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

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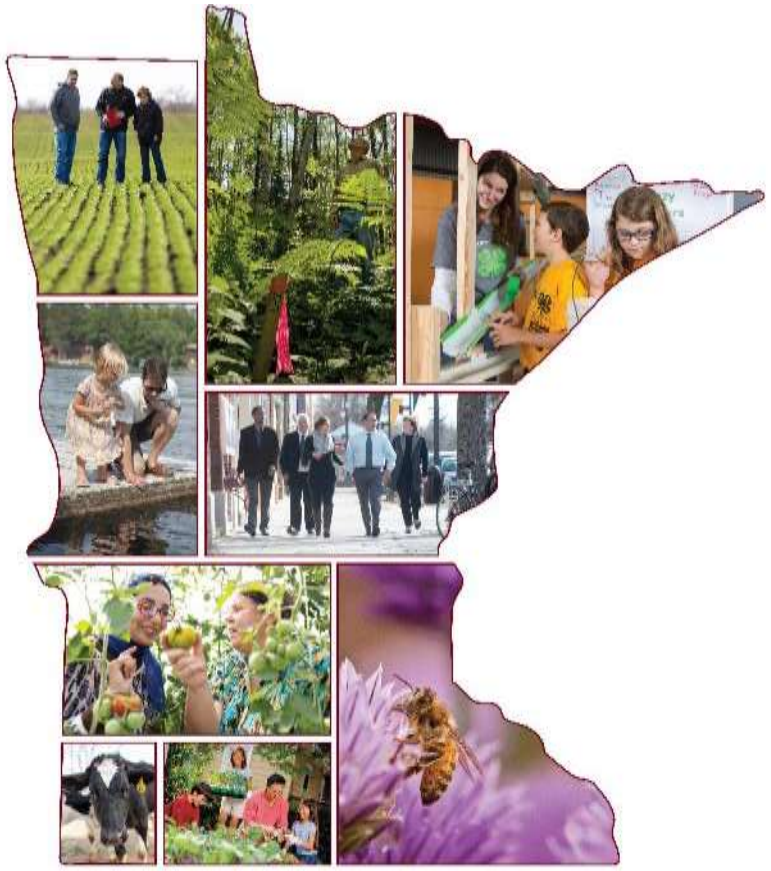

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ZEROING IN: THE PATH TO HIGH-PERFORMANCE MAY BE DIFFERENT THAN YOU THINK!

- Part 1: High-Performance Homes: Why & What
  - Building Science + Systems Approach = High-Performance
- Part 2: Pathways to High-Performance
  - Programs That Will Get You There
- Part 3: DOE Zero Energy Ready Homes
  - Business Case & Consumer Benefits
- Part 4: Zero Energy Homes Today
  - Keys to Success & Critical Challenges

KEEPING OUR EYE ON THE BALL

- Is it possible that we have over-invested in products (and some wishful thinking) 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?

A GROWING EPIDEMIC: NOTMYJOBITIS

THE CONTEXT: FIVE THINGS*

- How did we get here?
- What is driving these changes?
- What does it mean for building design and construction practices?

* BSI:-039: The Five Things by Jospeh Lstiburek

FIVE FUNDAMENTAL CHANGES

- Increase thermal resistance
  - more insulation => less heat flow => less drying!
- Changes in permeability of linings
  - while this may mean less wetting,
  - it also can lead to very slow drying!
- Increased water/mold sensitivity of materials
- Moisture storage and redistribution
- Complex 3-D airflow networks in buildings

FIVE INEVITABLE TRENDS

- Building Airtightness
  - getting tighter everyday; not certain where it will stop
- Mechanical Ventilation
  - must include air distribution; moving towards balanced
- Exterior Control Layers
  - especially insulation with vented cladding
- Ducts in Conditioned Space
  - will drive use of conditioned crawl spaces/attics
- Active Pressure Management
  - integrated make-up air

FIVE CHANGES WE MUST EMBRACE

- Step Back & Take a Broader Systems View
- Demand Performance Over Prescriptive
- Use Building Science, Engineered Approach
- Place a Premium on Robust
- Focus on Total Cost of Ownership

FIVE CHALLENGES IN GOING TO ZERO

- Must have a robust and forgiving building enclosure
- Must have a high-quality ventilation design, equipment, installation, and operation
- Must recognize the heating problem has been fixed and must focus on the new reality
- Must manage house pressures
- Must provide summer humidity control

MAKING THE CASE FOR ROBUST

- We must ensure our high-performance houses meet our expectations today and in the future?

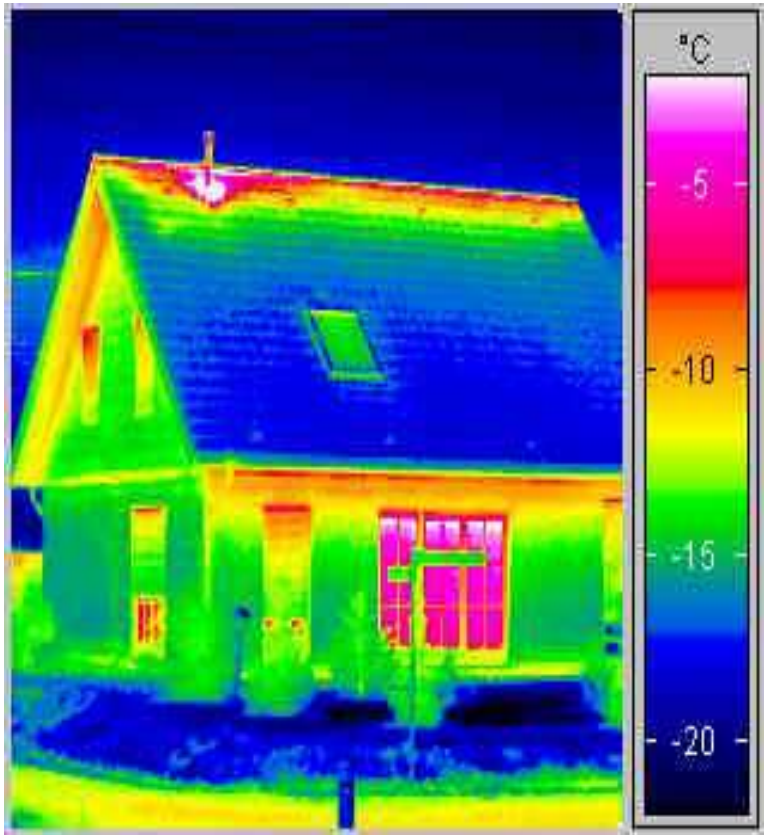
- High-performance houses will push our current approach. Therefore, we must …
  - design and engineer (not just build) our homes.
  - build forgiveness/tolerance into all systems.
  - build redundancy into critical materials.
    - or make it easy to repair and/or replace key components
  - develop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

PART 1: WHY HIGH-PERFORMANCE

- Energy Use in Our Homes
- What is High-Performance?
- Key Challenges to High-Performance
  - Modern Enclosure Conundrum
  - Modern Mechanical Systems Conundrum

THE POWER OF ZERO ENERGY HOMES

- Are there buyers who would like their utility bills (or carbon footprint) to go away?
  - How much is that worth to them?
  - Can it be done?
  - What does it cost?

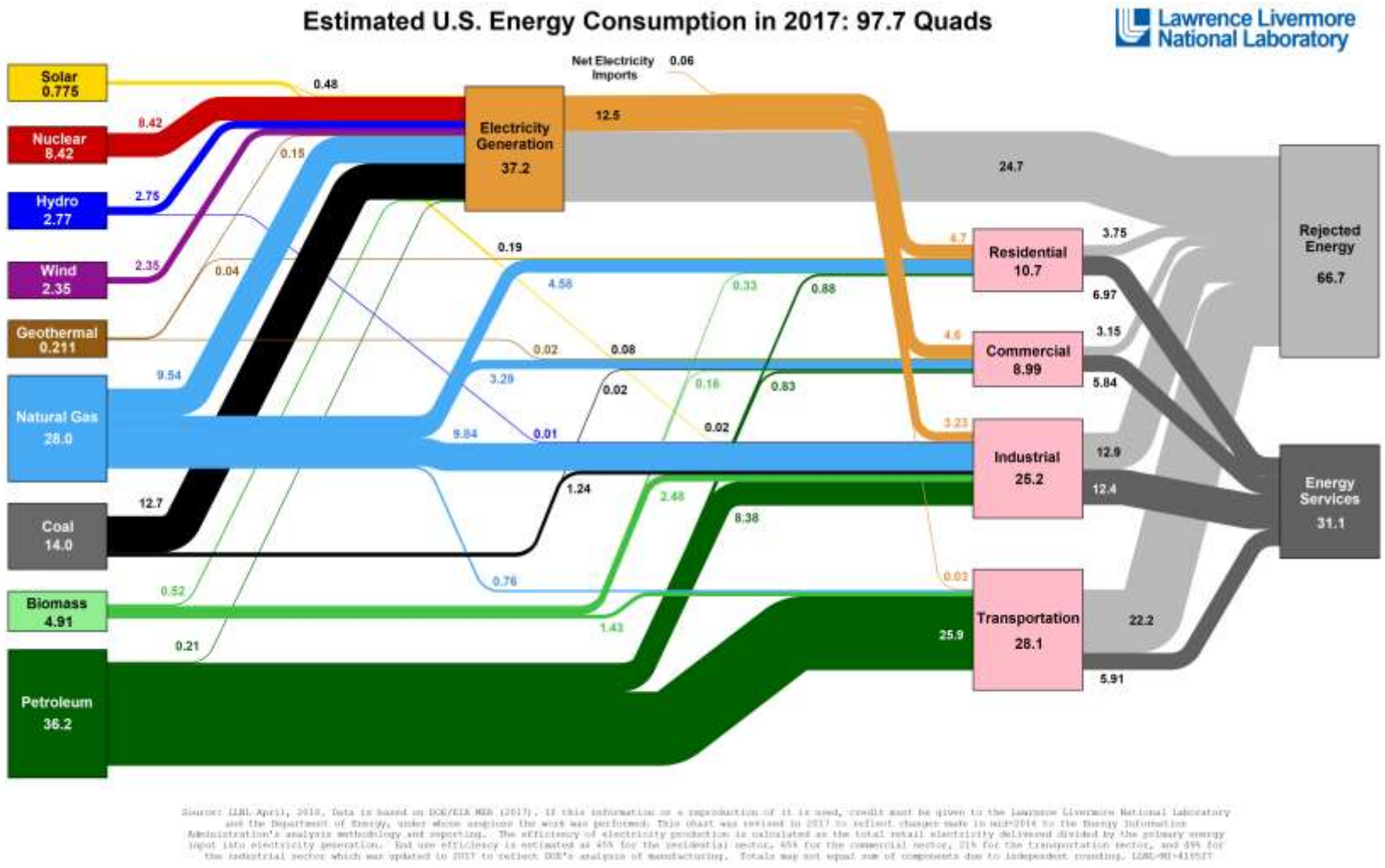


THE POWER OF ZERO ENERGY HOMES

- Absolutely – with a couple of caveats!
- Homes will always require energy.

