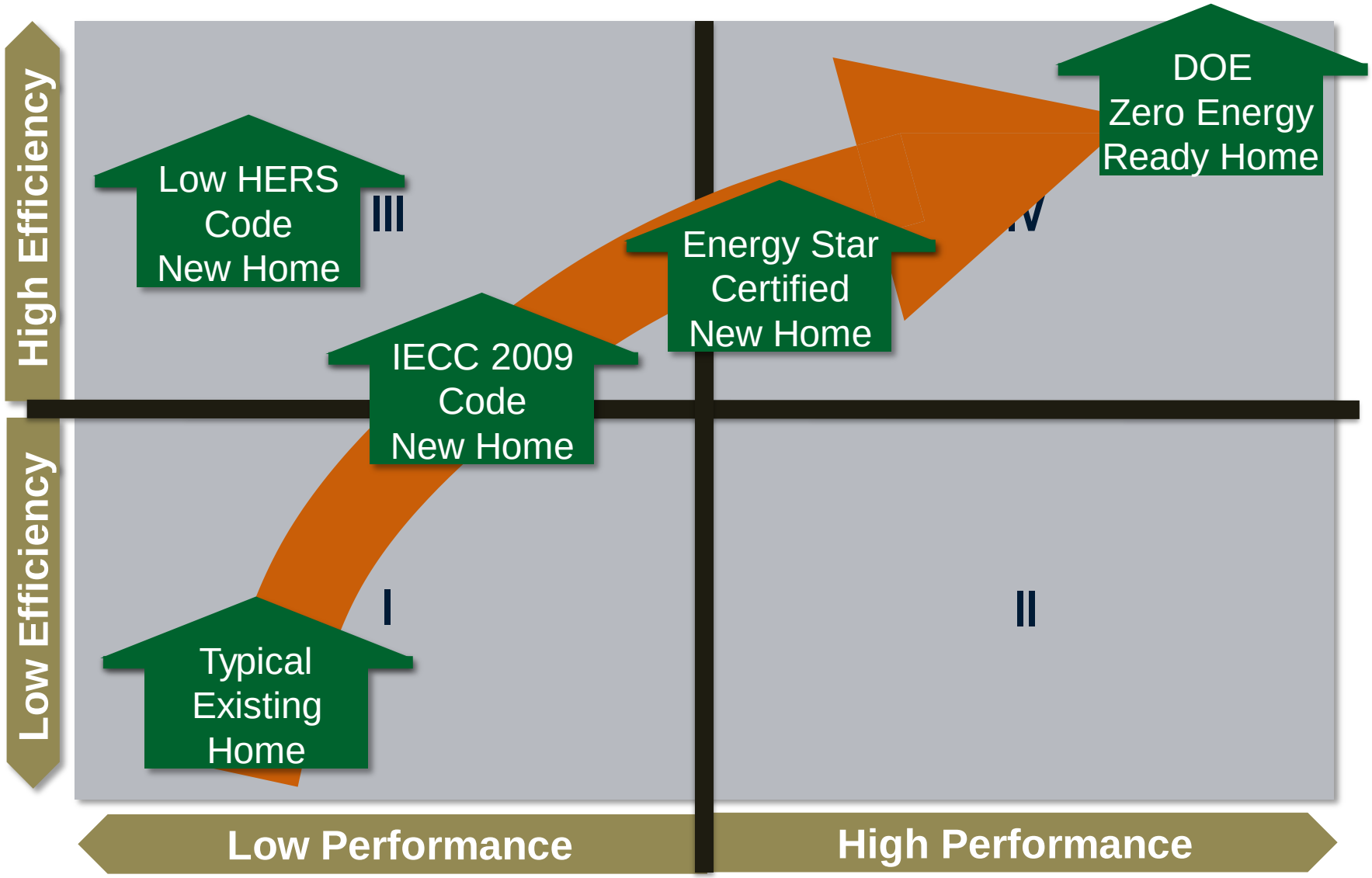
- Enclosure
- Low-Load HVAC
- Components

+

High-Performance

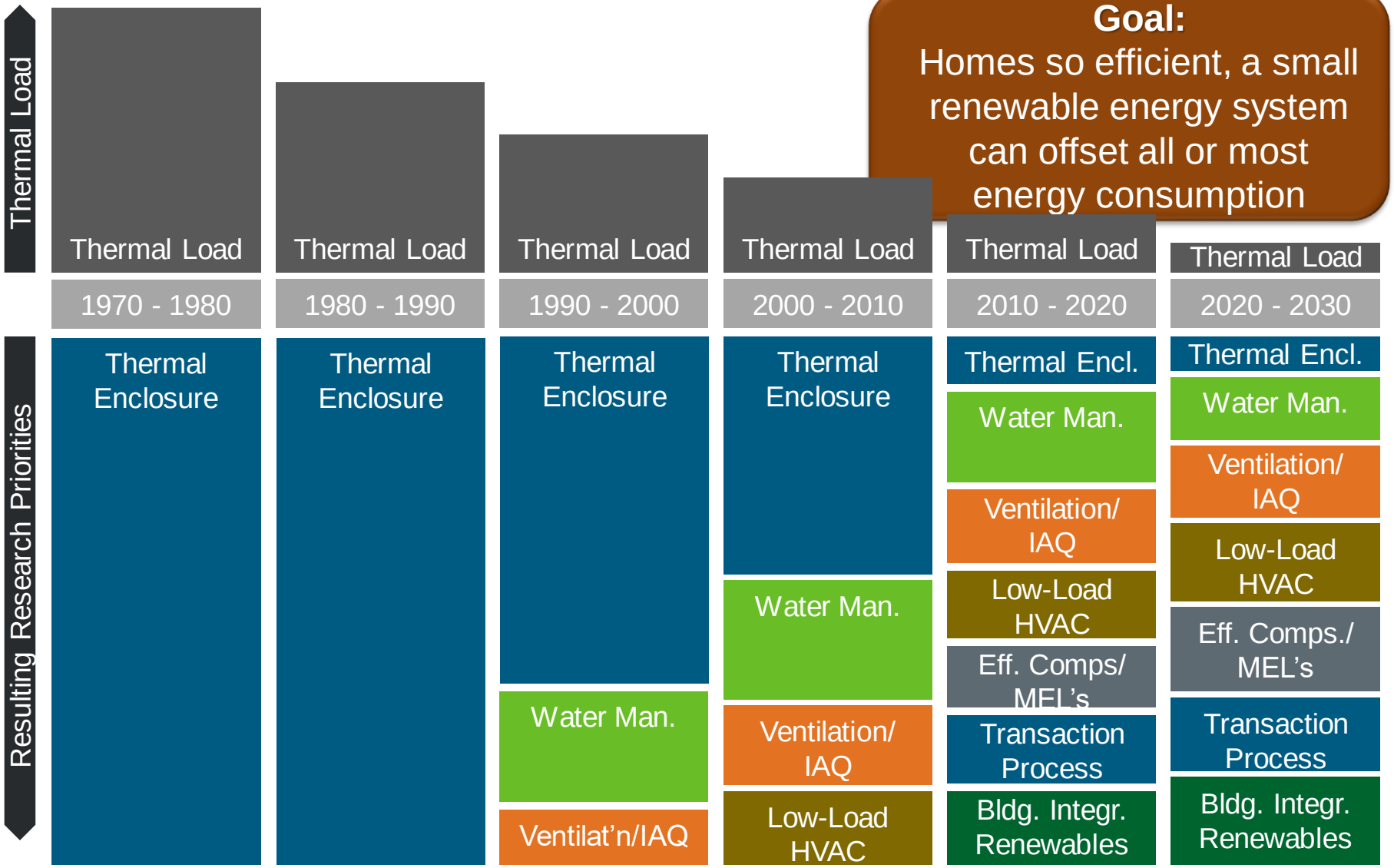
- Affordable
- Comfortable
- Healthy
- Durability & Resilence
- Disaster Resistance
- Renewable Readiness
- Water Conservation

