

Iowa High-Performance Prototype Home Final Report

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Iowa Energy Office
Iowa Economic Development Authority



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Process and Findings:

Introduction:

Currently, new home construction across the country, including Iowa, typically utilizes stock home plans that are not specifically designed for concepts of sustainability, energy efficiency, passive tempering strategies, orientation, and systems integration. In addition, while the understanding of construction methodologies for energy efficiency and sustainability have increased over the last twenty years for residential construction in Iowa, we believe there is still capacity for continued education and demonstration for stakeholders involved in the construction of new homes across the state. This is particularly true as new materials, technologies, best practices, programs and codes are adopted over time.

Through the CDBG integrated design assistance workshops BNIM has been facilitating for IEDA since 2013, the need was identified to create a new construction residential prototype for Iowa's climate zones that demonstrates the current best practice strategies and techniques for energy conservation, storm water management, and other sustainable design strategies embodied in the Iowa Green Streets Criteria and the adopted International Energy Conservation Code in Iowa. In addition to serving as an educational model, the schematic plans can also be utilized by future homeowners and builders across the state to further refine and build over time to increase energy efficient and sustainable home construction in Iowa.

Understanding HUD CDBG disaster funding will be invested in Mills, Fremont, and Harrison counties in 2021 and beyond in the near term, the designs completed as part of this project can be utilized by builders / developers and by the BNIM team for ongoing disaster and regular CDBG educational integrated design assistance workshops.

Goals:

The goals identified at the beginning of the project were to create a building design that would achieve the following:

- A. **Adaptability** – Considering the need for housing in Iowa for independent seniors and young families, investigate a design that is adaptable.
- B. **Affordability** - Study the drivers of the cost of the home and respond with appropriate design strategies to balance the overall cost of the home.
- C. **Energy Efficiency** – Evaluate through energy modeling various strategies to increase energy efficiency beyond current code compliance and look to the DOE Zero Energy Ready Home (ZERH) program for applicability to the design.

- D. **Educational** – Create a set of schematic documents that can be educational for the building construction community and create presentations that can be utilized for various groups, and seek participation in public radio programming.

Process

A stakeholder committee was established at the beginning of the project that included residents from Mills and Fremont Counties representing the following groups:

- A. Banker / Lender
- B. Residential Contractors
- C. Realtor
- D. Hamburg Mayor and City Clerk
- E. IEDA Representatives

Introductory meetings were held In September and October 2020 to discuss housing developments in the Glenwood, Iowa area along with recent homes constructed and to define the overall goals of the prototype house. It was identified through these discussions that the general plan should be to build a three bedroom, two bath home, or smaller, but could be adapted initially or modified over time.

Through these meetings, two topics in particular were discussed related to keeping the cost of the home as affordable as possible along with the need for continued education within the appraiser community to have appraisals for financing recognize energy efficiency and high-performance construction. The design of the home has addressed the affordability topics, but engaging the appraisal community is a future continued opportunity for the educational aspects of this prototype long-term.

The design team then generated concepts rooted in this guidance and continued to refine and develop the concepts concurrently with developing construction strategies that could be evaluated through energy modeling. The final design and efficiency strategies are defined in the schematic guide documents attached to this report.

Design

The final home plans address the goals of the project in the following ways:

- A. Adaptability:** The initial concepts for the house were diagrammed quickly to begin to consider the plan functionally in terms of living, eating, sleeping, and parking a car. These quick diagrams are shown below in Figure 1.



Figure 1 – concept diagrams

The initial concepts were then developed into various three-bedroom, 2 bath, slab-on-grade configurations as shown below in Figure 2. During this process and review by the stakeholder group, it was discussed that plans should be developed to build the home on a basement if the homeowner desired or lot topography enabled a walk-out. The team began to consider the home as a base plan that would have options that could be incorporated on day one or over time in an effort to potentially build a small two-bedroom home to reduce area and ultimate cost. Figure 4 illustrates early thoughts of how similar plans could be conceived as one or two-bedroom plans.



Figure 2: Early concepts considering two-bedroom base concepts

B. Affordability: In discussions with the stakeholder group, it was determined that the plan should be maintained as a very simple shape which would yield the most economy for envelope / floor area and minimize complexity of foundations, framed corners, simplicity of structure, etc. In addition, minimizing the finished area of the home was another key strategy for reducing construction costs. Therefore, a two-bedroom, one bath was developed that could be adapted over time or initially by taking the same footprint and creatively adding a stair to create an occupied attic and/or basement. Lastly, concepts of adhering to a 2' building module in plan and roof section along with advanced framing construction methodologies can assist in optimizing material use and minimizing waste. Detaching the garage also allows for reduction in costs in construction of a common wall and allows freedom to build the garage initially in another location on the property or at a future date.

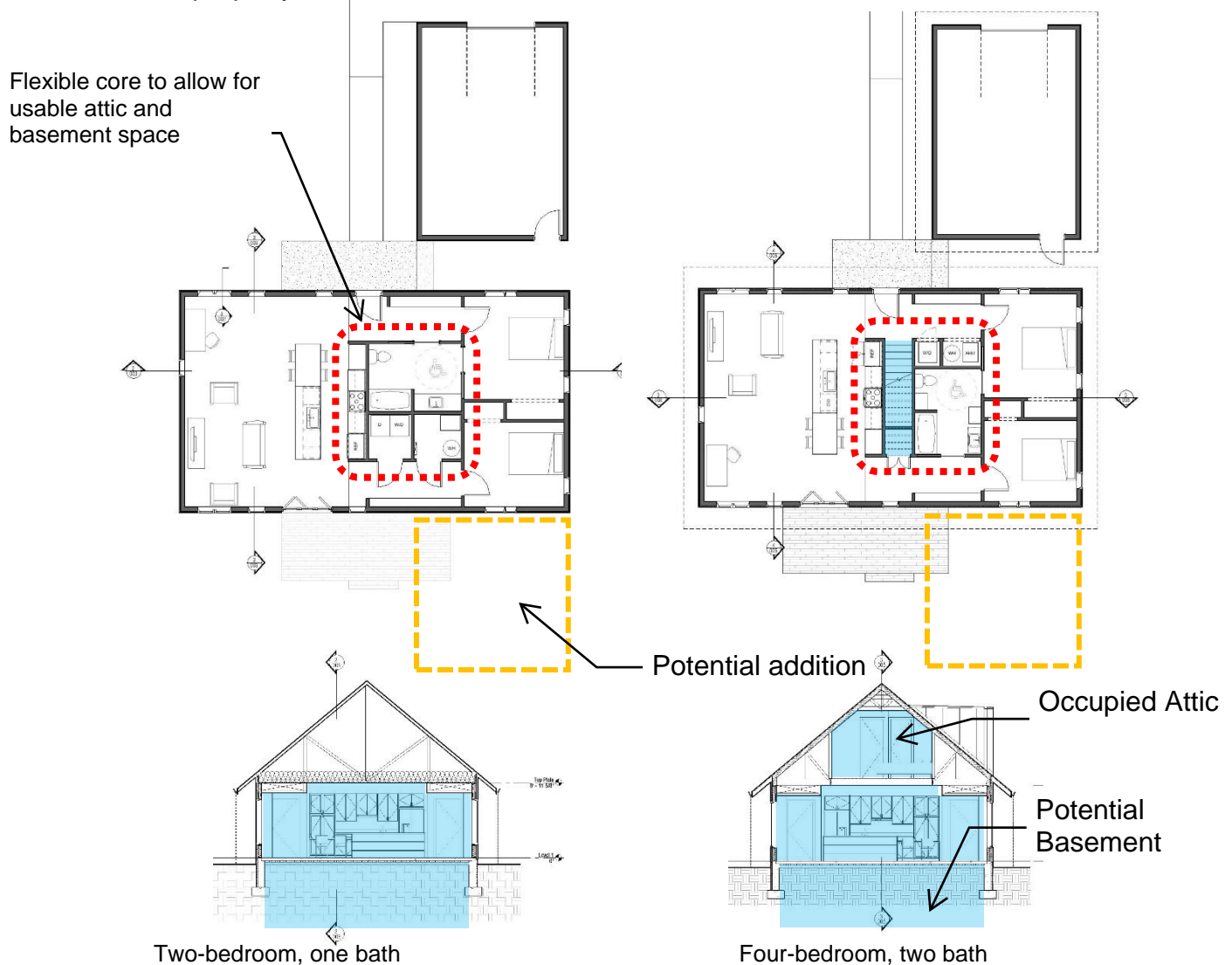


Figure 3: Prototype Plans and Sections

C. Energy Efficiency: Using the RESNET approved REMRate energy simulation software the variations of design were evaluated individually per their configuration. This process began with modeling the geometry of the dwelling and assigning thermal properties to each individual envelope component. From there the mechanical systems, lighting and appliances were assigned to further evaluate the energy consumption of the home. Final energy consumption and the home's corresponding HERS index reflect a year-round hourly simulation based on location. Using this simulation approach, the annual energy usage of the home is projected as designed. But as noted earlier, many variables can affect the final performance of the home once occupied; therefore, the final built home may achieve different results than what are projected below.

The spreadsheet that follows (Figure 4) tabulates various energy strategies organized by the following logic for both Climate Zone 5 and 6:

- A. **Option 1: Base Home:** 1196 sf – 2 Bedroom, 1 Bathroom, Slab-on-Grade (Sheets 003-004 in the schematic drawing set)
- B. **Option 2: 1 ½ Story Home:** 1841 sf – 4 Bedroom, 2 Bathroom, Slab-on-Grade (Sheets 005-006 in the schematic drawing set)
- C. **Option 3: 1 ½ Story Home:** 1841 sf – potential 5 Bedroom, 3 Bathroom, Slab-on Grade - With Basement

1. Baseline Energy Model: Each Option / concept has a Baseline Energy Model created for a current code-compliant home in Iowa. As of May 1, 2021 the adopted code in Iowa is the 2012 IECC with amendments.

- a. 4 ACH 50
- b. Windows U-0.32
- c. 2x6 wall, 16" oc, fiberglass batt, R-20
- d. R-49 ventilated attic
- e. Slab-on-grade R-10 perimeter (2' deep)
- f. 80 AFUE Gas Furnace (60 kbtu/h capacity),
- g. 13 Seer A/C - 2 ton
- h. 0.56 EF gas water heater,
- i. RESNET default appliance – gas where applicable
- j. 75% LED's.

2. Option 1, 2, 3 Models: Conceptually these models modify key components and performance to align with the 2018 IECC. All other items are unchanged. The items that change from the baseline models are:

- a. 3 ACH 50
- b. Window U-0.3
- c. 2x6 Advanced Framing, Blown Fiberglass cavity-R-22.5 + R-5 CI
- d. Slab-on-grade also includes R-5 below slab.
- e. Energy Star Appliances – gas included.
- f. 100% LED's, ductwork in conditioned space.

3. **Option 1.1 Model:** This modeled the Option 1 Scenario with the variation of 2" of insulating sheathing in lieu of 1".
4. **Option 1A, 2A, 3A Models:** These models only modify the exterior insulating sheathing thickness and cavity insulation. Cavity insulation is eliminated, 2x4 advanced framing is used, and 4" of rigid insulation is installed outboard of the sheathing.
5. **Option 1B, 2B, 3B Models:** These models utilize DOE ZERH Program Criteria. The following items are modified from the "A" options above:
 - a. 2 ACH 50
 - b. All-electric home
 - c. Air Source Heat Pump (9 HSPF, 16 Seer)
 - d. Balanced ventilation w/recovery
 - e. 2.0 EF Heat pump water heater
 - f. Energy Star Appliances - all electric.
6. **Results:** The following are some key findings regarding the energy modeling strategies for the 3 prototype scenarios.
 - a. Options 1B, 2B, and 3B meet the HERS threshold range of 48 – 55 for the DOE ZERH Program so the prototype concepts of a small home of 1196 sf finished area to a larger home of 2953 sf could achieve ZERH certification if program requirements for better envelope, all electric and efficient systems, water efficiency, etc. are met.
 - b. There was a slight improvement (2%) in overall efficiency to increase the continuous insulation in Option 1 from 1" to 2", but no real meaningful energy advantage to the Option "A" series to implement 4" of exterior CI. However, there are other advantages for builders to consider in this evaluation such as:
 - i. No need for vapor retarder on interior walls which eliminates that scope and detail, allows for electrical routing flexibility and for homeowner modifications over time without impacting the integrity of the wall. This benefit would need to be weighed against the additional costs for increased exterior sheathing thickness and related appurtenances.
 - c. Renewable Energy:
 - i. Utilizing NREL's PVwatts online calculator for communities in each climate zone, it appears that if the home can be oriented with the long roof face within 45 degrees of true south per the requirements of ZERH Program, that varying levels of % production of the home's energy needs can be provided. For the Option 1B home there is enough roof area to produce 100% of the electrical needs on a yearly basis.

									www.pvwatts.nrel.gov					
Energy Information									PV system Energy Production					
Climate Zone 5														
Des Moines, Iowa														
Model	HERS	Heating (kwh/yr)	Cooling (kwh/yr)	Water Heating (kwh/yr)	Lights and Appliances (kwh/yr)	Total (kwh/yr)	Monthly Average (kwh/yr)	% Energy Savings Over Baseline	kwh/yr	6kw	7kw	8kw	9kw	10kw
Baseline 1	96	9525	1260	4132	6787	21704	1809		8636	10075	11514	12953	14392	
Option 1	80	6360	1026	3810	5627	16823	1402	22.5%	kwh/mo -avg	720	840	960	1079	1199
Option 1.1	79	5920	1026	3810	5627	16383	1365	24.5%	area - sf	404	471	538	605	673
Option 1A	80	6272	1026	3810	5627	16735	1395	22.9%	Panels @ 300w	20	23	27	30	33
Option 1B	49	3839	615	879	3733	9066	756	58.2%						
Baseline 2	83	14888	1465	5568	7993	29914	2493							
Option 2	70	10052	1377	5099	6862	23390	1949	21.8%						
Option 2A	71	10697	1377	5099	6862	24035	2003	19.7%						
Option 2B	55	6858	879	1290	4857	13884	1157	53.6%						
Baseline 3	76	18962	1465	5568	8339	34334	2861							
Option 3	67	14654	1407	5187	8199	29447	2454	14.2%						
Option 3A	67	14566	1407	5187	8199	29359	2447	14.5%						
Option 3B	49	7503	879	1319	6077	15778	1315	54.0%						
Energy Modeling Information									PV system Energy Production					
Climate Zone 6														
Waterloo, Iowa														
Model	HERS	Heating (kwh/yr)	Cooling (kwh/yr)	Water Heating (kwh/yr)	Lights and Appliances (kwh/yr)	Total (kwh/yr)	Monthly Average (kwh/yr)	% Energy Savings Over Baseline	kwh/yr	6kw	7kw	8kw	9kw	10kw
Baseline 1	93	12485	967	4396	6759	24607	2051		8420	9823	11226	12629	14033	
Option 1	77	8440	762	4015	5663	18880	1573	23.3%	kwh/mo -avg	702	819	936	1052	1169
Option 1.1	75	7854	762	4015	5663	18294	1525	25.7%	area - sf	404	471	538	605	673
Option 1A	76	8499	733	4015	5663	18910	1576	23.2%	Panels @ 300w	20	23	27	30	33
Option 1B	50	5363	381	938	4073	10755	896	56.3%						
Baseline 2	83	17086	1465	5803	7975	32329	2694							
Option 2	67	13393	1026	5480	6927	26826	2236	17.0%						
Option 2A	69	14214	1055	5480	6927	27676	2306	14.4%						
Option 2B	55	9671	557	1436	5057	16721	1393	48.3%						
Baseline 3	76	22244	1143	5891	9320	38598	3217							
Option 3	64	19782	1026	5568	8078	34454	2871	10.7%						
Option 3A	64	19636	1026	5568	8078	34308	2859	11.1%						
Option 3B	49	10785	557	1436	6077	18855	1571	51.2%						
									www.pvwatts.nrel.gov					

Figure 4: Energy Modeling Scenarios Summary

D. Educational: The project has been presented at two conferences in 2020. Additional conferences for key audiences will continue to be pursued to expand the educational benefit of the project. A Powerpoint presentation is being developed with additional graphics for use at future presentations by BNIM and / or IEDA. The two conferences below were engaged in 2020.

- The Iowa Ideas Conference October 15, 2020
- The Iowa energy Summit November 10, 2020

Costs Analysis

The cost analysis includes what is believed to be the cost of the home if built in Iowa in 2021. These costs are estimated based on \$/sf data extrapolated from a NAHB 2020 review of 2019 national survey data along with recent local data from a comparable home project to be built in Western Iowa and a home recently purchased in Waukee. All data has been inflated to 2021 dollars and increases have been included for recent reports of increases in framing and other lumber items across the country. Figure 5 is a summary of calculated construction and sales costs in \$/sf for the referenced homes applied to the

prototype homes finished floor areas as a range of probable 2021 costs. These costs are projected estimates only, they do not reflect actual bids and could vary from reality. Figure 6: represents the data with modifications of the NAHB National Study – Ford, Carmel; *Cost of Constructing a Home, Special Studies January 2, 2020*, NAHB Economics Policy Group, www.nahb.org.

NAHB Survey Data <i>NAHB data from Figure 7 data and appendix report</i>	2019 data		2020	2021	2021 Lumber adjustment
Average Finished Floor Area	2594				
Construction Cost	\$ 296,652		\$ 307,034.82	\$ 317,781.04	\$ 364,210.24
\$/sf calculated on finished area	\$ 114.36		\$ 118.36	\$ 122.51	\$ 140.40
Total Sale Price of Home <i>Includes total costs including land and other overhead, profit, etc.</i>	\$ 485,127		\$ 502,106	\$ 519,680	\$ 566,109.37
\$/sf calculated on finished area	\$ 187.02				\$ 218.24
Comparable Iowa Home - planned build 2021 - Western Iowa					
Finished Floor Area	1100				
	w/bsmt				
Estimated Construction Cost	\$ 185,000				
\$/sf calculated on finished area	\$ 168.18	Construction only			
Total Sale Price Estimate <i>Includes total costs including land assumptions, overhead, etc.</i>	\$ 251,250				
	w/bsmt				
\$/sf calculated on finished area	\$ 228.41	Sale Price			
Comparable Home - Waukee, Iowa					
	2019		2020	2021	
Finished Floor Area	1643		3.50%	3.50%	
Sale Price	\$ 338,000		\$ 349,830.000	\$ 362,074.05	
\$/sf finished area (has basement)	\$ 205.72		\$ 212.92	\$ 220.37	
Range used to estimate probable costs for IEDA Prototype Home Concepts					
Construction Cost Range	\$ 142.25		\$ 172.25		
Sale Price Range	\$ 220.25		\$ 232.25		
<i>Includes Incremental ZERH Costs noted below</i>					
Cost Ranges for Prototype Homes					
			Option 1B	Option 2B	Option 3B
Area			1196	1841	1841
Construction cost range	\$ 142.25		\$ 170,131	\$ 261,882	\$ 261,882
	\$ 172.25		\$ 206,011	\$ 317,112	\$ 317,112
Sale Price Range	\$ 220.25		\$ 263,419	\$ 405,480	\$ 405,480
	\$ 232.25		\$ 277,771	\$ 427,572	\$ 427,572
Sale Price Accounting for no basement (1B,2B)	\$ (8,000)		\$ 255,419	\$ 397,480	\$ 405,480
	\$ (12,000)		\$ 265,771	\$ 415,572	\$ 427,572
ZERH Incremental Costs					
		2015	2019	2020	2021
Incremental Costs					
2012 IECC to ZERH		\$ 4,403	\$ 4,557	\$ 4,717	\$ 4,882
finishe area	2200			\$/sf	\$ 2.22

Figure 5: Cost Calculations – green areas have been added – not from NAHB

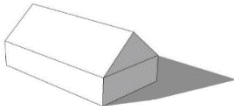
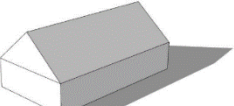
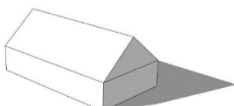
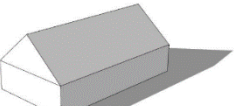
2019 National NAHB Results source: Ford, Carmel: Cost of Constructing a Home, January 2, 2020						Areas shaded in green were not in NAHB report			
						\$ /sf finished area			
Average Lot Size					22094				
Average Finished Area					2594				
							3.5%	3.5% framing	
Site and Overall Costs							2019	2020	2021 2021 adj
Finishes Lot Cost - including financing cost									
Total Construction Cost									
Financing Cost									
Overhead and General Expenses									
Marketing Cost									
Sales commission									
Profit									
Total Sale Price									
Increased Costs for Inflation									
Total 2020 Sales Price									
Total 2021 Sales Price									
2021 Market Increases in wood									
NAHB Construction Cost Breakdown									
Site Work									
Building Permit Fees									
Impact Fee									
Water / Sewer Inspection Fees									
Architecture / Engineering Fees									
Other									
Sitework total									
Foundations									
Excavation, Foundation, Concrete, Retaining walls, Backfill									
Other									
Foundations total									
Framing									
Framing - including roof									
Trusses - if not included above									
Sheathing - if not included above									
General Metal - Steel									
Other									
Framing total									
Exterior Finishes									
Exterior Wall Finish									
roofing									
Windows and Doors - including garage door									
Other									
Exterior Finishes total									
Major Systems Rough-ins									
Plumbing - except fixtures									
Electrical - except fixtures									
HVAC									
Other									
Major Systems Rough-ins total									
Interior Finishes									
Insulation									
Drywall									
Interior Trims, Doors, and Mirrors									
Painting									
Lighting									
Cabinets and Countertops									
Appliances									
Flooring									
Plumbing Fixtures									
Fireplace									
Other									
Interior Finishes total									
Final Steps									
Landscaping									
Outdoor Structures									
Driveway									
Clean up									
Other									
Final Steps total									
Other Total									
Total Construction									

Figure 7: NAHB 2019 Const. Cost Data – green areas have been added – not from NAHB

Orientation

- A. The most efficient Option 1B was utilized to study the impact of orientation and placement of windows on the energy performance of the home. The modeling demonstrates that the optimal design of a higher percentage of windows in the living space oriented south as designed in the concept plan consumes the least amount of yearly energy. Increasing windows from the concept plan on the south façade consumes slightly more energy and moving windows from the south to other sides consumes slightly more energy as well. In short, as these studies indicate, the energy impact of orientation and some modifications of fenestration is modest for the prototype plan. Further study could model the impact of U-Value alone on the optimal design and also consider beginning the analysis with no fenestration and gradually increasing percentage of windows for different façade orientations.