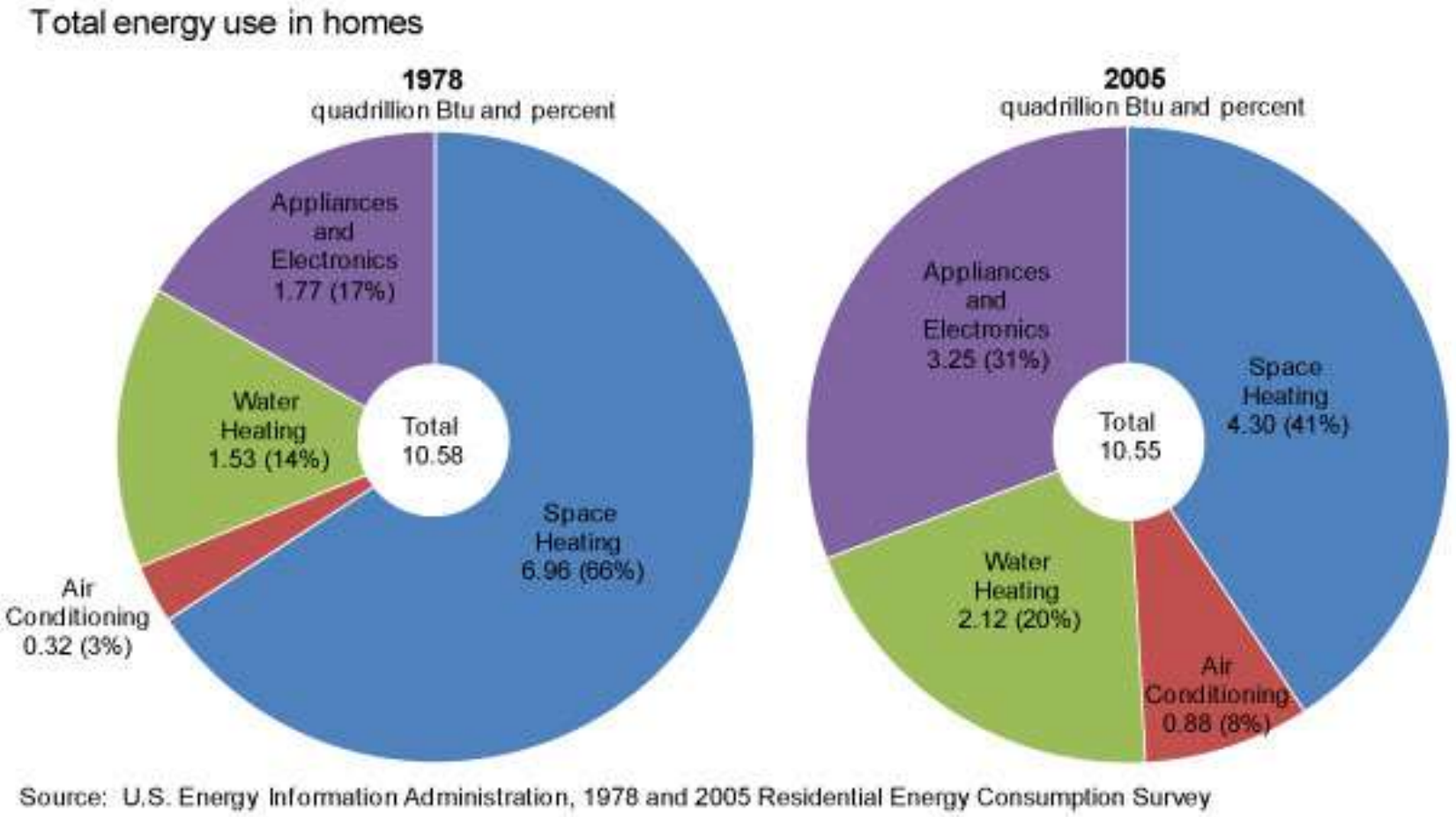
- Can the home produce as much as it uses?
  - Is it site energy or source energy?
  - If dollars, don't forget the $20 per month in fees.

THE ENERGY PICTURE IN THE U.S.



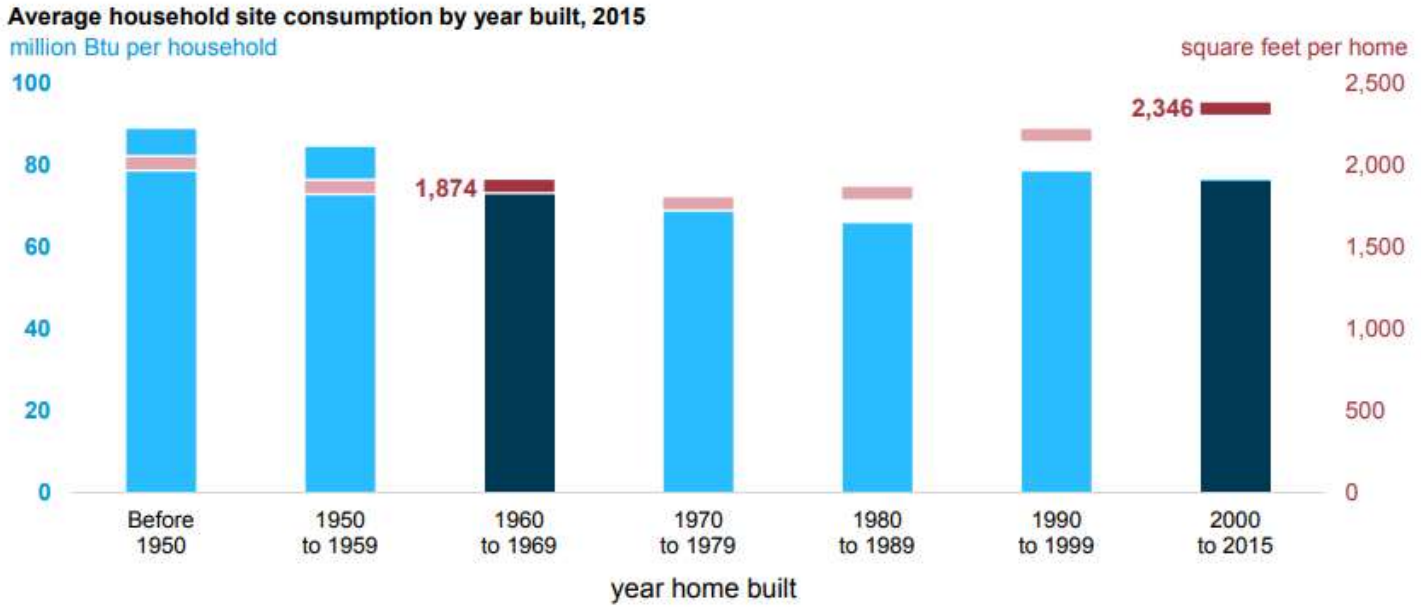
Source: LLNL April, 2018. Data is based on DOE/EIA MER (2017). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2014 to the Energy Information Administration's analysis methodology and reporting. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector, and 49% for the industrial sector which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-415527