DOE Zero Energy Ready Home Path



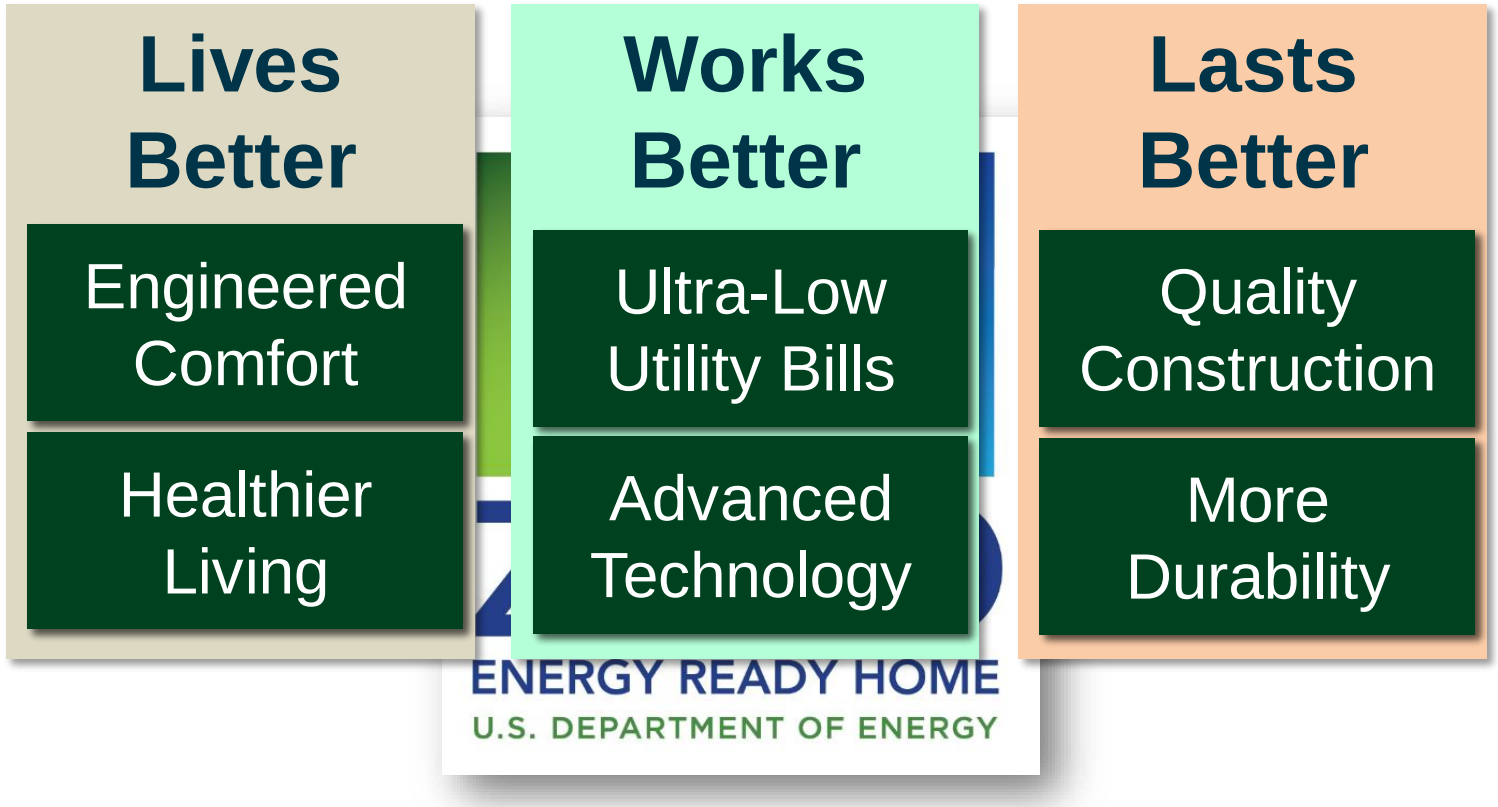
Building America Strategy

Goal:
Homes so efficient, a small renewable energy system can offset all or most energy consumption



Lots of Recognition Choices…

Why Build ZERH: The Value



General Requirements

- ENERGY STAR Certified Homes v3.1
- Advanced Windows
- Airtight Construction
- 2015 IECC Insulation Levels
- Energy Efficient Components
- Efficient Hot Water (WaterSense)
- Indoor Air Quality (Indoor Air+)
- Renewable Ready Construction

DOE ZERH Framework

Mandatory Reqts.

Must Comply

'Target Home' Specs

Trade-Off Flexibility

Size Adjust. Factor

Exhibit 1: DOE Zero Energy Ready Home Mandatory Requirements for All Labeled Homes

Area of Improvement	Mandatory Requirements
1. ENERGY STAR for Homes Baseline	☐ Certified under ENERGY STAR Qualified Homes Program Version 3, 3.1, or 3.2 (depending on state), or under ENERGY STAR Multifamily New Construction program Version 1.0 or 1.1 (depending on state) [8, 9, 10]
2. Envelope	☐ Fenestration shall meet or exceed ENERGY STAR requirements. See End Note for specific U, SHGC values, and exceptions. [11] ☐ Ceiling, wall, floor, and slab insulation shall meet or exceed 2015 IECC levels [12,13]
3. Duct System	☐ Duct distribution systems located within the home's thermal and air barrier boundary or an optimized location to achieve comparable performance. [14] ☐ HVAC air handler is located within the home's thermal and air barrier boundary.
4. Water Efficiency	☐ Hot water delivery systems (distributed and central) shall meet efficient design requirements [15] *or* ☐ Water heaters and fixtures shall meet efficiency criteria [16]
5. Lighting & Appliances	☐ All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. [17] ☐ 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	☐ Certified under EPA Indoor airPLUS [10]
7. Renewable Ready	☐ Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed [18]

Exhibit 2: DOE Zero Energy Ready Home Target Home [19]

HVAC Equipment[20]	Hot Climates (2015 IECC Zones 1,2) [21]	Mixed Climates (2015 IECC Zones 3, 4 except Marine)	Cold Climates (2015 IECC Zones 4 Marine 5,6,7,8)
AFUE	80%	90%	94%
SEER	18	15	13
HSPF	8.2	9	10 [22]
Geothermal Heat Pump	ENERGY STAR EER and COP Criteria		
ASHRAE 62.2 Whole-House Mechanical Ventilation System	2.8 cfm/W no heat exchange	2.8 cfm/W no heat exchange	1.2 cfm/W; heat exchange with 60% SRE

Insulation and Infiltration

- Insulation levels shall meet the 2015 IECC and achieve Grade 1 installation, per RESNET standards.
- Infiltration – Detached Dwellings[23] (ACH50): 3.0 in CZ's 1-2 | 2.5 in CZ's 3-4 | 2 in CZ's 5-7 | 1.5 in CZ 8
- Infiltration – Attached Dwellings (ACH50): 3.0 (all Climate Zones)

Windows[24, ,25, 26]

	Hot Climates (2015 IECC Zones 1,2,)	Mixed Climates (2015 IECC Zones 3, 4 except Marine)	Cold Climates (2015 IECC Zones 4 Marine, 5,6,7,8)
SHGC	0.25	0.25	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.[27]

Water Heater

ENERGY STAR levels for the system Energy Factor, as follows:
- Gas/propane systems of ≤ 55 gallons, EF = 0.67
- Gas/propane systems of > 55 gallons, EF = 0.77
- Electric systems in detached dwellings, EF = 2.0
- Electric systems in attached dwellings, EF = 1.5

For heating oil water heaters use EF = 0.60

Thermostat[28]

- Programmable thermostat (except for zones with radiant heat)

Lighting & Appliances

- For purposes of calculating the DOE Zero Energy Ready Home Target Home HERS Index, homes shall be modeled with an ENERGY STAR dishwasher, ENERGY STAR refrigerator, ENERGY STAR ceiling fans, and ENERGY STAR lamps (bulbs) in 80% of sockets or 80% of lighting fixtures are ENERGY STAR Qualified.

Exhibit 3: Benchmark Home Size[29]

Bedrooms in Home to be Built	0	1	2	3	4	5	6	7
Conditioned Floor Area Benchmark Home	1,000	1,000	1,600	2,200	2,800	3,400	4,000	4,600

DOE ZERH Mandatory Requirements

Exhibit 1: DOE Zero Energy Ready Home Mandatory Requirements for All Labeled Homes

Area of Improvement	Mandatory Requirements
1. ENERGY STAR for Homes Baseline	☐ Certified under ENERGY STAR Qualified Homes Program Version 3, 3.1, or 3.2 (depending on state), or under ENERGY STAR Multifamily New Construction program Version 1.0 or 1.1 (depending on state) [8, 9, 10]
2. Envelope	☐ Fenestration shall meet or exceed ENERGY STAR requirements. See End Note for specific U, SHGC values, and exceptions. [11] ☐ Ceiling, wall, floor, and slab insulation shall meet or exceed 2015 IECC levels[12,13]
3. Duct System	☐ Duct distribution systems located within the home's thermal and air barrier boundary or an optimized location to achieve comparable performance.[14] ☐ HVAC air handler is located within the home's thermal and air barrier boundary.
4. Water Efficiency	☐ Hot water delivery systems (distributed and central) shall meet efficient design requirements[15] ***or*** ☐ Water heaters and fixtures shall meet efficiency criteria[16]
5. Lighting & Appliances	☐ All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. [17] ☐ 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	☐ Certified under EPA Indoor airPLUS [10]
7. Renewable Ready	☐ Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed [18]

DOE ZERH Prescriptive Targets

Exhibit 2: DOE Zero Energy Ready Home Target Home [19]

HVAC Equipment[20]			
	Hot Climates (2015 IECC Zones 1,2)[21]	**Mixed Climates** (2015 IECC Zones 3, 4 except Marine)	**Cold Climates** (2015 IECC Zones 4 Marine 5,6,7,8)
AFUE	80%	90%	94%
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Insulation and Infiltration			
• Insulation levels shall meet the 2015 IECC and achieve Grade 1 installation, per RESNET standards. • Infiltration – Detached Dwellings[23] (ACH50): 3.0 in CZ's 1-2 | 2.5 in CZ's 3-4 | 2 in CZ's 5-7 | 1.5 in CZ 8 • Infiltration – Attached Dwellings (ACH50): 3.0 (all Climate Zones)			
Windows[24, .25, 26]			
	Hot Climates (2015 IECC Zones 1,2,)	**Mixed Climates** (2015 IECC Zones 3, 4 except Marine)	**Cold Climates** (2015 IECC Zones 4 Marine, 5,6,7,8)
SHGC	0.25	0.25	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.[27]			
Water Heater			
ENERGY STAR levels for the system Energy Factor, as follows: - Gas/propane systems of ≤ 55 gallons, EF = 0.67 - Gas/propane systems of > 55 gallons, EF = 0.77 - Electric systems in detached dwellings, EF = 2.0 - Electric systems in attached dwellings, EF = 1.5 For heating oil water heaters use EF = 0.60			
Thermostat[28]			
• Programmable thermostat (except for zones with radiant heat)			
Lighting & Appliances			
• For purposes of calculating the DOE Zero Energy Ready Home Target Home HERS Index, homes shall be modeled with an ENERGY STAR dishwasher, ENERGY STAR refrigerator, ENERGY STAR ceiling fans, and ENERGY STAR lamps (bulbs) in 80% of sockets or 80% of lighting fixtures are ENERGY STAR Qualified.			