Prototype Option 4 (Optimized Orientation)

	HERS Index Heating Cooling Water Heating Lights and Appliances Total	49 3839 kWh/yr 615 kWh/yr 879 kWh/yr 3722 kWh/yr 9067 kWh/yr
Oriented Per Plans		
	HERS Index Heating Cooling Water Heating Lights and Appliances Total	50 3927 kWh/yr 615 kWh/yr 879 kWh/yr 3722 kWh/yr 9143 kWh/yr
Rotated 90		
	HERS Index Heating Cooling Water Heating Lights and Appliances Total	50 4015 kWh/yr 557 kWh/yr 879 kWh/yr 3722 kWh/yr 9173 kWh/yr
Rotated 180		
	HERS Index Heating Cooling Water Heating Lights and Appliances Total	50 4015 kWh/yr 586 kWh/yr 879 kWh/yr 3722 kWh/yr 9202 kWh/yr
Rotated 270		

Prototype Option 4A (Optimized Orientation & Glazing Location)





	HERS Index Heating Cooling Water Heating Lights and Appliances Total	50 3898 kWh/yr 615 kWh/yr 879 kWh/yr 3722 kWh/yr 9114 kWh/yr
Move Single North Window to South Facade		
	HERS Index Heating Cooling Water Heating Lights and Appliances Total	50 3956 kWh/yr 586 kWh/yr 879 kWh/yr 3722 kWh/yr 9143 kWh/yr
Move Double South Window to North Facade		
	HERS Index Heating Cooling Water Heating Lights and Appliances Total	51 3986 kWh/yr 645 kWh/yr 879 kWh/yr 3722 kWh/yr 9232 kWh/yr
Additional Double Window on South Facade		
	HERS Index Heating Cooling Water Heating Lights and Appliances Total	51 4015 kWh/yr 615 kWh/yr 879 kWh/yr 3722 kWh/yr 9231 kWh/yr
Additional Double Window West Facade		

Figure 8. Model analysis impact on orientation and fenestration

Summary:

A. The summary data for Option 1B follows in Figures 9 and 10.

- a. Design built to ZERH standards could balance energy consumption with roof-mounted PV production.
- b. Sacrifices for a compact plan, no basement, and resultant lower energy consumption are:
 - i. Lack of walk-in closet and overall storage space
 - ii. Universal design strategies, providing more gracious clearances within a small footprint, reduces storage space / potential small study or ½ bath opportunities.
- c. Design Opportunities
 - i. The plan allows for very flexible re-orientation on various sites and allows for a small addition as shown in orange below. Energy modeling was not completed for this option and would require future study.
 - ii. The base plan Option 1B should be modeled to review if the increased energy consumption of a conditioned basement can maintain a realistic balance of PV to achieve net zero.

Energy Information									PV system Energy Production					
Climate Zone 5		Des Moines, Iowa							6kw	7kw	8kw	9kw	10kw	
Model	HERS	Heating (kwh/yr)	Cooling (kwh/yr)	Water Heating (kwh/yr)	Lights and Appliances (kwh/yr)	Total (kwh/yr)	Monthly Average (kwh/yr)	% Energy Savings Over Baseline	kwh/yr	8636	10075	11514	12953	14392
Baseline 1	96	9525	1260	4132	6787	21704	1809		kwh/mo -avg	720	840	960	1079	1199
Option 1B	49	3839	615	879	3733	9066	756	58.2%						
Energy Modeling Information									PV system Energy Production					
Climate Zone 6		Waterloo, Iowa							6kw	7kw	8kw	9kw	10kw	
Model	HERS	Heating (kwh/yr)	Cooling (kwh/yr)	Water Heating (kwh/yr)	Lights and Appliances (kwh/yr)	Total (kwh/yr)	Monthly Average (kwh/yr)	% Energy Savings Over Baseline	kwh/yr	8420	9823	11226	12629	14033
Baseline 1	93	12485	967	4396	6759	24607	2051		kwh/mo -avg	702	819	936	1052	1169
Option 1B	50	5363	381	938	4073	10755	896	56.3%						
Cost Ranges for Prototype Homes							Option 1B							
Area							1196							
Construction cost range						\$ 142.25	\$ 170,131							
						\$ 172.25	\$ 206,011							
Sale Price Range						\$ 220.25	\$ 263,419							
						\$ 232.25	\$ 277,771							
Sale Price Accounting for no basement (1B,2B)						\$ (8,000)	\$ 255,419							
						\$ (12,000)	\$ 265,771							

Figure 9. Summary data – Option 1B

Summary continued:

- iii. The small plan is the most “affordable” option largely because of its modest size and simple shape. This could make the house attractive for independent seniors or first-time buyers that can grow into a basement or small at-grade addition. Also, the trusses could be installed as attic trusses and not finished initially to reduce first costs but allow for future growth.

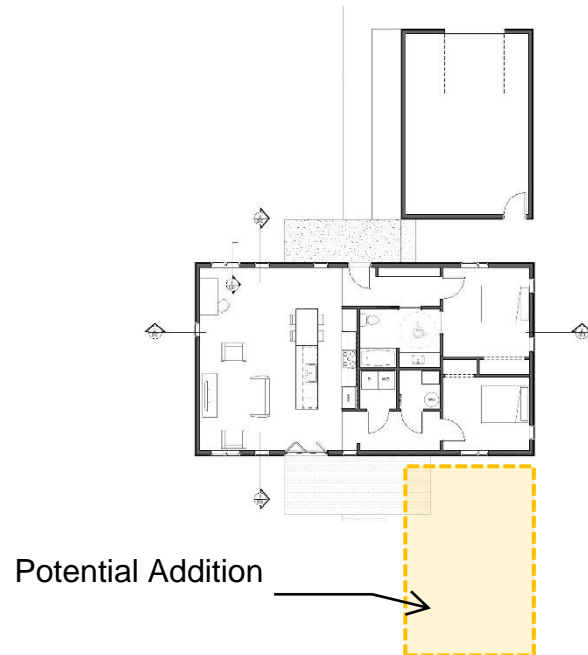
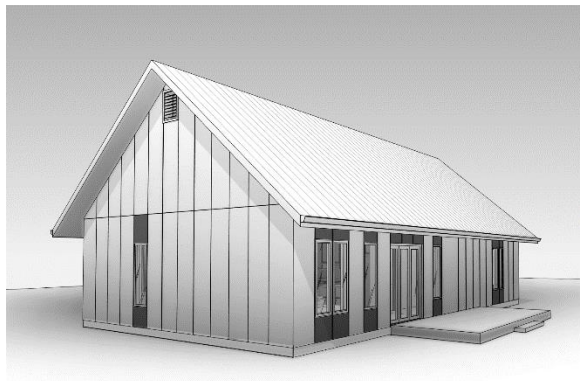


Figure 10. Summary concept – Option 1B

Reference List:

1. Ford, Carmel; *Cost of Constructing a Home*, Special Studies, NAHB Economics and Housing Policy Group, January 2, 2020, www.nahb.org (Accessed April 26, 2021)
2. Iowa Economic Development Authority (IEDA), *Iowa Green Streets Criteria*, **Post Nov. 1, 2020** www.iowaeda.com (Accessed April 26, 2021)
3. NREL, www.pvwatts.nrel.gov (Accessed April 26, 2021)
4. US Department of Energy (DOE), *DOE Zero Energy Ready Home – National Program Requirements (REV.07)*, **May 1, 2019**, www.buildings.energy.gov/zero (Accessed April 26, 2021)
5. US Department of Energy (DOE), *DOE Zero Energy Ready Home – Savings & Cost Estimate Summary*, **October 2015**, www.buildings.energy.gov/zero (Accessed April 26, 2021)

APPENDICES

- The Element Group - Energy Consumption Modeling Report
- DOE ZERH National Program Requirements
www.buidlings.energy.gov/zero
- DOE ZERH – Savings and Cost Estimate Summary – October **2015**
www.buidlings.energy.gov/zero
- Ford, Carmel ; Cost of Constructing a Home Special Studies NAHB
Economics Housing and Policy Group, January 2,2020 www.nahb.org

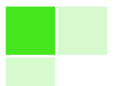
Net Zero Energy Ready Prototype Home

ENERGY CONSUMPTION MODELING REPORT

1.25.2021

Climate Zone 5

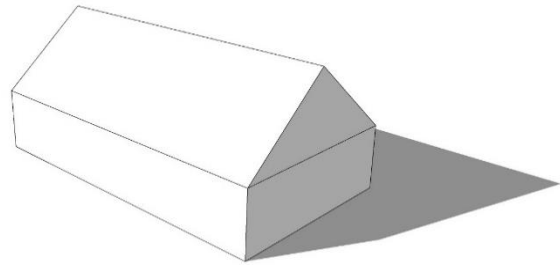
Des Moines, IA



Base Model (for Reference)

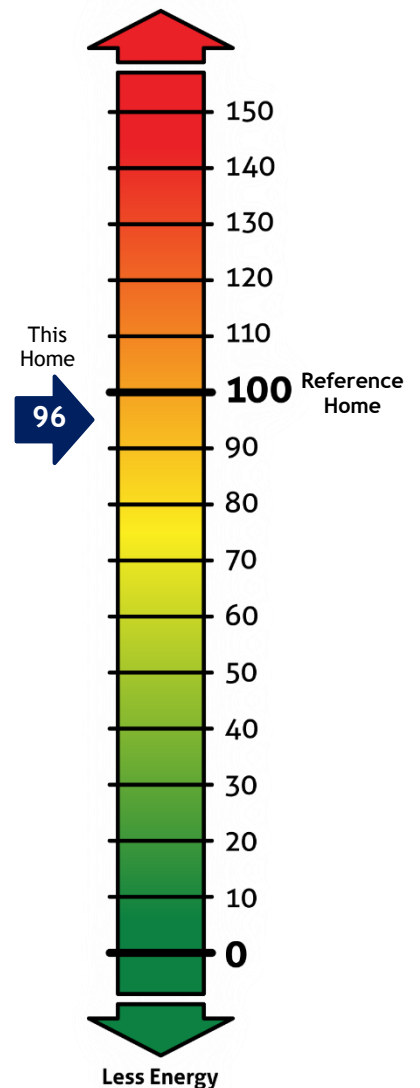
Model Information:

- Single Story, Slab on Grade
- Des Moines, IA (Climate Zone 5)
- 2 Bedroom, 1 Bathroom
- Gross Floor Area = 1196 SF
- 2012 IECC with Iowa Amendments
 - Total Building Leakage = 4 ACH50
 - Window U-Factor = 0.32
 - 2x6 Wood Frame, 16" O.C.
 - R-20 Fiberglass Batt Insulation
 - Ventilated Attic, R-49 Blown Fiberglass
 - Slab on Grade Foundation
 - R-10 Perimeter, 2' Deep
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork Exposed, Insulated Per 2012 IECC
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - RESNET Default Appliances (Natural Gas Where Applicable)
 - 75% LED Lighting Fixtures

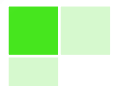
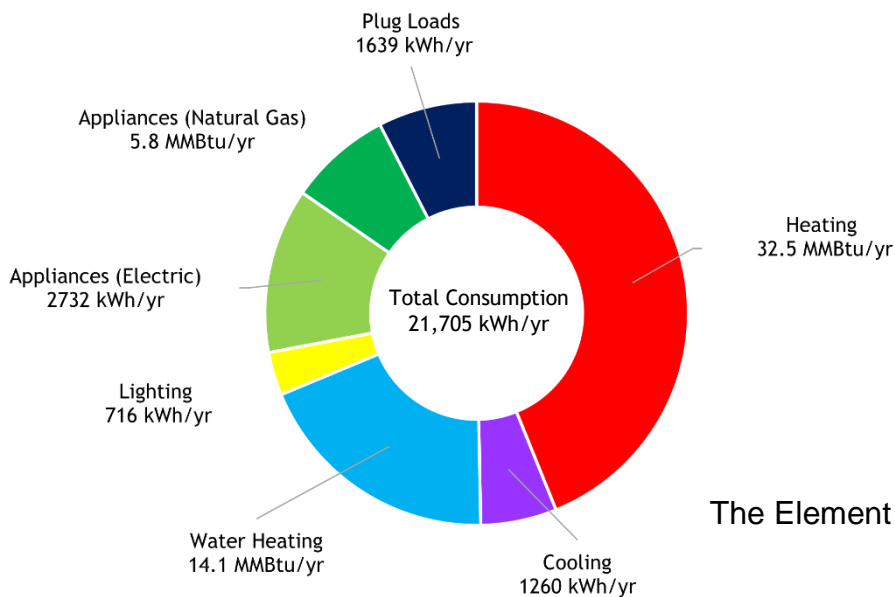


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More Energy



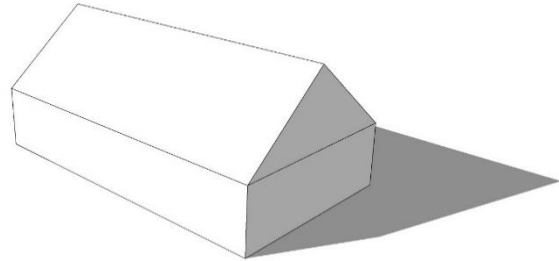
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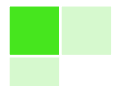
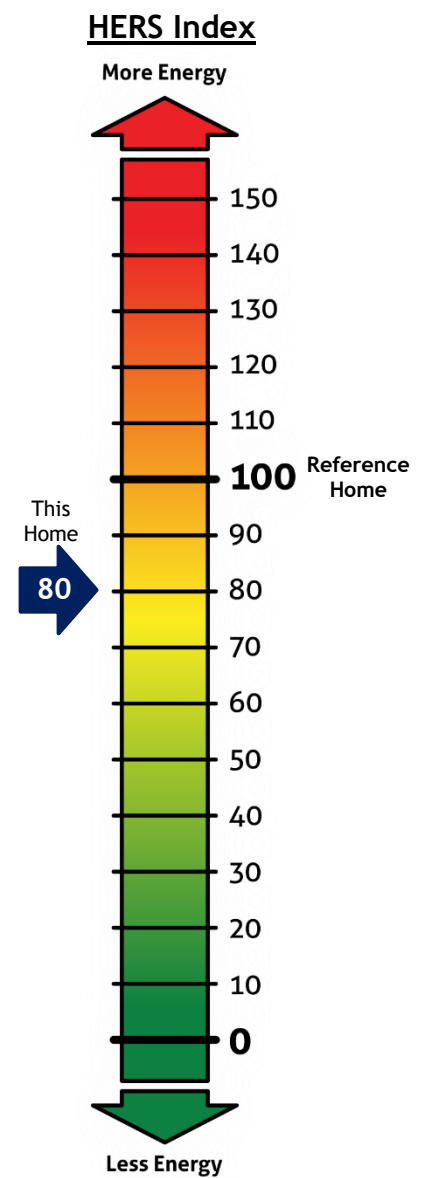
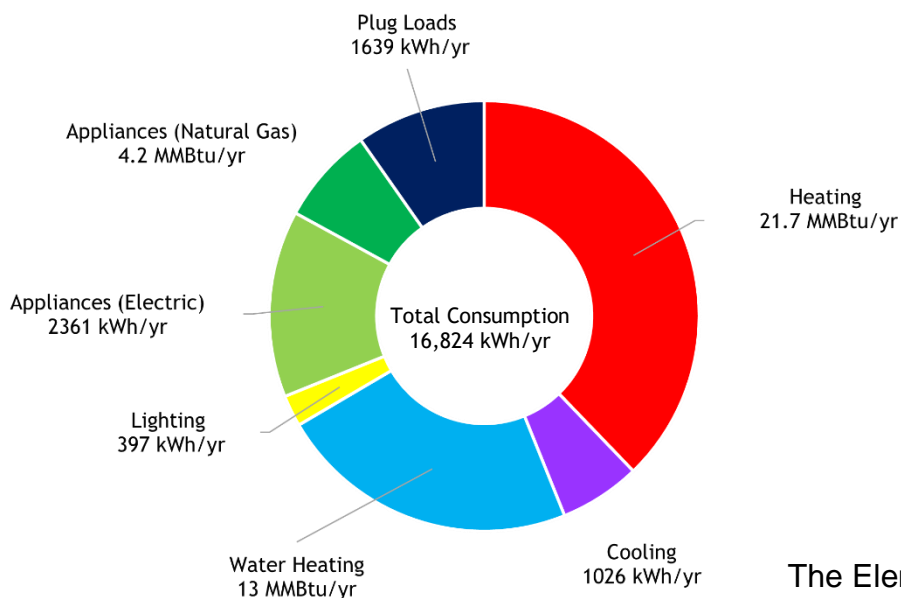
Prototype Option 1

Model Information:

- Single Story, Slab on Grade
- Des Moines, IA (Climate Zone 5)
- 2 Bedroom, 1 Bathroom
- Gross Floor Area = 1196 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30
 - 2x6 Wood Frame, 24" O.C.
 - R-22.5 Blown Fiberglass Cavity, R-5 CI
 - Ventilated Attic, R-49 Blown Fiberglass
 - Slab on Grade Foundation
 - R-10 Perimeter, 2' Deep
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



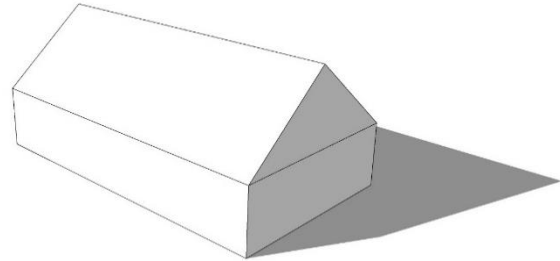
Annual Energy Consumption:



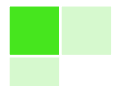
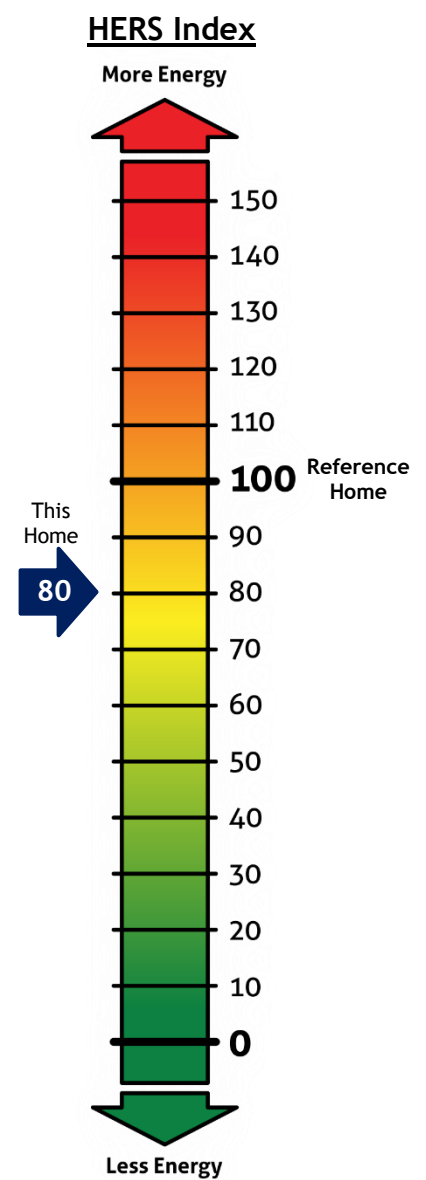
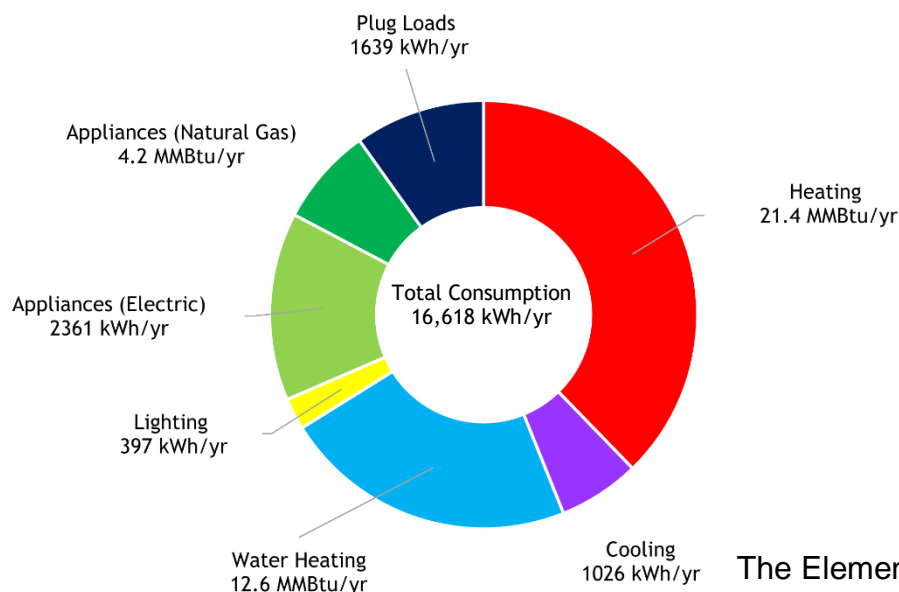
Prototype Option 1A (Modified Envelope)

Model Information:

- Single Story, Slab on Grade
- Des Moines, IA (Climate Zone 5)
- 2 Bedroom, 1 Bathroom
- Gross Floor Area = 1196 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Ventilated Attic, R-49 Blown Fiberglass
 - Slab on Grade Foundation
 - R-10 Perimeter, 2' Deep
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



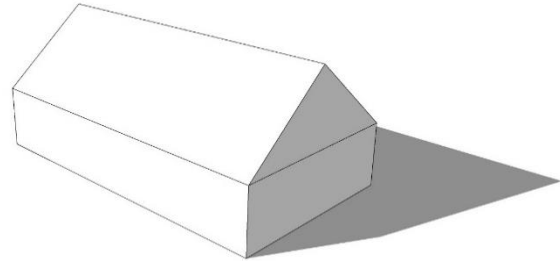
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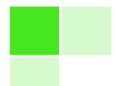
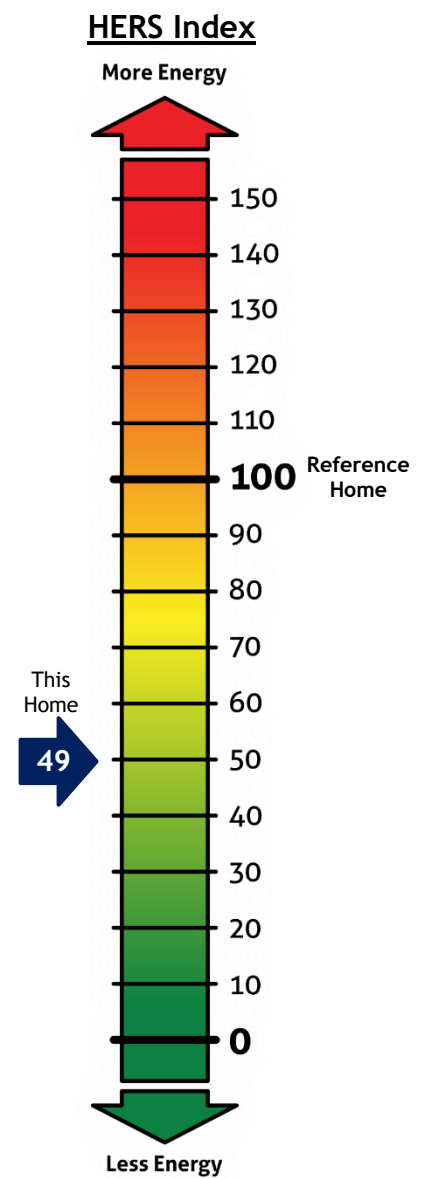
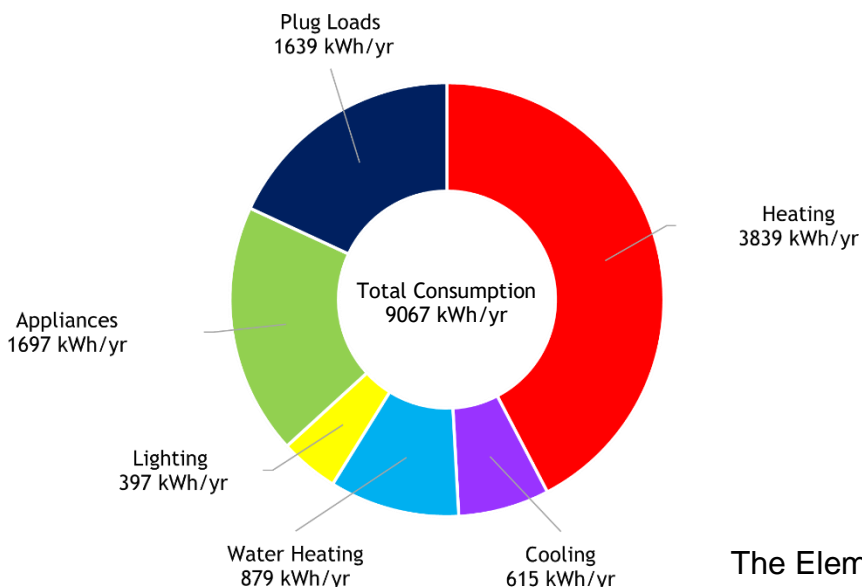
Prototype Option 1B (Modified Envelope & Systems)

Model Information:

- Single Story, Slab on Grade
- Des Moines, IA (Climate Zone 5)
- 2 Bedroom, 1 Bathroom
- Gross Floor Area = 1196 SF
- DOE Net Zero Ready Home
 - Total Building Leakage = 2 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Ventilated Attic, R-49 Blown Fiberglass
 - Slab on Grade Foundation
 - R-10 Perimeter, 2' Deep
 - R-5 Under Slab
 - Energy Star Mechanicals and Appliances
 - All Electric
 - Air Source Heat Pump (9 HSPF, 16 SEER)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - Balanced Ventilation w/ Recovery (SRE 64%)
 - 2.0 EF Heat Pump Water Heater
 - Energy Star Appliances
 - 100% LED Lighting Fixtures



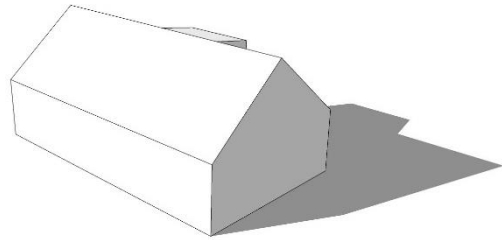
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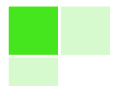
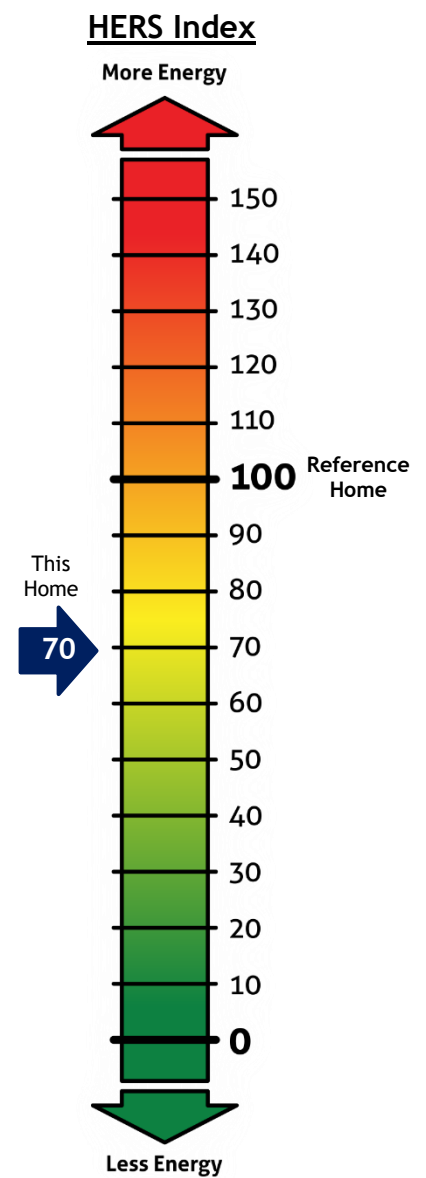
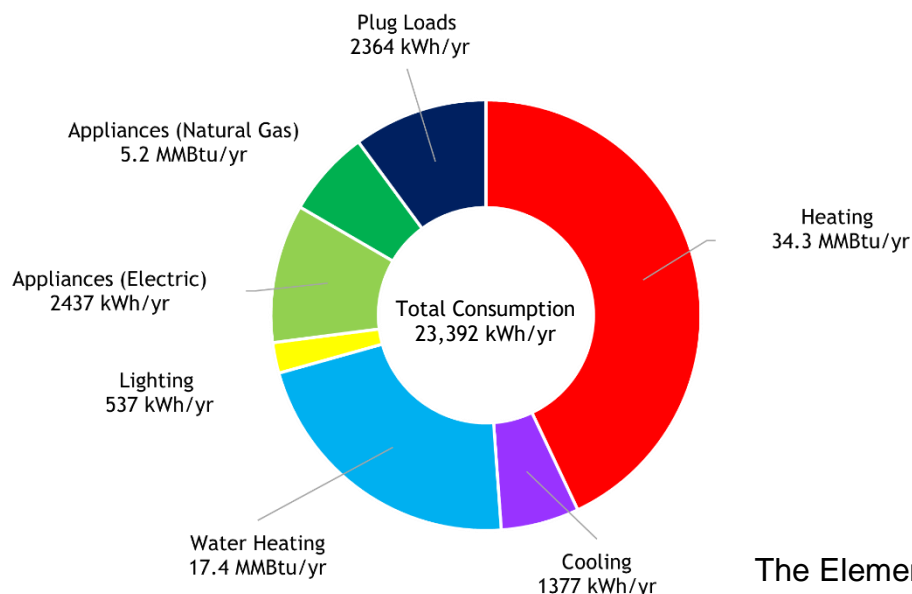
Prototype Option 2

Model Information:

- 1.5 Story, Slab on Grade
- Des Moines, IA (Climate Zone 5)
- 4 Bedroom, 2 Bathroom
- Gross Floor Area = 1841 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30
 - 2x6 Wood Frame, 24" O.C.
 - R-22.5 Blown Fiberglass Cavity, R-5 CI
 - Vaulted Ceiling, R-33.5 CCSP
 - Slab on Grade Foundation
 - R-10 Perimeter, 2' Deep
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



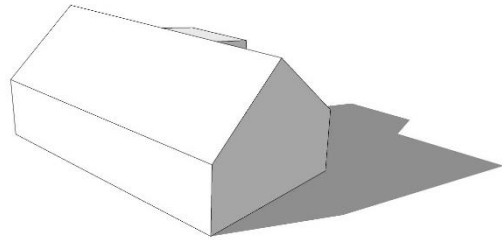
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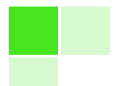
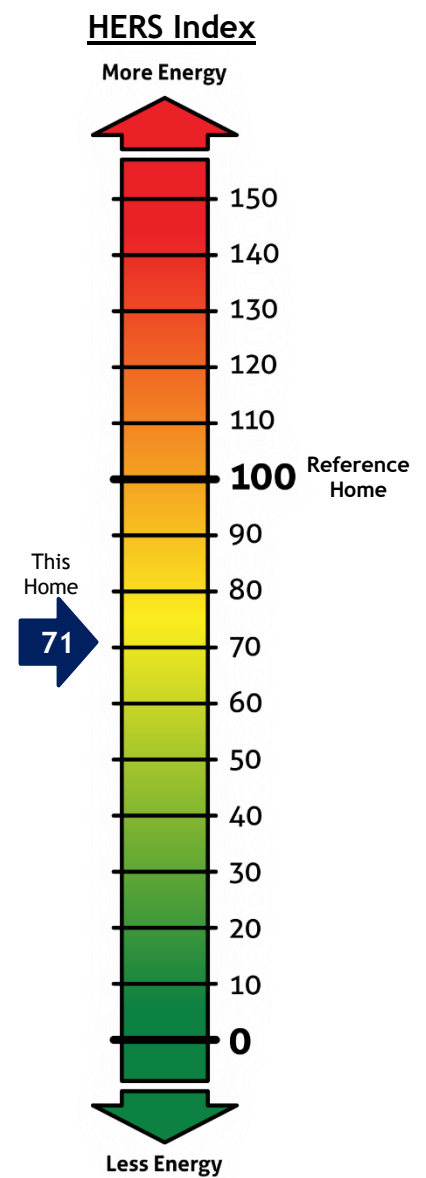
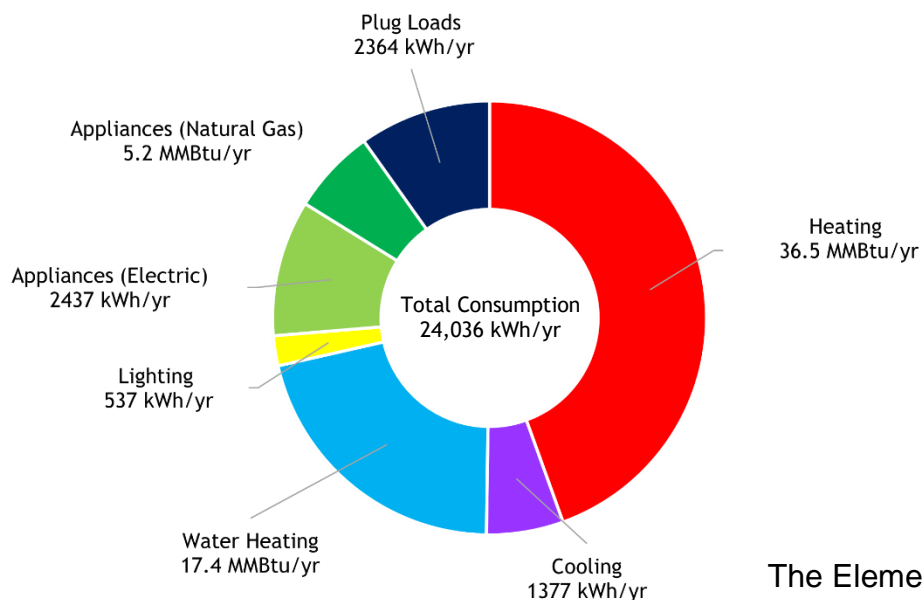
Prototype Option 2A (Modified Envelope)

Model Information:

- 1.5 Story, Slab on Grade
- Des Moines, IA (Climate Zone 5)
- 4 Bedroom, 2 Bathroom
- Gross Floor Area = 1841 SF
- DOE Net Zero Ready Home
 - Total Building Leakage = 2 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Vaulted Ceiling, R-33.5 CCSP
 - Slab on Grade Foundation
 - R-10 Perimeter, 2' Deep
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



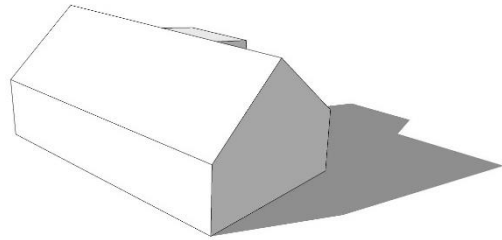
Annual Energy Consumption:



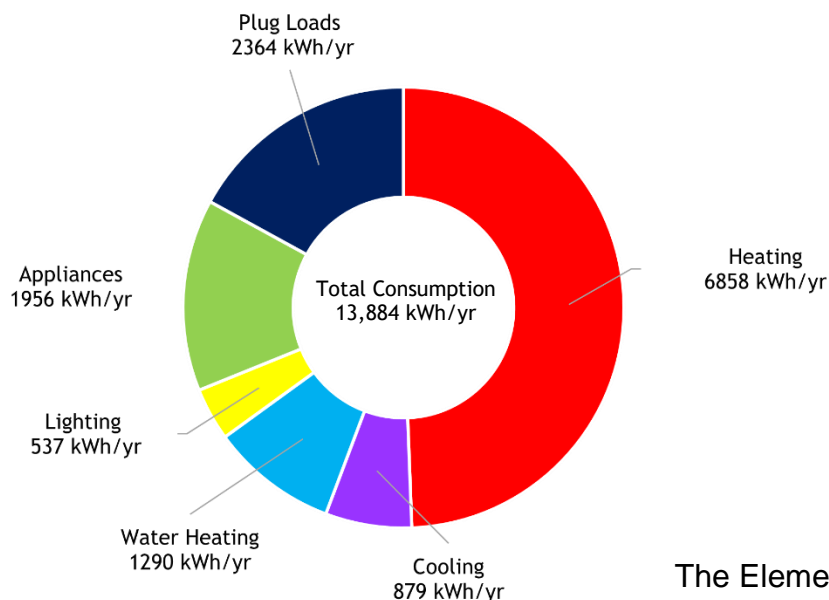
Prototype Option 2B (Modified Envelope & Systems)

Model Information:

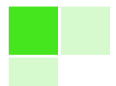
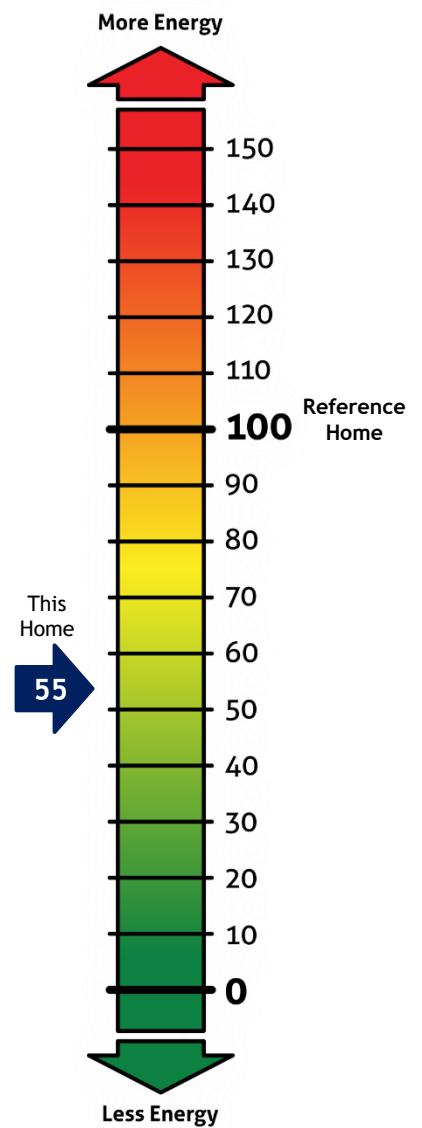
- 1.5 Story, Slab on Grade
- Des Moines, IA (Climate Zone 5)
- 4 Bedroom, 2 Bathroom
- Gross Floor Area = 1841 SF
- DOE Net Zero Ready Home
 - Total Building Leakage = 2 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Vaulted Ceiling, R-33.5 CCSP
 - Slab on Grade Foundation
 - R-10 Perimeter, 2' Deep
 - R-5 Under Slab
 - Energy Star Mechanicals and Appliances
 - Air Source Heat Pump (9 HSPF, 16 SEER)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - Balanced Ventilation w/ Recovery (SRE 64%)
 - 2.0 EF Heat Pump Water Heater, DHW Insulated R-3
 - Energy Star Appliances
 - 100% LED Lighting Fixtures
 - WaterSense Labeled Fixtures



Annual Energy Consumption:



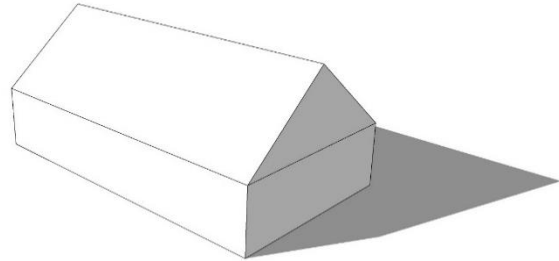
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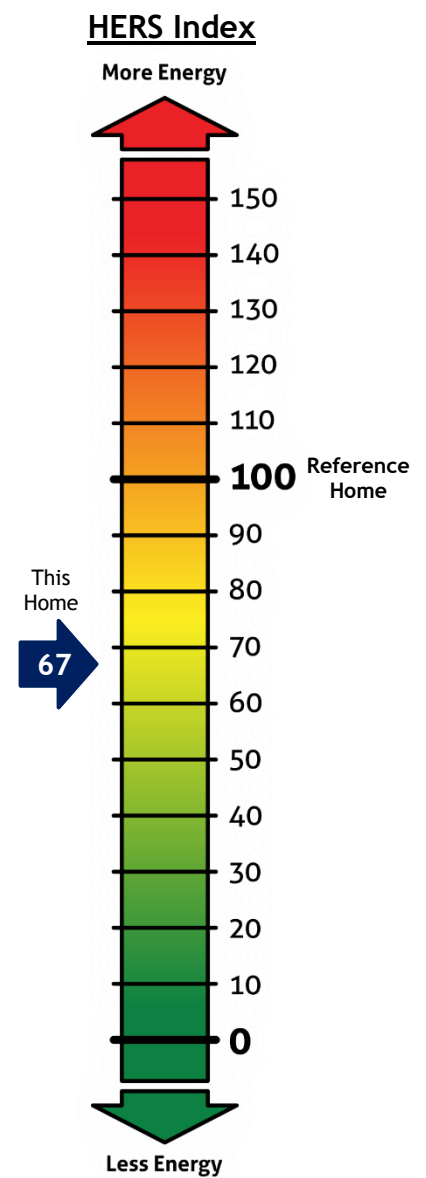
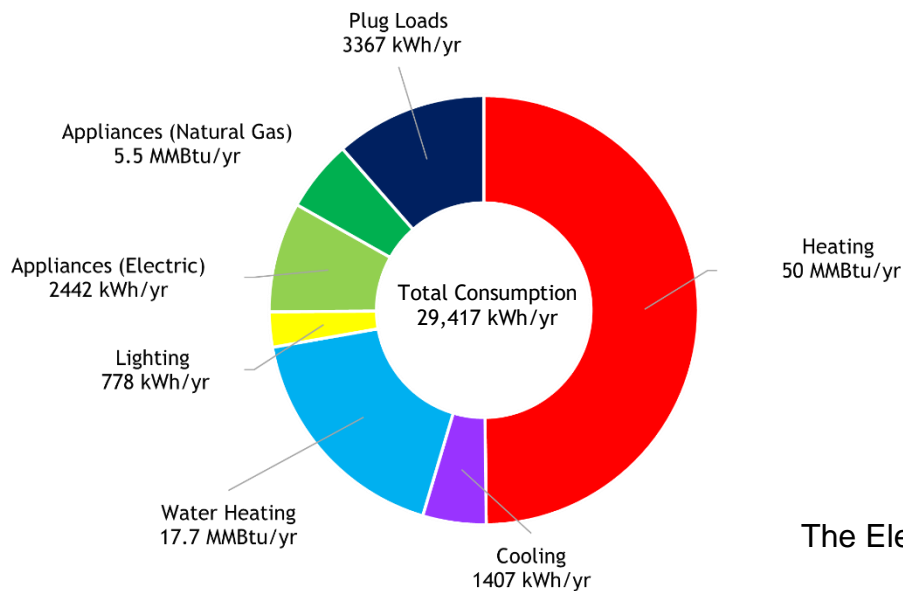
Prototype Option 3

Model Information:

- 2 Story, Finished Basement
- Des Moines, IA (Climate Zone 5)
- 4 Bedroom, 3 Bathroom
- Gross Floor Area = 2943 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30
 - 2x6 Wood Frame, 24" O.C.
 - R-22.5 Blown Fiberglass Cavity, R-5 CI
 - R-20 Closed Cell Spray Foam Rim Joist
 - Vaulted Ceiling, R-33.5 CCSP
 - Basement Foundation
 - R-15 CI Foundation Walls, 8'
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



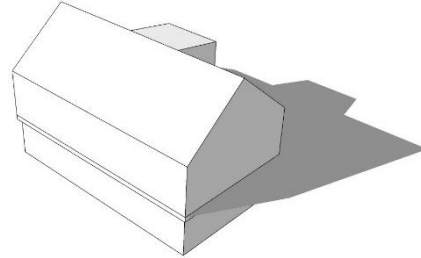
Annual Energy Consumption:



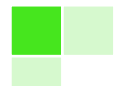
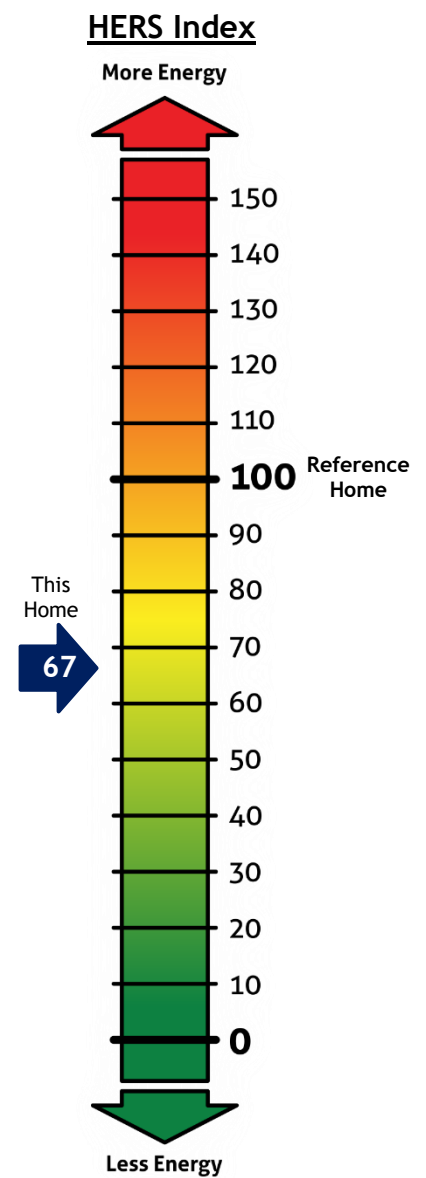
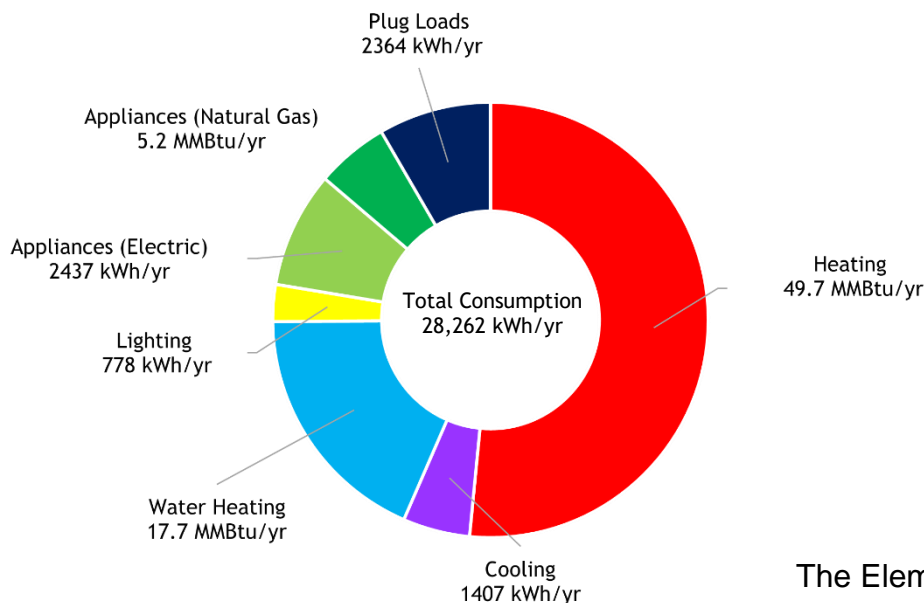
Prototype Option 3A (Modified Envelope)

Model Information:

- 2 Story, Finished Basement
- Des Moines, IA (Climate Zone 5)
- 4 Bedroom, 3 Bathroom
- Gross Floor Area = 2943 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Vaulted Ceiling, R-33.5 CCSP
 - Basement Foundation
 - R-15 CI Foundation Walls, 8'
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



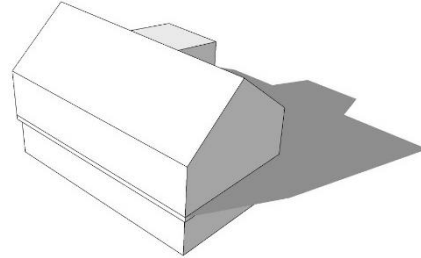
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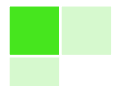
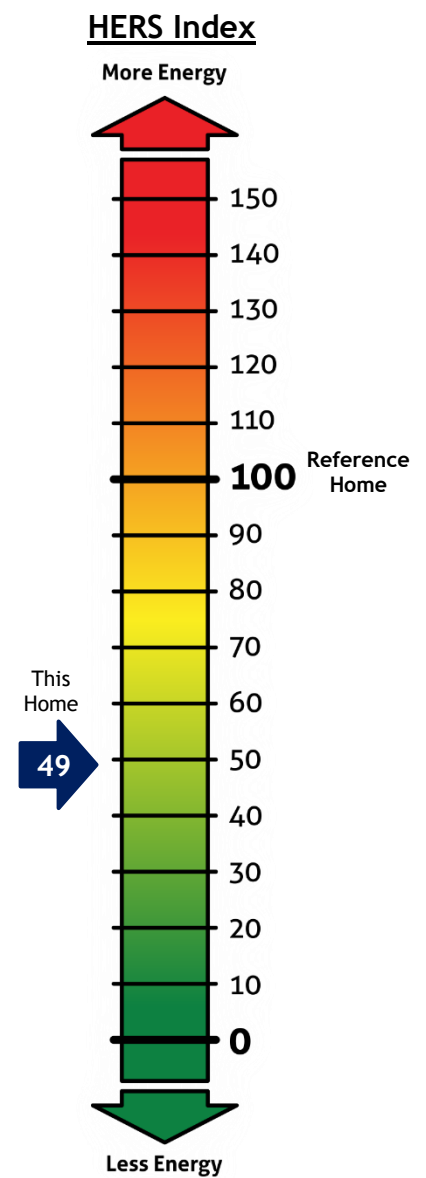
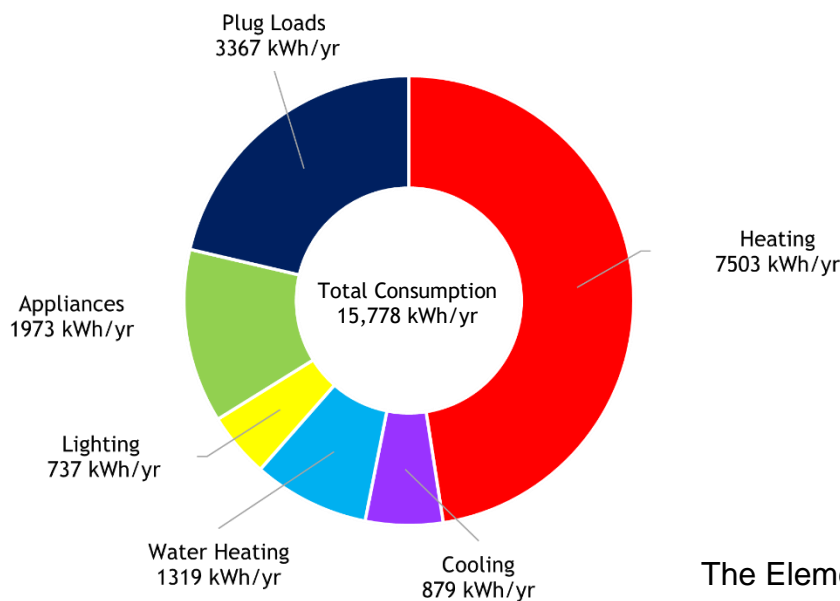
Prototype Option 3B (Modified Envelope & Systems)

Model Information:

- 2 Story, Finished Basement
- Des Moines, IA (Climate Zone 5)
- 4 Bedroom, 3 Bathroom
- Gross Floor Area = 2943 SF
- DOE Net Zero Ready Home
 - Total Building Leakage = 2 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Vaulted Ceiling, R-33.5 CCSP
 - Basement Foundation
 - R-15 CI Foundation Walls, 8'
 - R-5 Under Slab
 - Energy Star Mechanicals and Appliances
 - Air Source Heat Pump (9 HSPF, 16 SEER)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - Balanced Ventilation w/ Recovery (SRE 64%)
 - 2.0 EF Heat Pump Water Heater, DHW Insulated R-3
 - Energy Star Appliances
 - 100% LED Lighting Fixtures
 - WaterSense Labeled Fixtures

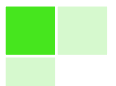


Annual Energy Consumption:



Climate Zone 6

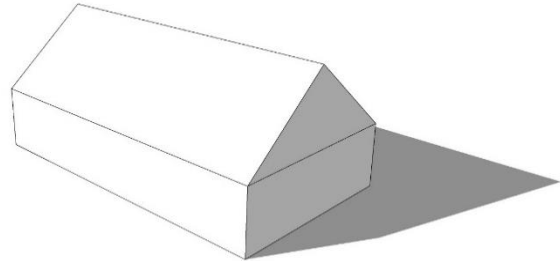
Waterloo, IA



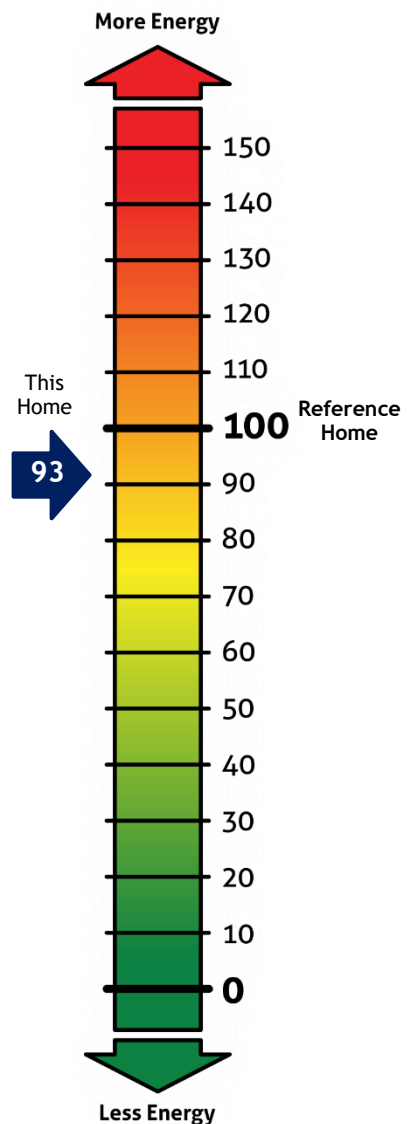
Base Model (for Reference)

Model Information:

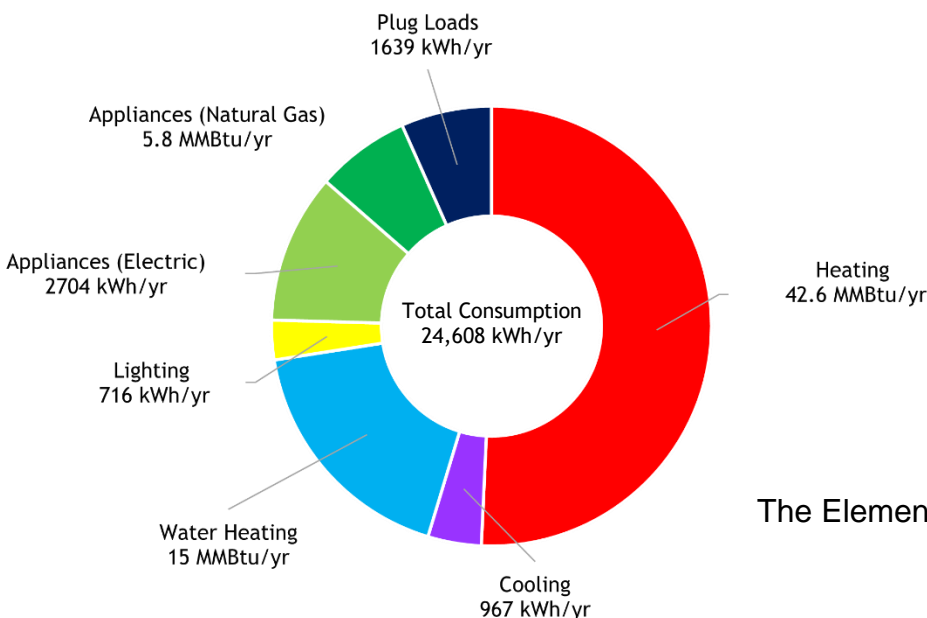
- Single Story, Slab on Grade
- Waterloo, IA (Climate Zone 6)
- 2 Bedroom, 1 Bathroom
- Gross Floor Area = 1196 SF
- 2012 IECC with Iowa Amendments
 - Total Building Leakage = 4 ACH50
 - Window U-Factor = 0.32
 - 2x6 Wood Frame, 16" O.C.
 - R-20 Fiberglass Batt Insulation
 - Ventilated Attic, R-49 Blown Fiberglass
 - Slab on Grade Foundation
 - R-10 Perimeter, 4' Deep
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork Exposed, Insulated Per 2012 IECC
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - RESNET Default Appliances (Natural Gas Where Applicable)
 - 75% LED Lighting Fixtures



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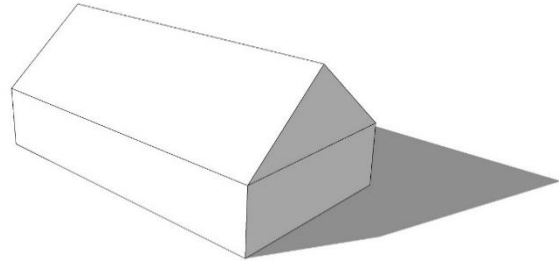
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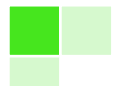
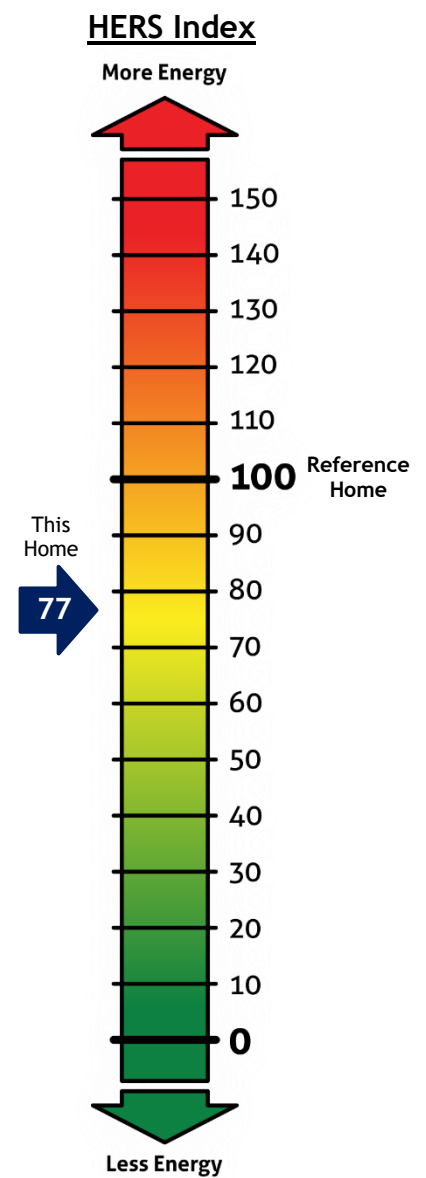
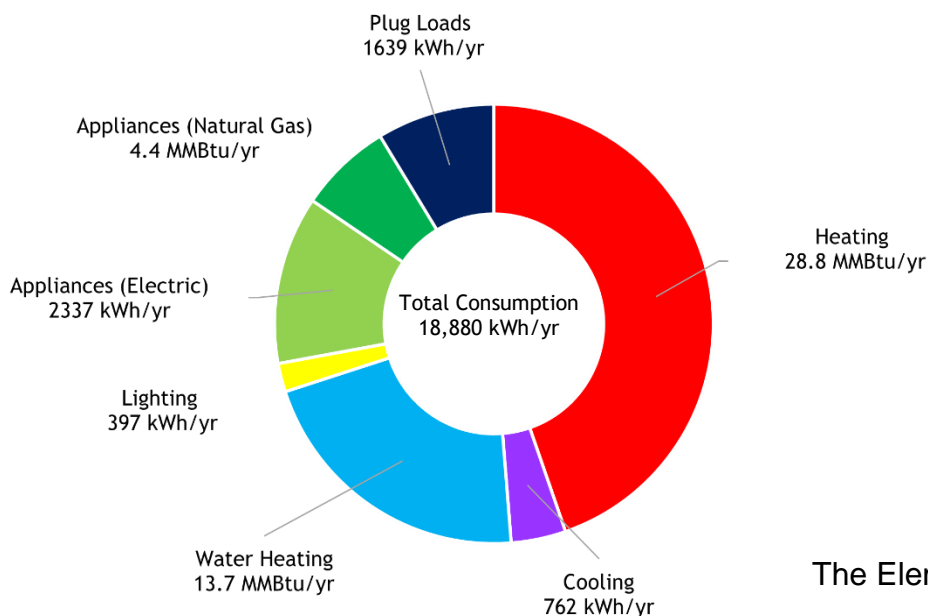
Prototype Option 1