ENERGY USE IN OUR HOMES



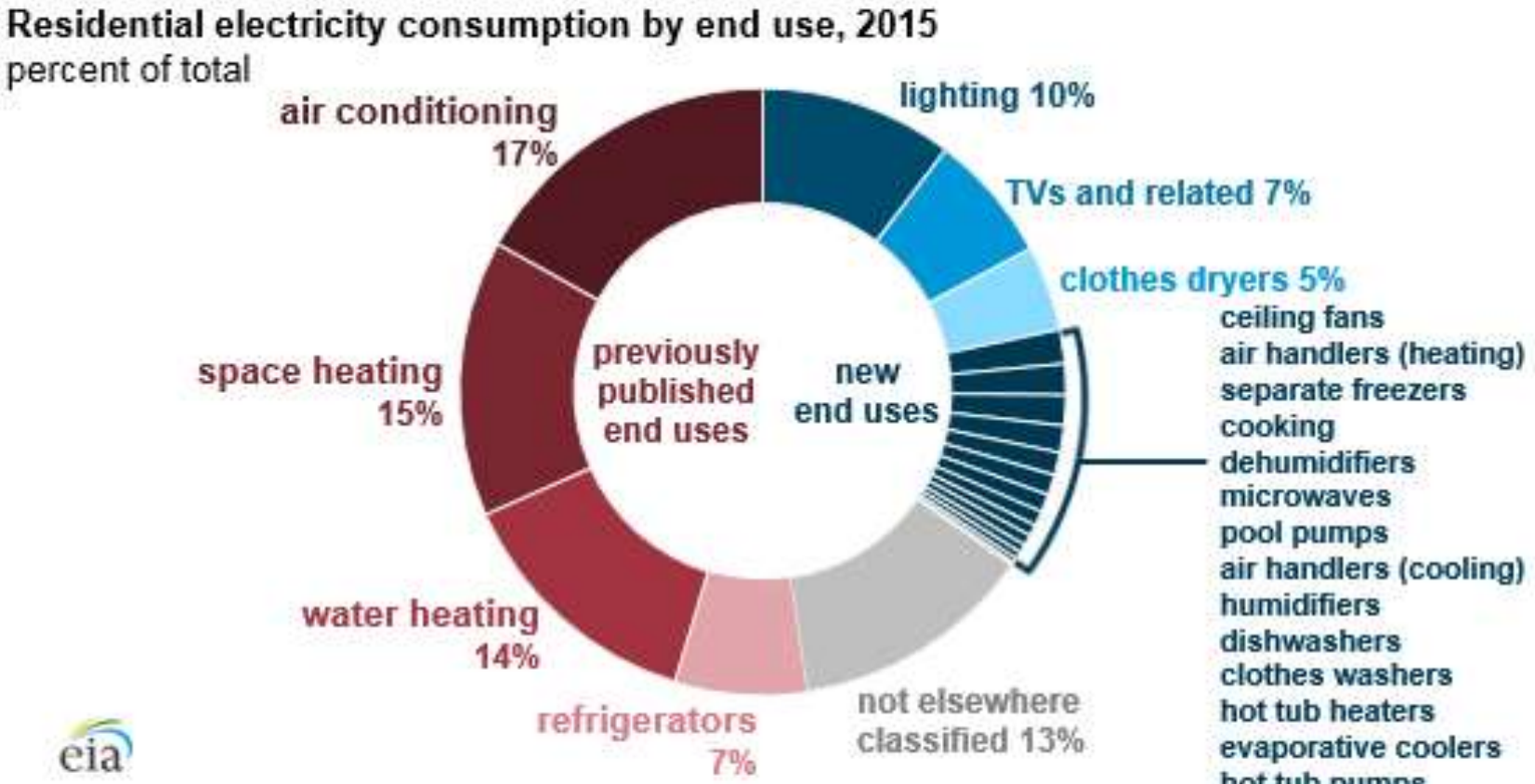
ENERGY USE IN OUR HOMES

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



Source: EIA, 2015 Residential Energy Consumption Survey

ENERGY USE IN OUR HOMES



RESIDENTIAL ENERGY OVERVIEW

Single-Family Consumption & Costs by End-Use*

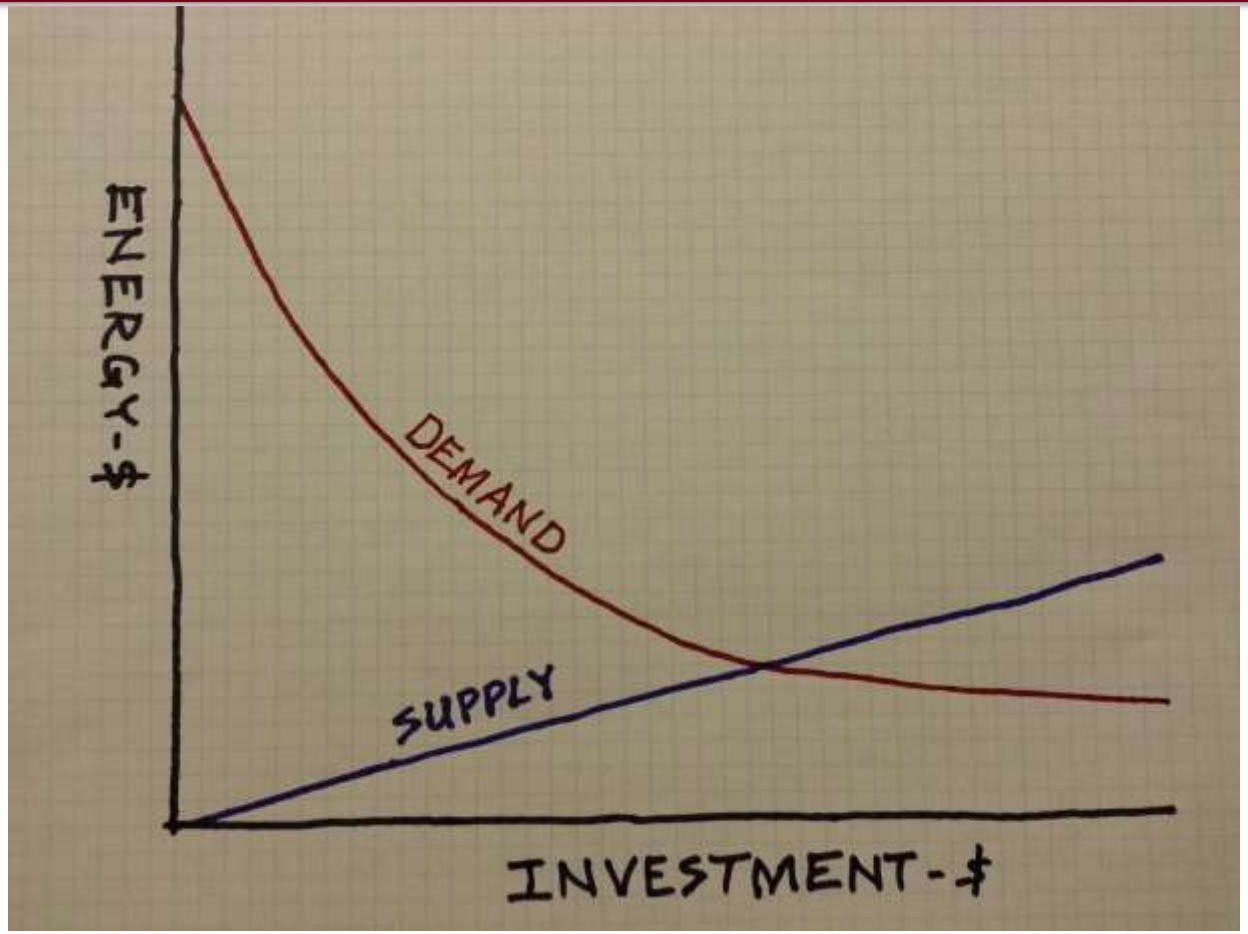
MBtu / $	U.S.	Upper Midwest
- Space Heating	35.3 / $ 543	52.7 / $ 604
- Air Conditioning	7.1 / $ 265	4.0 / $ 148
- Water Heating	14.8 / $ 296	15.9 / $ 246
- Refrigeration	2.6 / $ 103	2.6 / $ 99
- Appliances/Lighting	20.2 / $ 714	19.9 / $ 681
	77.1 / $1856	94.3 / $1760

* (EIA 2015)

FUNDAMENTAL ENERGY STRATEGIES

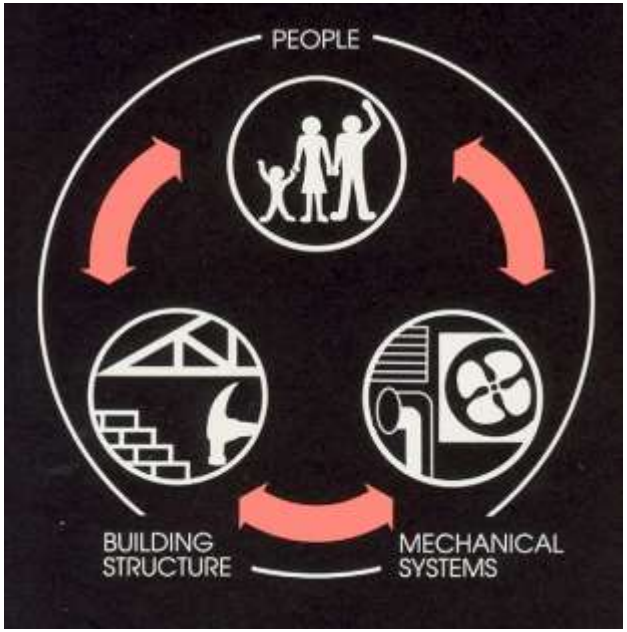
- Conservation
  - Lowest cost; best return
- Efficiency
  - Moderate expense; good return
- Alternatives
  - Most expensive; lowest return

ENERGY SAVED VS. DOLLAR SPENT



ENERGY EFFICIENT HOME FORMULA

- Passive Design
  - Simple shapes, good orientation
- Building Enclosure
  - More insulation
  - Efficient windows & doors
  - Airtight construction
- Mechanical Systems
  - High-efficiency equipment
  - Efficient appliances & lighting
- Proper Operation & Maintenance



BUT THAT IS THE EASY PART

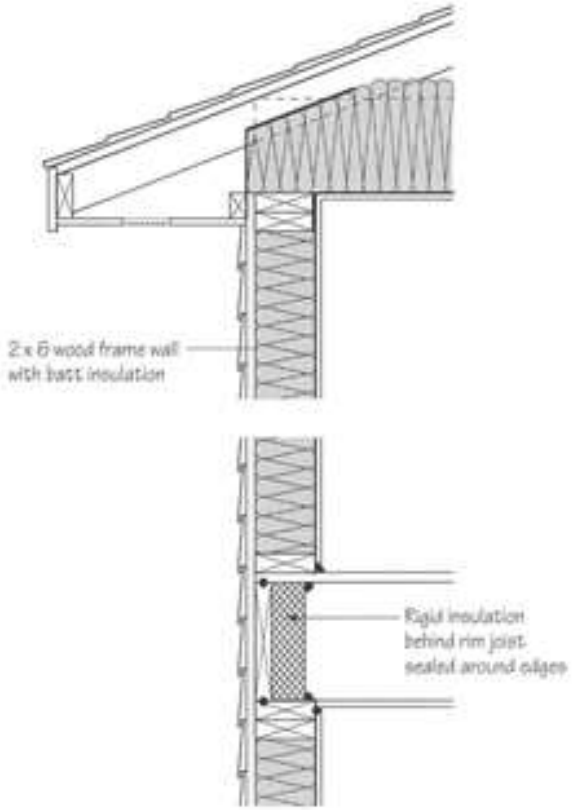
- The tougher part is how to save energy, without causing moisture and indoor air quality concerns?
  - When you remove heat flow you are also removing drying potential.
  - When you air seal (to retard moisture flows) you have less dilution of indoor pollutants.

MODERN ENCLOSURE CONUNDRUM

- It gets wet from outside in and inside out!
  - In general, it will wet outward in winter and inward in summer.
- Things will get wet at some point due to imperfect design, execution, or operation.
- Therefore, all moisture susceptible materials must be able to dry out.
  - that can be outward in winter; inward in summer
  - except below grade, which can only dry inward.

MODERN ENCLOSURE CONUNDRUM

- Has the 2x6 cavity wall hit the end of the road?
  - Too little thermal control
  - Too risky / not robust
    - requires high-end execution
  - Too little drying potential



MODERN ENCLOSURE CONUNDRUM

- Risks Go Way Up With …
  - Poor bulk water control
  - Cladding that is not drained & vented
    - especially for reservoir claddings
  - Significant air-conditioning use
    - increased and longer operation
    - lower indoor temperature and RH

MODERN MECHANICAL CONUNDRUM

- It appears that some designs, systems, materials, and operations are falling short of our performance expectations.

- Specifically, our mechanical systems are lagging way behind the rest of the high-performance house …
  - in both the technology and delivery system.

MODERN MECHANICAL CONUNDRUM

- Has the typical single-zone, forced-air heating and cooling system hit the end of the road?
  - It continues to be difficult to match peak loads.
  - Part-load operation can be both ineffective (uncomfortable) and inefficient (energy).
  - Usually provides poor zone control (temperature, humidity, fresh air) for high-performance homes.

MODERN MECHANICAL CONUNDRUM

- Should ventilation (fresh air for people) be an independent system?
  - It is harder to control when integrated with other systems.
  - Airtight homes have very limited internal mixing.
  - A critical need to provide better distribution to all habitable spaces.

MODERN MECHANICAL CONUNDRUM

- Can we justify two independent, high-end, sealed combustion, condensing plants for space and water heating?
  - We probably need to move towards integrated space and water heating systems.

MODERN MECHANICAL CONUNDRUM

- How are we going to manage pressures (both negative and positive) in our new, airtight homes?
  - Exhaust flow rates for range hoods and clothes dryers are simply too large.
  - Active pressure management is needed now.
  - But current make-up air is clumsy at best!

A BUILDING SCIENCE, SYSTEMS-GUIDED APPROACH TO HIGH-PERFORMANCE HOME

- What if you could build a home with…
  - incredibly low energy bills,
  - superior thermal and acoustical comfort,
  - built-in long-term durability,
  - good healthy indoor air?
- And you can have it all within a reasonable budget!

Lots of Recognition Choices…

PART 2. 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 our market/climate.
- Net Zero Today (by Joe Lstiburek)
  - provides a vision for the future.