DOE ZERH Size Adjustment

Exhibit 3: Benchmark Home Size[29]

Bedrooms in Home to be Built	0	1	2	3	4	5	6	7
Conditioned Floor Area Benchmark Home	1,000	1,000	1,600	2,200	2,800	3,400	4,000	4,600

Special Items to Note for ZERH

- DOE ZERH Must Meet EPA ENERGY STAR v3.1 (rev 12)
  - Modeling Targets
    - 95% AFUE; 13 SEER
    - 2012 IECC Insulation (Grade 1)
    - Airtightness of 3 ACH@50Pa
    - Window U-value = 0.27
    - All ducts in conditioned space
    - ENERGY STAR Appliances
    - ENERGY STAR Lighting

Hot Climates (2012 IECC Zones 1,2,3) [12]	Mixed and Cold Climates (2012 IECC Zones 4,5,6,7,8) [12]
Cooling Equipment (Where Provided)	
• Cooling equipment modeled at the applicable efficiency levels below:	
• 15 SEER / 12 EER AC, • Heat pump (See Heating Equipment)	• 13 SEER AC, • Heat pump (See Heating Equipment)
Heating Equipment	
• Heating equipment modeled at the applicable efficiency levels below, dependent on fuel and system type:	
• 80 AFUE gas furnace, • 80 AFUE oil furnace, • 80 AFUE boiler, • 8.2 HSPF / 15 SEER / 12 EER air-source heat pump with electric or dual-fuel backup	• 95 AFUE ENERGY STAR gas furnace, • 85 AFUE ENERGY STAR oil furnace, • 90 AFUE ENERGY STAR gas boiler, • 86 AFUE ENERGY STAR oil boiler, • Heat pump, with efficiency as follows: • *CZ 4:* 8.5 HSPF / 15 SEER / 12 EER air-source w/ electric or dual-fuel backup, • *CZ 5:* 9.25 HSPF / 15 SEER / 12 EER air-source w/ electric or dual-fuel backup, • *CZ 6:* 9.5 HSPF / 15 SEER / 12 EER air-source w/ electric or dual-fuel backup, • CZ 7-8: 3.6 COP / 17.1 EER ground-source w/ electric or dual-fuel backup
Envelope, Windows, & Doors	
• Insulation levels modeled to 2012 IECC levels and Grade I installation per ANSI / RESNET / ICC 301. • Infiltration rates modeled as follows:	
4 ACH50 in CZs 1,2	3 ACH50 in CZs 3,4,5,6,7,8
• ENERGY STAR windows and doors modeled, as illustrated below:	
Window U-Value: 0.40 in CZs 1,2	0.30 in CZ 3 / 0.30 in CZ 4 / 0.27 in CZs 5,6,7,8
Window SHGC: 0.25 in CZs 1,2	0.25 in CZ 3 / 0.40 in CZ 4 / Any in CZs 5,6,7,8
Door U-Value: Opaque: 0.17	≤½ lite: 0.25 / >½ lite: 0.30
Door SHGC: Opaque: Any	≤½ lite: 0.25 / >½ lite: 0.25 in CZs 1,2,3; 0.40 in CZs 4,5,6,7,8
Water Heater	
• DHW equipment modeled with the following efficiency levels as applicable:	
Gas: 30 Gal = 0.63 EF	40 Gal = 0.61 EF / 50 Gal = 0.59 EF / 60 Gal = 0.57 EF / 70 Gal = 0.55 EF / 80 Gal = 0.53 EF
Electric: 30 Gal = 0.94 EF	40 Gal = 0.93 EF / 50 Gal = 0.92 EF / 60 Gal = 0.91 EF / 70 Gal = 0.90 EF / 80 Gal = 0.89 EF
Oil: 30 Gal = 0.55 EF	40 Gal = 0.53 EF / 50 Gal = 0.51 EF / 60 Gal = 0.49 EF / 70 Gal = 0.47 EF / 80 Gal = 0.45 EF
Thermostat & Ductwork	
• Programmable thermostat modeled. • All ducts and air handlers modeled within conditioned space.	
Lighting & Appliances	
• ENERGY STAR refrigerators, dishwashers, and ceiling fans modeled. • ENERGY STAR light bulbs modeled in 90% of ANSI / RESNET / ICC 301-defined Qualifying Light Fixture Locations.	

Special Items to Note for ZERH

- DOE ZERH Must Meet EPA ENERGY STAR v3.1 (rev 12)

Exhibit 2: Mandatory Requirements for All Certified Homes

Party Responsible	Mandatory Requirements
Requirements Applicable to Track A & B	
Rater	• Completion of SFNH National Rater Design Review Checklist, Version 3 / 3.1 / 3.2 • Completion of SFNH National Rater Field Checklist, Version 3 / 3.1 / 3.2
Builder	• Completion of SFNH National Water Mgmt. System Builder Reqs., Version 3 / 3.1 / 3.2
Requirements Only Applicable to Track A - HVAC Grading [13]	
HVAC System Designer	• Completion of an HVAC design report compliant with ANSI / RESNET / ACCA / ICC 310, plus the SFNH / MFNC National HVAC Design Supplement to Std. 310 for Dwellings & Units, All Versions.
HVAC Installing Contractor	• None. While the HVAC contractor plays a critical role in properly installing and commissioning a system, the Rater is the party responsible for assessing its installation quality in accordance with ANSI / RESNET / ACCA / ICC 310.
Requirements Only Applicable to Track B - HVAC Credential	
HVAC System Designer	• Completion of SFNH National HVAC Design Report, Version 3 / 3.1 / 3.2
HVAC Installing Contractor	• Completion of SFNH National HVAC Commissioning Checklist, Version 3 / 3.1 / 3.2

Special Items to Note for ZERH

- DOE ZERH Must Meet All of the EPA Indoor airPlus
  - Moisture Control
    - foundation drainage/sumps, aggregate under the slab
    - exterior foundation protection with gutters or splash control
    - hard surface flooring in kitchens, baths, laundry, entry, utility rooms
  - Radon
    - radon-resistant features in Zone 1
  - Pests
    - corrosion proof rodent & bird screen

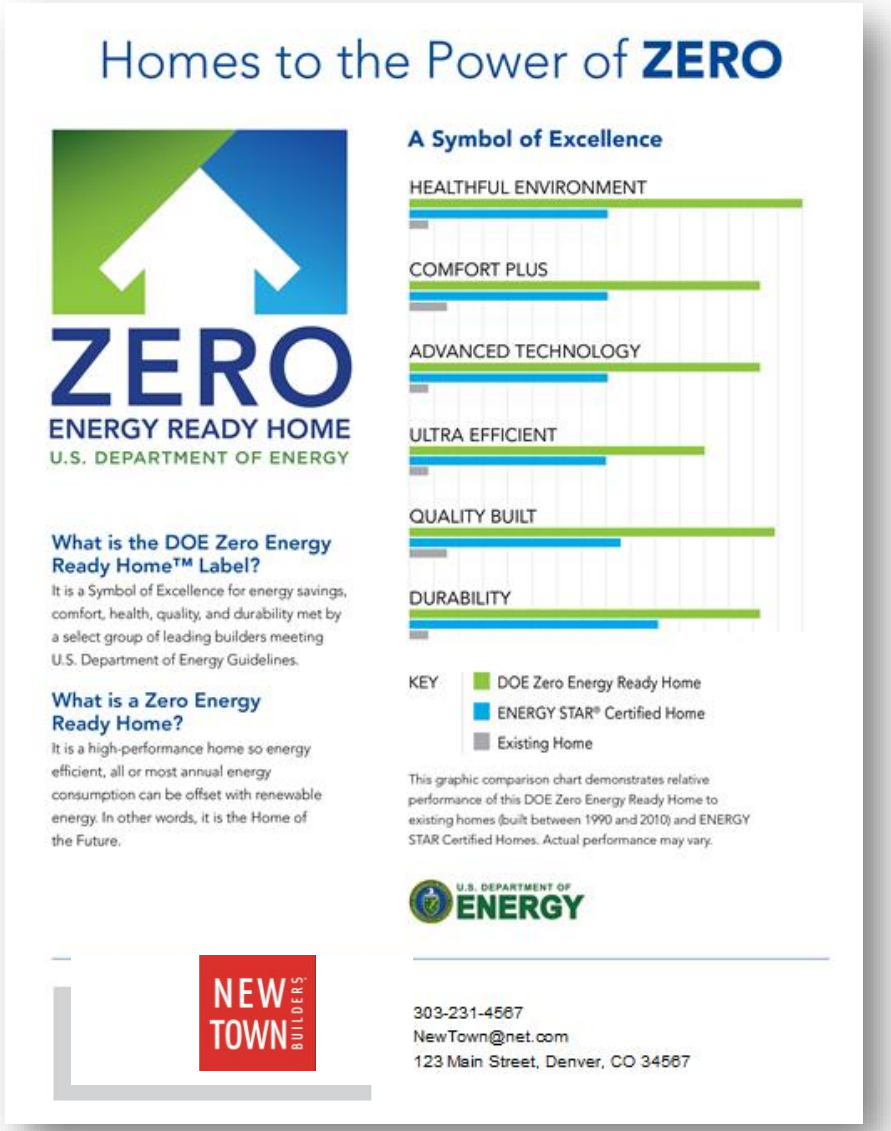
Special Items to Note for ZERH

- DOE ZERH Must Meet All of the EPA Indoor airPlus
  - HVAC System
    - hard-ducted supplies and returns; protection from construction debris
    - minimum of MERV 8 and no ozone generation
  - Combustion Pollutants
    - must meet emission standards for fuel burning appliances
    - attached garage with door closer and exhaust fan or tightness test
  - Materials
    - Certified low-emissions for wood composites, finishes, flooring
  - Commissioning
    - HVAC verification, manuals, labels, certificate

Special Items to Note for ZERH

- DOE ZERH Must Meet Some of the EPA WaterSense
  - Primarily around the hot water distribution system
  - Design to provide customer convenience while minimizing water waste and reduce water heating energy
  - Water heater and fixtures meet water sense criteria
  - 0.5 gallons or less in the piping between the hot water source and any hot water fixture
    - source is the water heater, manifold, or recirculating loop
    - from a cold start, must draw less than 0.6 gallons to reach desired delivery temperature

Translating the Value Proposition



TIME FOR A QUICK PAUSE

- Questions
- Thoughts
- Reflections
- Discussion

PART 4: KEYS TO HIGH-PERFORMANCE NZE HOMES

- 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.
- As solar PV prices fall, a small investment can take your energy bill and/or footprint to “zero”.