Model Information:

- Single Story, Slab on Grade
- Waterloo, IA (Climate Zone 6)
- 2 Bedroom, 1 Bathroom
- Gross Floor Area = 1196 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30
 - 2x6 Wood Frame, 24" O.C.
 - R-22.5 Blown Fiberglass Cavity, R-5 CI
 - Ventilated Attic, R-49 Blown Fiberglass
 - Slab on Grade Foundation
 - R-10 Perimeter, 4' Deep
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



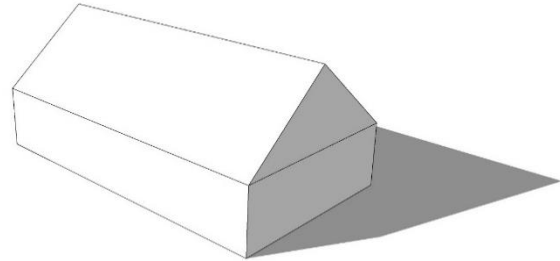
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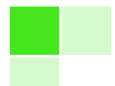
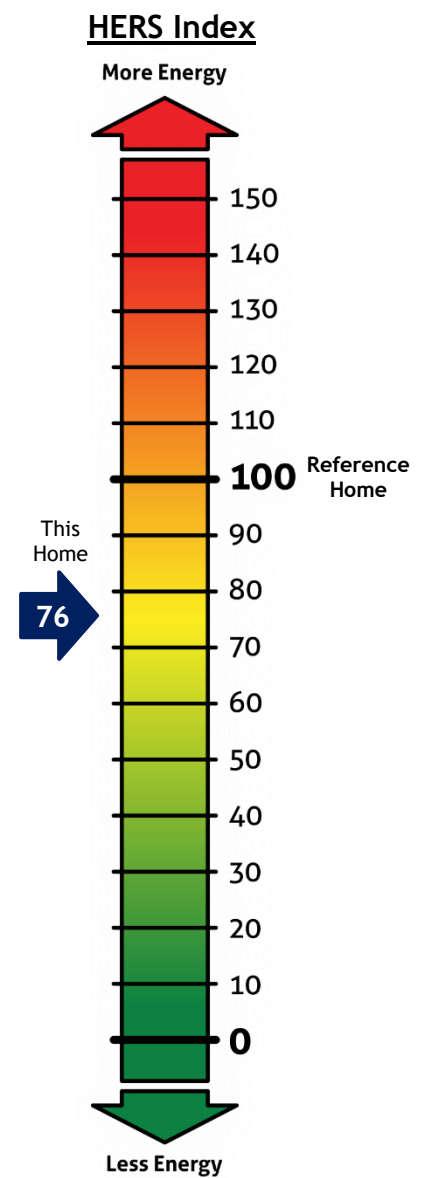
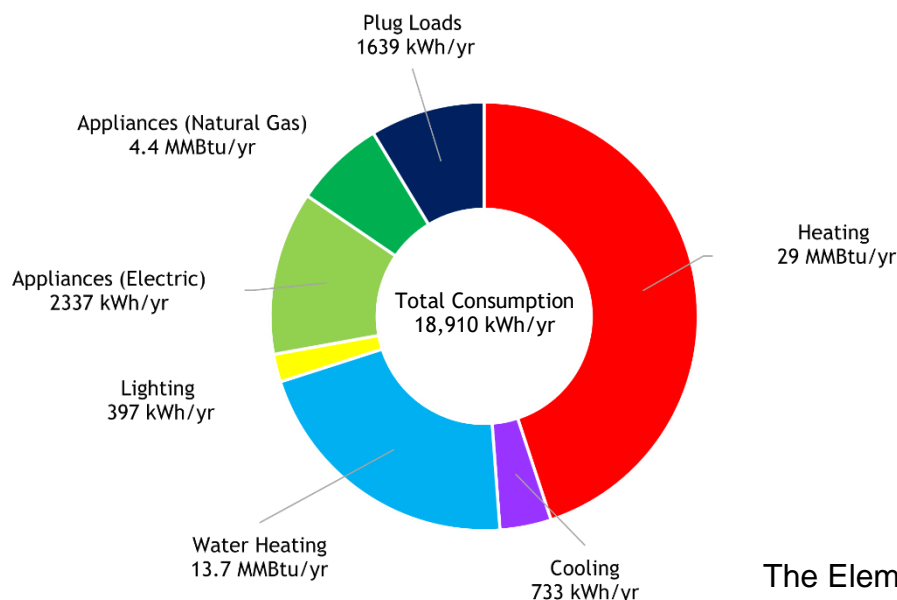
Prototype Option 1A (Modified Envelope)

Model Information:

- Single Story, Slab on Grade
- Waterloo, IA (Climate Zone 6)
- 2 Bedroom, 1 Bathroom
- Gross Floor Area = 1196 SF
- 2018 IECC Code Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Ventilated Attic, R-49 Blown Fiberglass
 - Slab on Grade Foundation
 - R-10 Perimeter, 4' Deep
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



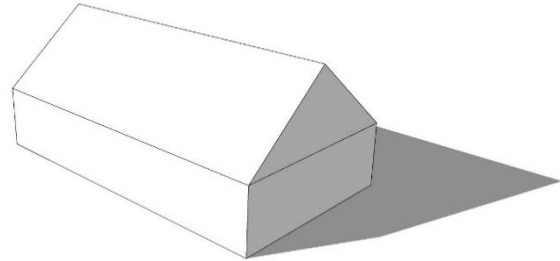
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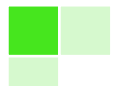
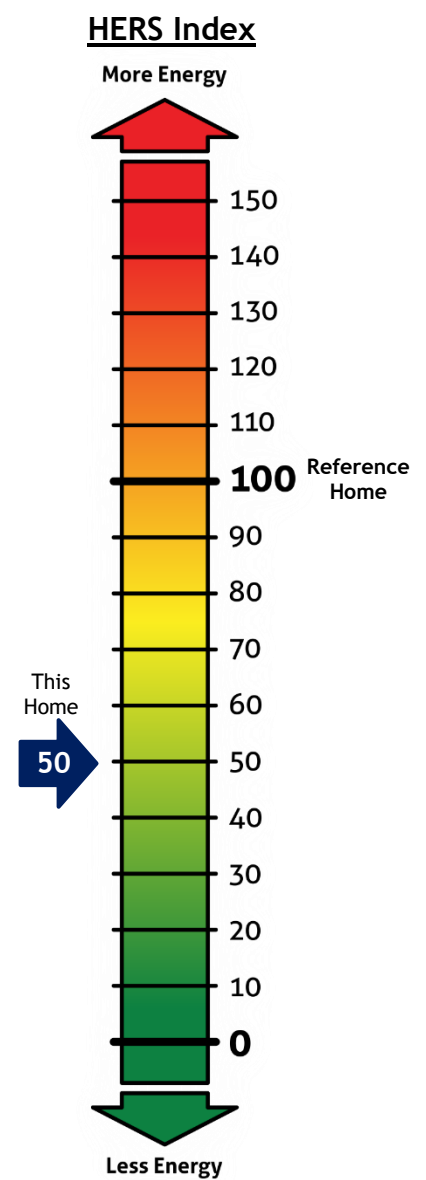
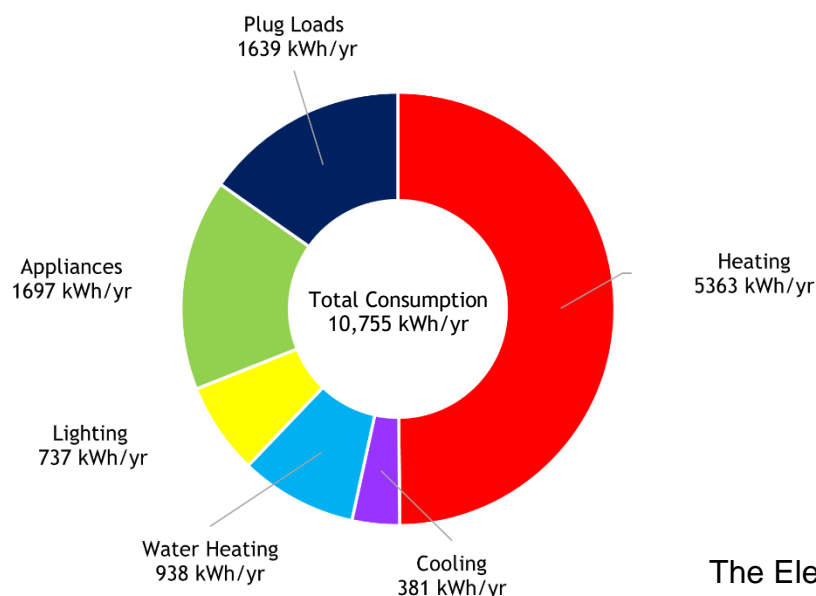
Prototype Option 1B (Modified Envelope & Systems)

Model Information:

- Single Story, Slab on Grade
- Waterloo, IA (Climate Zone 6)
- 2 Bedroom, 1 Bathroom
- Gross Floor Area = 1196 SF
- DOE Net Zero Ready Home
 - Total Building Leakage = 2 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Ventilated Attic, R-49 Blown Fiberglass
 - Slab on Grade Foundation
 - R-10 Perimeter, 4' Deep
 - R-5 Under Slab
 - Energy Star Mechanicals and Appliances
 - All Electric
 - Air Source Heat Pump (9 HSPF, 16 SEER)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - Balanced Ventilation w/ Recovery (SRE 64%)
 - 2.0 EF Heat Pump Water Heater
 - Energy Star Appliances
 - 100% LED Lighting Fixtures



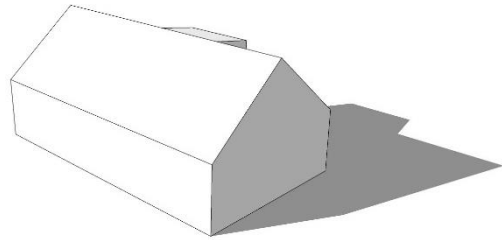
Annual Energy Consumption:



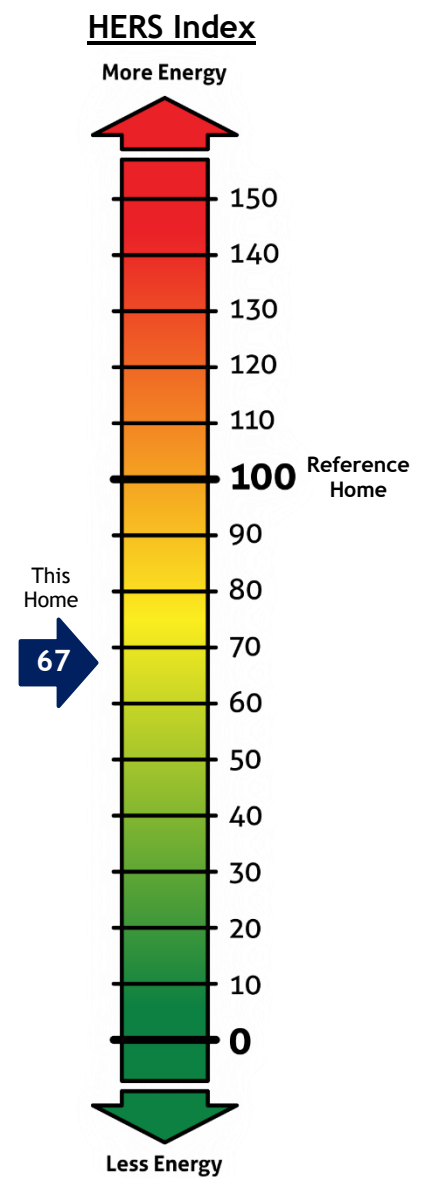
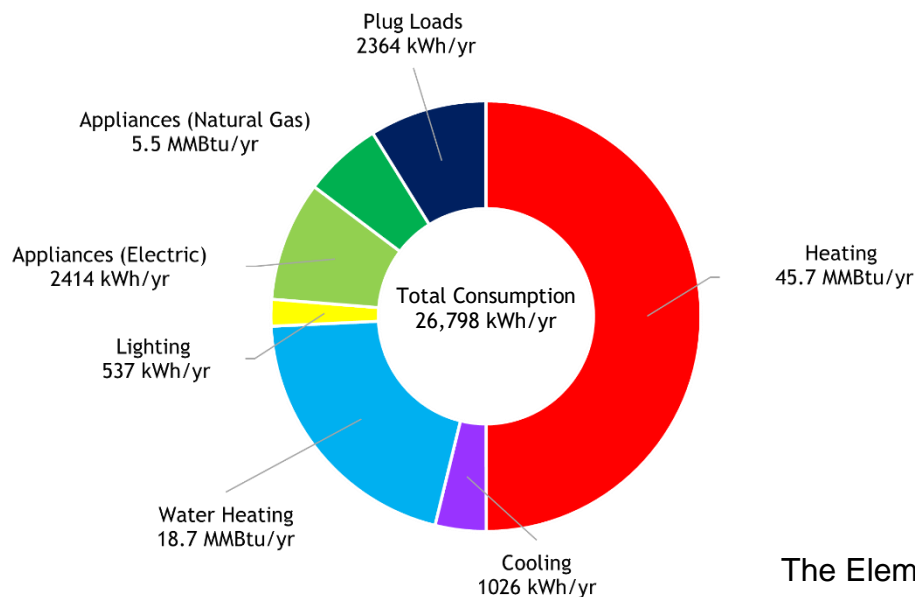
Prototype Option 2

Model Information:

- 1.5 Story, Slab on Grade
- Waterloo, IA (Climate Zone 6)
- 4 Bedroom, 2 Bathroom
- Gross Floor Area = 1841 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30
 - 2x6 Wood Frame, 24" O.C.
 - R-22.5 Blown Fiberglass Cavity, R-5 CI
 - Vaulted Ceiling, R-33.5 CCSP
 - Slab on Grade Foundation
 - R-10 Perimeter, 4' Deep
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



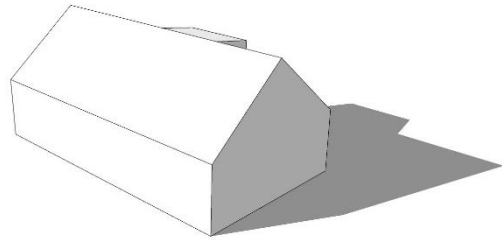
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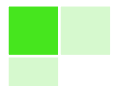
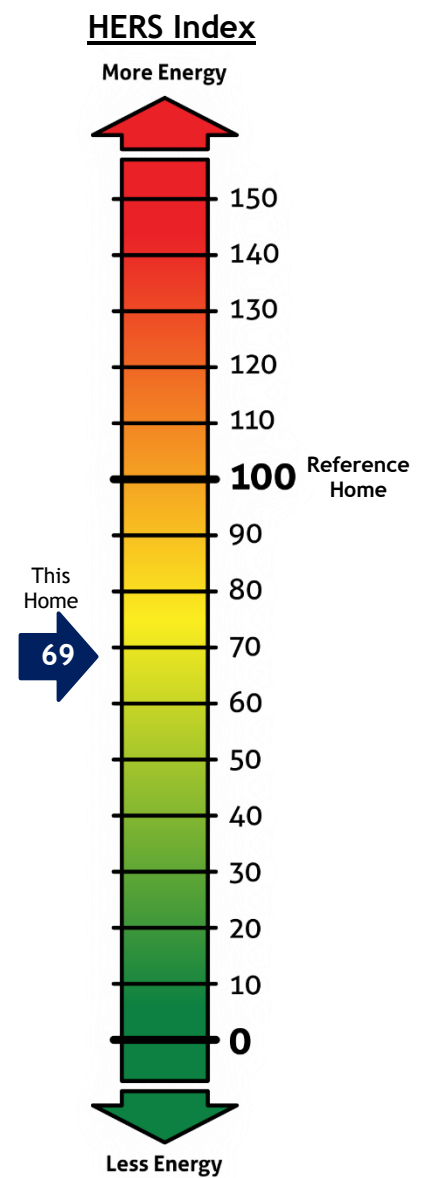
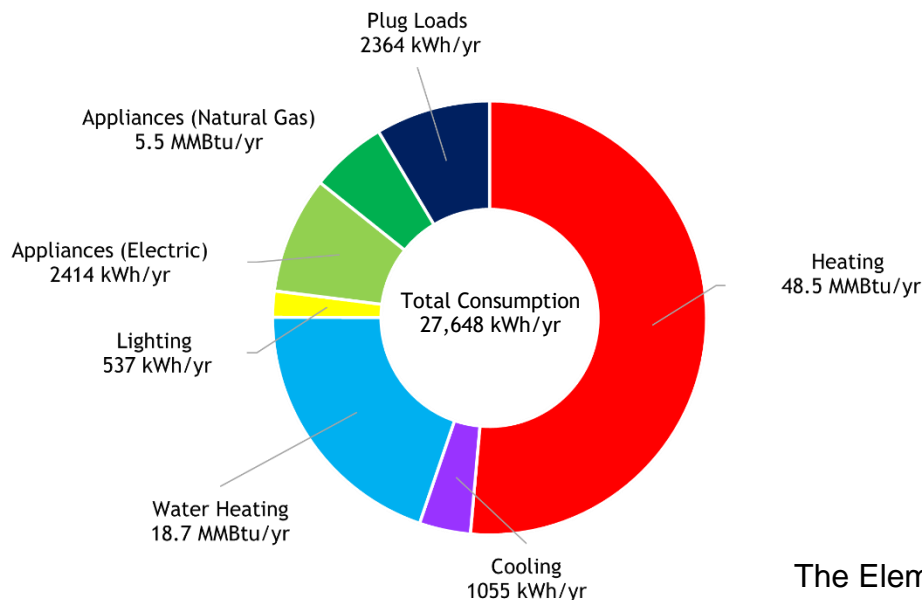
Prototype Option 2A (Modified Envelope)

Model Information:

- 1.5 Story, Slab on Grade
- Waterloo, IA (Climate Zone 6)
- 4 Bedroom, 2 Bathroom
- Gross Floor Area = 1841 SF
- DOE Net Zero Ready Home
 - Total Building Leakage = 2 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Vaulted Ceiling, R-33.5 CCSP
 - Slab on Grade Foundation
 - R-10 Perimeter, 4' Deep
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



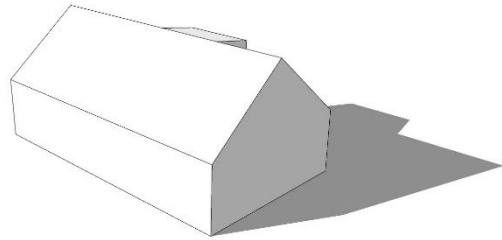
Annual Energy Consumption:



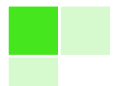
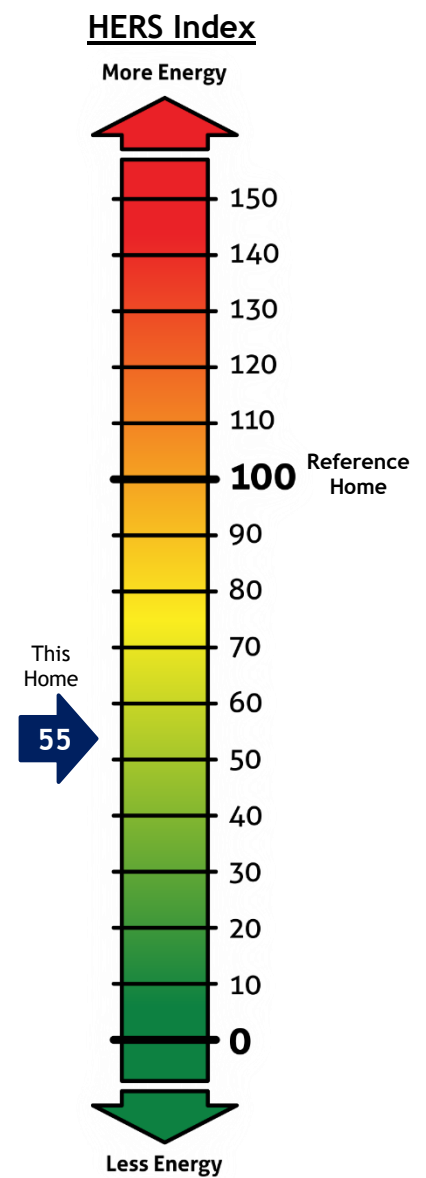
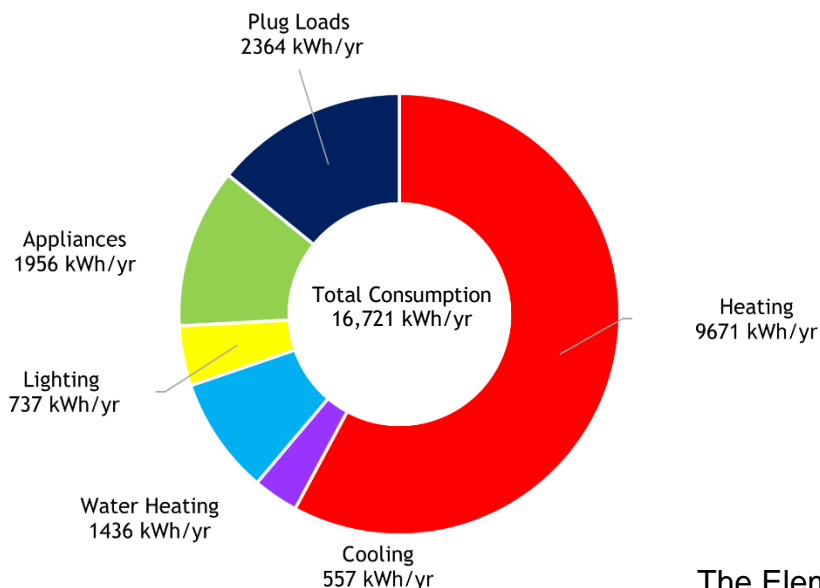
Prototype Option 2B (Modified Envelope & Systems)

