



Forest Refuge Home

Team Woodridge



April 22-23, 2017
Golden, Colorado
Race-To-Zero Final Presentations

Academic Institution

Team Woodridge
Ball State University



Walter Grondzik, PE

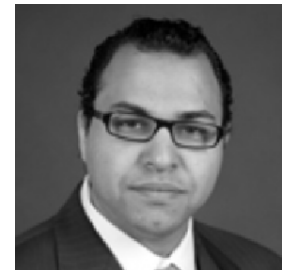


BALL STATE
UNIVERSITY[®]

Tom Collins, PhD, AIA, LEED AP



Tarek Mahfouz, PhD



Academic Team

Team Woodridge
Ball State University



Design Team



Consulting Team

ARCH 632
High-Performance Buildings



ARCH 633
Advanced Tech. for Green Buildings



Construction Management Students



Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

Finances

LEED

Innovation

Industry Partners

Team Woodridge
Ball State University



Primary Partner



Supporting Partners



Architecture

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Constructability

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Finances

LEED

Innovation

Design Goals



Positively Influence a Home Slated for Construction



Focus on Methods to Be Performed “In-House” by Industry Partner



High-Performance Home to Appeal to Target Market



Create Regional Connections Between Home Builders



Build Excitement in Bloomington for Zero Energy Ready Homes

Design Constraints



Industry Connections

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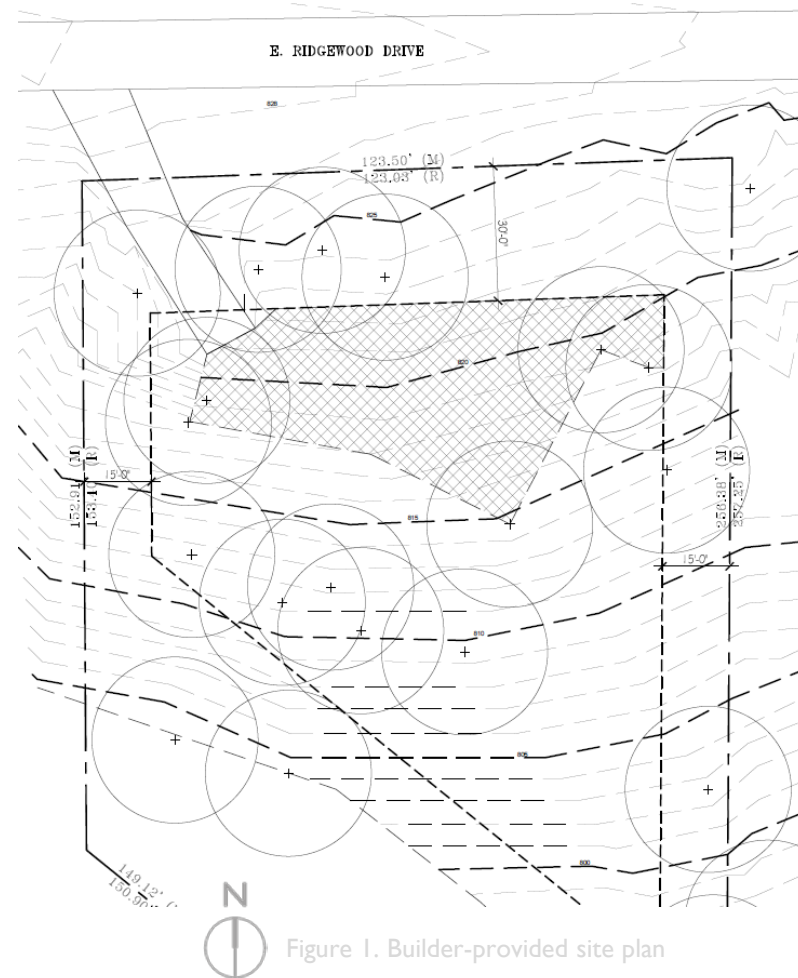


Figure 1. Builder-provided site plan

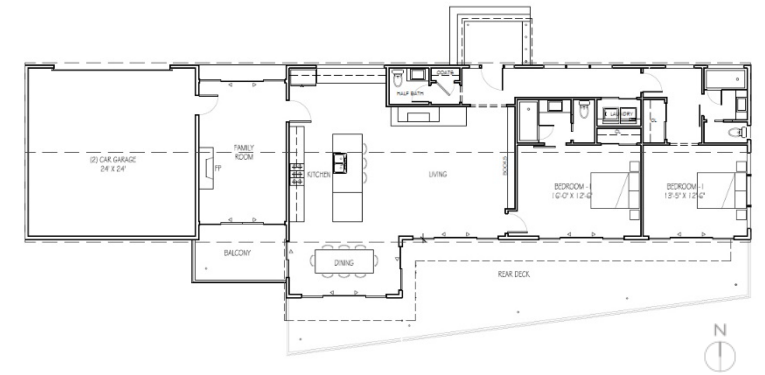


Figure 2. Builder-provided schematic plans

Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

Finances

LEED

Innovation

Site Inventory

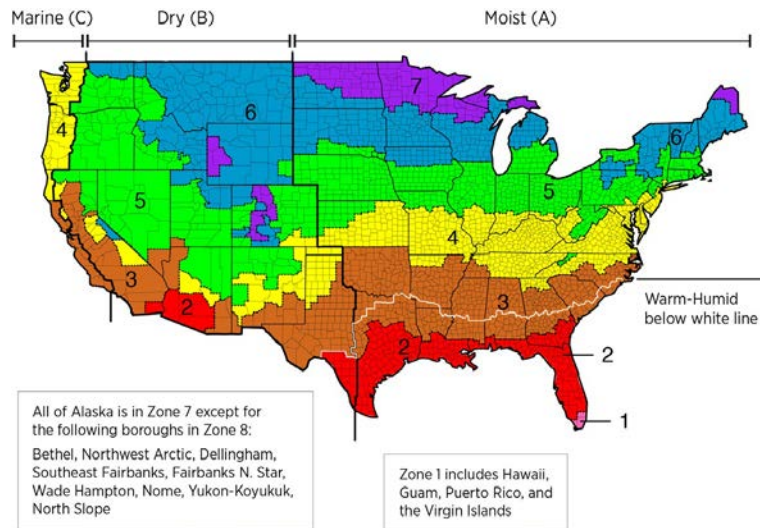


Figure 3. US Climate Zone Map

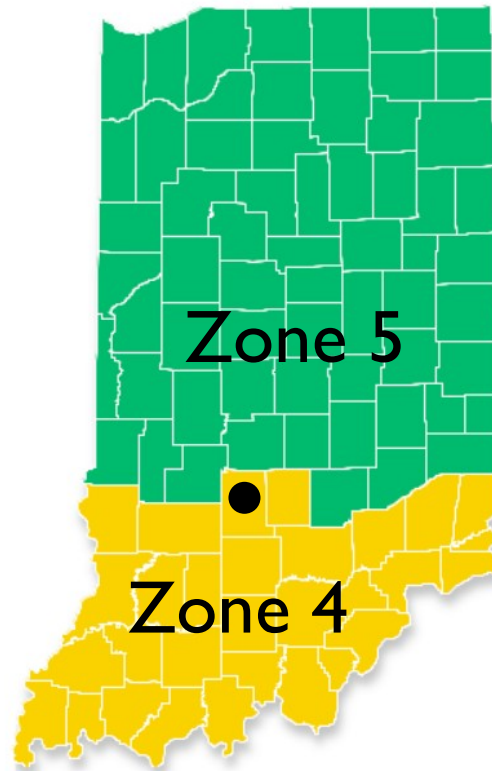


Figure 4. Indiana Climate Zone Map

Climate Implications:

- Need for Solar Shading
- 6 Mild Months
- Strong Temperature Swings
- Solar is Viable

Site

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Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

Finances

LEED

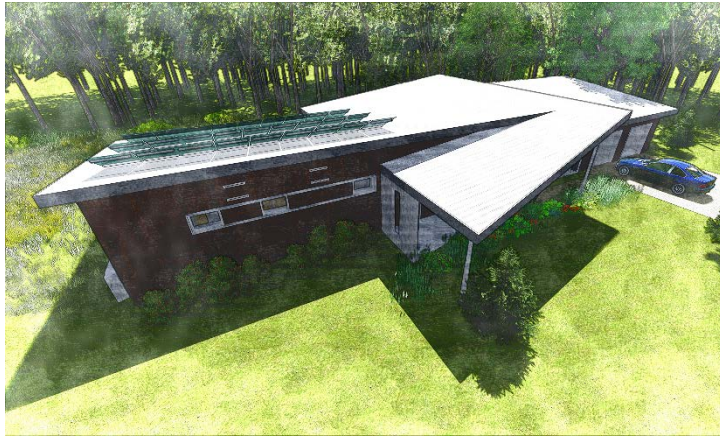
Innovation



Concept: A Forest Refuge

*refuge - a place that provides shelter, protection (Merriam-Webster)
a place to hide, have privacy (thesaurus.com)*

Architectural Design



Shelter from
the Road



Visual Connection
to the Outdoors

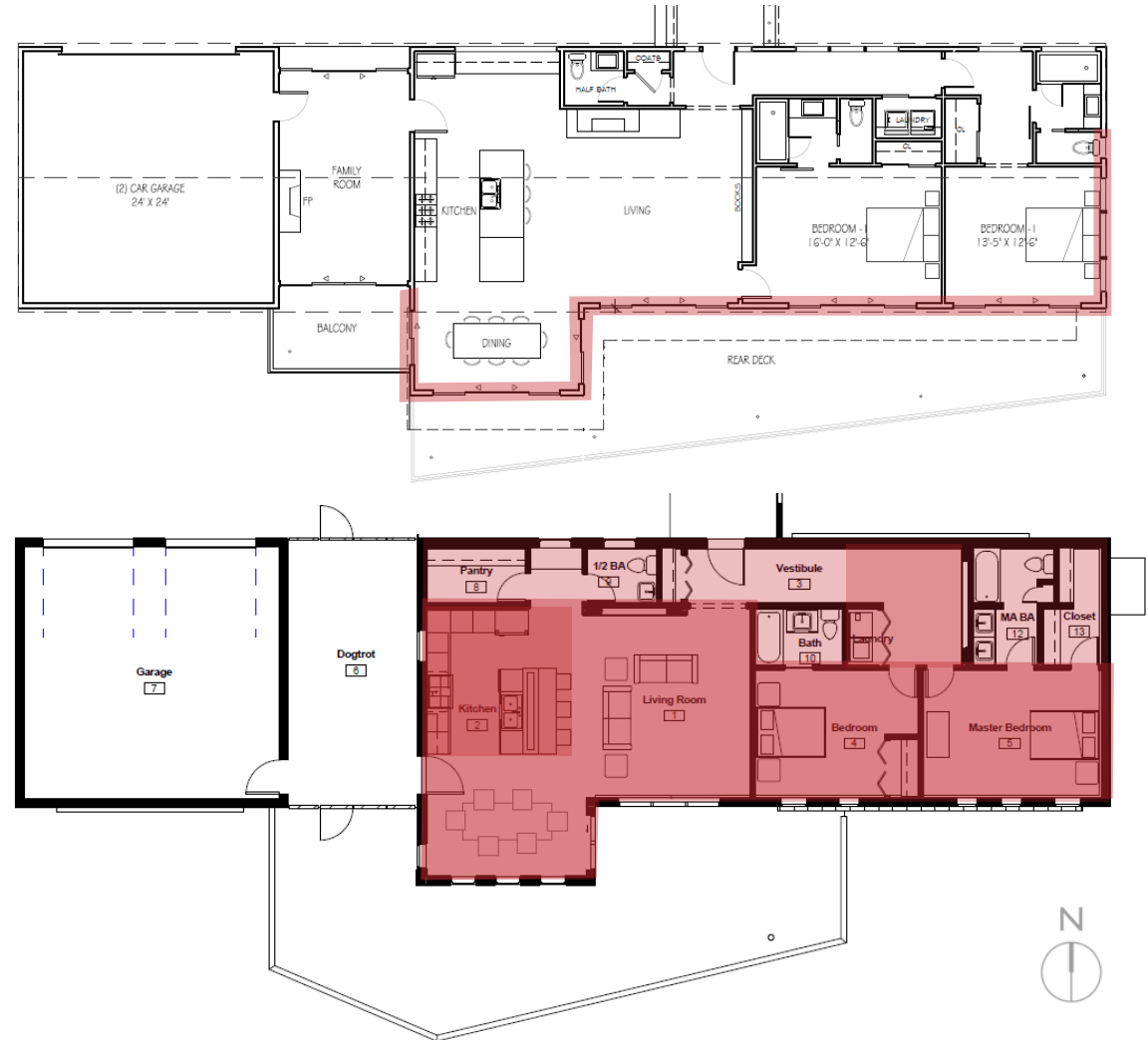


Physical Connection
to the Outdoors

Architectural Design



Reduce to 1600 SF Plan
Reevaluate Glazing Situation
Livable Space to South Side
Functional Space