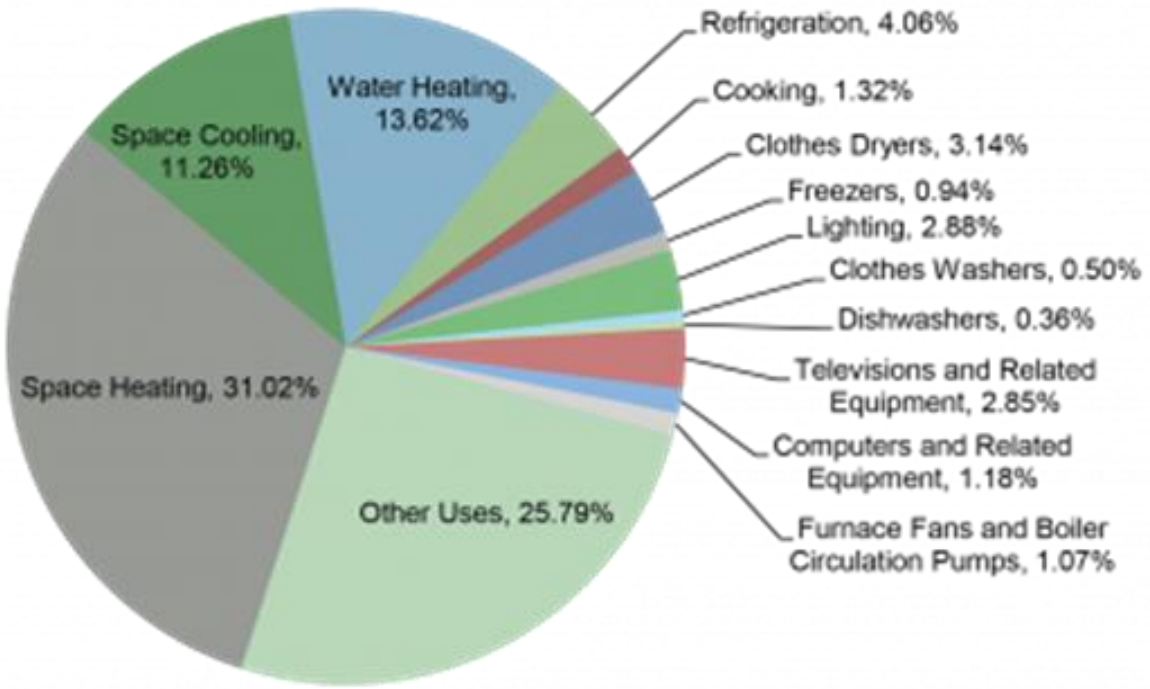
NET ZERO ENERGY TODAY

- Definition: the total amount of energy consumed is equal to the total amount of energy generated on-site.

- It can be done …
  - but it requires a careful examination of the trade off between the cost of energy reduction and the cost of solar generation.

THE POWER OF ZERO ENERGY HOMES

- Residential Energy End-Uses (EIA 2020)



GETTING TO NET ZERO ENERGY TODAY

- But be prepared – the whole building solution might look a bit different than you imagined.
  - It isn't simply adding more of the same.
  - There are several "new things" that will demand your attention to as you move to Net Zero Energy.
  - Adapted from "BSI-081 Zeroing In" by Joseph Lstiburek.
- These will be presented as challenges.
  - Important precautions necessary to ensure your successful pursuit of NZE homes.

5 CHALLENGES FOR ZERO ENERGY READY HOMES

- Creating a Forgiving Building Enclosure
- Designing & Installing a Superb Ventilation System
- Recognize the Changing Load Profile
- Providing “Year-Around” Humidity Management
- Implementing Active Pressure Management

CHALLENGE 1: CREATING A FORGIVING ENCLOSURE

- A “high-performance home” will demand a robust, durable, and forgiving building enclosure!
  - As energy efficiency improves moisture risks can go up.

THE MODERN ENCLOSURE CONUNDRUM

- We spent several decades focused on energy efficiency without concurrent attention to moisture management!
  - Initially we focused on management of condensation due to vapor diffusion and introduction of vapor retarders.
  - Later it was recognized that air leakage was a far bigger moisture risk so we began to address air barriers.
  - Then it became painfully apparent that we weren't paying sufficient attention to the management of bulk water and we introduced the water resistive barrier.

THE MODERN ENCLOSURE CONUNDRUM

- However, only recently has the conversation turned to the importance of safe storage and maintaining a drying potential.
  - We recognize that things can get wet at some point due to imperfect design, execution, or operation.
  - Therefore, all moisture susceptible materials must be able to dry out primarily by vapor diffusion
    - that can be outward in winter; inward in summer,
    - except below grade, which can only dry inward.

CREATING A FORGIVING ENCLOSURE

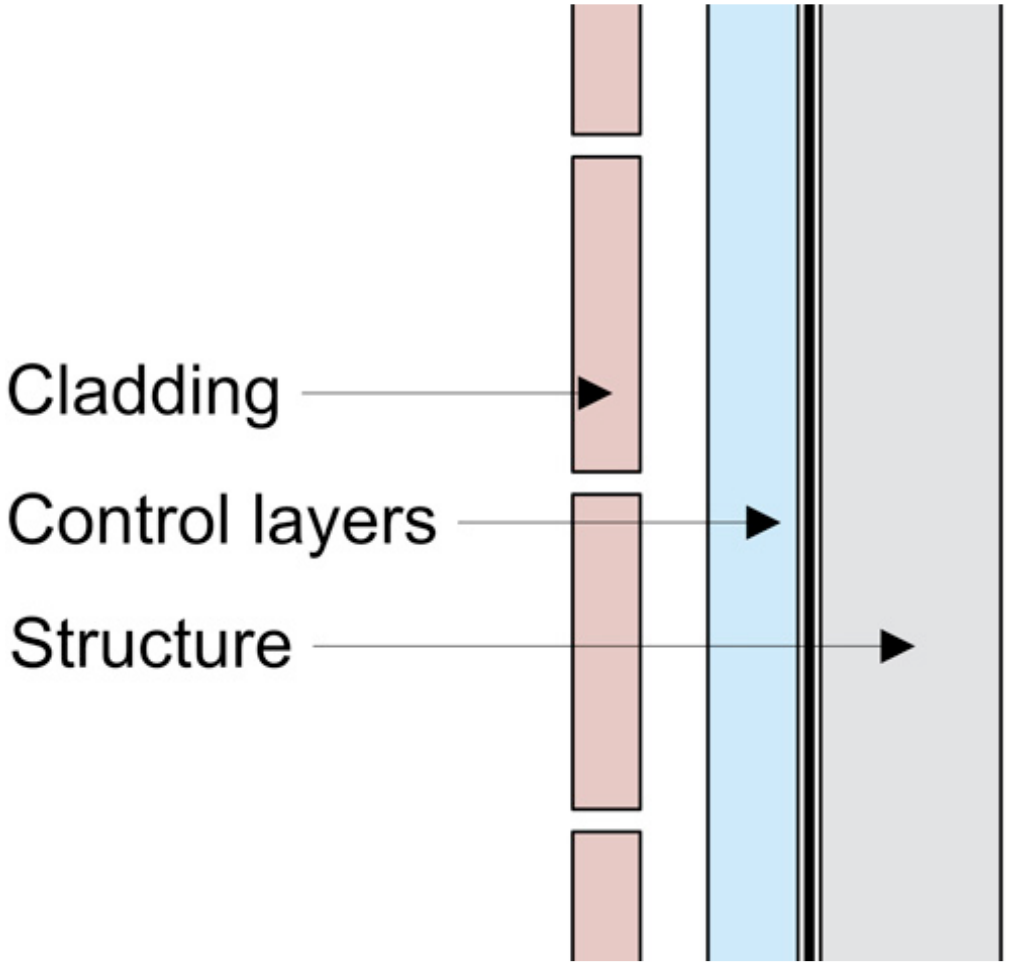
- The “Perfect” Approach
  - Walls
  - Roof
  - Slab
  - Foundation

- Move the structure to the inside and the control layers to the outside …
  - It simply works and works everywhere!!!