Model Information:

- 1.5 Story, Slab on Grade
- Waterloo, IA (Climate Zone 6)
- 4 Bedroom, 2 Bathroom
- Gross Floor Area = 1841 SF
- DOE Net Zero Ready Home
 - Total Building Leakage = 2 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Vaulted Ceiling, R-33.5 CCSP
 - Slab on Grade Foundation
 - R-10 Perimeter, 4' Deep
 - R-5 Under Slab
 - Energy Star Mechanicals and Appliances
 - Air Source Heat Pump (9 HSPF, 16 SEER)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - Balanced Ventilation w/ Recovery (SRE 64%)
 - 2.0 EF Heat Pump Water Heater, DHW Insulated R-3
 - Energy Star Appliances
 - 100% LED Lighting Fixtures
 - WaterSense Labeled Fixtures



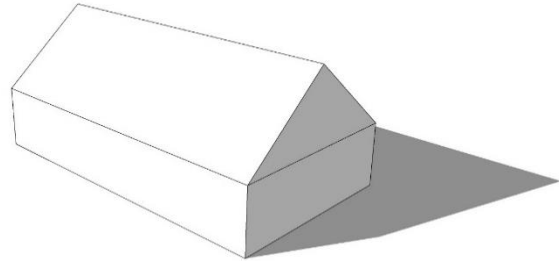
Annual Energy Consumption:



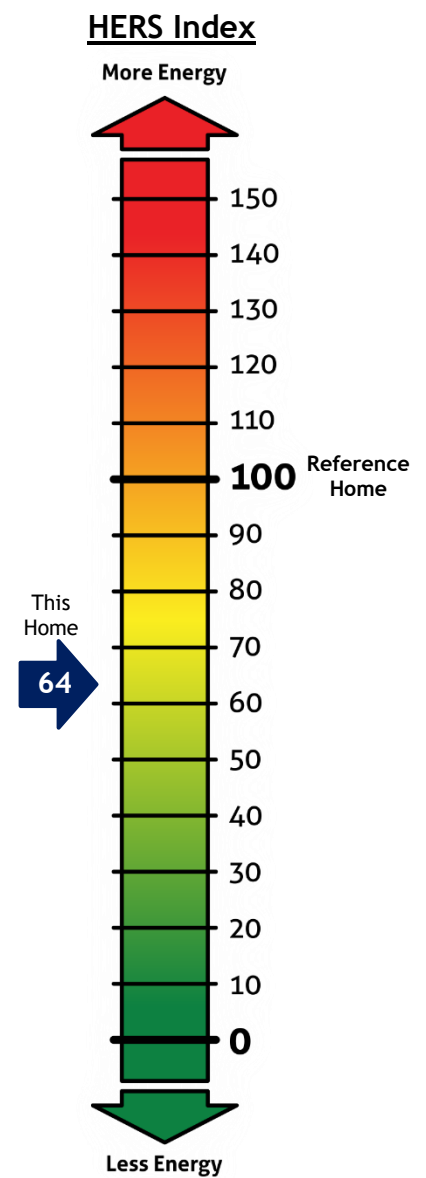
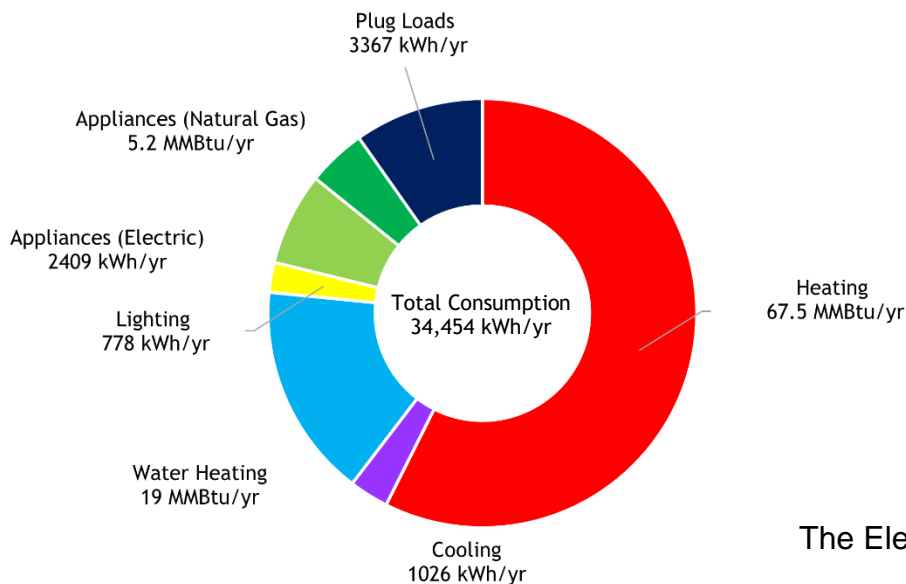
Prototype Option 3

Model Information:

- 2 Story, Finished Basement
- Waterloo, IA (Climate Zone 6)
- 4 Bedroom, 3 Bathroom
- Gross Floor Area = 2943 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30
 - 2x6 Wood Frame, 24" O.C.
 - R-22.5 Blown Fiberglass Cavity, R-5 CI
 - R-20 Closed Cell Spray Foam Rim Joist
 - Vaulted Ceiling, R-33.5 CCSP
 - Basement Foundation
 - R-15 CI Foundation Walls, 8'
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



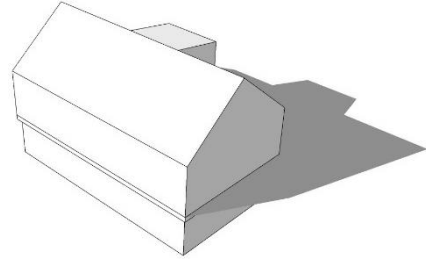
Annual Energy Consumption:



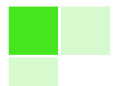
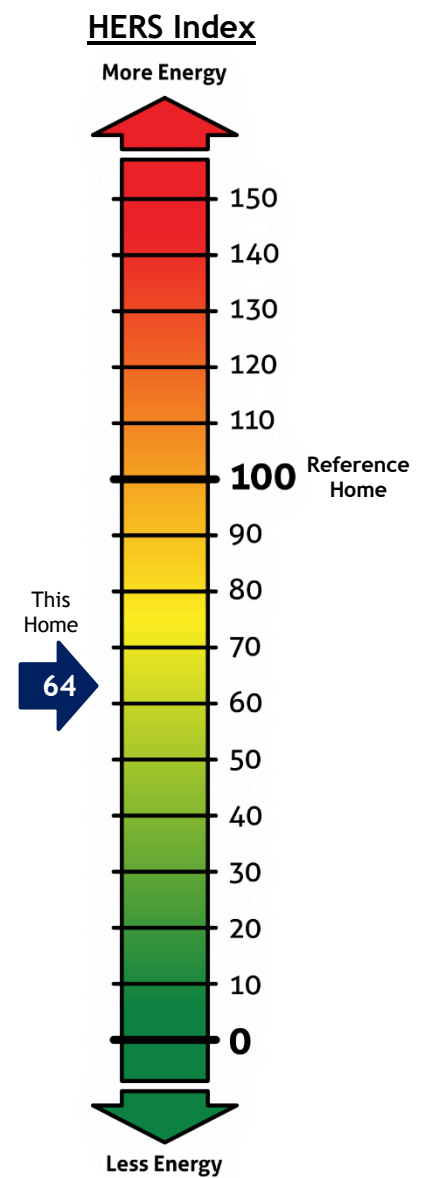
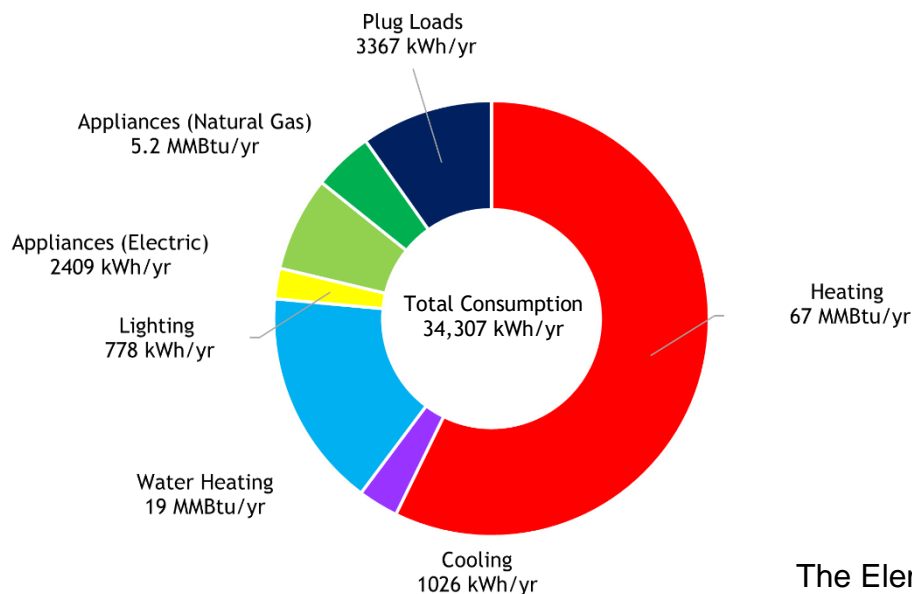
Prototype Option 3A (Modified Envelope)

Model Information:

- 2 Story, Finished Basement
- Waterloo, IA (Climate Zone 6)
- 4 Bedroom, 3 Bathroom
- Gross Floor Area = 2943 SF
- 2018 IECC Baseline
 - Total Building Leakage = 3 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Vaulted Ceiling, R-33.5 CCSP
 - Basement Foundation
 - R-15 CI Foundation Walls, 8'
 - R-5 Under Slab
 - Worst Case Mechanicals and Appliances
 - 80 AFUE Natural Gas Furnace (60 kBtu/h Capacity)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - 13 Seer Air Conditioner (2 Ton Capacity)
 - Air Cycler Ventilation Strategy (RESNET Default)
 - 0.56 EF Natural Gas Water Heater
 - Energy Star Appliances (Gas Where Applicable)
 - 100% LED Lighting Fixtures



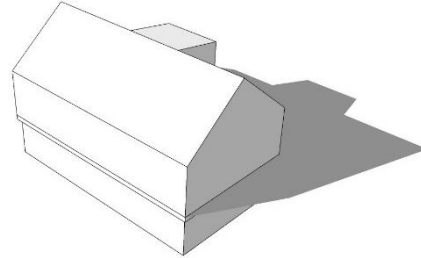
Annual Energy Consumption:



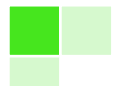
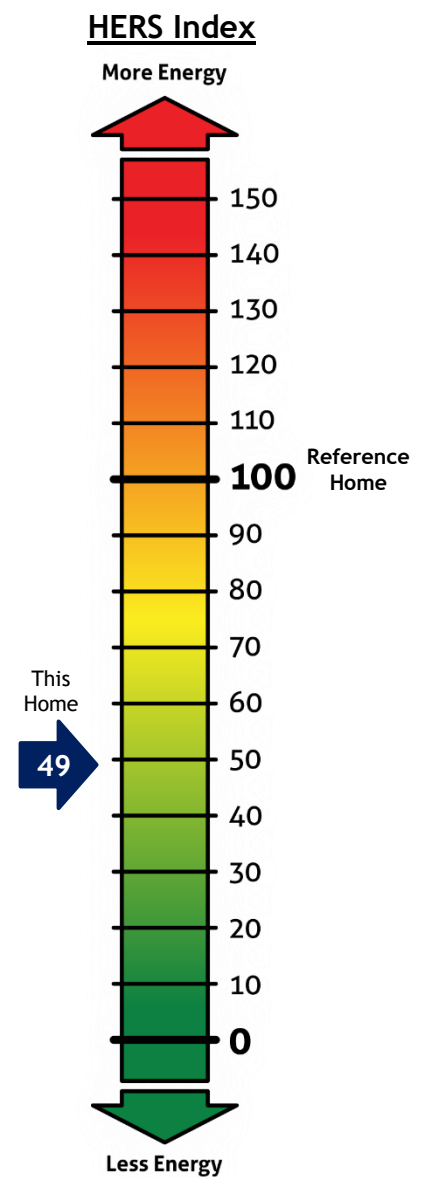
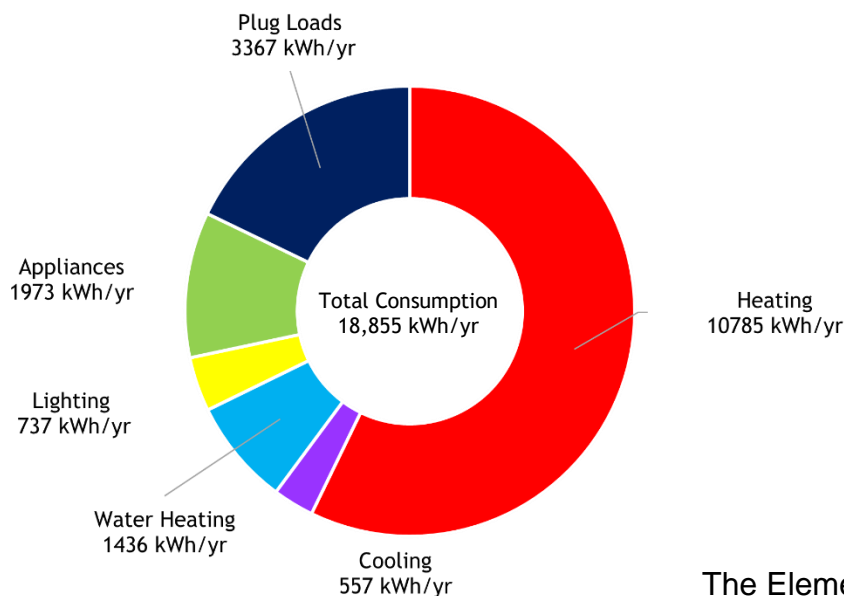
Prototype Option 3B (Modified Envelope & Systems)

Model Information:

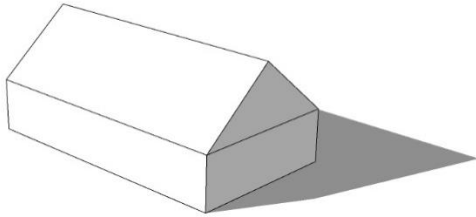
- 2 Story, Finished Basement
- Waterloo, IA (Climate Zone 6)
- 4 Bedroom, 3 Bathroom
- Gross Floor Area = 2943 SF
- DOE Net Zero Ready Home
 - Total Building Leakage = 2 ACH50
 - Window U-Factor = 0.30, 0.40 SHGC
 - Increased South Facing Fenestration
 - R-20 Cont. Insulation, 4" Rigid Foam
 - Vaulted Ceiling, R-33.5 CCSP
 - Basement Foundation
 - R-15 CI Foundation Walls, 8'
 - R-5 Under Slab
 - Energy Star Mechanicals and Appliances
 - Air Source Heat Pump (9 HSPF, 16 SEER)
 - Ductwork in Conditioned Space
 - Duct Leakage at Code Maximum Threshold
 - Balanced Ventilation w/ Recovery (SRE 64%)
 - 2.0 EF Heat Pump Water Heater, DHW Insulated R-3
 - Energy Star Appliances
 - 100% LED Lighting Fixtures
 - WaterSense Labeled Fixtures



Annual Energy Consumption:

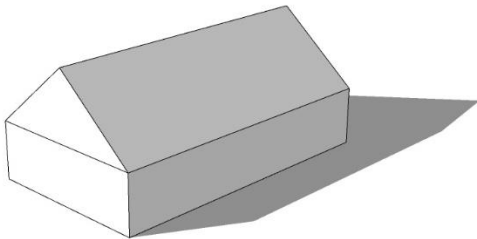


Prototype Option 4 (Optimized Orientation)



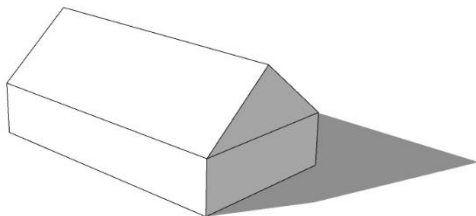
HERS Index	49
Heating	3839 kWh/yr
Cooling	615 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9067 kWh/yr

Oriented Per Plans



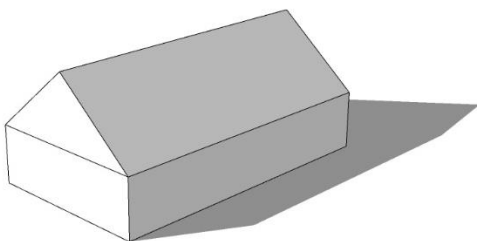
HERS Index	50
Heating	3927 kWh/yr
Cooling	615 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9143 kWh/yr

Rotated 90



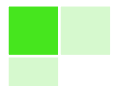
HERS Index	50
Heating	4015 kWh/yr
Cooling	557 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9173 kWh/yr

Rotated 180

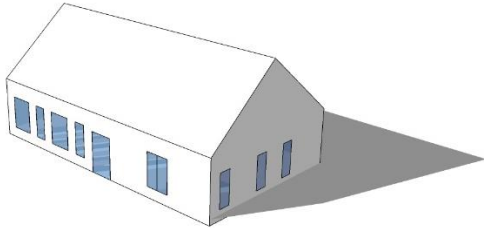


HERS Index	50
Heating	4015 kWh/yr
Cooling	586 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9202 kWh/yr

Rotated 270

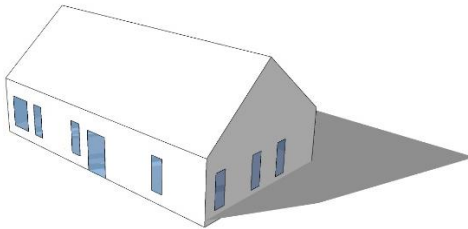


Prototype Option 4A (Optimized Orientation & Glazing Location)



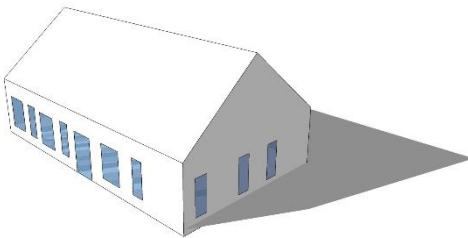
Move Single North Window to South Facade

HERS Index	50
Heating	3898 kWh/yr
Cooling	615 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9114 kWh/yr



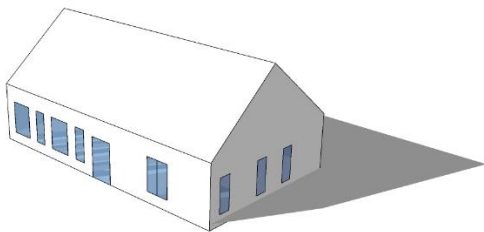
Move Double South Window to North Facade

HERS Index	50
Heating	3956 kWh/yr
Cooling	586 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9143 kWh/yr



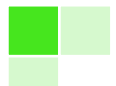
Additional Double Window on South Facade

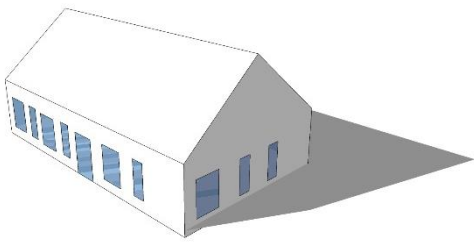
HERS Index	51
Heating	3986 kWh/yr
Cooling	645 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9232 kWh/yr