Architectural Design

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Street Privacy

Sheltered Entry

Screened Dogtrot

Solar Shading

Outdoor Living

Solar Production

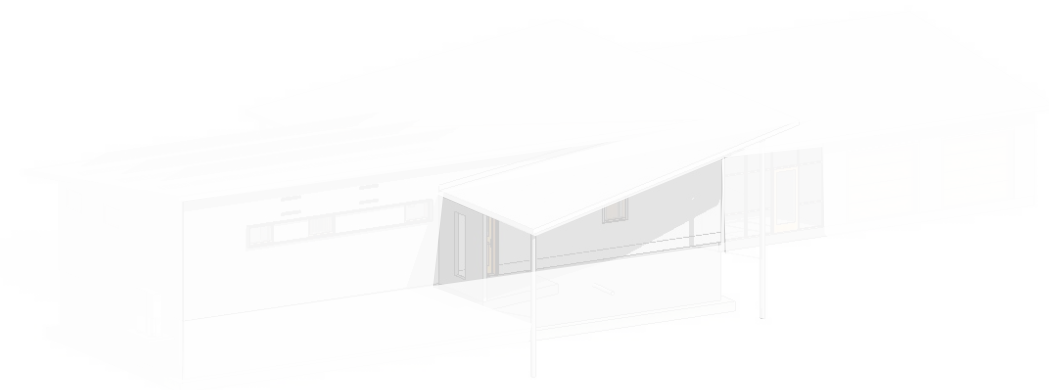


Figure 5. Front of home axonometric



Figure 6. Rear of home axonometric



Reclaimed Exterior Materials





Plan Presented by LWB

Team Woodridge Transformations

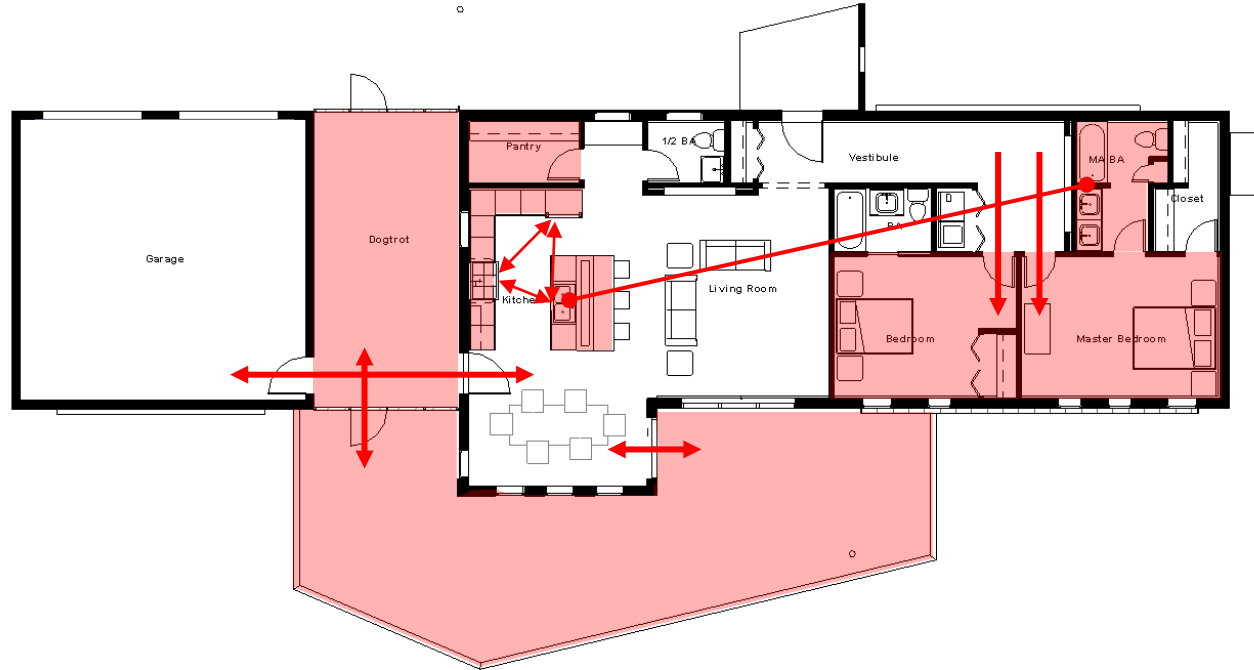
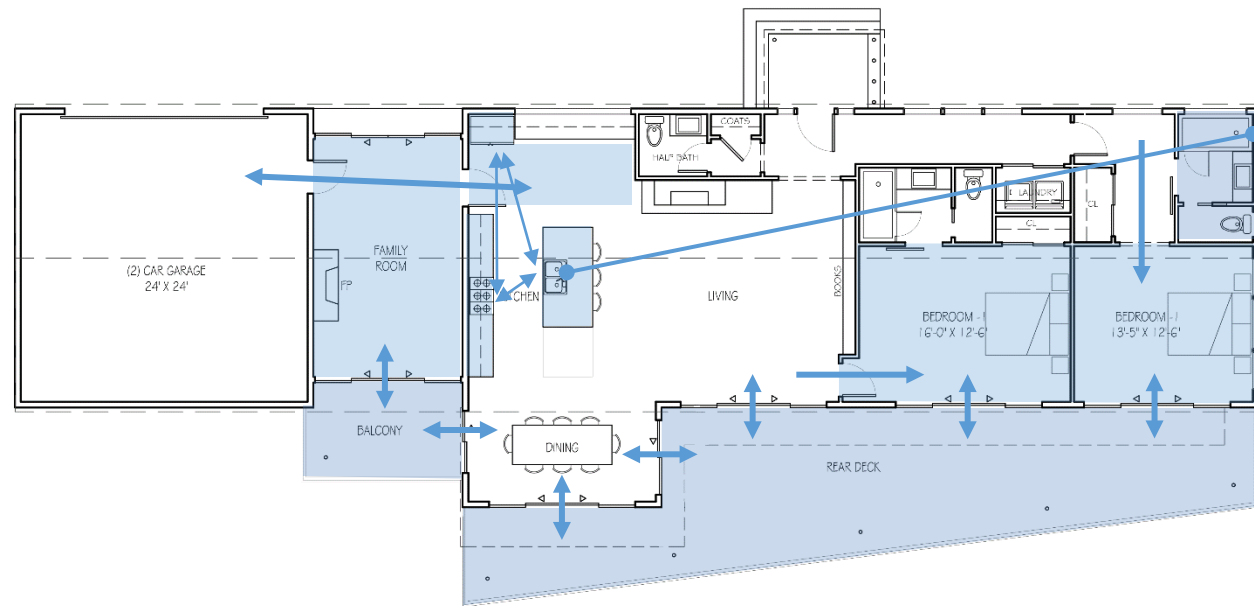
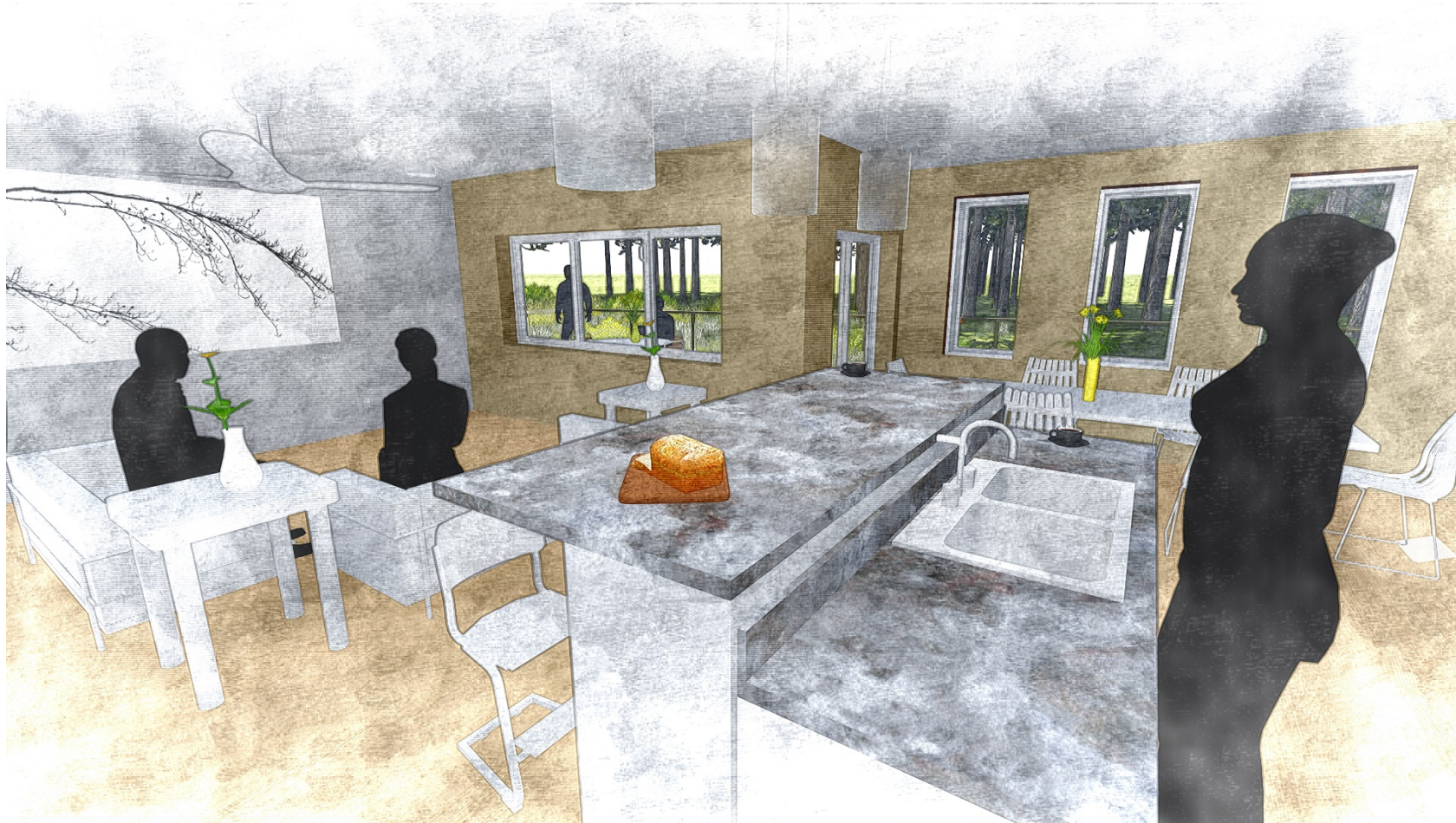


Figure 7. LWB Original Schematic First Floor Plan

Figure 8. Team Woodridge New First Floor Plan

Interiors

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Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

Finances

LEED

Innovation

Lighting

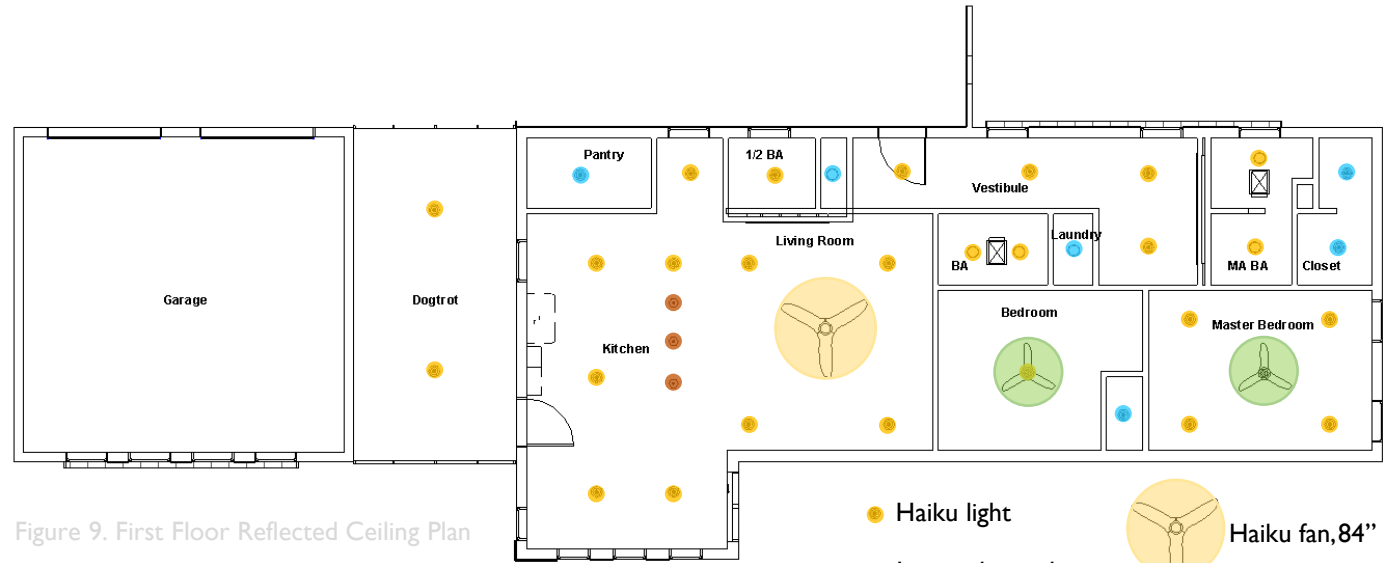
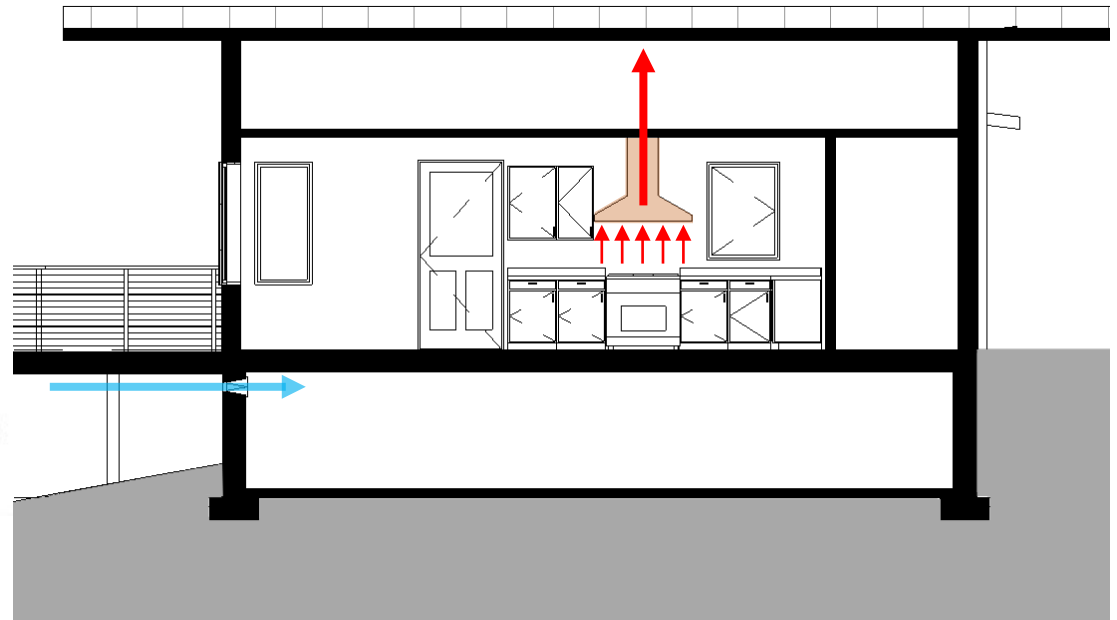


Figure 9. First Floor Reflected Ceiling Plan

- Haiku light
- Luxmode pendant
- Surface-mount LED
- Haiku fan, 84"
- Haiku fan, 52"

Appliances

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Ball State University



Architecture

Interiors

Constructability

Energy

Envelope

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Finances

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Double Stud Wall

2x8 Base / 2x4 Studs

R-43.1 (30.5 Cavity + 12.6 Continuous)

Mitigate thermal bridging

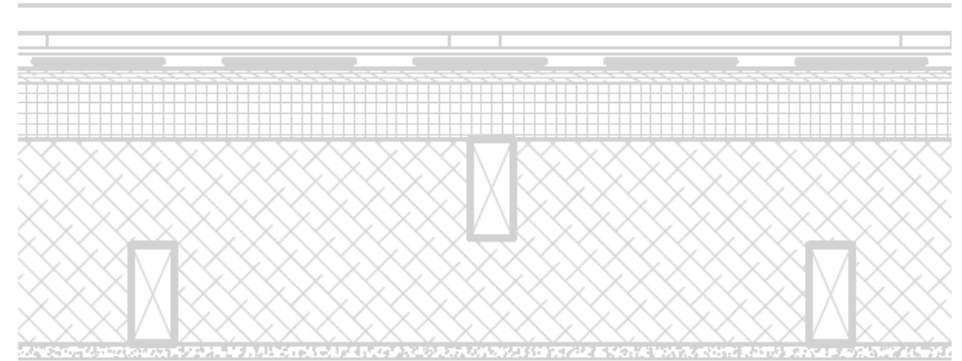


Figure 10. Double Stud Wall System

Optimum Value-Engineered Wall

2x6 Stud Wall

R-35.7 (23.1 Cavity + 12.6 Continuous)