PUTTING THE LAYERS TOGETHER

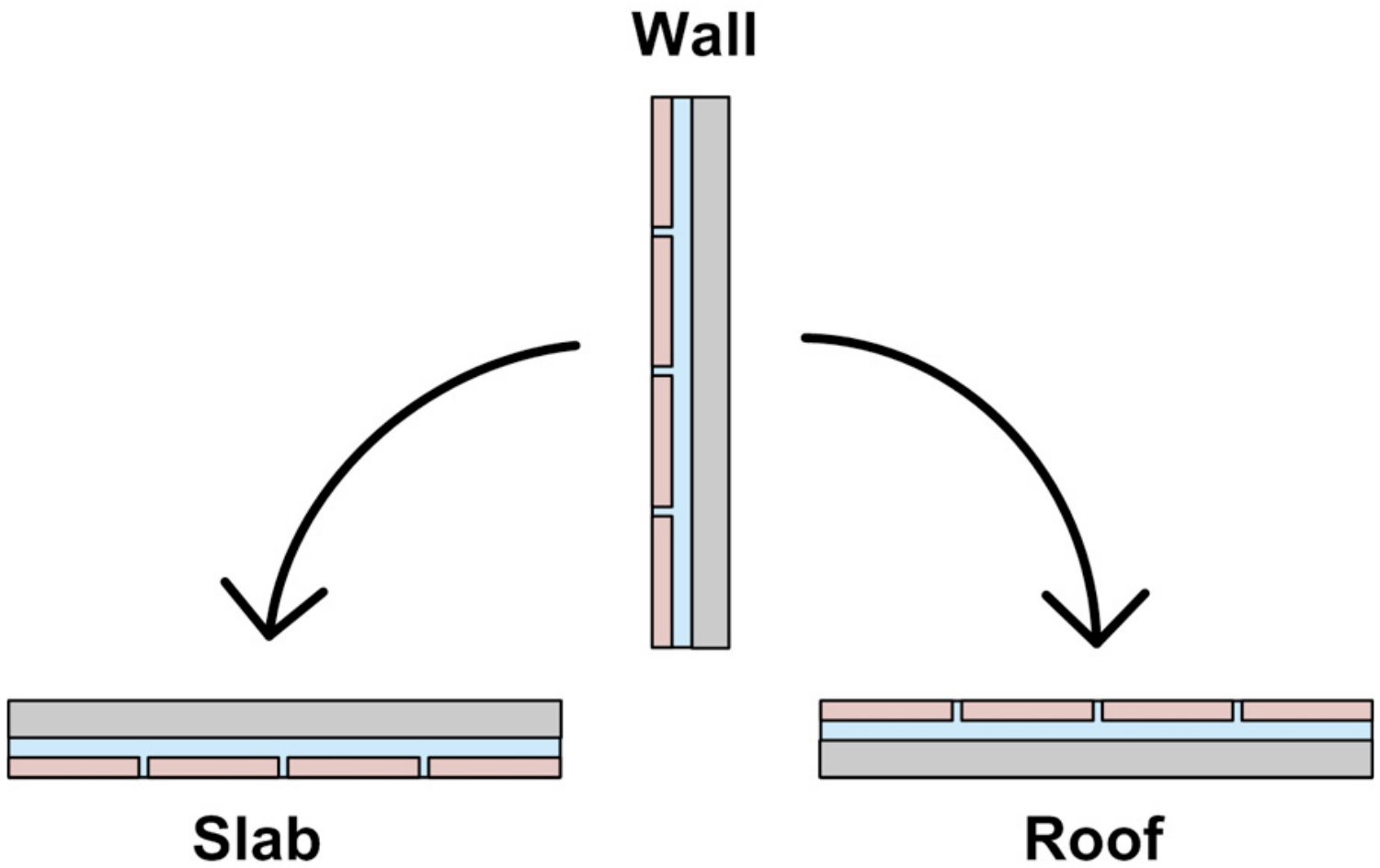
- All enclosure components must include the four critical control layers
  - Water
  - Air
  - Thermal
  - Vapor

THE PERFECT WALL*

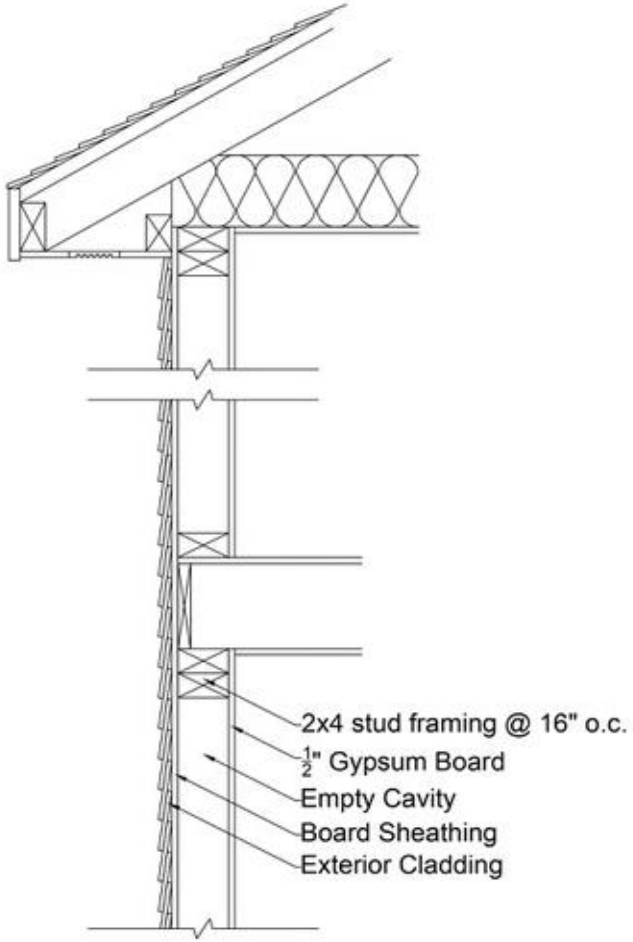


* Source: Building Science Corporation

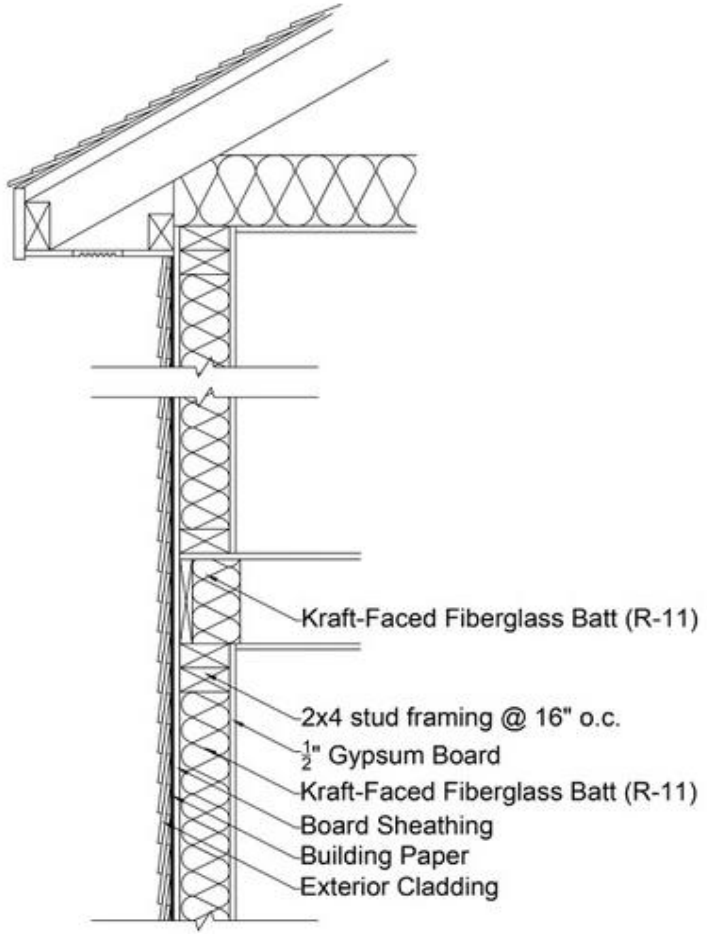
WORKS FOR ROOF & SLAB, TOO!



Wall A: Older, Uninsulated Frame Wall

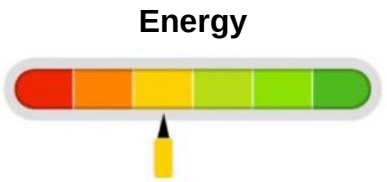


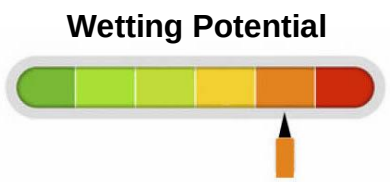
- Energy performance is very poor
  - especially in cold and hot climates
- Moisture is managed by substantial heat and air flows
  - wetting potential is high, but so is the drying potential
- Poor comfort due to drafts and cold/hot interior surface temperatures
- ***It may be durable, but it is unacceptably inefficient and uncomfortable!***

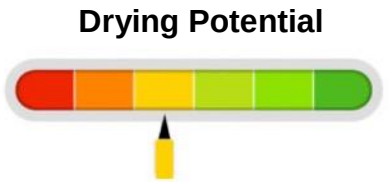


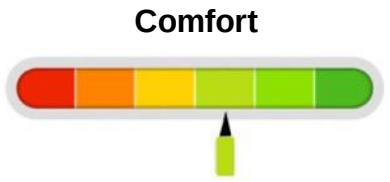
Wall B: Older, Insulated Frame Wall

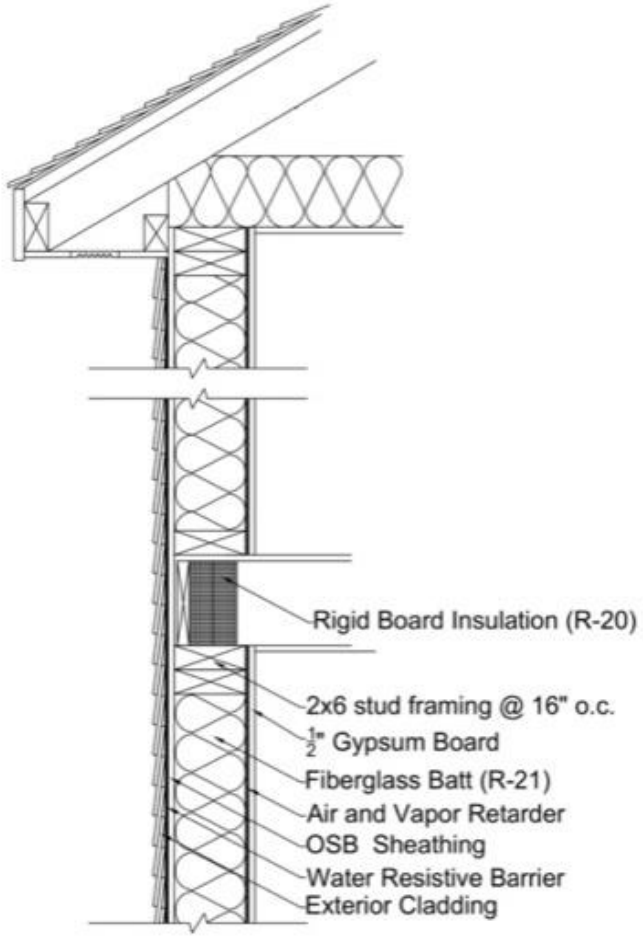
- Improved thermal efficiency
- Wetting potential goes up due to possible condensation; water intrusion potential remains
- Drying potential is reduced as a result of less heat transfer and less permeable layers/linings
- Improved surface temperature, but may still be drafty
- ***More efficient and comfortable, but not as durable or robust!***