Additional Double Window West Facade

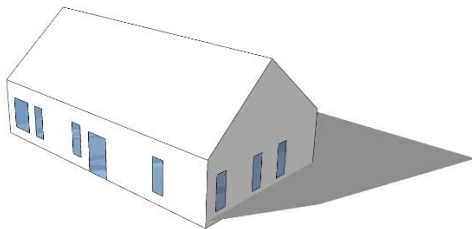
HERS Index	51
Heating	4015 kWh/yr
Cooling	615 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9231 kWh/yr





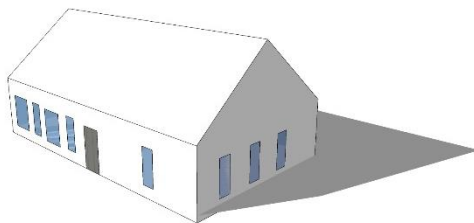
Move Single North Window to East Facade

HERS Index	50
Heating	3898 kWh/yr
Cooling	615 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	9114 kWh/yr



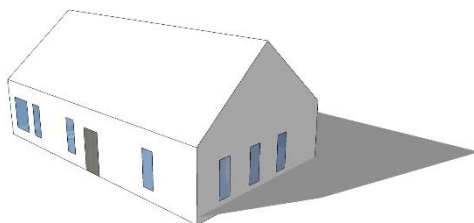
Remove North Façade Glass Entry Door

HERS Index	49
Heating	3751 kWh/yr
Cooling	586 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	8938 kWh/yr



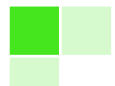
Remove North Façade Glass Entry Door
Replace South Façade Glass Entry Door with Opaque

HERS Index	47
Heating	3751 kWh/yr
Cooling	528 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	8880 kWh/yr



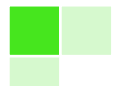
Remove North Façade Glass Entry Door
Replace South Façade Glass Entry Door with Opaque
Remove Double Window South Façade

HERS Index	46
Heating	3722 kWh/yr
Cooling	498 kWh/yr
Water Heating	879 kWh/yr
Lights and Appliances	3722 kWh/yr
Total	8821 kWh/yr



Annual Consumption Modeling Results

IEDA Net Zero Energy Ready Prototype House						
Climate Zone 5 (Des Moines, IA)						
Model	HERS	Heating (kWh/yr)	Cooling (kWh/yr)	Water Heating (kWh/yr)	Lights and Appliances (kWh/yr)	Total (kWh/yr)
Baseline	96	9525	1260	4132	6770	21705
1.0	80	6360	1026	3810	5627	16824
1A	80	6389	1172	3693	7385	16618
1B	49	3839	615	879	3722	9067
2.0	70	10052	1377	5099	6858	23392
2A	71	10697	1377	5099	6858	24036
2B	55	6858	879	1290	4865	13884
3.0	67	14654	1407	5187	8206	29417
3A	67	14566	1407	5187	8118	28262
3B	49	7503	879	1319	6125	15778
Climate Zone 6 (Waterloo, IA)						
Baseline	93	12485	967	4396	6741	24608
1.0	77	8440	762	4015	5656	18880
1A	76	8499	733	4015	5099	18910
1B	50	5363	381	938	3722	10755
2.0	73	13393	1026	5480	6916	26798
2A	74	14214	1055	5480	6829	27648
2B	55	9671	557	1436	4865	16721
3.0	64	19782	1026	5568	8089	34454
3A	64	19636	1026	5568	8177	34307
3B	49	10785	557	1436	6125	18855





DOE Zero Energy Ready Home National Program Requirements (Rev. 07) May 1, 2019

To qualify as a DOE Zero Energy Ready Home, a home shall meet the minimum requirements specified below, be verified and field-tested in accordance with HERS Standards by an approved verifier, and meet all applicable codes¹. Builders may meet the requirements of either the Performance Path or the Prescriptive path to qualify a home.²

The following homes are eligible for DOE Zero Energy Ready Home qualification:

- Detached dwelling units³ (e.g. single family homes)
- Dwelling units³ in any multifamily building with 4 units or fewer
- Dwelling units³ in multifamily buildings with 3 stories or fewer above-grade⁴
- Dwelling units³ in multifamily buildings with 4 or 5 stories above-grade⁴

Dwellings in eligible multifamily buildings as listed above may be served by central heating, cooling, or hot water⁵ systems. Partners are also advised that DOE is developing a revised program design for multifamily dwellings, consistent with the ENERGY STAR Multifamily New Construction program, which will be available for use (but not yet required) on/after March 1, 2020.

Homes may qualify for DOE Zero Energy Ready Home using either the Prescriptive Path or Performance Path in all locations except CA, for which regional program requirements have been developed. Note that compliance with these guidelines is not intended to imply compliance with all local code requirements that may be applicable to the home to be built.

DOE Zero Energy Ready Home Prescriptive Path

The prescriptive path provides a single set of measures that can be used to construct a DOE Zero Energy Ready Home labeled home. Modeling is not required, but no tradeoffs are allowed. Follow these steps to use the prescriptive path:

1. Assess eligibility by using the number of bedrooms in the home to be built to determine the conditioned floor area (CFA) of the Benchmark Home, Exhibit 3. If the CFA of the home to be built exceeds this value, the performance path shall be used.
2. If the prescriptive path is eligible for use based on the prior step, build the home using the mandatory requirements for all labeled homes, Exhibit 1, and all requirements of the DOE Zero Energy Ready Home Target Home, Exhibit 2. The rigor of the specifications in Exhibit 2 shall be met **or** exceeded.
3. Verify that all requirements have been met using an approved verifier.⁶

All homes certified through the Prescriptive Path shall be submitted to DOE (email: zero@newportpartnersllc.com).

DOE Zero Energy Ready Home Performance Path

While all mandatory requirements for labeled homes in Exhibit 1 shall be met, the performance path provides flexibility to select a custom combination of measures that meet the performance level of the DOE Zero Energy Ready Home HERS Target Home (Exhibit 2). Modeling is required, but measures can be optimized for each particular home or builder. Follow the steps below to use the performance path with RESNET-accredited Home Energy Rating Software programs:

1. The HERS Index of the DOE Zero Energy Ready Home Target Home is determined. The DOE Zero Energy Ready Home Target Home is identical to the home that will be built, except that it is configured with the energy efficiency features of the DOE Zero Energy Ready Home Target Home as defined in Exhibits 1 and 2. The HERS Index of the Target Home is automatically calculated in accordance with the RESNET Mortgage Industry National Home Energy Rating Standards.
2. A size modification factor is next calculated using the following equation:

$$\text{Size Modification Factor} = [\text{CFA}_{\text{Benchmark Home}} / \text{CFA}_{\text{Home To Be Built}}]^{0.25}, \text{ but not to exceed } 1.0$$

Where:

$\text{CFA}_{\text{Benchmark Home}}$ = Conditioned Floor Area of the Benchmark Home, using Exhibit 3



DOE Zero Energy Ready Home National Program Requirements (Rev. 07) May 1, 2019

CFA_{Home to be Built} = Conditioned Floor Area of the Home to be Built

Since the Size Modification Factor cannot exceed 1.0, it only modifies the HERS Index score for homes larger than the CFA of the Benchmark Home.

- The HERS Index of the DOE Zero Energy Ready Home Target Home is calculated next

$$\text{DOE Zero Energy Ready Home HERS Index Target} = \text{HERS Index of DOE Zero Energy Ready Home Target Home} \times \text{Size Modification Factor}$$

- Complete HERS software calculations for preferred set of energy measures and verify resulting HERS Index Score at or below DOE Zero Energy Ready Home Target Home HERS Index Score modified, as required, for house size.⁷
- Construct the home using measures that result in a HERS Index at or below the DOE Zero Energy Ready Home HERS Target, calculated above, and the mandatory requirements for all labeled homes, Exhibit 1.
- Verify that all requirements have been met using an approved verifier.

All homes certified through the Performance Path shall be submitted to DOE by submitting the home to the RESNET National Registry or by submitting the compliance verification report to zero@newportpartnersllc.com.

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

Area of Improvement	Mandatory Requirements
1. ENERGY STAR for Homes Baseline	<input type="checkbox"/> Certified under ENERGY STAR Qualified Homes 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	<input type="checkbox"/> Fenestration shall meet or exceed ENERGY STAR requirements. See End Note for specific U, SHGC values, and exceptions. ¹¹ <input type="checkbox"/> Ceiling, wall, floor, and slab insulation shall meet or exceed 2015 IECC levels ^{12,13}
3. Duct System	<input type="checkbox"/> Duct distribution systems located within the home's thermal and air barrier boundary or an optimized location to achieve comparable performance. ¹⁴ <input type="checkbox"/> HVAC air handler is located within the home's thermal and air barrier boundary.
4. Water Efficiency	<input type="checkbox"/> Hot water delivery systems (distributed and central) shall meet efficient design requirements ¹⁵ or <input type="checkbox"/> Water heaters and fixtures shall meet efficiency criteria ¹⁶
5. Lighting & Appliances	<input type="checkbox"/> All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. ¹⁷ <input type="checkbox"/> 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets <input type="checkbox"/> All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified
6. Indoor Air Quality	<input type="checkbox"/> Certified under EPA Indoor airPLUS ¹⁰
7. Renewable Ready	<input type="checkbox"/> Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed ¹⁸



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Exhibit 2: DOE Zero Energy Ready Home Target Home ¹⁹

HVAC Equipment²⁰			
	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			
<ul style="list-style-type: none"> Insulation levels shall meet the 2015 IECC and achieve Grade 1 installation, per RESNET standards. Infiltration – Detached Dwellings²³ (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			
Thermostat²⁸			
<ul style="list-style-type: none"> Programmable thermostat (except for zones with radiant heat) 			
Lighting & Appliances			
<ul style="list-style-type: none"> 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 Size²⁹

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



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Endnotes:

¹ Where requirements of the local codes, covenants, manufacturers' installation instructions, or engineering documents overlap with the requirements of these guidelines, DOE offers the following guidance:

- a. In cases where the overlapping requirements exceed the DOE Zero Energy Ready Home guidelines, these overlapping requirements shall be met;
- b. In cases where overlapping requirements conflict with a requirement of these DOE Zero Energy Ready Home guidelines, then the home is exempt from conflicting requirement within these guidelines. However, certification shall only be allowed if the Rater has determined that no equivalent option is available that could meet the intent of the conflicting requirement of these DOE Zero Energy Ready Home guidelines. Note that, under the Performance Path, a home must still meet the Target Home HERS Index Target. Therefore, other efficiency measures may be needed to compensate for the omission of the conflicting requirement.

² In the event that a Rater is not able to determine whether an item is consistent with the intent of a provision, (e.g., an alternative method of meeting a checklist requirement has been proposed), then the Rater shall consult their Provider. If the Provider also cannot make this determination, then the Rater or Provider shall report the issue to DOE prior to project completion at: zero@newportpartnersllc.com and will typically receive an initial response within 5 business days. If DOE believes the current program guidelines are sufficiently clear to determine whether the intent has been met, then this guidance will be provided to the Partner and enforced beginning with the house in question. However, if DOE believes the program guidelines require revisions to make the intent clear, then this guidance will be provided to the Partner but only enforced for homes permitted after a specified transition period after the release of the revised guidelines, typically 60 days in length. This process will allow DOE to make formal policy decisions as Partner questions arise and to disseminate these policy decisions through the periodic release of revised program documents to ensure consistent application of the program guidelines.

³ A dwelling unit, as defined by the 2015 IECC, is a single unit that provides complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

⁴ Any above-grade story with 20% or more occupiable space, including commercial space, shall be counted towards the total number of stories for the purpose of determining eligibility to participate in the program. The definition of an 'above-grade story' is one for which more than half of the gross surface area of the exterior walls is above-grade. All below-grade stories, regardless of type, shall not be included when evaluating eligibility. Per ASHRAE 62.2-2010, occupiable space is any enclosed space inside the pressure boundary and intended for human activities or continual human occupancy, including, but not limited to, areas used for living, sleeping, dining, and cooking, toilets, closets, halls, storage and utility areas, and laundry areas.

⁵ Central systems for domestic hot water are allowed in multifamily buildings. Such central systems must include on-demand recirculation which operates based on both a demand indicator and the loop temperature. Central systems in multifamily buildings do not have a stored volume limit at this time (see Advisory under Endnote 15).

⁶ The term "verifier" refers to the person completing the third-party inspections required for qualification. This party may be a certified Home Energy Rater, Rating Field Inspector, BOP Inspector, or an equivalent designation as determined by a Verification Oversight Organization such as RESNET.

⁷ On-site power generation may not be used to qualify a home for the DOE Zero Energy Ready Home Target Home requirements, but can be used to achieve additional HERS Index Score reductions needed for homes larger than the Benchmark Home.



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⁸ The version of ENERGY STAR Homes or ESMFNC to be used shall be determined based on ENERGY STAR program requirements and implementation timelines. See the ENERGY STAR Homes program site for information: https://www.energystar.gov/newhomes/homes_prog_reqs/national_page. See the ESMFNC program site for information: https://www.energystar.gov/newhomes/homes_prog_reqs/multifamily_national_page#site-built.

⁹ DOE Zero Energy Ready Home requires projects to be certified under the ENERGY STAR Certified Homes program or under the ENERGY STAR Multifamily New Construction (ESMFNC) program. Projects certifying under the ESMFNC program are advised that DOE ZERH certification requires that such projects use either the HERS or Prescriptive paths within the ESMFNC program, and that such projects are limited to 5 stories above grade or less to be eligible for DOE ZERH certification. Partners are also advised that DOE is developing a revised program design for multifamily dwellings, consistent with the ENERGY STAR Multifamily New Construction program, which will be available for use (but not yet required) on/after March 1, 2020. This program design is likely to be limited to buildings 5 stories above grade or less. Project certification under the ENERGY STAR Multifamily High-Rise program is not accepted at this time.

Sampling of those requirements for ENERGY STAR Homes qualification is permitted consistent with the ENERGY STAR for Homes V3 allowances for sampling (see ENERGY STAR Homes National Program Requirements). Sampling for Indoor airPLUS qualification is permitted consistent with the Indoor airPLUS program requirements.

With respect to Provision 1.3 within the ENERGY STAR Qualified Homes, Version 3/3.1 (REV09) Rater Field Checklist requiring RESNET-defined Grade I installation of insulation, where ceiling, wall, or floor assembly insulation is installed "blind" between layers of sheathing and therefore cannot be visually inspected, such assemblies are deemed equivalent to a RESNET-defined Grade I installation if the assembly insulation level is at least 50% greater than the specified value for the DOE Zero Energy Ready Home Target Home, based on nominal R-value.

¹⁰ For homes achieving PHIUS+ certification, DOE will allow compliance with the 2015 IRC kitchen ventilation airflow rates (M 1507.4) as an alternative to those specified within ASHRAE 62.2. This alternative will remain in effect while DOE works to develop an ASHRAE 62.2-compliant solution optimized for very low-load homes.

¹¹ Windows shall meet the ENERGY STAR Window Product Criteria as listed in this table. Note that the Cold Climate U and SHGC values shown below are based on the older ENERGY STAR v5.0 Window Specifications. DOE will periodically review the feasibility of adopting ENERGY STAR v6.0 Window Specifications for the Cold Climate Zones, which entail lower U values. Any program update to require the v6.0 window specs in Cold Climates will be announced with a minimum 1-year phase-in.

Window Specs Required for DOE Zero Energy Ready Home Projects	Hot Climates IECC CZ 1-2		Mixed Climates IECC CZ 3-4 except Marine		Cold Climates IECC CZ 5-8 and 4 Marine	
	U-Value	SHGC	U-value	SHGC	U-Value	SHGC
	0.40	0.25	[CZ 3] 0.30 [CZ 4] 0.30	[CZ 3] 0.25 [CZ 4] 0.40	0.30 0.31 0.32	Any ≥0.35 ≥0.40

The following exceptions apply:

- An area-weighted average of fenestration products shall be permitted to satisfy the U-factor requirements;



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- b. An area-weighted average of fenestration products $\geq 50\%$ glazed shall be permitted to satisfy the SHGC requirements;
- c. 15 square feet of glazed fenestration per dwelling unit shall be exempt from the U-factor and SHGC requirements, and shall be excluded from area-weighted averages calculated using a) and b), above;
- d. One side-hinged opaque door assembly up to 24 square feet in area shall be exempt from the U-factor requirements and shall be excluded from area-weighted averages calculated using a) and b), above;
- e. Fenestration utilized as part of a passive solar design shall be exempt from the U-factor and SHGC requirements, and shall be excluded from area-weighted averages calculated using a) and b), above. Exempt windows shall be facing within 45 degrees of true South and directly coupled to thermal storage mass that has a heat capacity $> 20 \text{ btu} / \text{ft}^3 \times \text{F}$ and provided in a ratio of at least 3 sq. ft. per sq. ft. of South facing fenestration. Generally, thermal mass materials will be at least 2 in. thick.
- f. For homes achieving PHIUS+ certification where triple glazed window assemblies with thermal breaks/spacers between the panes are used, such windows are deemed to meet this requirement even in the absence of an ENERGY STAR certification.

¹² Building envelope assemblies, including exterior walls and unvented attic assemblies (where used), shall comply with the relevant vapor retarder provisions of the 2015 International Residential Code (IRC).

¹³ Insulation levels in a home shall meet or exceed the component insulation requirements in the 2015 International Energy Conservation Code (IECC) – Table R402.1.2. The following exceptions apply:

- a. Steel-frame ceilings, walls, and floors shall meet the insulation requirements of the 2015 IECC – Table 402.2.6.
- b. For ceilings with attic spaces, R-30 shall satisfy the requirement for R-38 and R-38 shall satisfy the requirement for R-49 wherever the full height of uncompressed insulation at the lower R-value extends over the wall top plate at the eaves. This exemption shall not apply if the alternative calculations in d) are used;
- c. For ceilings without attic spaces, R-30 shall satisfy the requirement for any required value above R-30 if the design of the roof / ceiling assembly does not provide sufficient space for the required insulation value. This exemption shall be limited to 500 sq. ft. or 20% of the total insulated ceiling area, whichever is less. This exemption shall not apply if the alternative calculations in d) are used;
- d. An alternative equivalent U-factor or total UA calculation may also be used to demonstrate compliance, as follows: An assembly with a U-factor equal to or less than specified in Table 402.1.4 of the 2015 IECC complies. A total building thermal envelope UA that is less than or equal to the total UA resulting from the U-factors in Table 402.1.4 also complies. The insulation levels of fenestration, ceilings, walls, floors, and slabs can be traded off using the UA approach under both the Prescriptive and the Performance Path. Also, note that while ceiling and slab insulation can be included in trade-off calculations, Items 3.1 through 3.3 of the ENERGY STAR Rev09 Rater Field Checklist shall be met regardless of the UA tradeoffs calculated. The UA calculation shall be done using a method consistent with the ASHRAE Handbook of Fundamentals and shall include the thermal bridging effects of framing materials. The calculation for a steel-frame envelope assembly shall use the ASHRAE zone method or a method providing equivalent results, and not a series-parallel path calculation method.

¹⁴ Exceptions and alternative compliance paths to locating 100% of forced-air ducts in home's thermal and air barrier boundary are:

- a. Up to 10' of total duct length is permitted to be outside of the home's thermal and air barrier boundary.
- b. Ducts are located in an unvented attic, regardless of whether this space is conditioned with a supply register
- c. Ducts are located in a vented attic with all of the following characteristics:
 - i. In Moist climates (Zones 1A, 2A, 3A, 4A, 5A, 6A and 7A per 2015 IECC Figure R301.1) and Marine climates (all "C" Zones per 2015 IECC Figure R301.1), minimum R-8 duct insulation with an additional minimum 1.5" of closed-cell spray foam insulation encapsulating the ducts; duct leakage to outdoors $\leq 3 \text{ CFM}_{25}$ per 100 ft^2 of conditioned floor area (in addition to meeting *total* duct leakage requirements from Section 4.1 of the ENERGY STAR HVAC Rater checklist); and ductwork buried under at least 2" of blown-in insulation.



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- ii. In Dry climates (all "B" Zones per 2015 IECC Figure R301.1), minimum R-8 duct insulation; duct leakage to outdoors ≤ 3 CFM25 per 100 ft² of conditioned floor area (in addition to meeting *total* duct leakage requirements from Section 4.1 of the ENERGY STAR HVAC Rater checklist); and ductwork buried under at least 3.5" of blown-in insulation.

Note that in either of these designs the HVAC equipment must still be located within the home's thermal and air barrier boundary.