HERS score increase of 1 point

Reduced Materials

Less Labor Costs

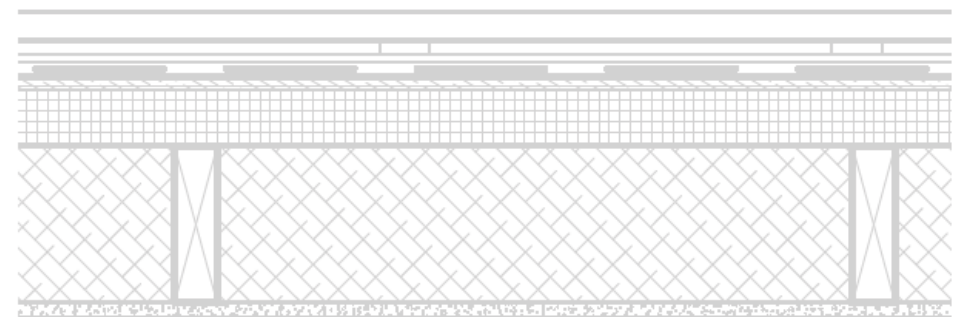


Figure 11. OVE Value-Engineered Wall System

Continuous Wall System

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Ball State University



ZIP System® R-Sheathing

2" Insulation

1/2" Sheathing

Integrated + Parallel Control Layers

- Water-Resistant Barrier,
- Taped Joint Seams
- Continuous Air Barrier
- Continuous Insulation