PATH 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	NS
Foundation	15(10)	15	15	15	20
Slabs					
- Basement	0	0	0	10	10
- On-grade	10	10	10	15	20

PATH TO ZERO: METRICS

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

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	NS
Cooling (SEER)	13	13	13	15	18
Ventilation					
- Type	Balanced	NR*	Balanced	Balanced	Balanced
- HRV/ERV (Eff)	NR	NR	60%	70%	NS
- Distribute	All Rooms	NR*	NR*	All Rooms	All Rooms
Filtration(MERV)	8	8	8	11	NS

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	NA	NA	Vented	Vent/MUA	Vent/MUA
Dryer	???	Vented	Vented	Vent/MUA	Vent/MUA
Exhaust Fan	Allowed	Allowed	Allowed	Small/MUA	NS

PATH TO ZERO: METRICS

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

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	NS
Garage Vent	NA	NA	Yes*	Yes*	NS
Radon	Rn Ready	Rn Ready	Rn Ready	ASD	NS

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

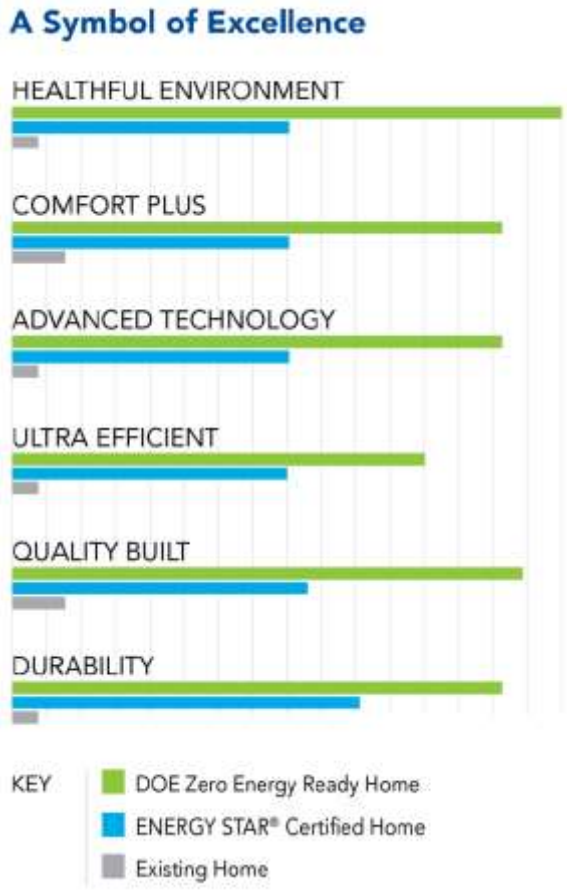
PATH TO ZERO: COST SUMMARY*

	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 3: ZERO ENERGY READY HOME

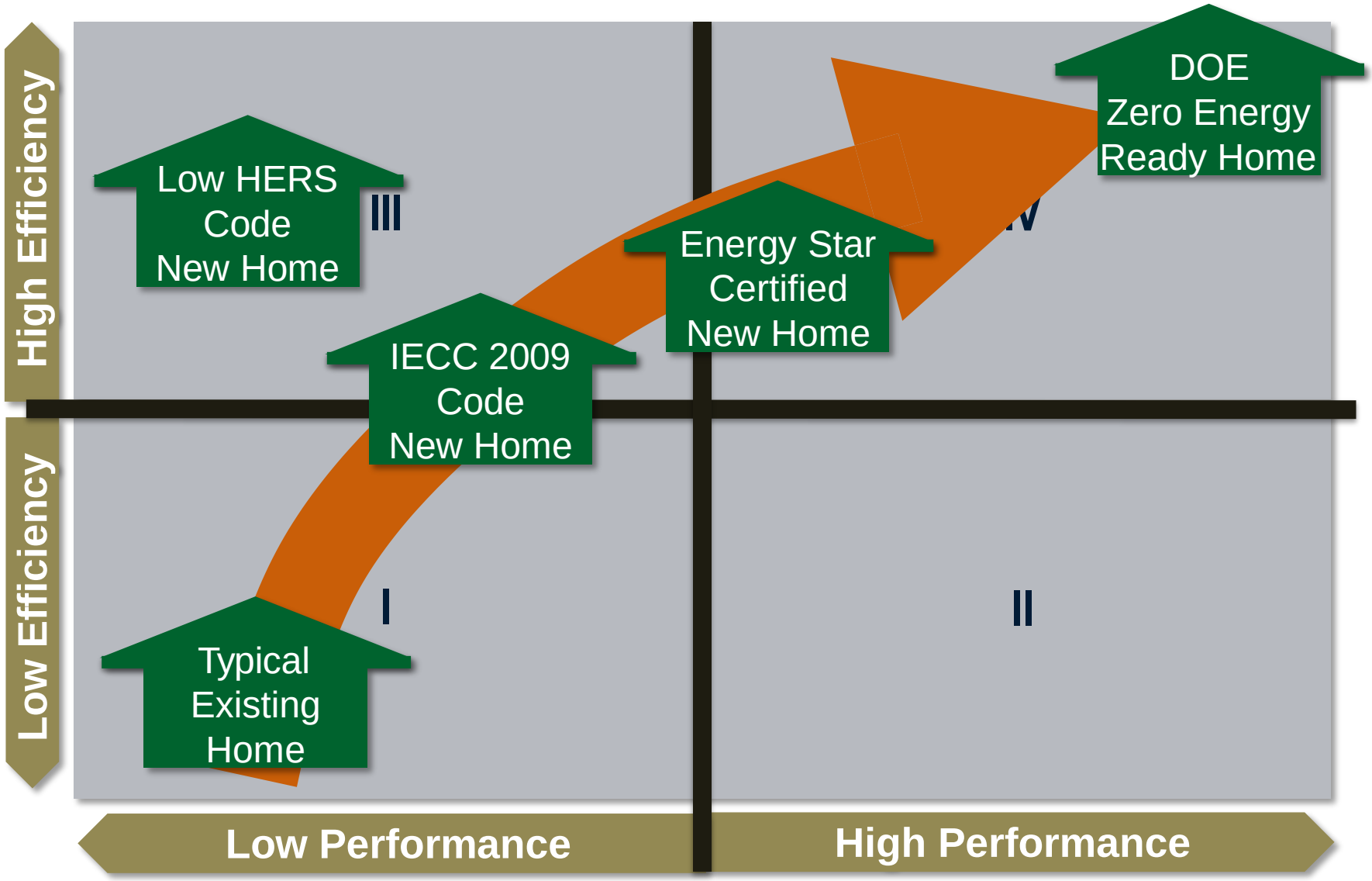
ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY



DOE ZERO ENERGY READY HOME

- In my view, this program is …
  - Built on a technically solid 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.

DOE Zero Energy Ready Home Path



Zero Energy Ready Home
Why Build:

The Business Case

What's In It For You?

By constructing DOE Zero Energy Ready Homes, you will be:

- in a select group of builders

  Only the top one percent of builders in the country meet the extraordinary energy efficiency, comfort, health, safety, durability, and quality levels associated with the DOE Zero Energy Ready Home.

- providing unprecedented value

  Your customers will receive immediate energy savings of 40-50% and a home that can be easily adapted to net-zero performance with a small renewable energy system.

- differentiated from the competition

  About 12 in 13 homes sales nationwide are 'used' homes. In addition, the majority of new homes are constructed to minimum code. Based on a foundation of comprehensive home performance, including ENERGY STAR Qualified Home v.3 and the latest proven innovations from DOE Building America, this program provides a path to constructing zero net-energy ready homes that none of your competition has.

Why Build: The Business Case

Risk Management

Zero Differentiation

Exceed Expectations

Zero Energy Ready Home Spec

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

Risk Management | **Zero** Differentiation | **Exceed** Expectations

Optimized Enclosure

Risk Management:

Optimized Comfort System

Complete Water Protection

Comprehensive IAQ System

Zero Differentiation:

Efficient Components

Solar Ready Construction

Zero Energy Ready Home Defined

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

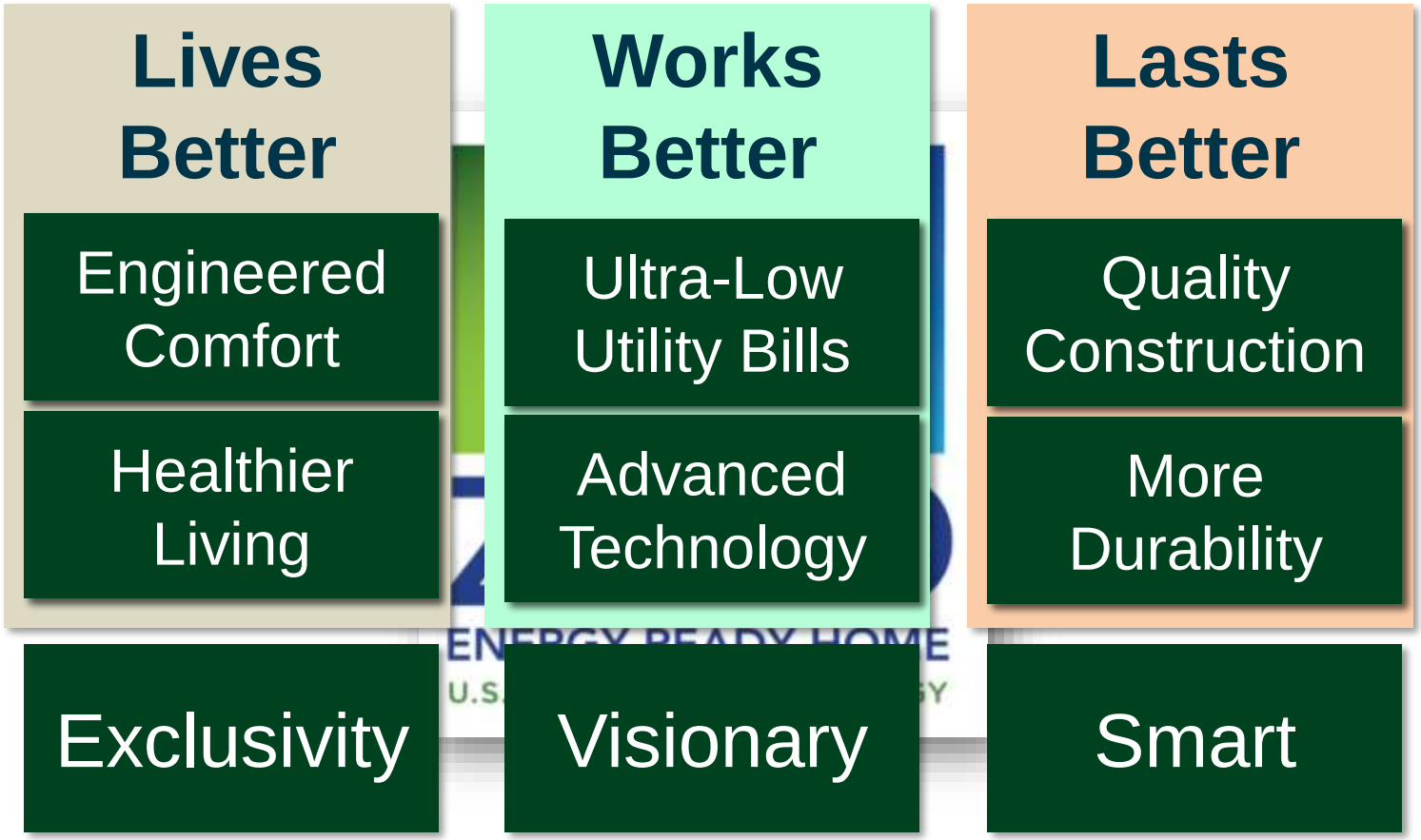
Risk Management | **Zero** Differentiation | **Exceed** Expectations

High-performance home, so energy efficient, all or most annual energy consumption can be offset by renewable energy.