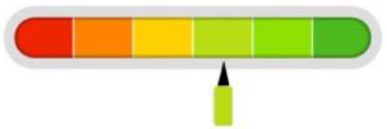




Wall C: Typical Frame Wall

- Improved thermal and air control for higher energy efficiency
- With excellent craftsmanship all wetting mechanisms can be reduced
- However, drying potential is extremely limited
  - a bulk water leak or localized condensation could be disastrous
- High level of occupant comfort
- ***Very efficient and comfortable, but potentially risky and not very robust!***

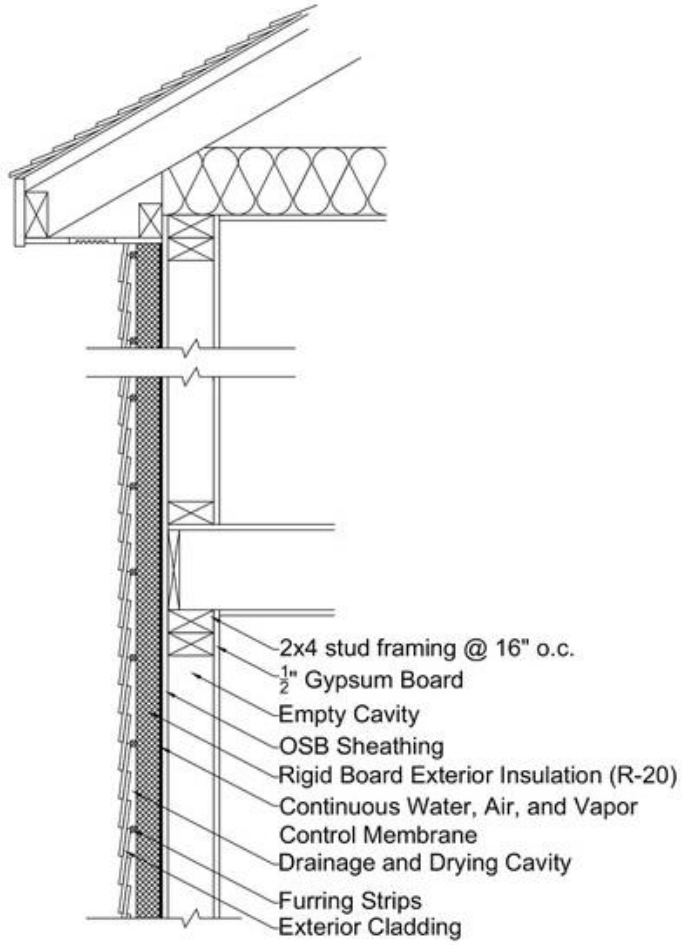
Energy



Wetting Potential

Drying Potential

Comfort



Wall D: "Perfect Wall" w/ CEI

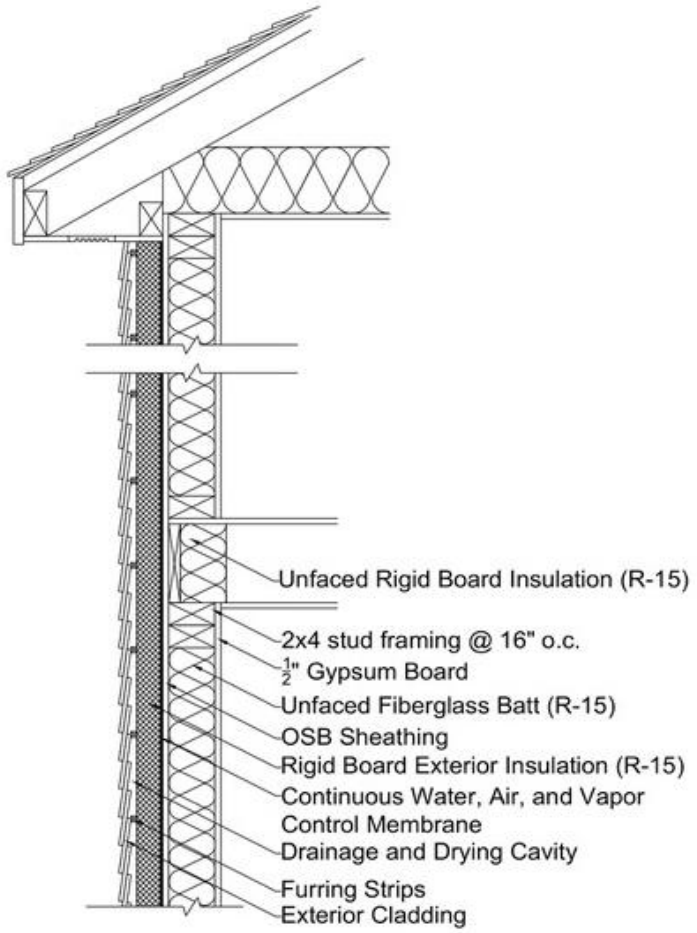
- Improved thermal and air control for higher energy efficiency
- All moisture transport mechanisms can be easily addressed to reduce the wetting potential
- Excellent ability to dry in both directions
- High level of occupant comfort
- Works in all climates (R-values can be adjusted to suit)
- Flexible framing, electrical, and interior finishes
- ***Very durable, efficient, comfortable, and robust!***

Energy

Wetting Potential

Drying Potential

Comfort



Wall E: Hybrid Wall w/ CEI

- Outstanding energy performance
- All moisture transport mechanisms can be easily addressed to reduce the wetting potential
- Maintains ability to dry in both directions
- Very high level of occupant comfort
- Works for all climate zones
  - R-values and ratios can be adjusted to fit
- Flexible framing, electrical, and interior finishes
- ***Extremely efficient, comfortable, durable and robust!***

Energy

Wetting Potential

Drying Potential

Comfort

FOCUS ON ULTRA-EFFICIENCY

- Insulation levels must be high, however …
  - excessive insulation will have diminishing returns,
  - so insulation optimization is the key.
- Shift focus to …
  - minimizing thermal bridging,
  - reducing enclosure surface area,
  - improving window U-values, and
  - using high-efficiency equipment, lighting, and appliances.

ULTRA-TIGHT IS ESSENTIAL

- But it has consequences!
  - Remember that tightness is driven by moisture management more so than energy.
  - Large exhaust devices will 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 say no!

CHALLENGE 2: SUPERB VENTILATION

- Good may not be not good enough!
  - You must have a very tight enclosure.
  - Always start by managing pollutants (and moisture).
  - Recognize that humid outdoor air will create some special challenges, especially under part-load conditions.

START BY MANAGING THE POLLUTANT

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

VENTILATION SYSTEM MUST BE TOP SHELF

- Balance ventilation with heat/energy recovery is essential.
  - Use the HRV/ERV to satisfy bathroom exhaust requirements to avoid additional exhaust fans.
  - Be certain to provide fresh air to where the people are spending their time!

INTERNAL CIRCULATION IS A MUST

- In an ultra-tight home …
  - Air isn't moving bottom to top or side to side.
  - You need mixing for thermal comfort.
  - You must distribute fresh air for IAQ.
- This approach also supports better filtration and fine particulate control.
- You can choose to use the space conditioning or ventilation system to meet this need.

VENTILATION SUMMARY

- Must be balanced energy 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 or rarely used.

CHALLENGE 3: RECOGNIZE CHANGING LOAD PROFILE

- Heating isn’t the big problem any longer!
- Overheating (and cooling) are quickly taking center stage even in colder climates!
  - Internal loads, solar gains, and latent loads must be carefully managed.
  - Significant cooling hours when the outside temperature is below the setpoint.

DON'T OVERDO THE PASSIVE SOLAR

- South windows are usually good, but …
  - The heat gain in the winter may not be needed.
  - The heat gain in the summer will likely hurt you.
- But people like windows
  - So give them windows; just use good judgement on orientation, placement, type, and treatments.
- Shift solar focus towards PV.
  - Which is needed to satisfy non-thermal loads.

SPACE COOLING

- To AC or not to AC?
  - For many reasons, this is changing fast.
  - Cooling loads and hours are growing quickly.
- 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.

SPACE COOLING

- High performance enclosures will make space cooling look very different.
  - Loads may look lower.
  - But the cooling demand will be longer and move further into the shoulder seasons.
  - Load diversity & ratios between spaces will be much higher.

CHALLENGE 4: HUMIDITY MANAGEMENT

- This is critical in low-load homes, as typical oversized air-conditioning systems simply don’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.

HUMIDITY MANAGEMENT IS HUGE

- Perhaps the greatest challenge in high-performance homes will be latent load management!
  - Latent loads are hard to reduce.
  - In swing seasons and under part-load conditions indoor moisture levels can float out of control.
- You might think this can be done with your air-conditioning or ventilation system?
  - It is tougher than it sounds and for many homes, independent dehumidification will be needed.