Builder-Approved

LWB has experience with ZIP System®



Architecture

Interiors

Constructability

Energy

Envelope

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Innovation



Pre-engineered Clinch Plate Truss

Installation Efficiency
Reduced Material

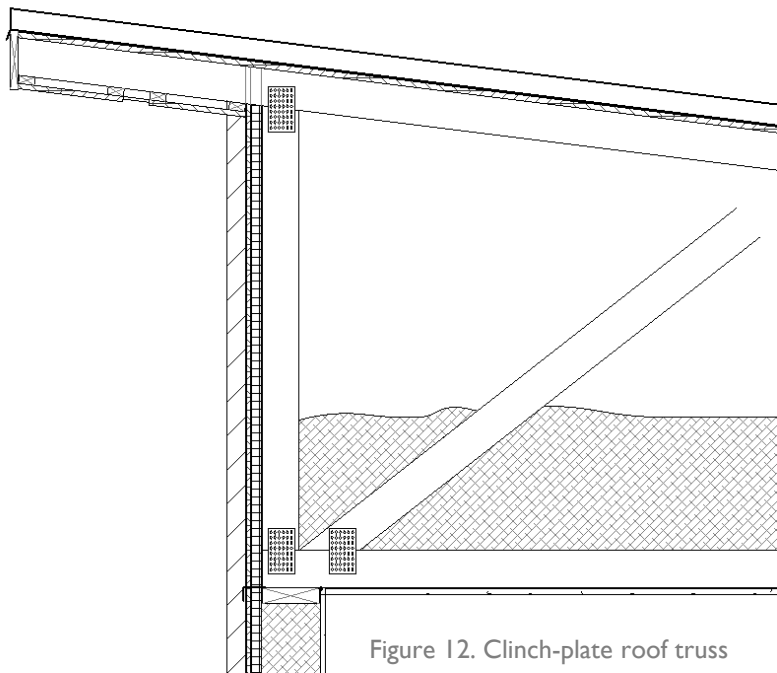


Figure 12. Clinch-plate roof truss

Insulated Concrete Form Foundation

Thermal Performance
Robust System
Aligned Control Layers



ICF – Wall Joint



Version 1

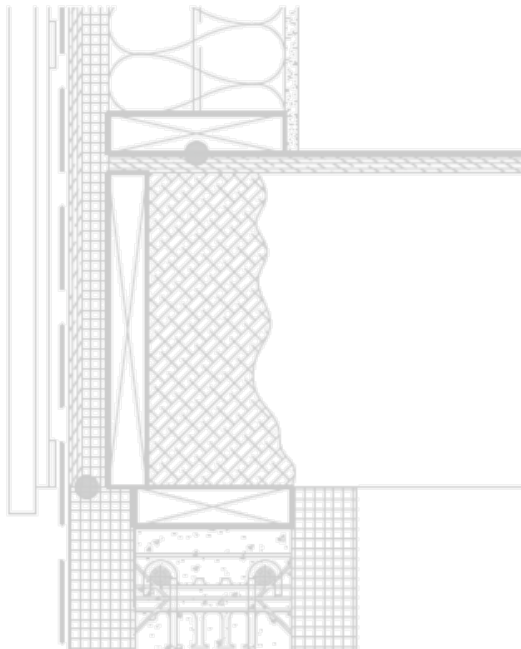


Figure 13. 1st Floor/Wall Connection Assembly

Version 2

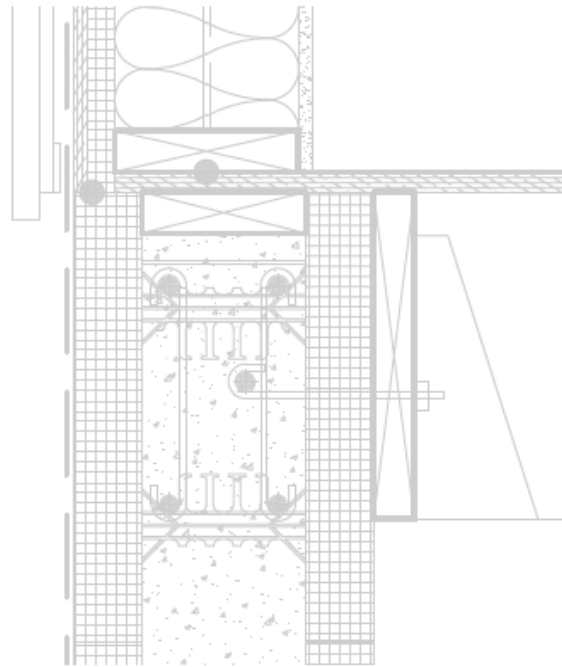


Figure 14. 2nd Floor/Wall Connection Assembly

Version 3

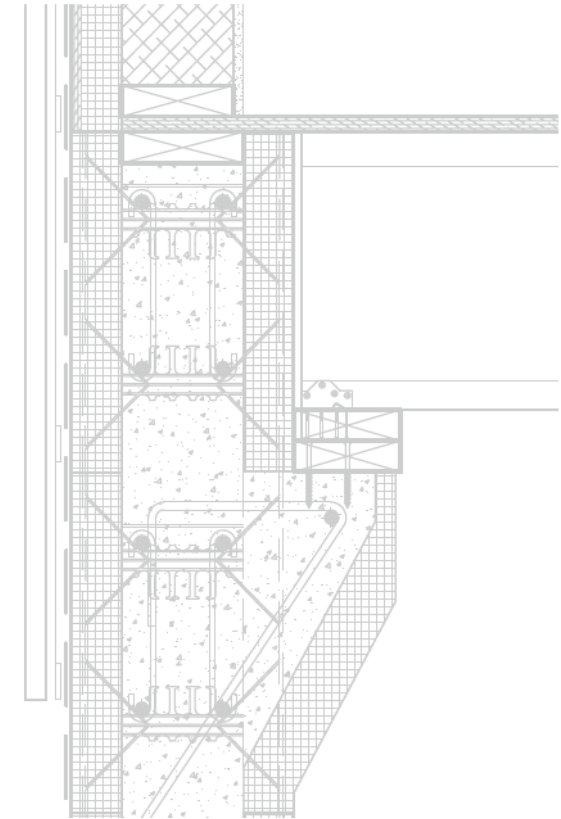


Figure 15. 3rd Floor/Wall Connection Assembly

ICF - Wall Joint

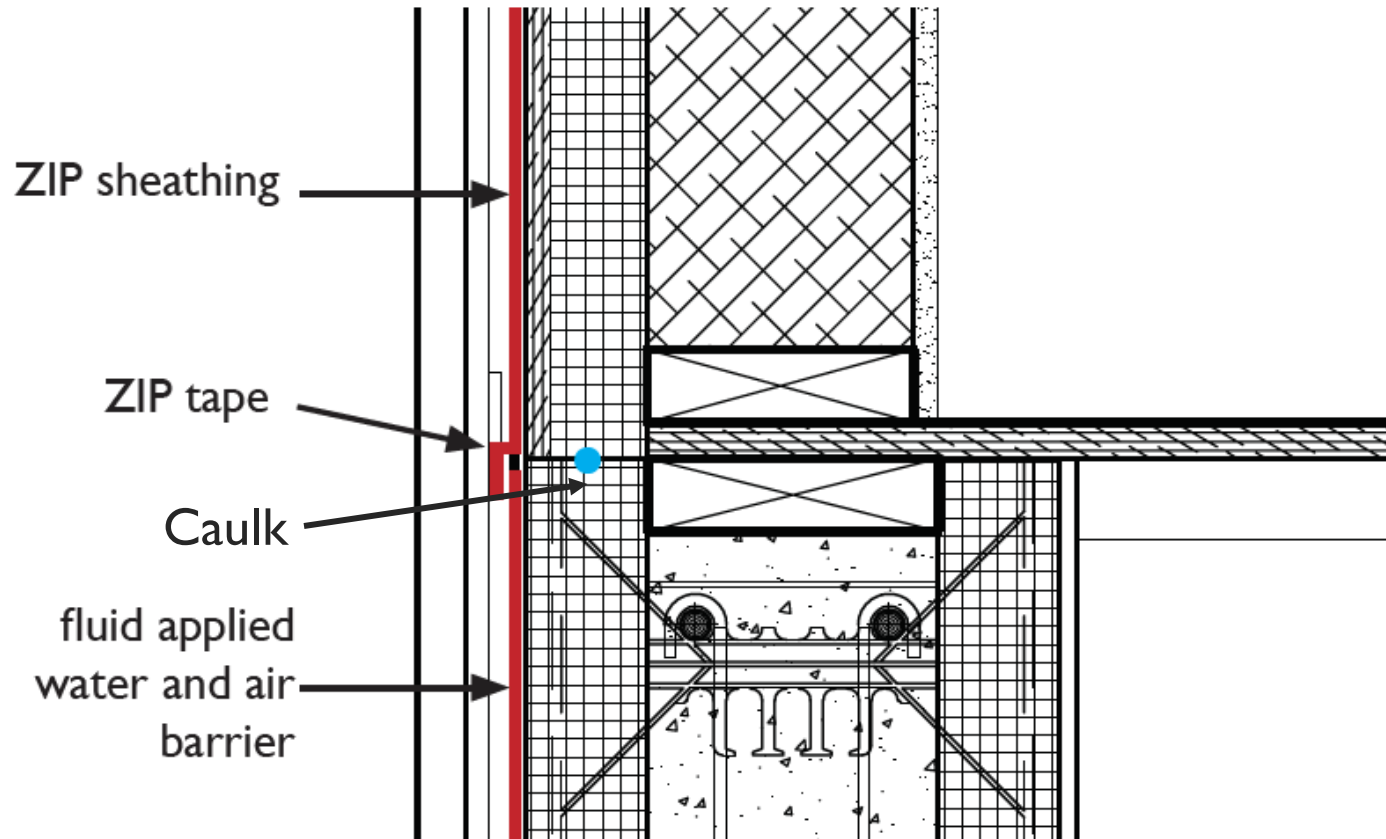


Figure 16. Wall – Foundation Control Layer Joint

Roof – Wall Joint

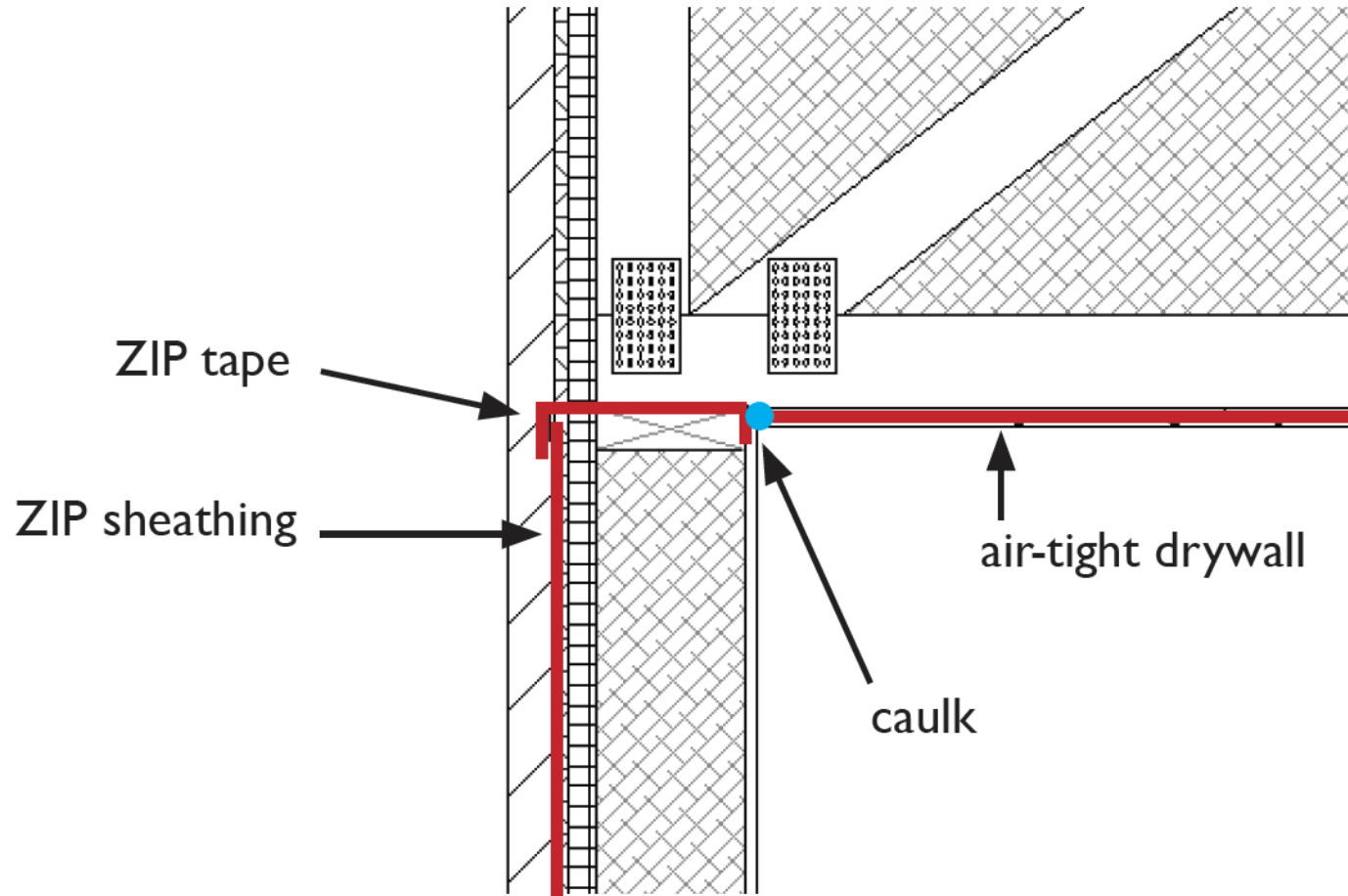


Figure 17. Wall – Roof Control Layer Joint



REM/RateTM

Official HERS Index Value



Corroborate HERS, Optimization

HEED: Home Energy Efficient Design

Passive Envelope Performance



Hygrothermal Modeling

HERS Analysis

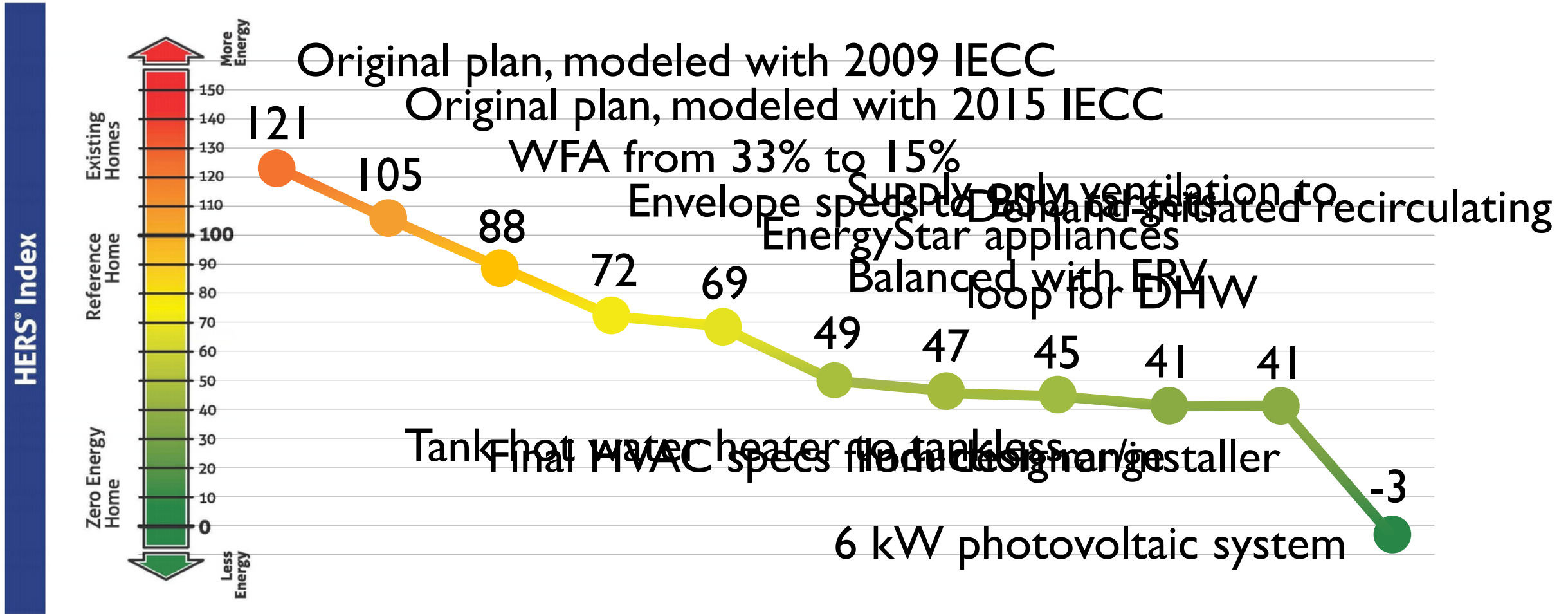


Figure 18. HERS Score Analysis and Transformation

Moisture and Dewpoint



Double-stud wall

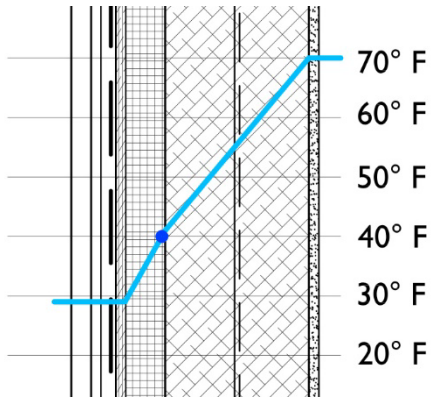


Figure 19. Double Stud Wall Thermal Gradient

2x6 OVE wall

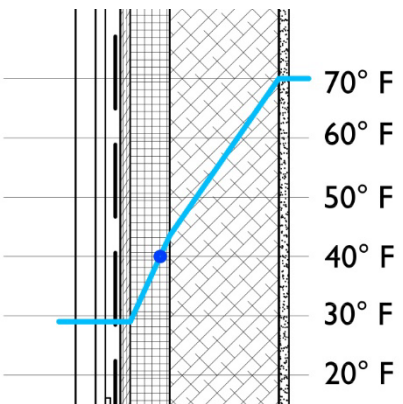
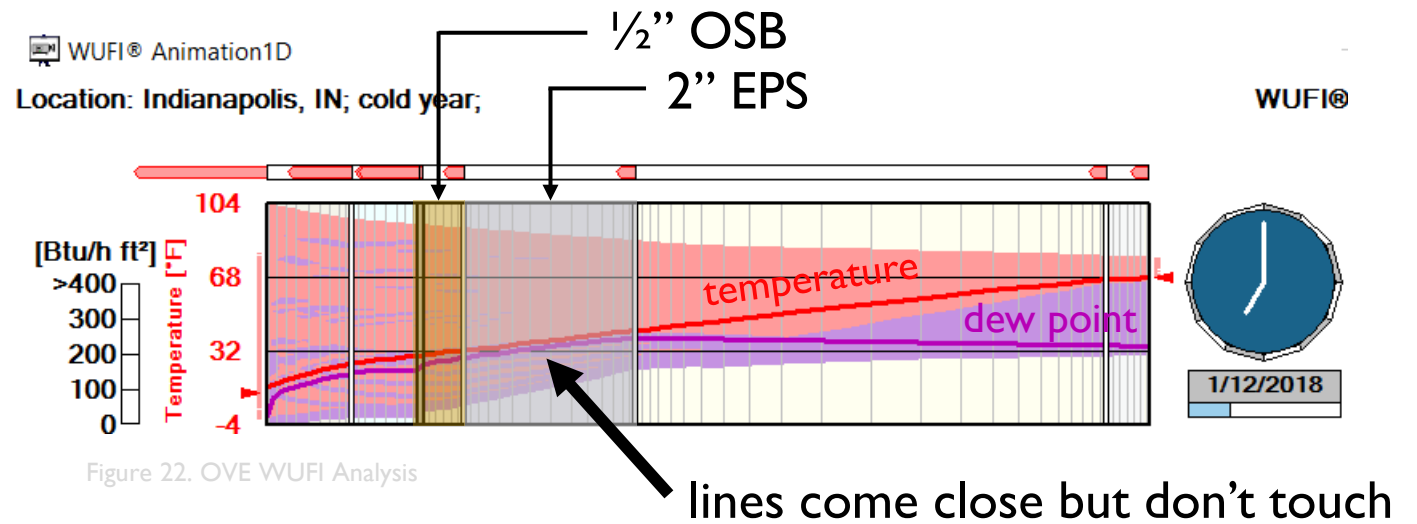
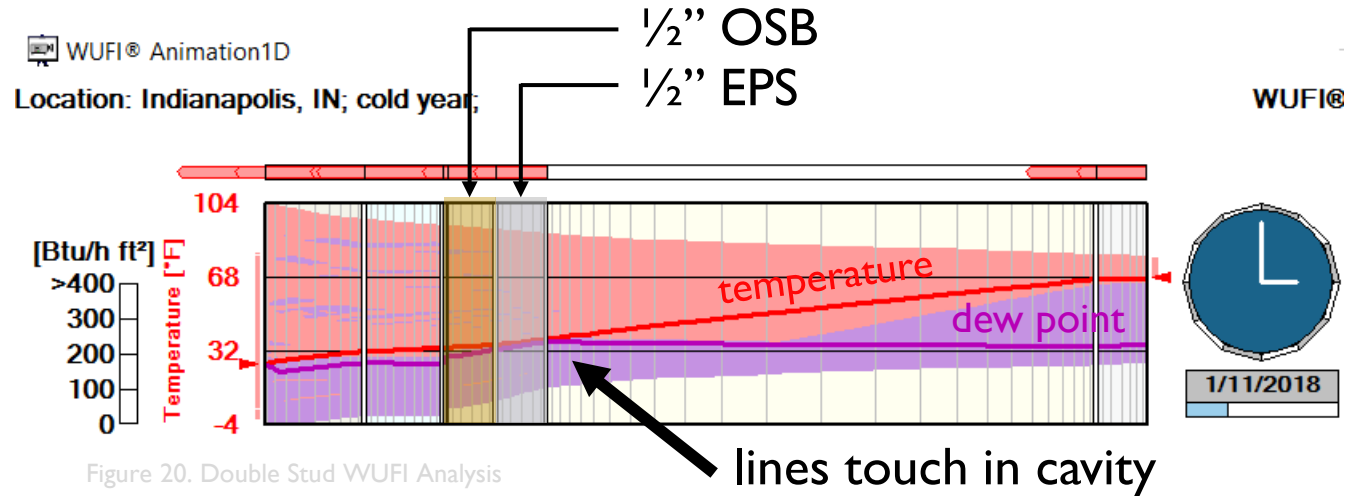
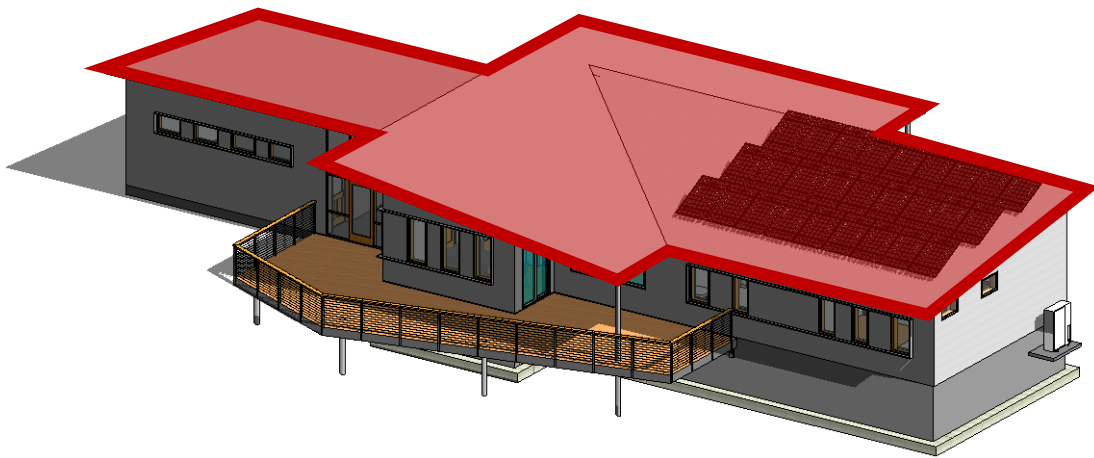