Why Build: The Value

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

Risk Management | **Zero** Differentiation | **Exceed** Expectations



Zero Energy Ready Home Systems

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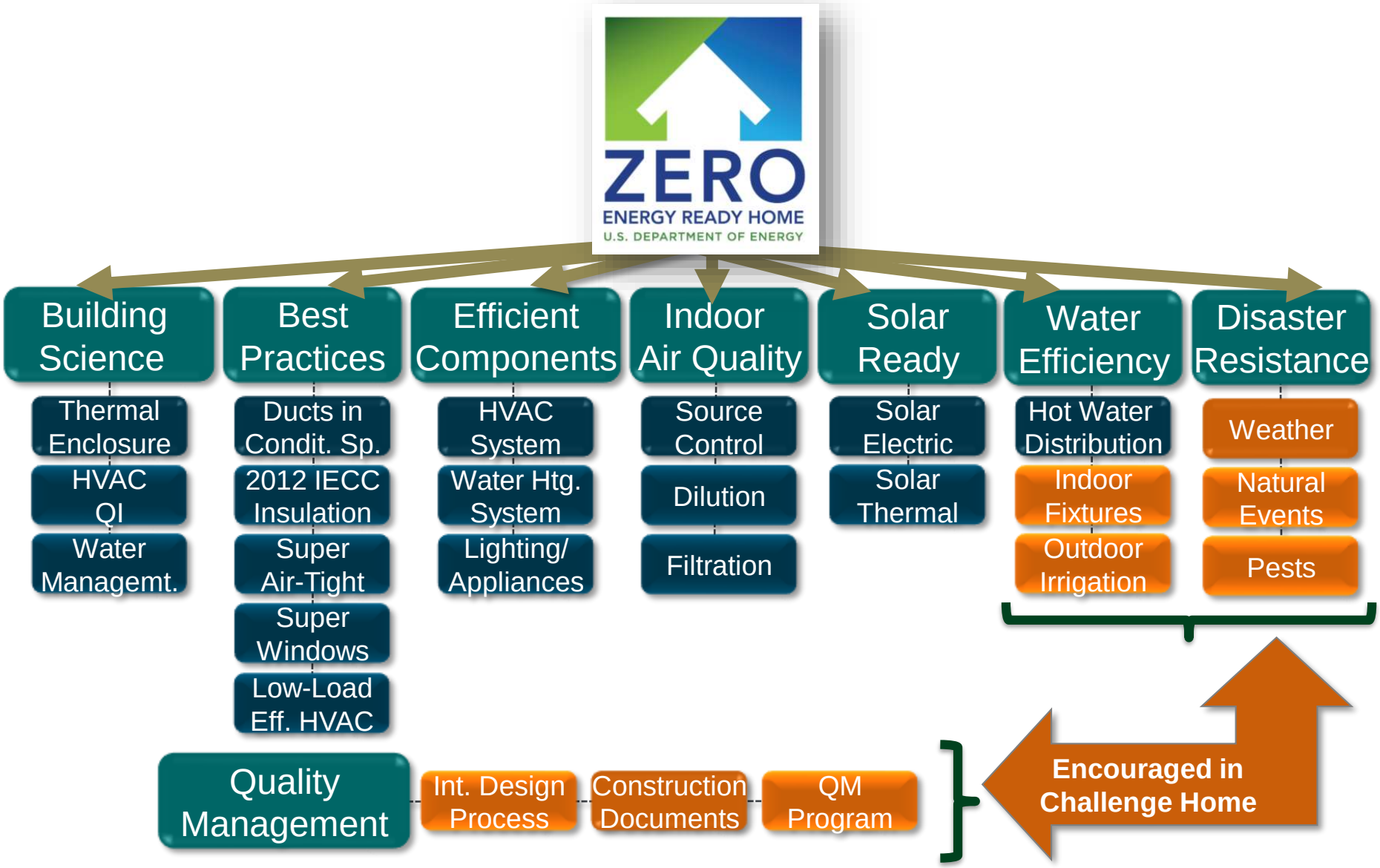


For More Information

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

for more Information:

www.buildings.energy.gov/zero/

e-mail contact:

zero@newportpartnersllc.com

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 their 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 start by paying attention to the trade off between the cost of energy reduction and the cost of solar generation.

NET ZERO ENERGY TODAY

- Next be prepared – the whole building solution might look a bit different than you imagined.
  - There are a few other things that need your attention to as you move to Net Zero Energy.
  - From “BSI-081 Zeroing In” by Joseph Lstiburek

ZEROING IN*

- Don’t get carried away with passive solar!
  - The heat gain in the winter is not needed.
  - The heat gain in the summer will hurt you.
  - But people want windows -- so pay attention and use good judgement on the window orientation, placement, and type.
- Ultra-efficiency crushes super-insulated.
- Collect the solar energy with PV.

ZEROING IN*

- 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 …
    - don’t even think about it!

ZEROING IN*

- Ventilation system must be top-drawer!
  - Balance with heat/energy recovery is required.
  - Run the bathroom exhaust(s) through the HRV/ERV 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*

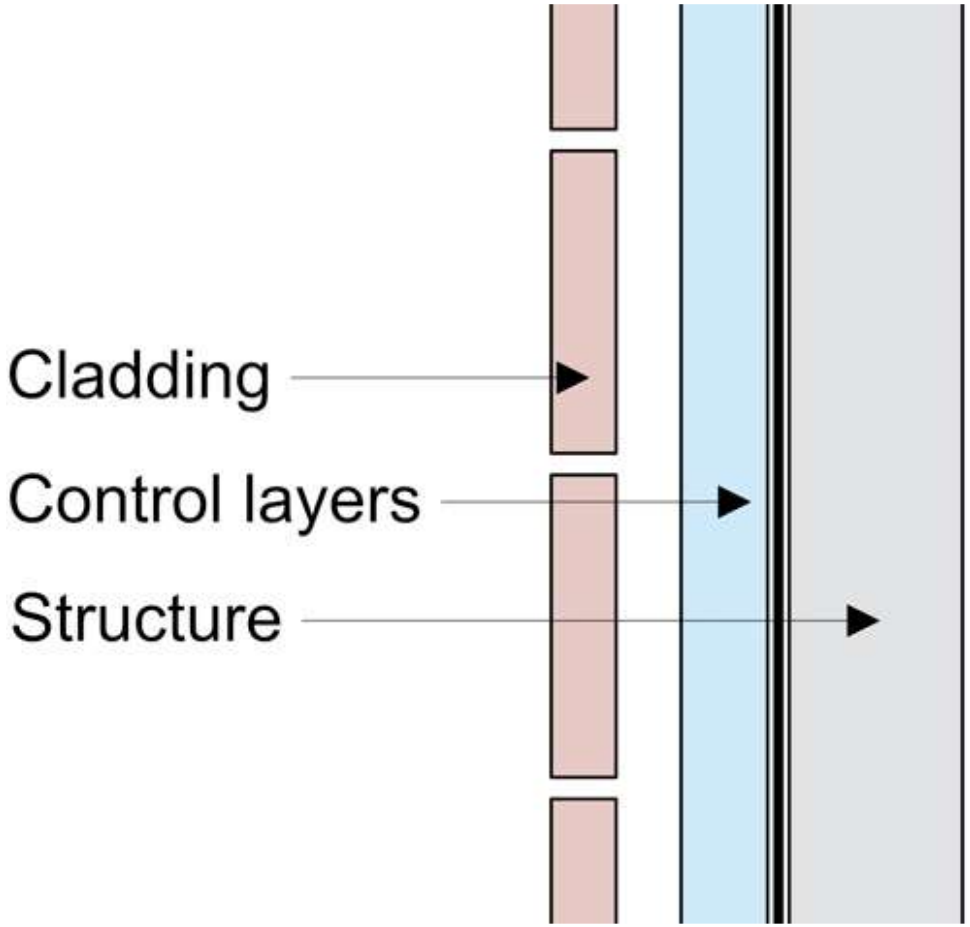
- Perhaps the greatest challenge will be latent load management!
  - In the swing seasons and under part-load conditions moisture can float out of control.
- Do you think you can do this with your space conditioning or ventilation system?
  - It is tougher than it sounds.
  - Dehumidification may need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