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.
- Downsizing the AC is great, but only when there are sufficient sensible loads.
  - Two-stage or variable capacity AC can help, too!
- But for best summer humidity control, consider a whole house dehumidifier.

CHALLENGE 5: PRESSURE MANAGEMENT

- This becomes increasingly harder with tighter enclosures and larger exhaust devices.
  - Very large negative pressures are very real.
- Furthermore, we should probably be aiming for positive pressure for improved comfort and to manage soil gases, exterior pollutants, and summer moisture.
  - However, during the cold winter temperature balanced would be best.

MAKE-UP AIR

- Equipment Strategies
  - 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 or condensing dryer

MAKE-UP AIR

- Make-Up Air Strategies
  - 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)

TIME FOR A QUICK PAUSE

- Questions
- Thoughts
- Reflections
- Discussion

BONUS SECTION: WHAT WOULD PAT DO?

- Our First New Home

  1994

- Primary Theme
  - Best readily available & affordable technologies for an efficient, durable, and healthy home
- Performance Metrics
  - 3100 sf conditioned floor area
    - w/ walk-out basement
  - 360 cfm@50Pa (<1 ACH@50Pa)
  - approx. $75/mo (heat & cool) today
  - almost DOE ZERH

WHAT WOULD YOU DO?

- My Next New Home

- Primary Theme
  - Smart, practical, resilient, high-performance, net zero energy ready home on a reasonable budget
- Performance Targets
  - Approx 2400 sf conditioned
  - <1.0 ACH@50
  - DOE ZERH+
  - HERS 35 (pre-PV)
  - NZE w/ 5-7 kW PV

GENERAL DESIGN

- Rectangular 1-1/2 story
  - w/ lookout basement facing south
  - garage to protect west and/or north
  - screen porch on east
- Steep gable roof (E-W)
  - vented hybrid sloped roof
  - kneewall space for storage & ductwork
  - good overhangs to manage sun and water
  - designed to support solar PV

OVERALL ENERGY DESIGN

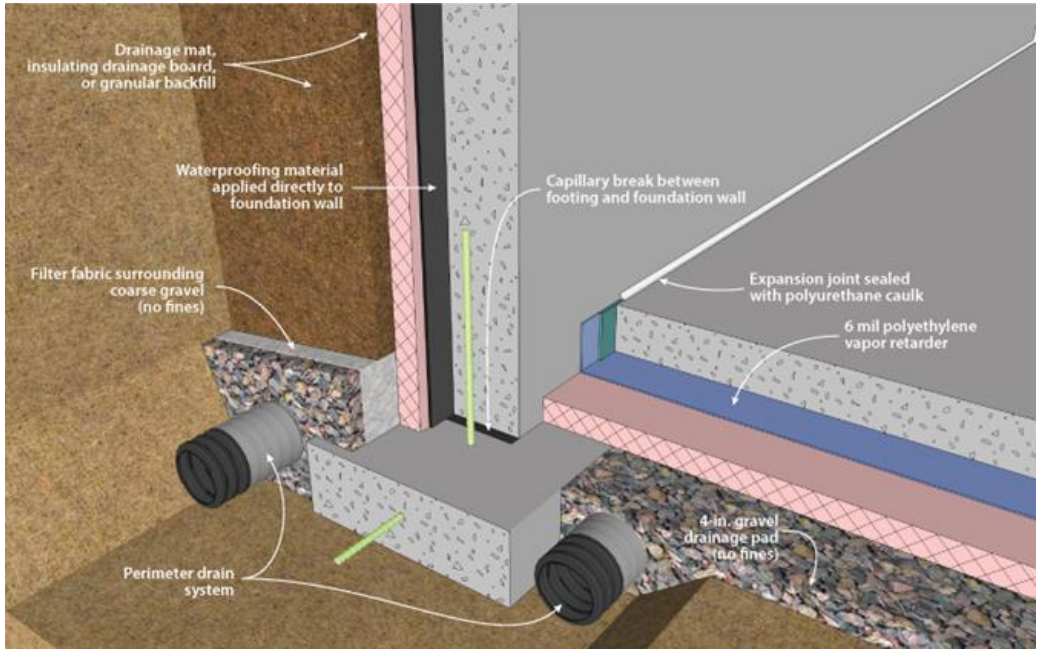
- Optimized enclosure
  - increased insulation; reduced thermal bridging
  - better windows
  - very airtight
  - limited passive solar and natural ventilation
- Stepped up efficiency
  - integrated HVAC+DHW
  - heavy focus on LAMELs
- Improved home energy management

OVERALL SOLAR DESIGN

- Passive design
  - strategic glazing
  - use existing mass
- Solar PV
  - roof mounted
  - micro-inverter
  - battery storage (?)
- Vehicle charging station

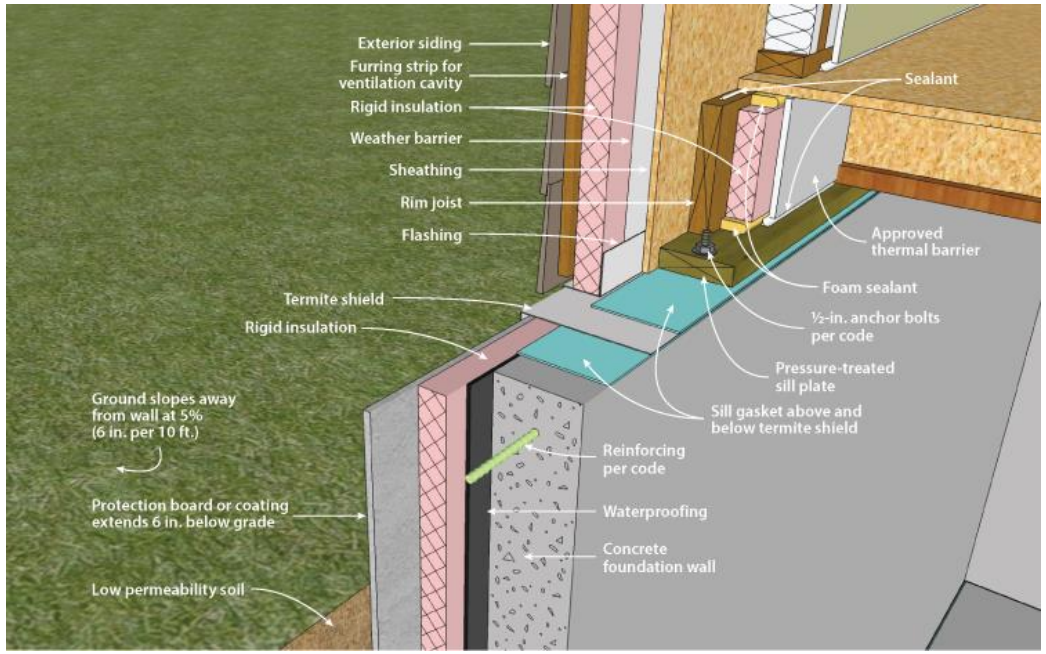
SLAB CONSTRUCTION

- Large washed aggregate (no fines)
- 3” XPS (possibly EPS)
  - 2 layers staggered
- Cross-laminated poly (?)
- 4” slab
  - sealed edges & joints
- Sealed sump basket
  - interior drain tile; passive radon pipe



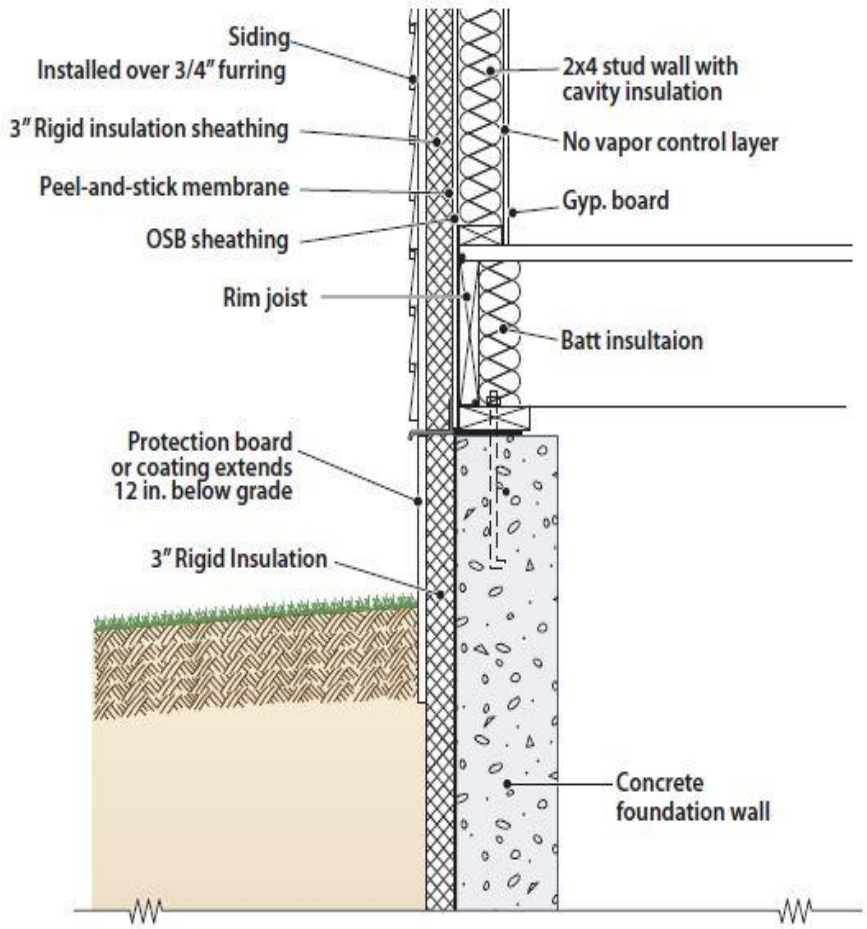
FOUNDATION CONSTRUCTION

- Cast-in-place concrete
  - w/ waterproofing
- Exterior insulation
  - 2” XPS (possibly EPS)
  - 2” semi-rigid fiberglass
  - fiber-cement protective panel
- Exterior drain tile
  - washed aggregate wrapped in filter fabric
  - to daylight, if possible