Figure 21. OVE Wall Thermal Gradient





Sloped roof with overhangs



ZIP system insulated sheathing



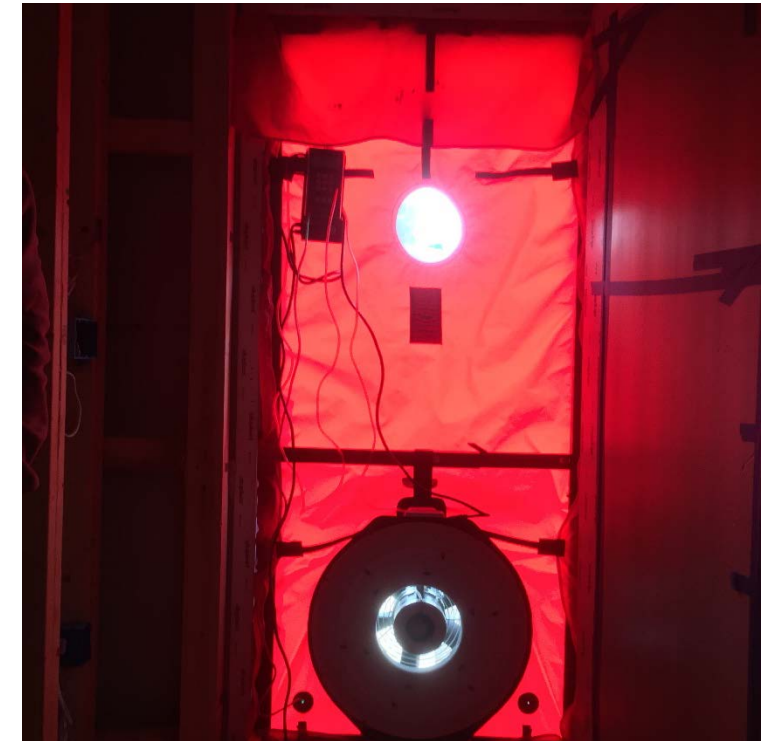
Image from Huber Wood Systems

Figure 23. Rear Home Axonometric Roof



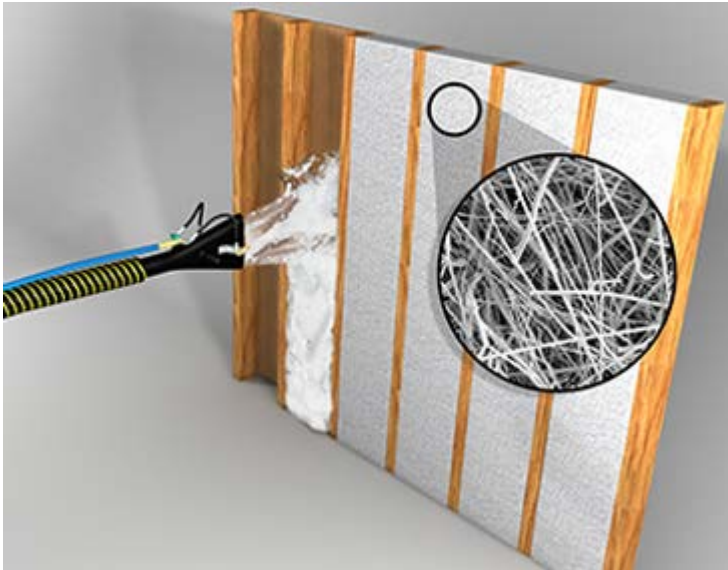
Field Observation

IACH50





“Spider” blown fiberglass



R-4.2 per inch

R-23.1 total for cavity

ZIP system insulated sheathing



R-12.6 total continuous



Building Science Corp. Recommendation

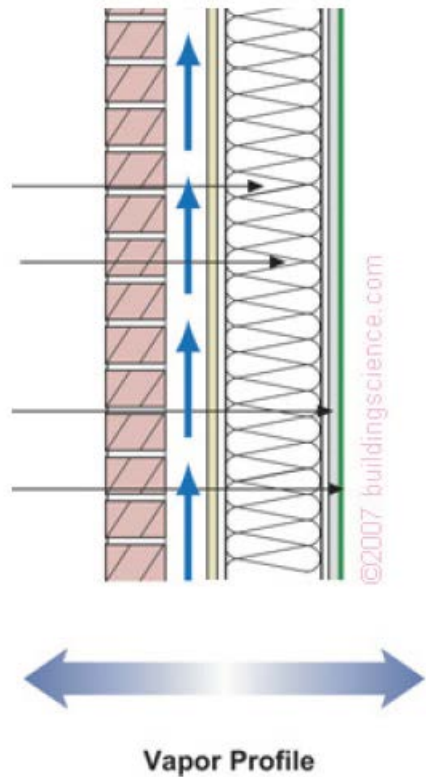


Figure 24. BSC Recommended Vapor Profile

Forest Refuge Home Adaptation

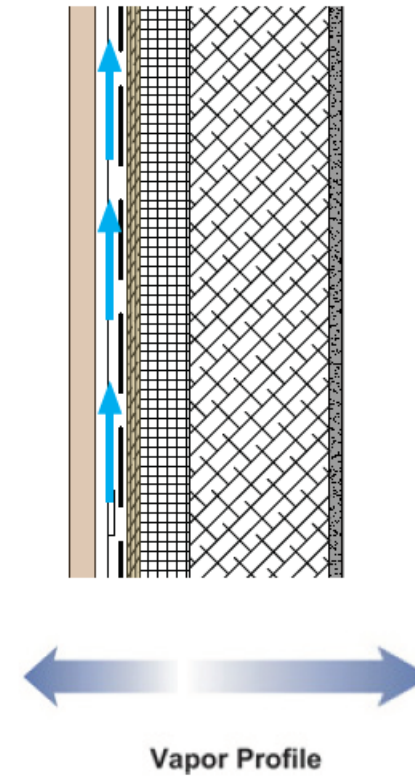


Figure 25. Forest Refuge Vapor Profile



Passive Survivability

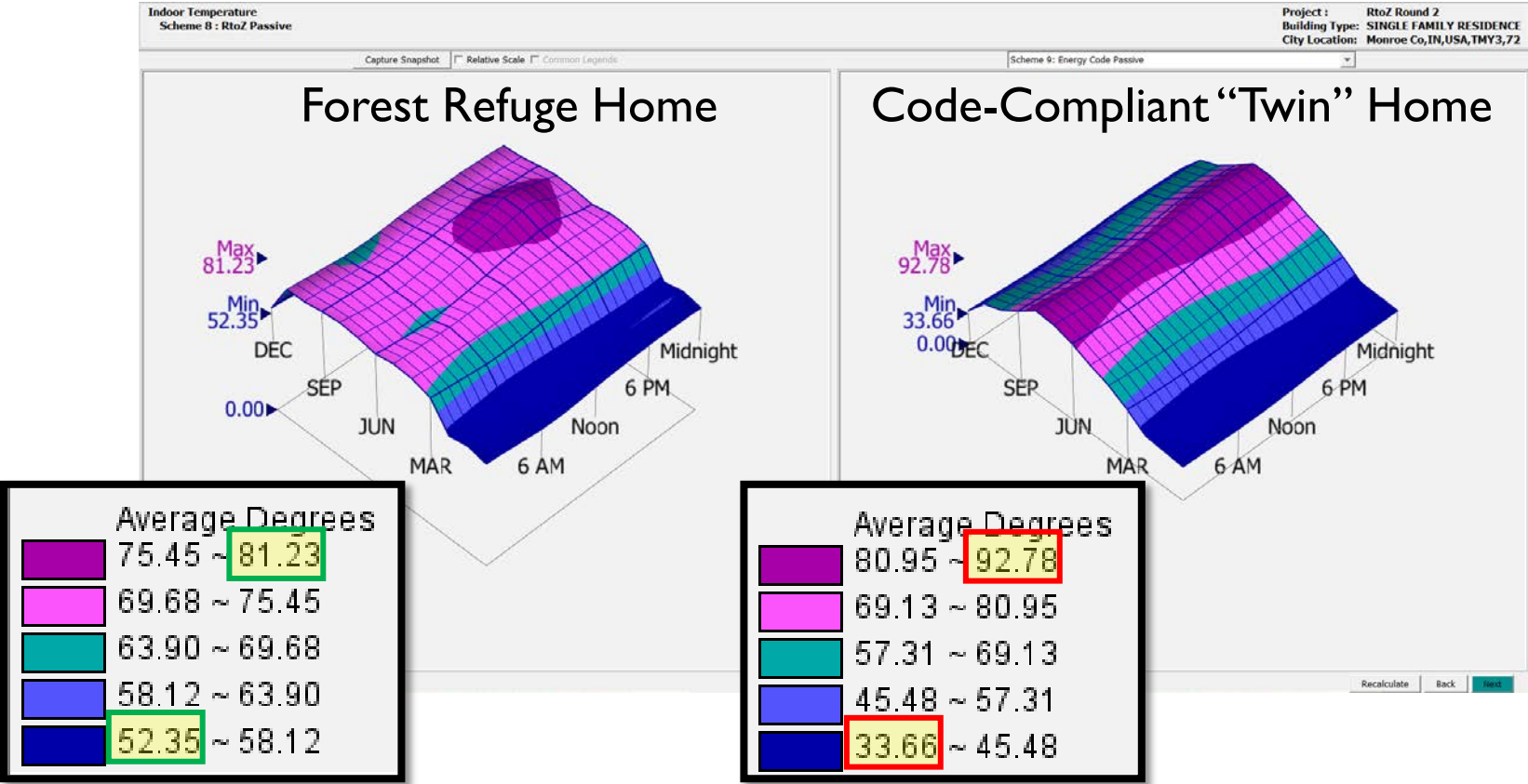
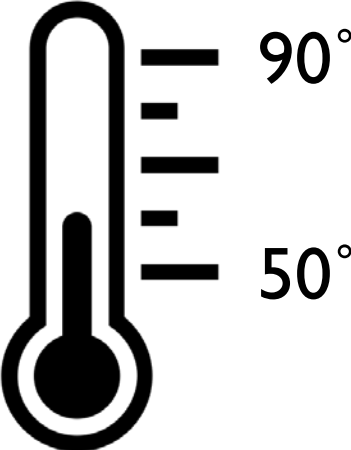
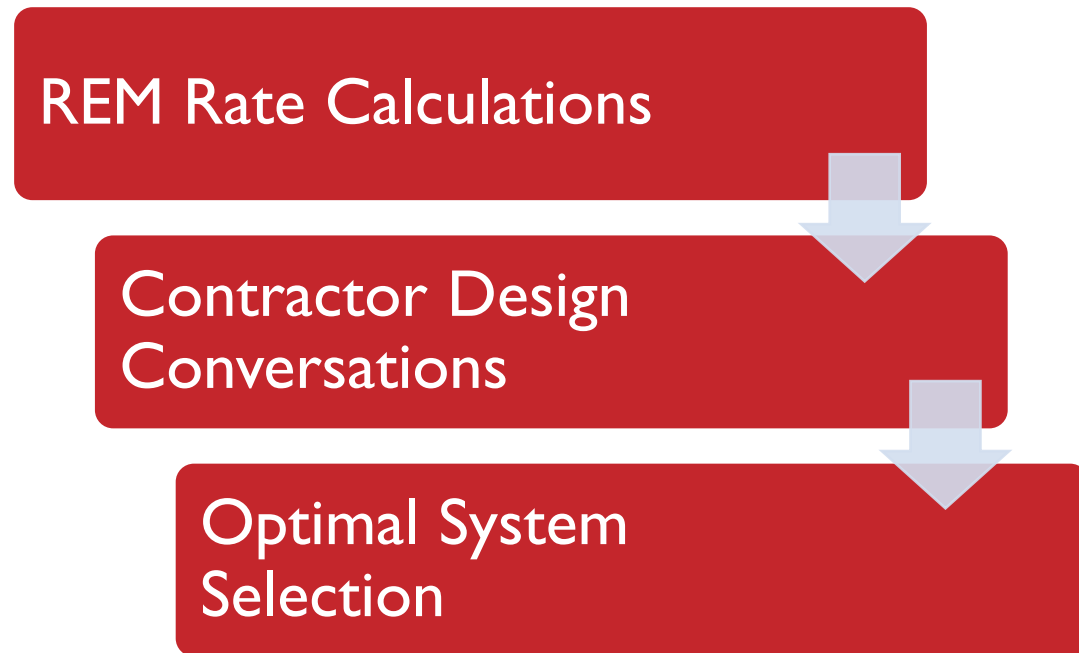


Figure 26. Indoor Temperature Analysis



Design Process



Design Loads

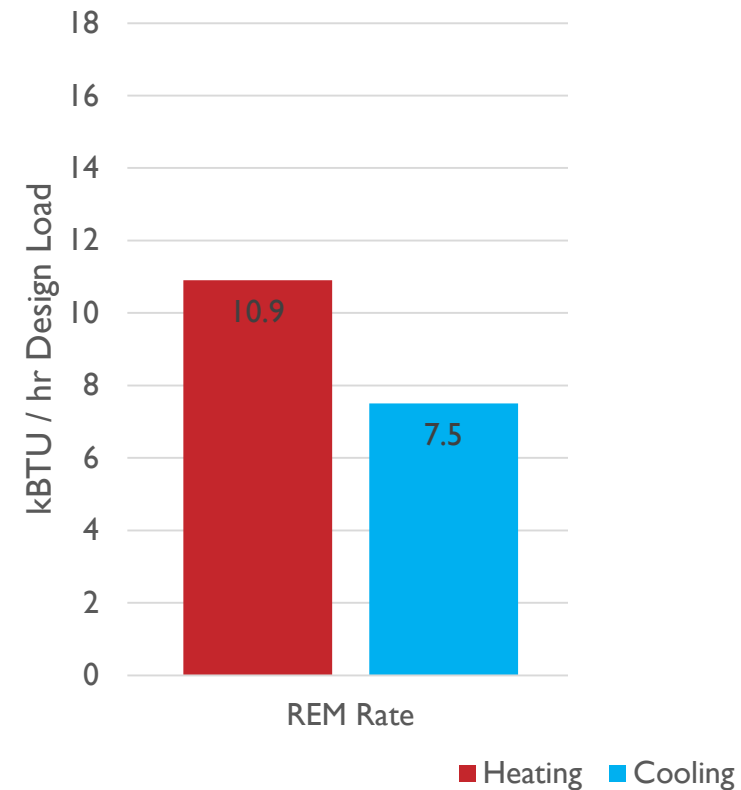


Figure 27. Heating and Cooling Design Loads



Heat Pump Outdoor Unit



Variable Capacity

22 kBTUs Heating (5° F)

20 kBTUs Cooling
(SEER 15.0 / EER 11.0)

Heating COP:

3.70 @ 47° F

2.53 @ 17° F

Cooling COP:

3.22

Ducted Mini-Split Indoor Unit (2)