CHALLENGE 1: FORGIVING ENCLOSURE

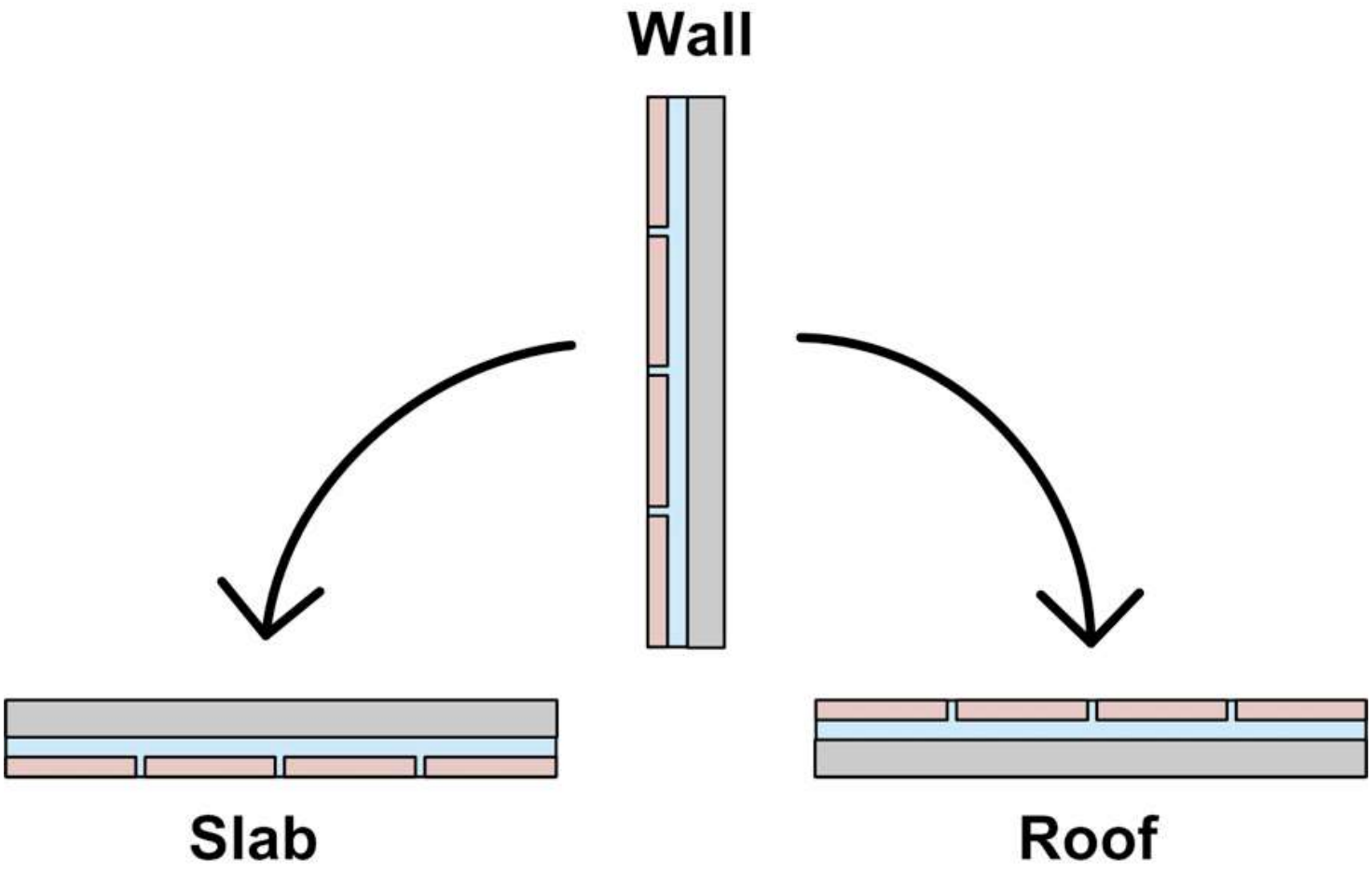
- The “Perfect” Approach
  - Walls
  - Roof
  - Slab
  - Foundation

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

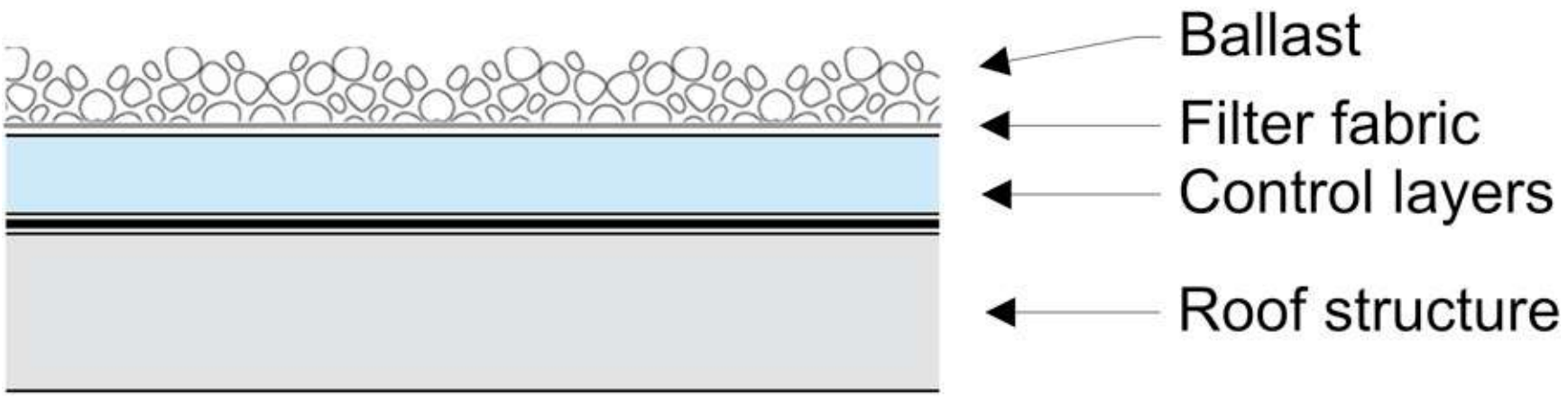
THE PERFECT WALL



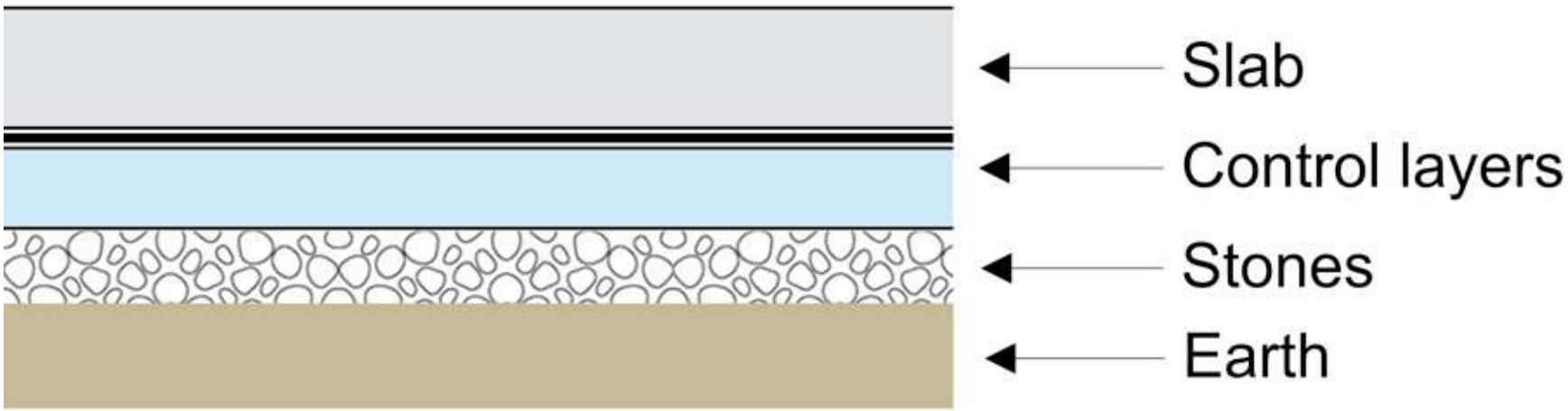
WORKS FOR ROOF & SLAB, TOO!