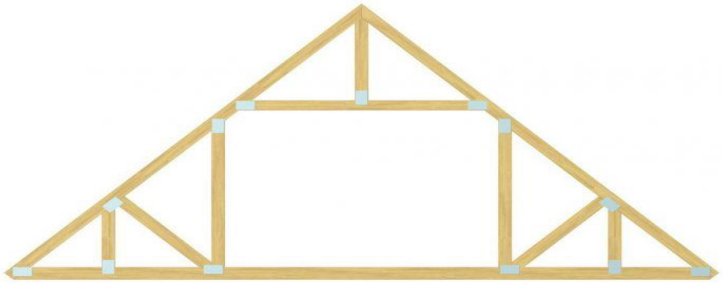
WALL CONSTRUCTION

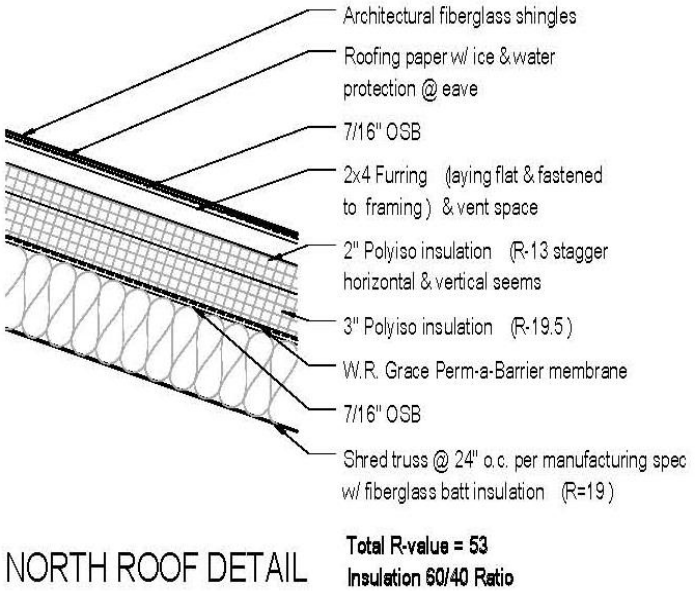
- 2x4 frame hybrid wall
  - 16” framing w/ R-15 cavity insulation
  - No interior membrane or sealed boxes
  - 1-1/8” OSB sheathing
- Fully-adhered membrane
  - water, air, vapor control
- 3 - 4” rigid insulation
  - 2 layers XPS/gEPS/PIC/MW
  - 1x4 furring w/ fiber-cement siding



ROOF ASSEMBLY

- Modified roof truss
  - 1-1/8” OSB sheathing
  - R-21 kraft-faced batt in top chord
- Fully-adhered membrane
  - water, air, vapor control
- 5 - 6” rigid insulation R-30+
  - 2 (or 3) layers XPS/gEPS/PIC staggered
  - 2x4 furring strips flat
  - Sheathing, roofing paper, & metal roof



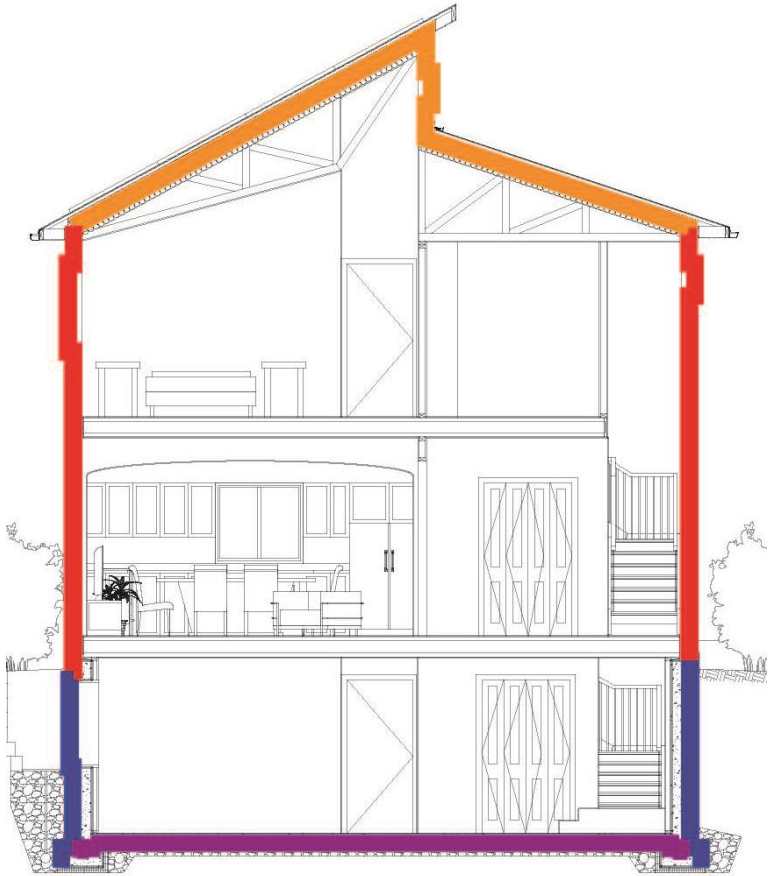


NORTH ROOF DETAIL

Total R-value = 53
Insulation 60/40 Ratio

AIRTIGHTNESS

- Fully-adhered (or fluid applied) membrane for foundation, wall, & roof
  - Integrated with all windows, doors, and penetrations
  - Regular electrical boxes & ceiling fixtures can be placed anywhere!
  - Drywall can be glued & screwed
  - Can mount anything we want on exterior walls w/o compromising the air barrier



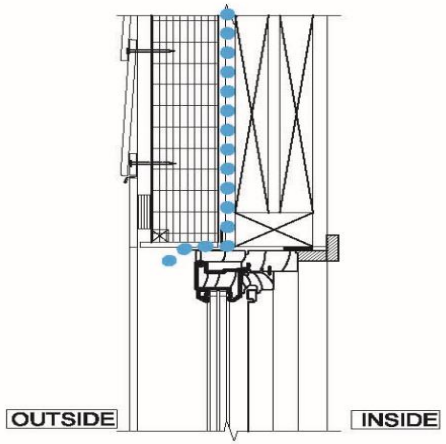
FENESTRATION TYPE

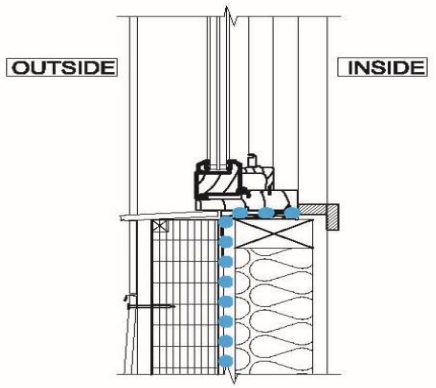
- Triple glazed, awning windows
  - double low-E^2
  - krypton gas-filled
  - warm-edge spacer

- Possible alternate???
  - double glazed low-E^2 with argon gas-filled, warm-edge spacer
  - double-hung window w/ low-E exterior storm

FENESTRATION INSTALLATION

- "Innie" attached at the sheathing plane and integrated to fully-adhered membrane
  - sloped pan flashing w/ back dam
  - rough openings (head & jambs) sealed with low-expanding foam
  - exterior trim returned to window frame





HEATING SYSTEM

- Central forced-air system
  - air-source heat pump; 11 HSPF
  - sized for cooling
  - w/ potable hot water coil
- Storage water heater
  - sealed combustion condensing; modulating
  - 94% CAE
- Spot hot water radiant heat
  - bathrooms

COOLING SYSTEM

- ASHP
  - 18 SEER / 11 HSPF
  - Sized for cooling
- Dehumidification
  - stand alone high capacity DH
  - possibly use hot water coil for reheat

FILTRATION

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

VENTILATION SYSTEM

- High quality ERV
  - fully-ducted source-point exhaust
    - bathrooms (no bath fans)
    - kitchen area (w/ range hood)
    - laundry room
  - supply air to forced-air return
    - medium continuous
    - button boost for high

DHW

- High-efficiency DHW
  - sealed combustion; condensing tank-type
  - modulating burner
  - 94% CAE
- Structured plumbing
  - designed plumbing core
  - recirculation pump
  - end-use switches
- Insulate all hot water pipes

OTHER ITEMS

- Range Hood
  - 150 to 200 cfm
  - extended front w/ side panels
- Clothes Dryer
  - condensing
  - ventilation pick-up
- Woodstove (maybe?)
  - w/ make-up air switch

MAKE-UP AIR

- Make-Up Air Unit
  - 150 - 200 cfm
  - multi-speed
  - tempering
    - blended w/ house air
    - electric resistance
- Also used for
  - supply air ventilation
  - summer economizer

GENERAL CONTROLS

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

FINAL NOTES & CAUTIONS

- High-performance NZE 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

- High-performance enclosures will demand a new approach for 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

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 (and contractors).

DOE RESOURCES

- DOE Building America Resources
  - https://www.energy.gov/eere/buildings/building-america
- DOE Zero Energy Ready Home (ZERH)
  - https://www.energy.gov/eere/buildings/zero-energy-ready-home-program
- Building America Solution Center
  - https://www.energy.gov/eere/buildings/building-america-solution-center
- Building Science Advisor
  - https://bsa.ornl.gov

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
- Moisture Control for Residential Buildings: Principles & Practices
  - Joseph Lstiburek, 2020

TIME TO WRAP

- Questions
- Thoughts
- Reflections
- Discussion

- Discussion & Questions

Contact Information

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