Dual-Zone Control
9k BTU + 12k BTU

MERV 8 Filtration



Whole-Home ERV

Duct Layout

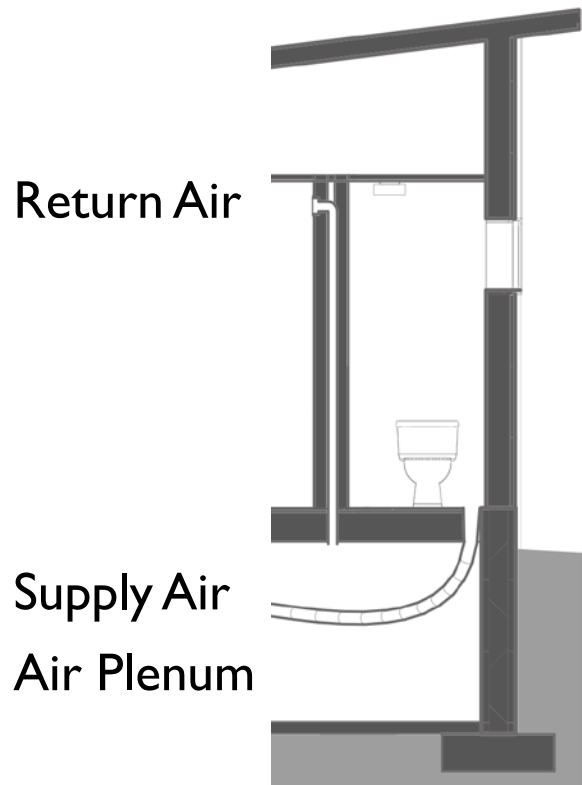


Figure 28. Ventilation Strategy

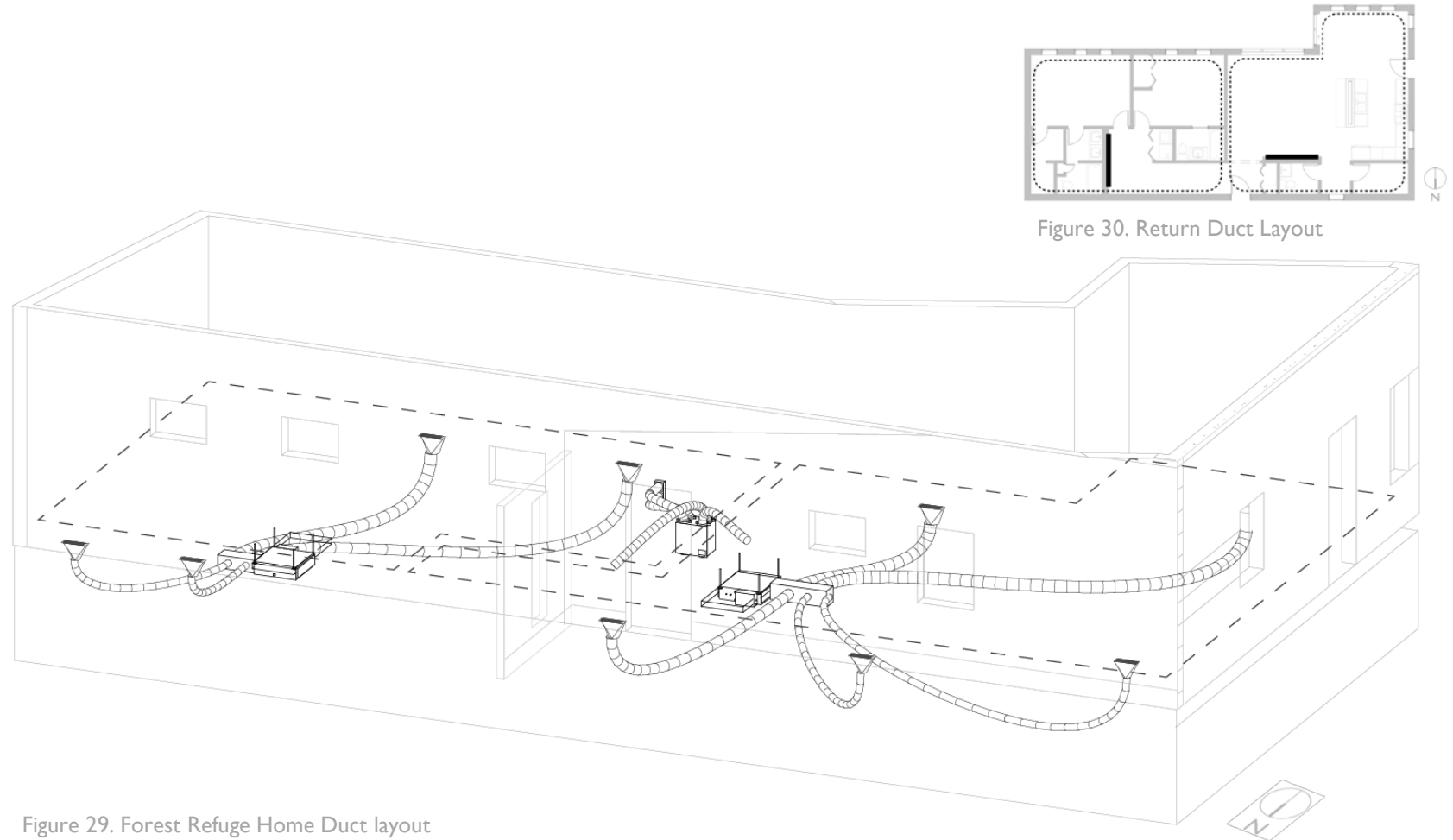


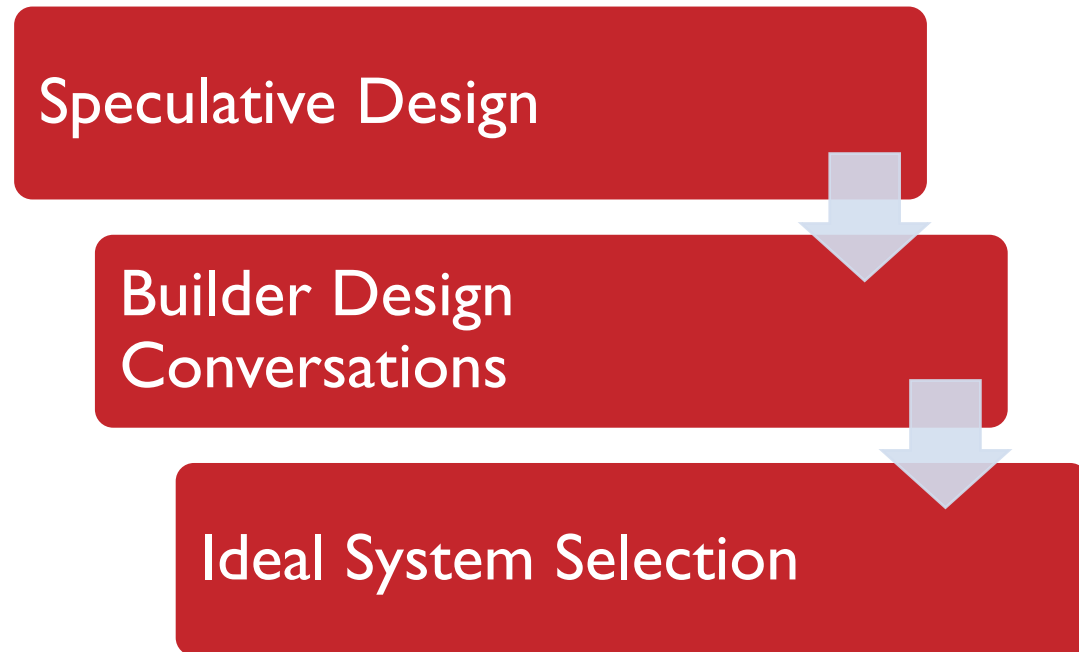
Figure 29. Forest Refuge Home Duct layout

Figure 30. Return Duct Layout

Hot Water System



Design Process



Selection

Rinnai Ultra
Tankless Unit



50 GAL
Electric / 3.5 EF

Layout Design

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Ball State University

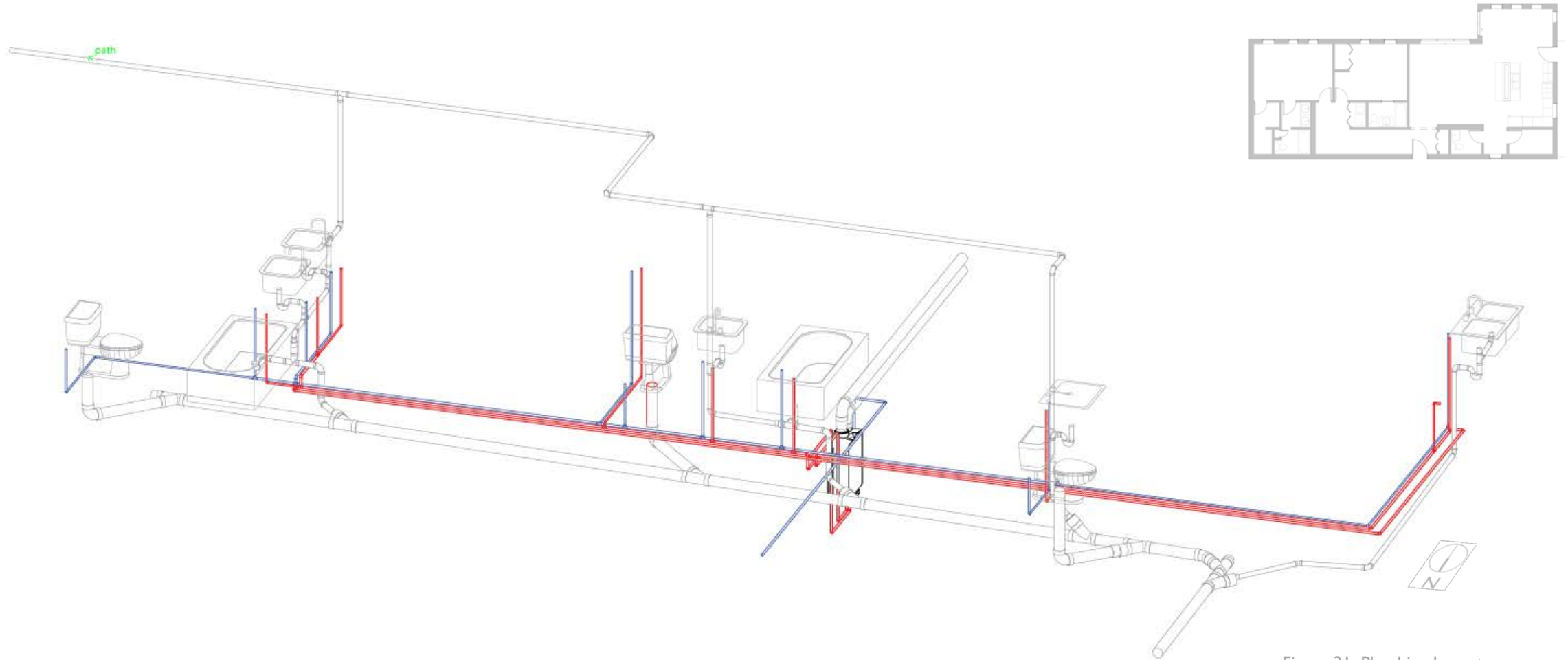


Figure 31. Plumbing Layout

Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

Finances

LEED

Innovation

Recirculation

Built-In Recirculation

Integrated Pump
No Water Wasted
Layout Already Optimized for Recirculation



On-Demand Operation

Keep Benefits of Recirculation
Minimizes Excess Wasted Energy
Control-R System Integrated w/ System

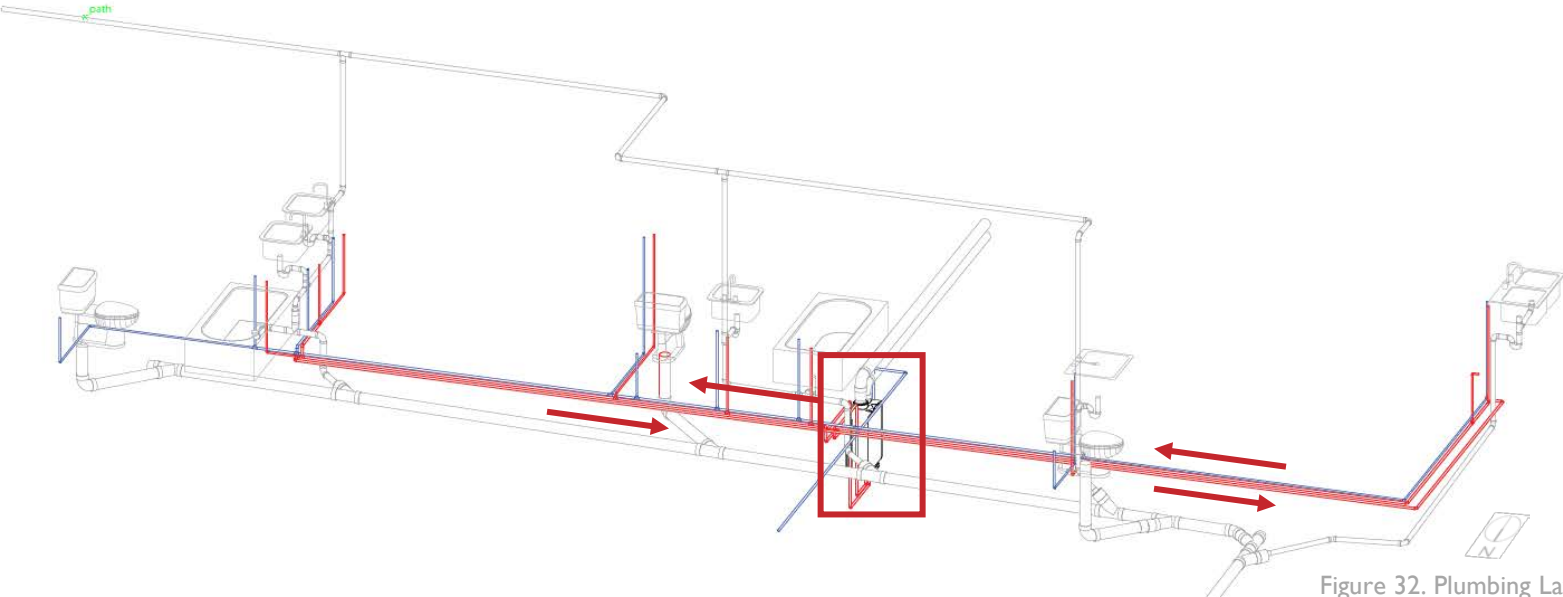


Figure 32. Plumbing Layout

Interior Air Quality

Team Woodridge
Ball State University



Sealed
Envelope

Contaminant
Mitigation

Ventilation +
Filtration

Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

Finances

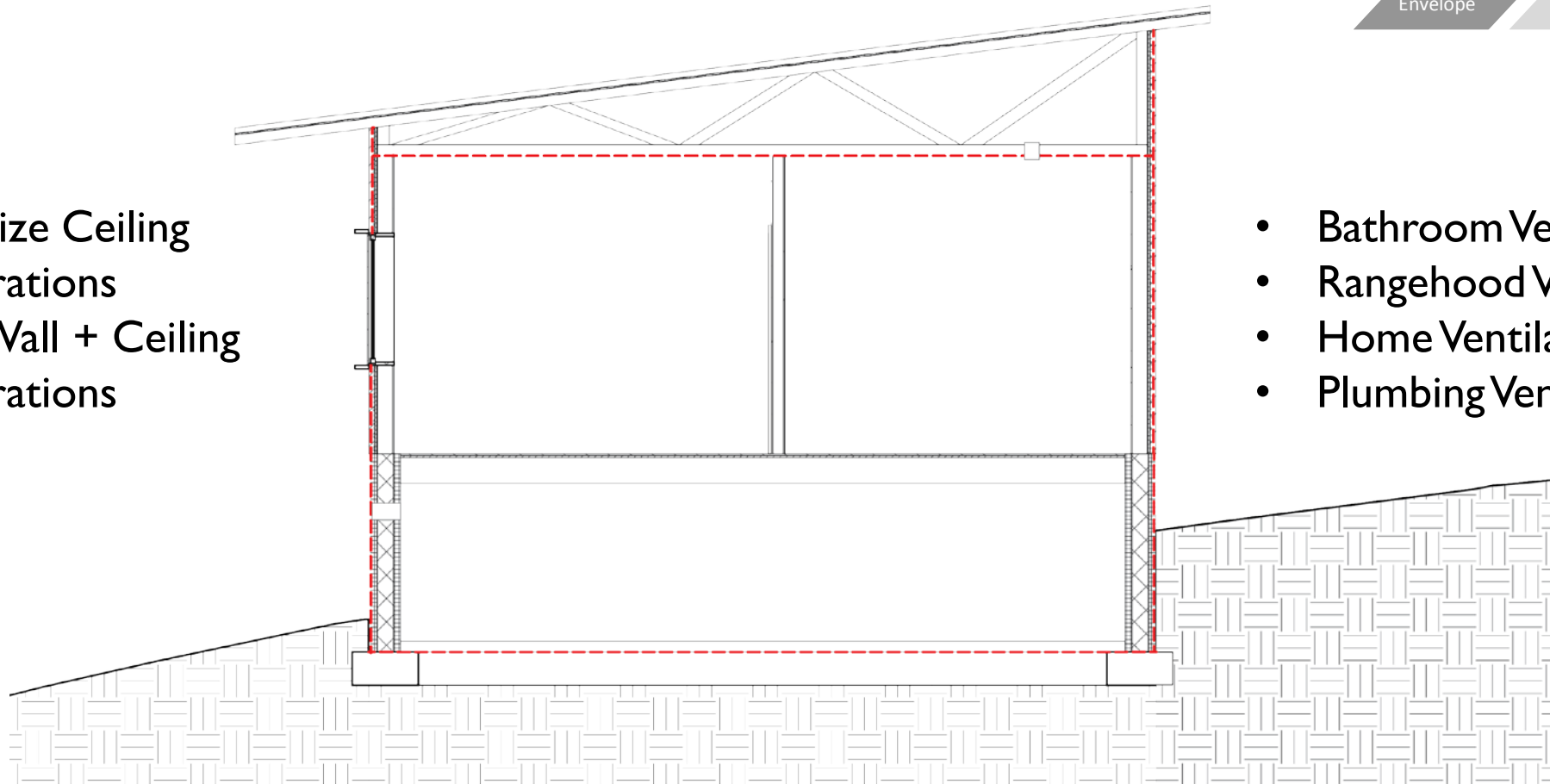
LEED

Innovation

Sealed Envelope



- Minimize Ceiling Penetrations
- Seal Wall + Ceiling Penetrations



- Bathroom Ventilation
- Rangehood Ventilation
- Home Ventilation
- Plumbing Vents