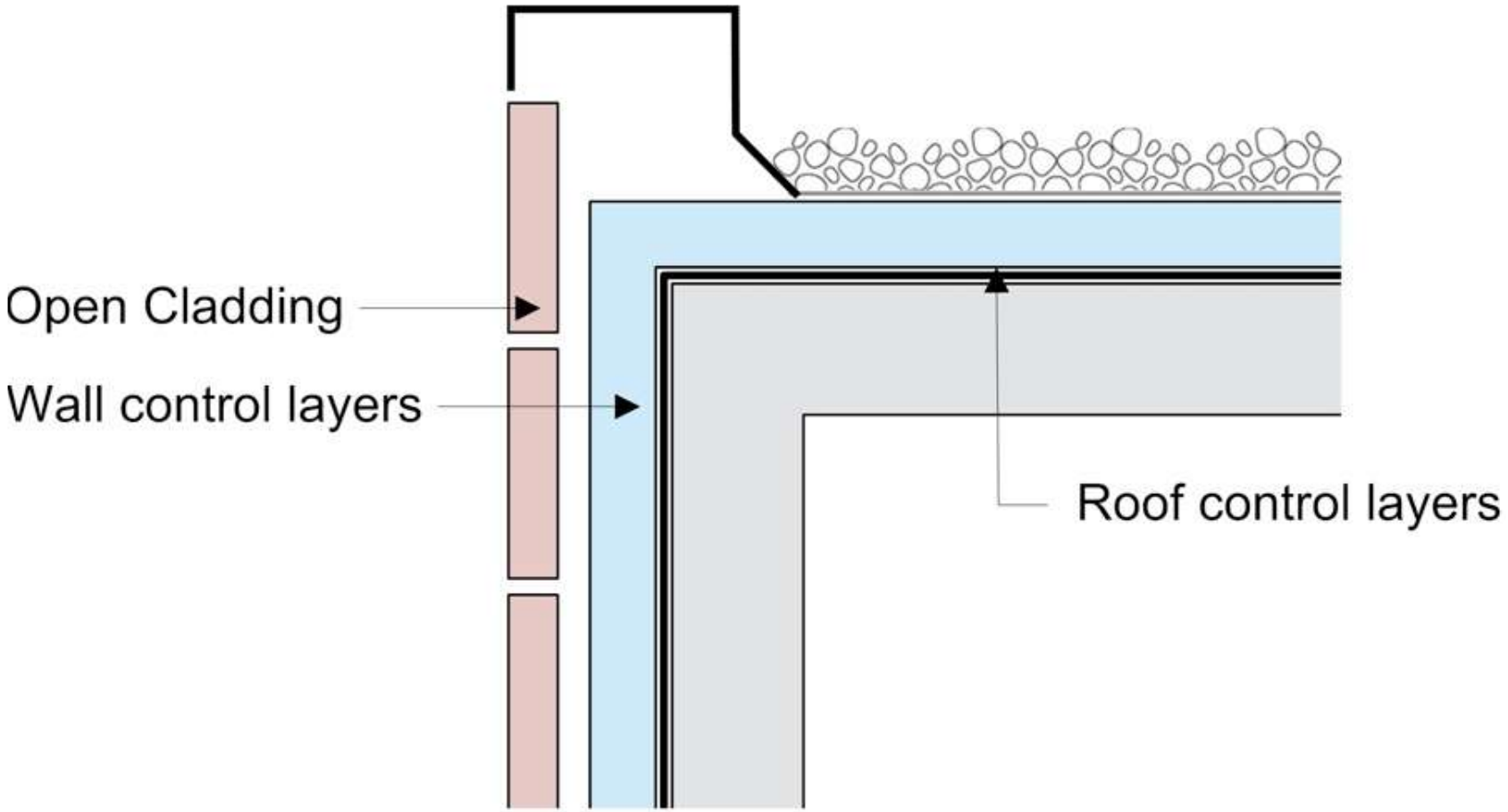
THE PERFECT ROOF



THE PERFECT SLAB



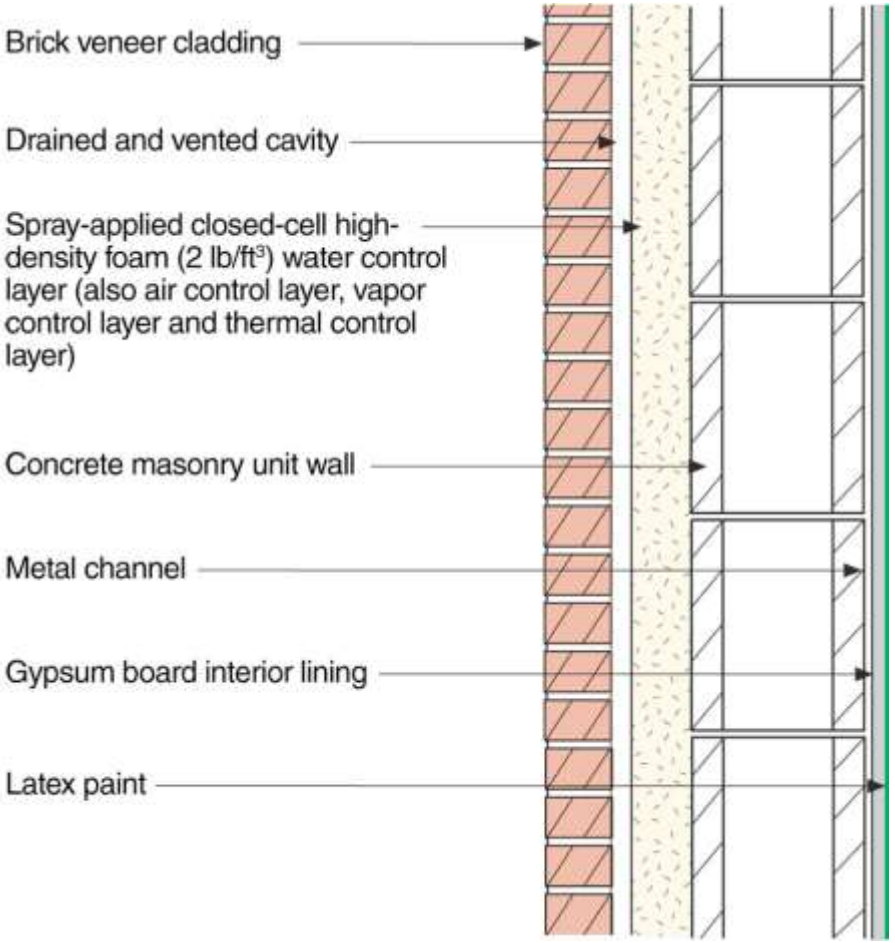
PERFECT CONNECTIONS



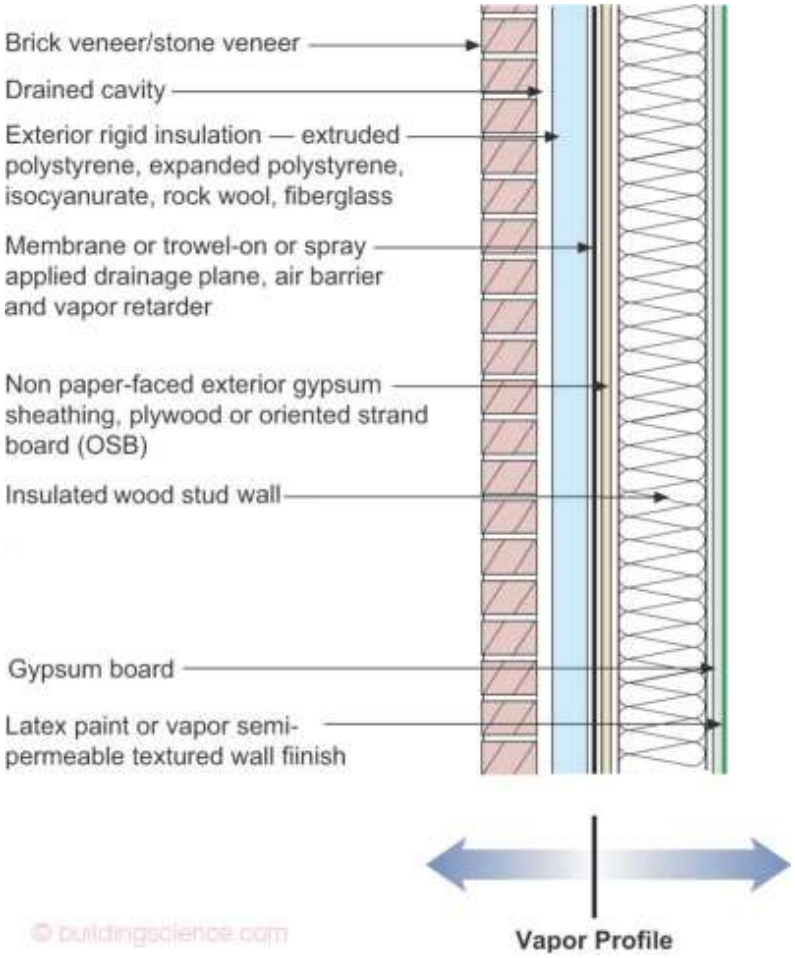
PUTTING THE LAYERS TOGETHER

- 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!

4 IN 1 CONTROL LAYER

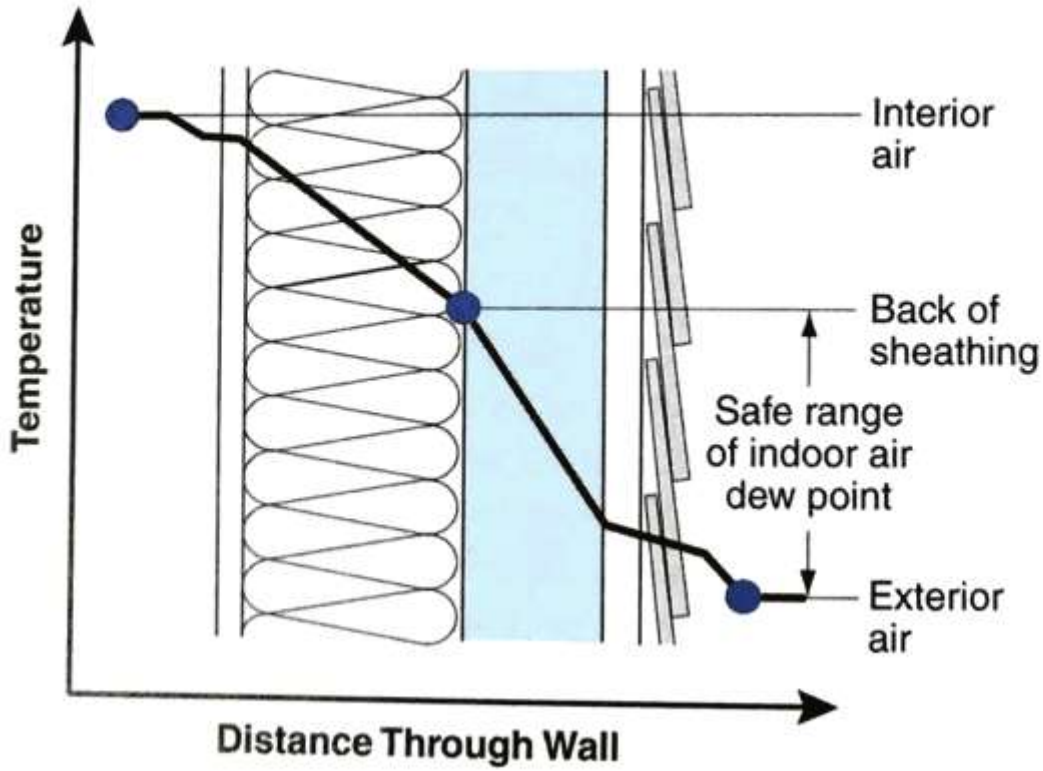


THE PERFECT RESIDENTIAL WALL



HOW MUCH EXTERIOR INSULATION?

$$T_{back\ of\ sheathing} = T_{interior} - (T_{interior} - T_{exterior}) \frac{R_{batt}}{R_{total}}$$

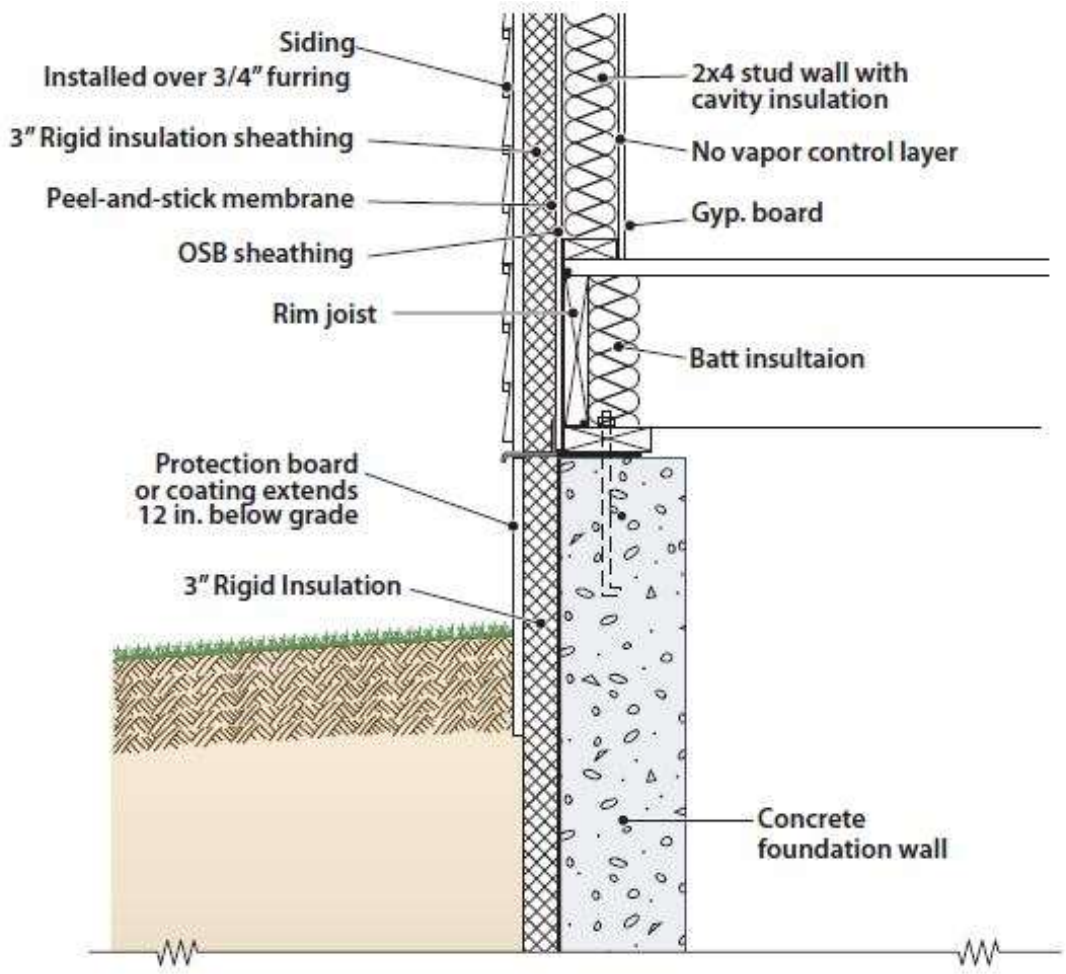


RATIO OF EXTERIOR TO INTERIOR

Indoor		RH	20	25	30	35	40	50	60
Dew point		°C	-3.0	0.0	2.5	4.7	6.6	9.9	12.7
		°F	26.6	32.0	36.6	40.5	44.0	49.9	54.8
$T_{outdoor}$	°C	°F							
	0	32	0.00	0.00	0.12	0.23	0.32	0.47	0.60
	-5	23	0.08	0.19	0.29	0.37	0.45	0.57	0.68
	-10	14	0.23	0.32	0.40	0.48	0.54	0.64	0.73
	-15	5	0.33	0.42	0.49	0.55	0.60	0.69	0.77
	-20	-4	0.41	0.49	0.55	0.60	0.65	0.73	0.80
	-25	-13	0.48	0.54	0.60	0.65	0.69	0.76	0.82
	-30	-22	0.53	0.59	0.64	0.68	0.72	0.78	0.84
	-35	-31	0.57	0.63	0.67	0.71	0.74	0.80	0.85
	-40	-40	0.61	0.66	0.70	0.73	0.76	0.82	0.86