Figure 33. Envelope Sealing Plan

Contamination Mitigation



- No Open Combustion
- Walk-off Entrance Mats
- Garage Separation
- Range Hood Ventilation
- No Carpet

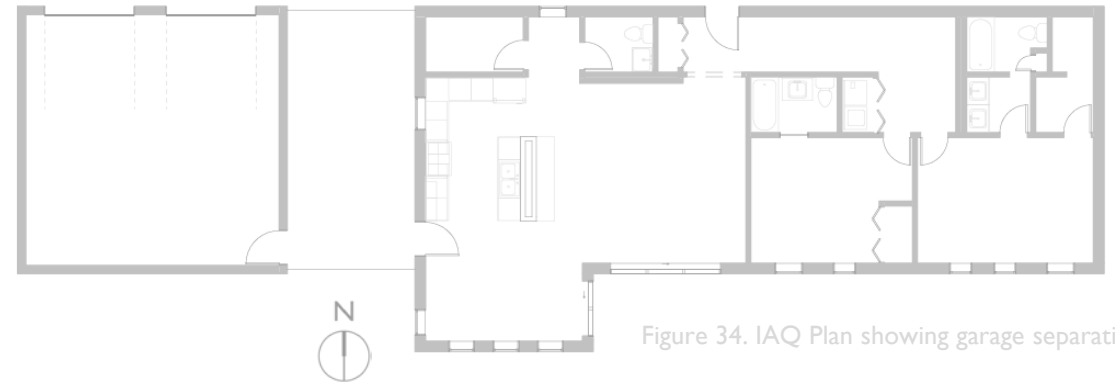


Figure 34. IAQ Plan showing garage separation





“Build Tight, Ventilate Right”

- Pressure Balanced Ventilation
- Recover Humidity and Heat when Possible

Whole Home Ventilation

- ERV in Conditioned Crawlspace

Localized Ventilation

- Humidistat-controlled Ventilation (ERV) in Bathrooms
- Rangehood w/ Makeup Air



Bloomington, IN

Team Woodridge
Ball State University



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Industry Partner



Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

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Bloomington, IN Real Estate Market Trends ⓘ

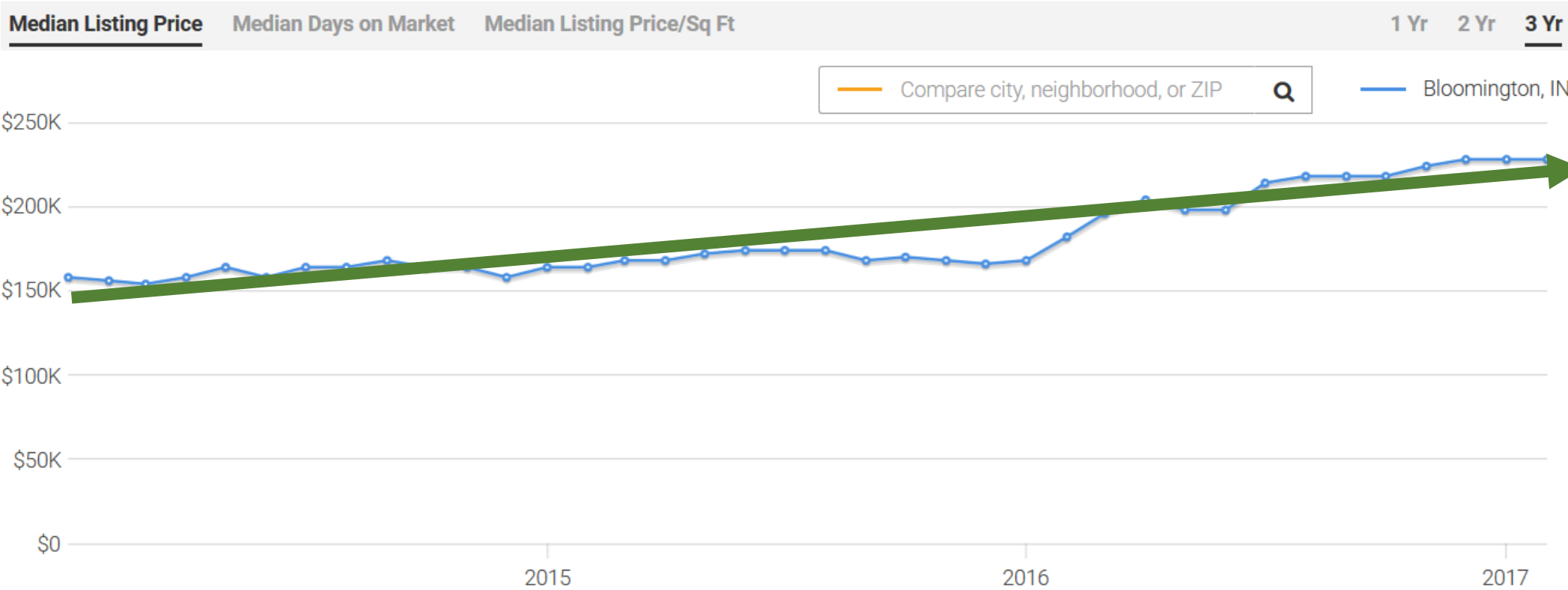


Figure 35. Bloomington Real Estate Market Trends, 2014-2017



Bloomington, IN Real Estate Market Trends ⓘ

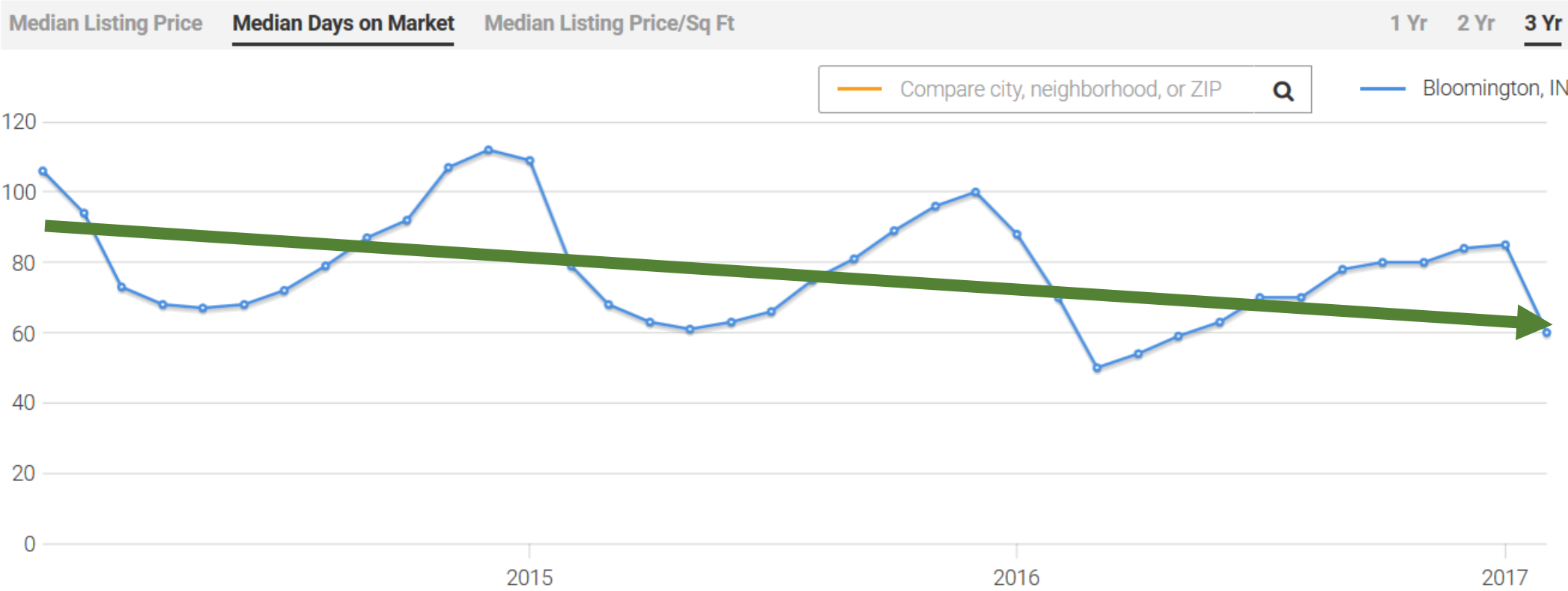


Figure 36. Bloomington Real Estate Market Trends, 2014-2017

Cost Estimate



Construction Cost Breakdown	NAHB 2013 Average Sq. Ft.		Team sq. ft.		Team Estimate	Team Estimate	Notes	Justification/Notes (Required for Values different than Default Value)
	Value	Per sq. ft.	Value	Per sq. ft.				
Site Work (sum of A to E)	\$ 16,825	\$ 6.45	\$ 16,780	\$ 10,761.00	\$ 4.13			
A Building Perm Fees	\$ 3,647	\$ 1.40	\$ 3,637	\$ 520	\$ 0.20	YES	Reviewed city permit fees for new single family.	
B Impact Fee	\$ 3,312	\$ 1.27	\$ 3,303	\$ 2,975	\$ 1.14	YES	Average cost by location	
C Water & Sewer Fees/Inspections	\$ 4,346	\$ 1.67	\$ 4,334	\$ 3,808	\$ 1.46	YES	Average cost by location	
D Architecture, Engineering	\$ 3,721	\$ 1.43	\$ 3,711	\$ 1,664	\$ 0.64	YES	Custom design has higher fees than typical builder	
E Other	\$ 1,799	\$ 0.69	\$ 1,794	\$ 1,794	\$ 0.69	YES	Using default estimate.	
Foundations (sum of F to G)	\$ 23,401	\$ 8.98	\$ 23,338	\$ 27,453	\$ 10.53			
F Excavation, Foundation, Concrete, Retaining Walls, and Backfill	\$ 23,028	\$ 8.83	\$ 22,966	\$ 27,081	\$ 10.42	YES	added 13% for ICF construction based on local contractor's advice	
G Other	\$ 373	\$ 0.14	\$ 372	\$ 372	\$ 0.14	YES	Using default estimate.	
Framing (sum of H to L)	\$ 47,036	\$ 18.04	\$ 46,910	\$ 47,589	\$ 18.25			
H Framing (including roof)	\$ 36,438	\$ 13.98	\$ 36,340	\$ 46,391	\$ 17.84	YES	Structural system including OVE walls, roofing, ZIP sheathing, joist floor system, stairs, and connections.	
I Trusses (if not included above)	\$ 5,461	\$ 2.09	\$ 5,446	\$ -	\$ -	YES	Trusses included above.	
J Sheathing (if not included above)	\$ 2,332	\$ 0.89	\$ 2,326	\$ -	\$ -	YES	included above	
K General Metal, Steel	\$ 1,604	\$ 0.62	\$ 1,600	\$ -	\$ -	YES	not needed	
L Other	\$ 1,201	\$ 0.46	\$ 1,198	\$ 1,198	\$ 0.46	YES	default	
Exterior Finishes (sum of M to P)	\$ 35,473	\$ 13.61	\$ 35,378	\$ 79,419	\$ 30.46			
M Exterior Wall Finish	\$ 16,867	\$ 6.47	\$ 16,822	\$ 16,428	\$ 6.32	YES	Including rainscreen for exterior finish, roofing and connections	
N Roofing	\$ 7,932	\$ 3.04	\$ 7,911	\$ 10,120	\$ 3.89	YES	metal panel roofing	
O Windows and Doors (including garage door)	\$ 10,117	\$ 3.88	\$ 10,090	\$ 52,315	\$ 20.12	YES	includes high performance windows (Zola tilt and turn) curtain wall, exterior doors, railing and garage doors	
P Other	\$ 557	\$ 0.21	\$ 556	\$ 556	\$ 0.21	YES	default	
Major Systems Rough-ins (sum of Q to T)	\$ 32,959	\$ 12.64	\$ 32,871	\$ 37,302	\$ 14.31			
Q Plumbing (except fixtures)	\$ 11,823	\$ 4.54	\$ 11,791	\$ 10,296	\$ 3.96	YES	Efficient plumbing runs and fewer bathrooms than typical	
R Electrical (except fixtures)	\$ 9,967	\$ 3.82	\$ 9,940	\$ 11,312	\$ 4.35	YES	traditional electrical work for house of this size	
S HVAC	\$ 10,980	\$ 4.21	\$ 10,951	\$ 15,505	\$ 5.96	YES	Direct quote from Commercial Services	
T Other	\$ 189	\$ 0.07	\$ 188	\$ 388	\$ 0.07	YES	Default	
Interior Finishes (sum of U to AE)	\$ 72,241	\$ 27.71	\$ 72,047	\$ 79,796	\$ 30.99			
U Insulation	\$ 4,786	\$ 1.84	\$ 4,773	\$ 8,713	\$ 3.35	YES	including blown fiberglass insulation for walls, roofing insulation and other items	
V Drywall	\$ 9,376	\$ 3.60	\$ 9,351	\$ 4,741	\$ 1.82	YES	gypsum wallboard on walls, standard, taped and finished (level 4), 1/2" thick	
W Interior Trim, Doors, and Mirrors	\$ 10,536	\$ 4.04	\$ 10,508	\$ 5,554	\$ 2.14	YES	minimal interior doors	
X Painting	\$ 8,355	\$ 3.20	\$ 8,333	\$ 8,375	\$ 3.22	YES	paints & coatings, walls & ceilings, interior concrete, drywall or plaster, zero VOC latex, 2 coats, smooth finish	
Y Lighting	\$ 3,008	\$ 1.15	\$ 3,000	\$ 7,528	\$ 2.90	YES	high efficiency and LED lighting as specified	
Z Cabinets, Countertops	\$ 12,785	\$ 4.90	\$ 12,751	\$ 11,044	\$ 4.25	YES	Flooring systems include hardwood flooring and concrete garage slab as specified	
AA Appliances	\$ 4,189	\$ 1.61	\$ 4,178	\$ 7,618	\$ 2.93	YES	High efficiency energy star appliances as specified.	
AB Flooring	\$ 12,378	\$ 4.75	\$ 12,345	\$ 16,412	\$ 6.31	YES	Flooring systems include hardwood flooring and concrete slab as specified.	
AC Plumbing Fixtures	\$ 4,265	\$ 1.64	\$ 4,234	\$ 9,266	\$ 3.56	YES	Traditional number of fixtures for a house this size	
AD Fireplace	\$ 2,057	\$ 0.79	\$ 2,051	\$ -	\$ -	YES	No fireplace.	
AE Other	\$ 306	\$ 0.19	\$ 305	\$ 505	\$ 0.19	YES	Default	
Final Steps (sum of AF to AJ)	\$ 16,254	\$ 6.23	\$ 16,210	\$ 24,705	\$ 9.46			
AF Landscaping	\$ 3,744	\$ 2.20	\$ 3,729	\$ 6,790	\$ 2.61	YES	landscaping with natives plants and shrubs	
AG Outdoor Structures (deck, patio, porches)	\$ 2,891	\$ 1.11	\$ 2,883	\$ 12,611	\$ 4.85	YES	deck including posts, flooring system	
AH Driveway	\$ 3,741	\$ 1.43	\$ 3,731	\$ 1,436	\$ 0.55	YES	short driveway	
AI Clean up	\$ 2,261	\$ 0.87	\$ 2,235	\$ 2,255	\$ 0.87	YES	Default	
AJ Other	\$ 1,617	\$ 0.62	\$ 1,613	\$ 1,613	\$ 0.62	YES	Default	
Other	\$ 2,265	\$ 0.87	\$ 2,259	\$ 16,299	\$ 6.28			
AK Other	\$ 2,265	\$ 0.87	\$ 2,259	\$ 2,259	\$ 0.87	YES	Default	
AL Renewable Energy Systems (Optional)	\$ -	\$ -	\$ -	\$ 14,100	\$ 5.42	YES	Solar PV system (27 panels @ 275 watt)	
Total	\$ 246,454	\$ 94.54	\$ 245,792	\$ 323,343	\$ 124.36			