- High Performance Enclosures: John Straube, 2012

CONTROL LAYERS – HYBRID WALL



CONTROL LAYERS – ENHANCED ROOF

- Traditional Vented Attic
  - Ceiling drywall direct to 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”

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

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

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

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 layer

CHALLENGE 2: GREAT VENTILATION

- Good is not good enough!
- You have an incredibly tight enclosure
- Summer air will create special challenges

VENTILATION SUMMARY

- Must be balanced heat recovery ventilation
  - Using source point exhaust
  - In most cases an ERV
  - Filtration (MERV 10+) 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.

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

CHALLENGE 3: WHAT ARE WE CHASING?

- Heating isn't the problem any longer!
- Overheating (and cooling) have taken over!
  - Internal & solar gains must be 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 colling demand will be longer
  - And diversity between spaces will be higher

WHAT TO DO IN THE MIDDLE?

- Highly-insulative, airtight enclosures with 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
  - And your ERV/HRV is 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 DEHUMIDIFCATION

- It takes 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.
  - variable capacity AC can help, too!
- But for best summer humidity control, consider a whole house dehumidifier.

SPACE DEHUMIDIFCATION

- Whole House Dehumidification
  - Since ventilation does not equal humidity control, it is critical to provide systematic dehumidification.
  - Independent control for indoor humidity for 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	+	+

PRESSURE MANAGEMENT

- Pressure Triangle (Hole, Flow, Pressure)
  - If we know the house tightness flow,
  - It is easy to predict the resultant pressure.
  - For example: 2200 SF House at 2 ACH@50Pa
    - 150 cfm of exhaust will cause a -6 Pa
    - 300 cfm of exhaust will causes -18 Pa

HOUSE TIGHTNESS, FLOWS & PRESSURES

				House Tightness - Blower Door CFM @ 50Pa (& Hole Size with 0.65 exponent)								
Flow (cfm)	100	200	300	400	500	600	800	1000	1250	1500	2000	3000
Hole (sq. in.)	7	15	22	29	37	44	59	73	92	110	147	220
ACH (20,000 cf)	0.3	0.6	0.9	1.2	1.5	1.8	2.4	3.0	3.8	4.5	6.0	9.0
Δ Pressure (Pa)					Unbalanced Flow in CFM							
100	157	314	471	628	785	942	1255	1569	1961	2354	3138	4708
75	130	260	390	521	651	781	1041	1302	1627	1952	2603	3905
50	100	200	300	400	500	600	800	1000	1250	1500	2000	3000
40	86	173	259	346	432	519	692	865	1081	1297	1730	2595
30	72	143	215	287	359	430	574	717	897	1076	1435	2152
25	64	127	191	255	319	382	510	637	797	956	1275	1912
20	55	110	165	220	276	331	441	551	689	827	1102	1654
15	46	91	137	183	229	274	366	457	572	686	914	1372
12	40	79	119	158	198	237	316	395	494	593	791	1186
10	35	70	105	141	176	211	281	351	439	527	703	1054
9	33	66	98	131	164	197	262	328	410	492	656	984
8	30	61	91	122	152	182	243	304	380	456	608	912
7	28	56	84	111	139	167	223	279	348	418	557	836
6	25	50	76	101	126	151	202	252	315	378	504	756
5	22	45	67	90	112	134	179	224	280	336	448	672
4	19	39	58	77	97	116	155	194	242	290	387	581
3	16	32	48	64	80	96	128	161	201	241	321	482
2	12	25	37	49	62	74	99	123	154	185	247	370
1	8	16	24	31	39	47	63	79	98	118	157	236

By Patrick Huelman, University of Minnesota **March 5 ,2018**

Clothes dryer @ 130 cfm

Small range hood @ 250 cfm

Large range hood @ 500 cfm

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 with a heating element.

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,
  - ???

MECHANICAL SYSTEM INTEGRATION

- Space Heating
- Space Cooling
- Space Filtration
- Dehumidification
- Ventilation w/ Distribution/Circulation
- Water Heating
- Make-Up Air

FINAL NOTES & CAUTIONS

- Net Zero Energy Homes will require new enclosure strategies and systems:
  - Higher insulation levels
  - Improved 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
  - Increased attention to indoor air quality
    - source control
    - filtration
    - ventilation & distribution
  - Improved make-up air solutions
  - New focus on summer humidity management

RESOURCES

- Your New Partners
  - Home Energy Raters
  - Home Performance Consultants
  - Utility Providers & Programs

- Other Resources
  - ENERGY STAR
  - Building America

KEY 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

BA Top Innovations "Hall of Fame"

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

ADVANCED TECHNOLOGIES

- Building Science Solutions
- Energy Efficient Components
- Assured Health and Safety

HOUSE-AS-A-SYSTEM BUSINESS CASE

- New Homes with Whole-House Packages
- Existing Homes with Whole-House Packages
- Whole-House Program Support

EFFECTIVE GUIDANCE AND TOOLS

- High Performance Home Solutions
- High Performance Home Metrics
- Research Tools

INFRASTRUCTURE DEVELOPMENT

- Educating Professionals
- Recognizing Value in Transaction Process
- Informing Codes and Standards

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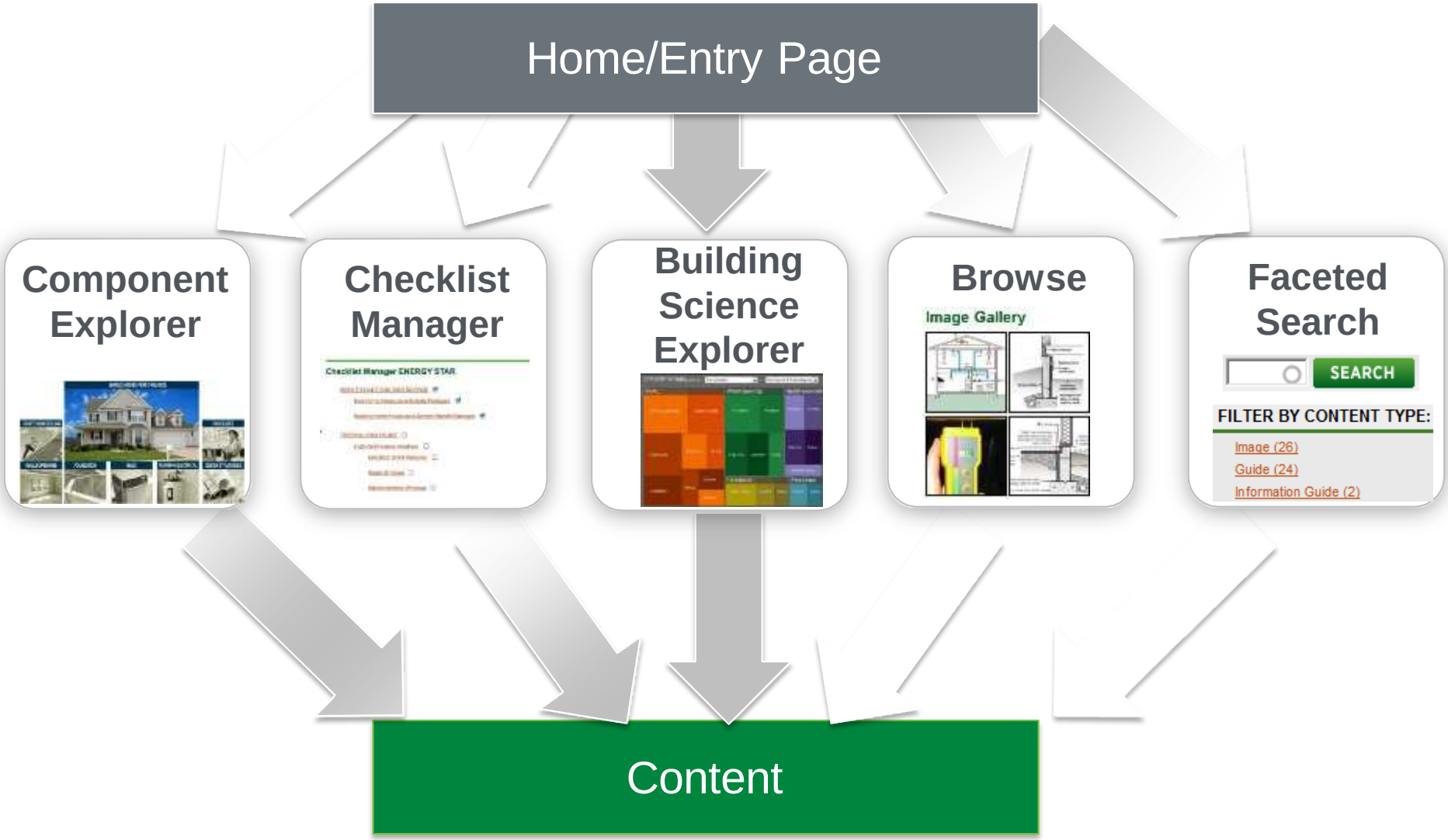
Multiple Interfaces



Quick Tour: Component Explorer

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Walls/Openings Water
Managed Walls
Minimum Thermal Bridging
Insulation
Air Sealing
Fully Aligned Air Barriers

Fully Aligned Air Barriers
Behind Showers and Tubs
Behind Fireplaces
Attic Knee Walls
Skylight Shaft
Walls Adjoining Porch
Double Walls
Garage Rim/Band Joist

Quick Tour: Guides

Solution Center Home
Component Explorer
Checklist Manager
Building Science Explorer
Browser
Guides
CAD Files
Case Studies
Image Gallery
References

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

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

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

KEY RESOURCES

- BSI-039: The Five Things
  - 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
- BSI-081: Zeroing In
  - Joseph Lstiburek
- EEBA Ventilation Guide
  - Armin Rudd, 2011

- Discussion & Questions

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