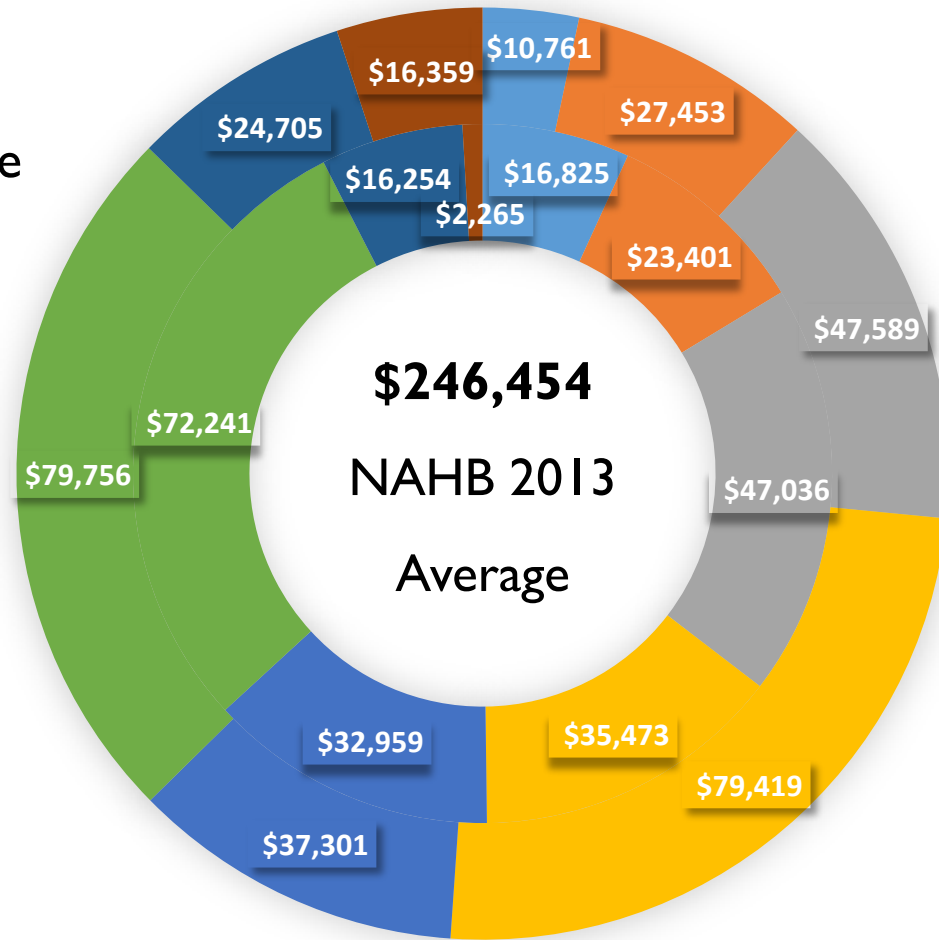
NAHB Sales Price Breakdown	2013 Value	Team Default Estimate	Team Adjusted Estimate	Justification/Notes (Required for Values different than Default Value)
Finished Lot Cost (including financing costs)	\$ 74,509	\$ 74,309	\$ 80,000	Standard costs
Financing Costs	\$ 5,479	\$ 5,464	\$ 6,656	Standard financing fee 2.5%
Overhead and General Expenses	\$ 17,340	\$ 17,293	\$ 21,300	Standard overheads and general expenses 8%
Marketing Cost	\$ 4,260	\$ 4,249	\$ 4,526	Standard marketing cost of 1.7%
Sales Commission	\$ 14,235	\$ 14,197	\$ 15,675	sales commission of 6%
Profit	\$ 37,255	\$ 37,155	\$ 40,000	profit of 32% including contingency
Total Sales Price	\$ 399,532	\$ 398,459	\$ 483,749	

\$483,749

Construction Cost



\$323,343
Forest Refuge
Home



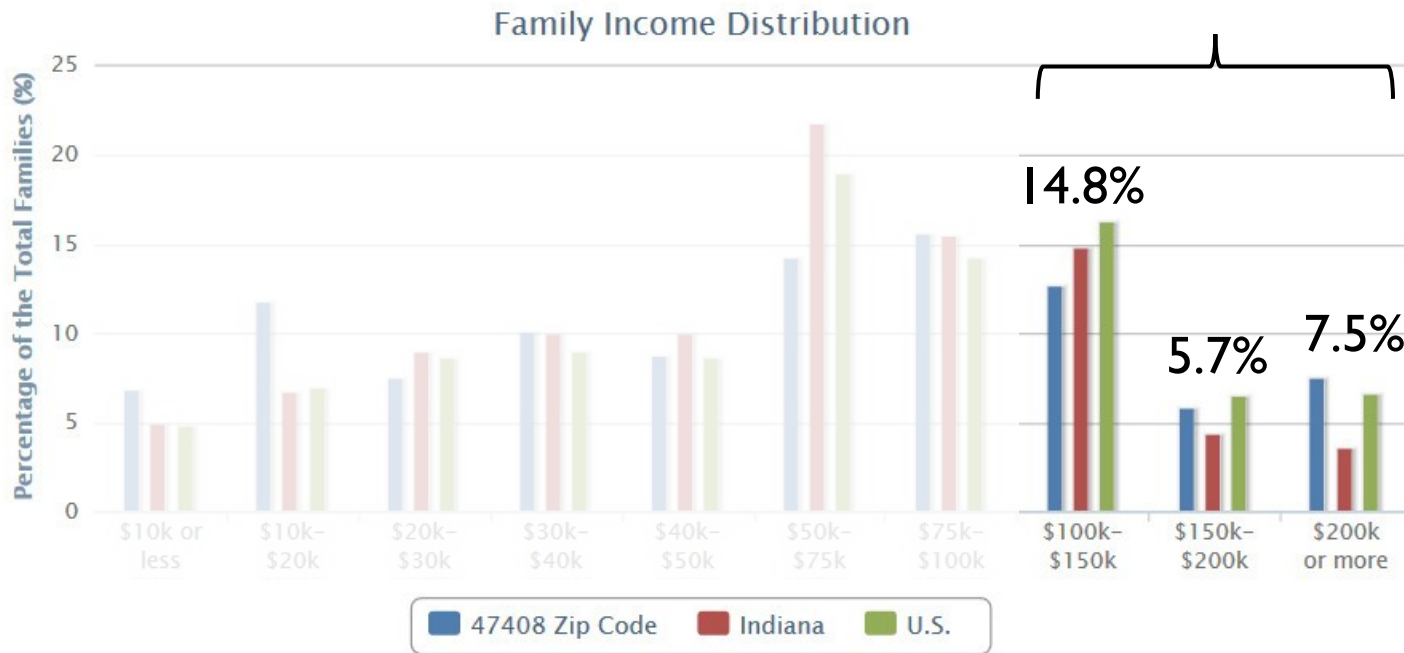
- Site Work
- Foundations
- Framing
- Exterior Finishes
- Major Systems
- Interior Finishes
- Final Steps
- Other/Renewable Energy

Figure 37. NAHB Average and Forest Refuge Construction Cost Breakdowns

Affordability



28% households



Debt-to-Income

37%	\$100,000
31%	\$125,000
27%	\$150,000
23%	\$175,000
21%	\$200,000

Figure 38. Affordability and Family Income Projections

LEED for Homes



Design Team ←----- ARCH 632 Team



Forest Refuge
Home











BALL STATE
UNIVERSITY.

Projected LEED Points

Team Woodridge
Ball State University



LT	SS	WE	EA	MR	EQ	IN	RP
							
$\frac{15}{2}$	$\frac{7}{5}$	$\frac{12}{5}$	$\frac{38}{36}$	$\frac{10}{7}$	$\frac{16}{13.5}$	$\frac{6}{2}$	$\frac{4}{4}$

PROJECTED TOTAL: 74.5 / 110

PROJECTED RATING: **GOLD**

Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

Finances

LEED

Innovation



- Location constrains Platinum
- Impressive EA Score
- Good MR, IEQ Scores

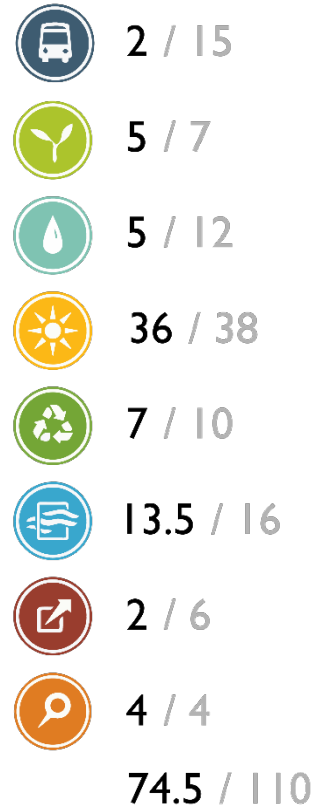


Figure 39. Projected LEED Points

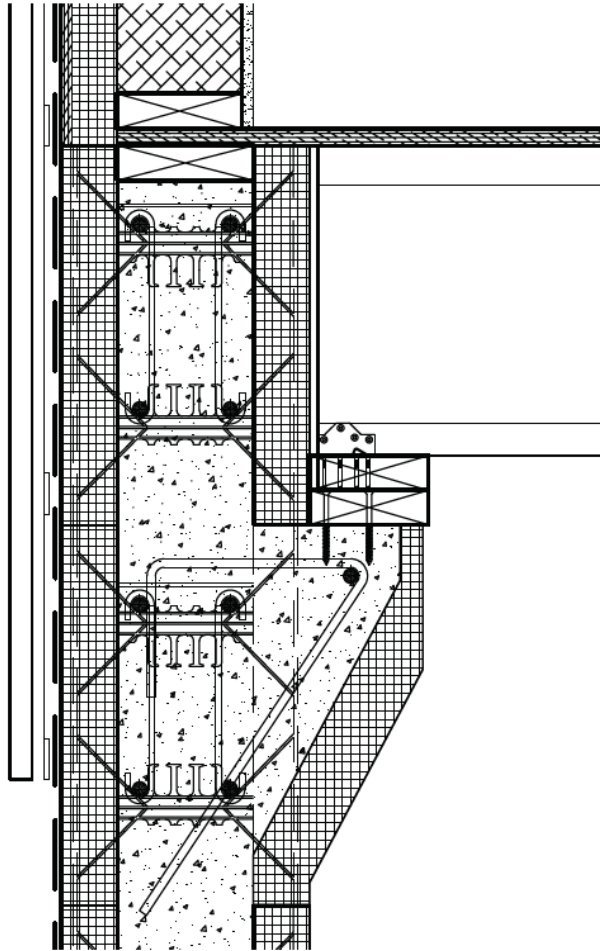
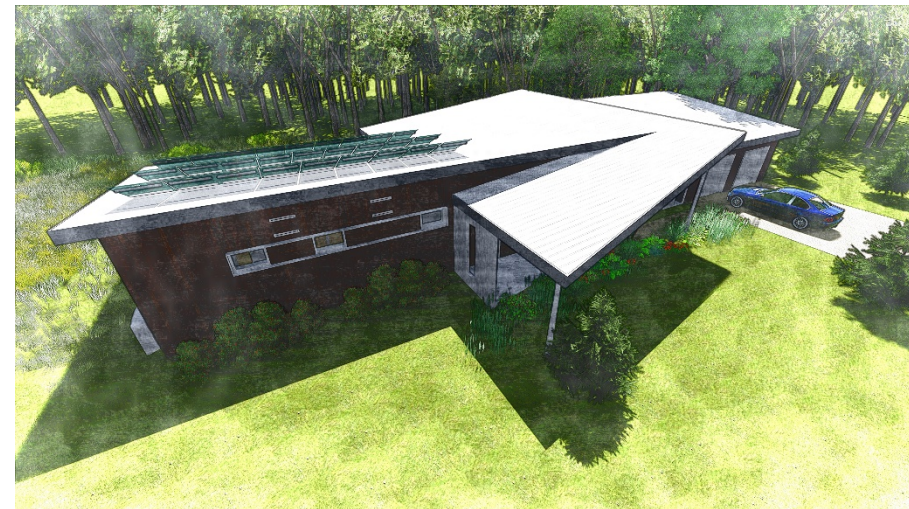


Figure 40. ICF Wall Foundation Detail



Innovation

Team Woodridge
Ball State University



TEAM
WOODRIDGE



BALL STATE
UNIVERSITY.



ARCH 632 ARCH 633

CONSTRUCTION MGMT.



Next Steps

Team Woodridge
Ball State University



Architecture

Interiors

Constructability

Energy

Envelope

MEP

IAQ

Finances

LEED

Innovation



Chris Reinhart



Luke Kamp