- d. Systems which meet the criteria for "Ducts Located in Conditioned Space" as defined by the 2018 IECC Section R403.3.7
- e. Jump ducts which do not directly deliver conditioned air from the HVAC unit may be located in attics if all joints, including boot-to-drywall, are fully air sealed with mastic or foam, and the jump duct is fully buried under the attic insulation.
- f. Ducts are located within an unvented crawl space
- g. Ducts are located in a basement which is within the home's thermal boundary
- h. Ductless HVAC system is used

¹⁵ Hot water delivery systems **in single family homes and distributed (individual water heater) systems in multifamily buildings** meet the following efficiency requirements:

To minimize water wasted while waiting for hot water, the hot water distribution system shall store no more than 0.5 gallons (1.9 liters) of water in any piping/manifold between the hot water source and any hot water fixture. In the case of on-demand recirculation systems, the 0.5 gallon (1.9 liter) storage limit shall be measured from the point where the branch feeding the fixture branches off the recirculation loop, to the fixture itself. To verify that the system stores no more than 0.5 gallons (1.9 liters), verifiers shall calculate the stored volume using the piping or tubing inside diameter and the length of the piping/tubing. System options include manifold-fed systems; structured plumbing systems; core plumbing layouts, and on-demand recirculation systems. The following requirements apply to recirculation systems:

- a. Recirculation systems must be based on an occupant-controlled switch or an occupancy sensor, installed in each bathroom which is located beyond a 0.5 gallon stored-volume range from the water heater.
- b. Recirculation systems which operate based on "adaptive" scheduling, meaning that they "learn" the hot water demand profile in the home and adapt their operation to anticipate this profile, are permitted at this time, and do not require the use of occupant-controlled switches or occupancy sensors.
- c. Recirculation systems that are activated based **solely** on a timer and/or temperature sensor are not eligible.

No more than 0.6 gallons (2.3 liters) of water shall be collected from the hot water fixture before hot water is delivered. Only the fixture with the greatest stored volume between the fixture and the hot water source (or recirculation loop) needs to be tested. To field verify that the system meets the 0.6 gallon (2.3 liter) limit, verifiers shall first initiate operation of on-demand recirculation systems, if present, and let such systems run for at least 40 seconds. If an Adaptive Scheduling system cannot be "forced" into recirculation mode, contact DOE for further guidance. Next, a bucket or flow measuring bag (pre-marked for 0.6 gallons) shall be placed under the hot water fixture. The hot water shall be turned on completely and a digital temperature sensor used to record the initial temperature of the water flow. Once the water reaches the pre-marked line at 0.6 gallons (approximately 24 seconds for a lavatory faucet), the water shall be turned off and the ending temperature of the water flow (not the collection bucket) shall be recorded. The temperature of the water flow must increase by ≥ 10 °F. Under the DOE Zero Energy Ready Home program, the approved verifier may confirm compliance with these requirements.



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Central hot water delivery systems in multifamily buildings must include on-demand recirculation which operates based on both a demand indicator and the loop water temperature. For qualifying central systems, verifiers must confirm that the pump is installed with flow in the correct direction and that the system's temperature sensors are installed.

Advisories:

- On-demand central systems in multifamily buildings do not currently have a stored volume limit. DOE encourages partners to design central hot water distribution systems in multifamily buildings to limit the stored volume between the recirculation loop and the furthest fixture to 1.0 gallons.
- Piping for central system recirculation loops in multifamily buildings should be insulated per the local code requirements. DOE encourages the use of R-4 pipe insulation on recirculation loop piping.
- DOE encourages that the recirculation pump for central systems be set to operate at a temperature which is at least 5°F less than the water heater set point temperature.

DOE will evaluate the possibility of making these recommendations into requirements in future updates to these specifications.

¹⁶ Water heaters and fixtures in single family homes and in multifamily dwellings with their own independent water heater meet the following efficiency criteria:

- a. Gas water heaters, if present, shall have an Energy Factor ≥ 0.90 or a Uniform Energy Factor ≥ 0.87
- b. Electric water heaters, if present, shall have an Energy Factor ≥ 2.2 or a Uniform Energy Factor ≥ 2.2
- c. All showerheads and bathroom sink faucets shall be WaterSense labeled.
- d. The hot water distribution system shall store no more than 1.2 gallons between the hot water source and the furthest fixture. This shall be verified by either 1) a calculation using the piping or tubing interior diameter and the system length based on plans, or 2) by a field verification test, using the protocol described in Endnote 15, which demonstrates a minimum temperature rise of 10 °F by the time 1.4 gallons of water is delivered to the furthest hot water fixture.

These provisions do not apply to multifamily buildings with central hot water delivery systems. These project types must instead satisfy the Efficient Hot Water Distribution provision instead (see Endnote 15).

¹⁷ For products in categories which are not covered by ENERGY STAR product criteria, such as combination all-in-one clothes washer-dryers, these products are exempt.

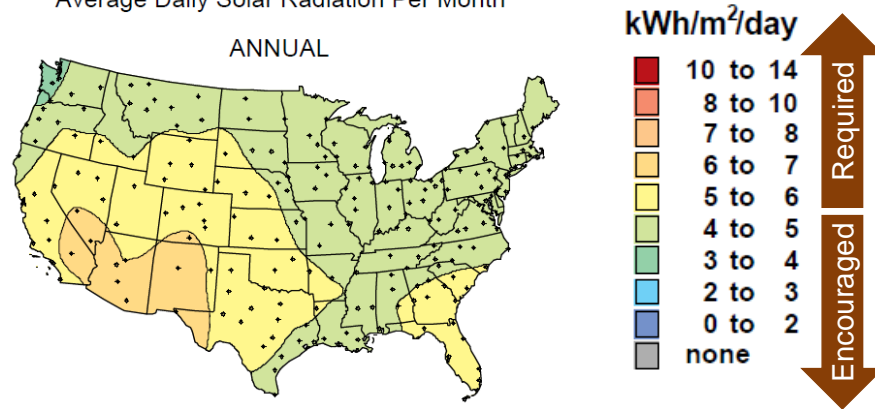
¹⁸ DOE Zero Energy Ready Home requires that the provisions of the PV-Ready Checklist are completed based on the requirements and allowances in this end note. For multifamily buildings, the PV-Ready provisions may be applied to the electric service for the building's common space instead of being applied to each dwelling unit. DOE encourages, but does not require, the use of the Solar Water Heating-Ready provisions.

The PV-Ready Checklist only applies when all of the following conditions a through d below are satisfied. Homes for which the PV-Ready Checklist does not apply based on these criteria may still qualify for DOE Zero Energy Ready Home if all other program requirements are satisfied. Homes that utilize renewable energy from utilities or third parties on a contractual basis may also be exempt from the PV-Ready Checklist – contact DOE for further guidance.

- a. The home does not already include a PV system. This includes installed community solar systems which contribute some amount of offset to the home's electrical usage.
- b. Location, based on zip code, has at least 5 kWh/m²/day average daily solar radiation based on annual solar insolation using this online tool: <http://pvwatts.nrel.gov/pvwatts>. Users should enter the project location zip code, use the System Info default settings, and then proceed to the "Results" tab on the tool to see the Average Annual Solar Radiation value in kWh/m²/day.

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Average Daily Solar Radiation Per Month

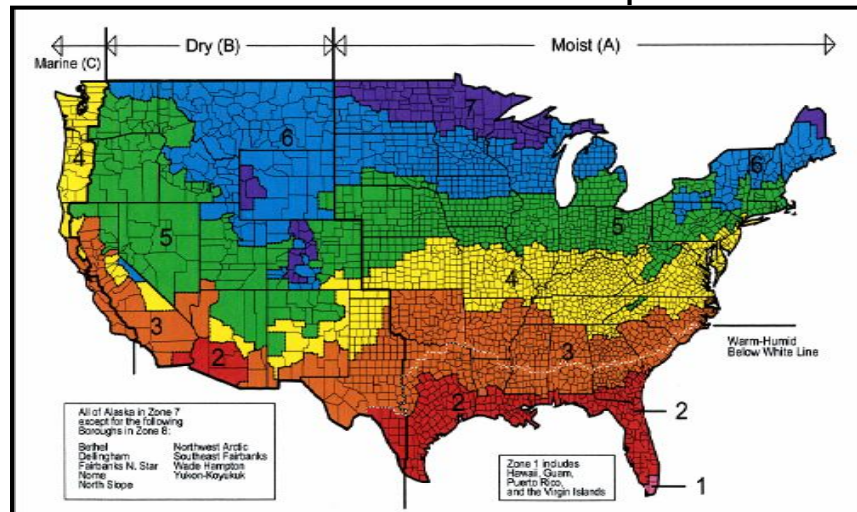


- c. Location does not have significant natural shading (e.g., trees, tall buildings on the south-facing roof).
- d. Home as designed has the minimum free roof area within +/- 45° of true south as noted in the table below.

Conditioned Floor Area of House (ft ²)	Minimum Roof Area within +/- 45° of True South for PV-Ready Checklist to Apply (ft ²)
≤ 2000	110
≤ 4000	220
≤ 6000	330
>6000	440

¹⁹ The following Map is shown to depict climate zone boundaries. It is for illustrative purposes only and is based on the 2015 IECC.

2015 IECC Climate Zone Map



²⁰ HVAC System Type for the Target Home shall be the same as the Rated Home, with the following exceptions. The Target Home is configured with an air-source heat pump in Climate Zones 1-6 when the Rated Home is modeled with a ground-source heat pump, electric strip or baseboard heat; and the Target Home is configured with ground-source heat



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pump in Climate Zones 7 & 8 when the Rated Home is modeled with an air-source or ground-source heat pump, electric strip or baseboard heat. Applicable efficiency levels shall be selected from Exhibit 2.

²¹ DOE recommends, but does not require, that cooling systems in hot/humid climates utilize controls for immediate blower shutoff after condenser shutoff, to prevent re-evaporation of moisture off the wet coil.

²² Air source heat pumps with electric resistance backup cannot be used in homes qualified in Climate Zones 7 & 8 using the Prescriptive Path.

²³ Envelope leakage shall be determined by an approved verifier using a RESNET-approved testing protocol.

²⁴ All decorative glass and skylight window areas count toward the total window area to above-grade conditioned floor area (WFA) ratio.

²⁵ DOE strongly encourages all DOE Zero Energy Ready Home partners to consider using R-5 windows in cold climates in anticipation of them becoming the state-of-the-art window choice in the near future.

²⁶ For homes using Exhibit 2 for Prescriptive compliance with the DOE Zero Energy Ready Home, the following exceptions to the U-Value and SHGC requirements in Exhibit 2 apply:

- a. An area-weighted average of fenestration products shall be permitted to satisfy the U-factor requirements;
- b. An area-weighted average of fenestration products $\geq 50\%$ glazed shall be permitted to satisfy the SHGC requirements;
- c. 15 square feet of glazed fenestration per dwelling unit shall be exempt from the U-factor and SHGC requirements, and shall be excluded from area-weighted averages calculated using a) and b), above;
- d. One side-hinged opaque door assembly up to 24 square feet in area shall be exempt from the U-factor requirements and shall be excluded from area-weighted averages calculated using a) and b), above;
- e. Fenestration utilized as part of a passive solar design shall be exempt from the U-factor and SHGC requirements, and shall be excluded from area-weighted averages calculated using a) and b), above. Exempt windows shall be facing within 45 degrees of true South and directly coupled to thermal storage mass that has a heat capacity > 20 btu / ft³ x °F and provided in a ratio of at least 3 sq. ft. per sq. ft. of South facing fenestration. Generally, thermal mass materials will be at least 2 in. thick.

²⁷ *For Prescriptive Path:* All decorative glass and skylight window areas count toward the total window area to above-grade conditioned floor area (WFA) ratio. For homes using the Prescriptive Path that have a WFA ratio $> 15\%$, the following additional requirements apply:

- a. In Climate Zones 1, 2, and 3, an improved window SHGC is required and is determined by:

$$\text{Improved SHGC} = [0.15 / \text{WFA}] \times [\text{ENERGY STAR SHGC}]$$

Where the ENERGY STAR SHGC is the maximum allowable SHGC in Exhibit 1, ENERGY STAR Reference Design, for the Climate Zone where the home will be built.

- b. In Climate Zones 4, 5, 6, 7, and 8, an improved window U-Value is required and is determined by:

$$\text{Improved U-Value} = [0.15 / \text{WFA}] \times [\text{ENERGY STAR U-Value}]$$

Where the ENERGY STAR U-Value is the maximum allowable U-Value in Exhibit 1, ENERGY STAR Reference Design, for the Climate Zone where the home will be built.

²⁸ In homes with heat pumps, programmable thermostats shall have "Adaptive Recovery" technology to prevent the excessive use of electric back-up heating.



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²⁹ The average-size home for a specific number of bedrooms is termed "Benchmark Home". The conditioned floor area for a Benchmark Home (CFA Benchmark Home) is determined by selecting the appropriate value from Exhibit 3. For homes with more than 8 bedrooms, the CFA Benchmark Home shall be determined by multiplying 600 sq. ft. times the total number of bedrooms and adding 400 sq. ft.

Example 10 Bedroom Home: Benchmark Home = (600 sq. ft. x 10) + 400 sq. ft. = 6,400 sq. ft.

DOE Zero Energy Ready Home

Savings & Cost Estimate Summary



October 2015

www.buildings.energy.gov/zero



DOE Zero Energy Ready Home Savings & Cost Estimate Summary

October 2015

INTRODUCTION

In considering the business strategy for constructing and selling Zero Energy Ready Homes through the DOE Zero Energy Ready Home program, builders and other program partners understandably want to know about the added costs. Upgrades in insulation, air sealing, mechanical equipment and other systems will mean both energy savings and added costs above code-minimum specifications. Therefore, this document presents an analysis-based cost estimate for building to DOE Zero Energy Ready Home levels relative to:

- A 2009 International Energy Conservation Codes baseline house
- A 2012 International Energy Conservation Codes baseline house

The purpose of this analysis is to give builders, contractors, utilities, energy programs, and other stakeholders a general sense of 1) the magnitude and type of added costs, and 2) how these costs compare to the energy savings. It is critical to understand that both sets of findings are heavily dependent on several factors, including the following:

- The “real” baseline house. In this analysis, the baseline is a bare minimum IECC house (either 2009 or 2012). In many “real world” cases the baseline home will be somewhat above code.
- How a home actually complies. DOE Zero Energy Ready Home affords great flexibility to reach the required performance targets, and the data in this analysis are based on a very small set of design solutions. Different design approaches will incur different added costs.
- Assigned costs for upgrades. As described below this analysis utilizes recognized cost data sources and maintains a methodology consistent with a similar study for ENERGY STAR Homes V3. In actual projects the cost impacts for various upgrades will vary.
- Project location. Specifications and pricing for actual projects are a function of the project location.

METHODOLOGY

DOE evaluated 3-bedroom, 2,200 ft² detached single-family prototype homes in Climate Zones 3 and 5 to provide estimates for a warmer and a colder climate zone. Window area to floor area ratio was 15% with windows evenly distributed on all four sides of the home. The Climate Zone 3 models assumed a slab on grade foundation with ducts in unconditioned space for the baseline home, while the zone 5 homes were modeled with a basement foundation and ducts in conditioned space for the baseline home. In each climate zone, an all-electric prototype was modeled along with a prototype using natural gas for space and water heating.

The energy efficiency features of the baseline homes were aligned with the 2009 IECC and 2012 IECC prescriptive paths, respectively, though Grade III insulation installation was assumed for walls and Grade II insulation installation was assumed for ceilings. The assumption of degraded insulation installation reflects DOE Zero Energy Ready Home experience with typical homes built to code.

The DOE Zero Energy Ready Home prototype models were designed based on a combination of prescriptive measures drawn from the Target Home and performance-based measures which optimized cost versus performance. The DOE Zero Energy Ready Home prototype models were confirmed to meet the energy threshold of the program through the use of REM/Rate Version 14.3 software.



DOE Zero Energy Ready Home Savings & Cost Estimate Summary

October 2015

A large part of the “delta” between a DOE Zero Energy Ready Home and a minimally compliant IECC home is the jump to ENERGY STAR Homes Version 3 qualification, which is a prerequisite for DOE Zero Energy Ready Home qualification. Therefore, this savings and cost estimate is designed to be consistent with a concurrent savings/cost analysis for ENERGY STAR Homes V3¹ in the following ways:

- Consistent costs for the same changes in building systems. In cases where a DOE Zero Energy Ready Home implements the same measure as does an ENERGY STAR Home, then the added cost for that measure is the same as stated in the ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary (cited in the footnote below and often referred to as the “ENERGY STAR Analysis” in this report). This is the case for the ENERGY STAR checklists.
- Consistent data sources for similar changes in measures. In cases where a DOE Zero Energy Ready Home implemented a similar measure as did the ENERGY STAR Home relative to code, then the DOE Zero Energy Ready Home adopted the same cost data source and applied it in a similar fashion. For instance, in evaluating the cost to move from an 80 AFUE furnace to a 95 AFUE furnace in the Climate Zone 5 model, the DOE analysis uses the same cost data source (National Residential Efficiency Measures Database²) as the ENERGY STAR analysis used for an 80 to 90 AFUE upgrade, and applies the cost data in a consistent manner.
- Consistent energy savings from the 4 ENERGY STAR checklists. The ENERGY STAR analysis accounts for the impacts of the quality-control checklists that are not currently credited in the RESNET standards (i.e., Fully-Aligned Air Barrier and Air Sealing Sections of the Thermal Enclosure System Rater checklist and HVAC System Quality Installation Contractor and Rater checklists). These serve to increase energy savings for DOE Zero Energy Ready Homes. The detailed adjustments are explained fully in the ENERGY STAR analysis.

For DOE Zero Energy Ready Home measures not related to ENERGY STAR qualification, such as locating ducts within conditioned space, installing renewable-ready features, or installing renewable-ready features, industry data sources were used to estimate the added costs. These costs and associated data sources are noted in the summary tables which follow. Notable assumptions include:

- The cost to install the renewable readiness features required by DOE Zero Energy Ready Home was estimated to be \$350, based on DOE experience. In many circumstances, including all project sites where the average solar radiation is less than 5 kWh/m²/day, the renewable ready checklist is not mandatory. The \$350 cost is included in all models in this study, so sites where these measures are not required will not incur this cost.
- The cost to comply with the indoor air quality provisions of the EPA Indoor airPLUS is estimated at \$1000. The actual cost of complying will vary based on house, site, and climate characteristics, baseline building practices, and numerous other factors. It should also be noted that many provisions of the Indoor airPLUS specification are already included within the ENERGY STAR checklists and the costs for those measures are not included within the \$1000 estimate.

¹ “ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary.” November 2013. Available online at: http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/EstimatedCostandSavings.pdf

² National Renewable Energy Laboratory, National Residential Efficiency Measures Database. Last accessed October 2013. Available online at: <http://www.nrel.gov/ap/retrofits/>



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In terms of economic assumptions, energy rates used in this analysis were \$0.11/kWh and \$1.06/therm of natural gas. Monthly net cash flow calculations assumed a 30-year fixed rate mortgage with a 5% interest rate.

RESULTS

Table 1 below provides a summary of the HERS Index, energy savings, incremental costs for upgrades, and net monthly cash flow for the DOE Zero Energy Ready Home models compared to a 2009 IECC baseline home. Table 2 shows the same information for DOE Zero Energy Ready Home relative to a 2012 IECC baseline.

Appendix A, which follows Tables 1 and 2, contains the detailed cost estimating models for the 2009 and 2012 baseline homes, for both the all-electric prototype and the gas-electric prototype (for a total of 8 models). These tables are arranged into 3 main sections of specifications: the Mandatory DOE Zero Energy Ready Home provisions; measures used to meet the Performance Path of compliance; and the 4 ENERGY STAR checklists. Appendix B summarizes the cost estimating data sources which were utilized.

Table 1: DOE Zero Energy Ready Home Energy & Cost Comparison to 2009 IECC Baseline

Climate Zone	Space & Water Heating Energy Source	09 IECC - HERS Index	ZERH - HERS Index	Monthly Energy Cost Savings for ZERH House vs. 09 IECC House (\$)	Estimated Marginal First Cost for ZERH House (\$)	Amortized Marginal First Cost for ZERH House (\$)	Net Monthly Cashflow (\$)
3	Electric	88	57	\$66	\$7,291	\$39	\$26
3	Gas	86	54	\$66	\$6,868	\$37	\$29
5	Electric	78	53	\$101	\$5,590	\$30	\$71
5	Gas	72	49	\$70	\$5,083	\$27	\$43

Table 2: DOE Zero Energy Ready Home Energy & Cost Comparison to 2012 IECC Baseline

Climate Zone	Space & Water Heating Energy Source	12 IECC - HERS Index	ZERH - HERS Index	Monthly Energy Cost Savings for ZERH House vs. 12 IECC House (\$)	Estimated Marginal First Cost for ZERH House (\$)	Amortized Marginal First Cost for ZERH House (\$)	Net Monthly Cashflow (\$)
3	ELECTRIC	74	57	\$37	\$4,663	\$25	\$12
3	GAS	72	54	\$37	\$4,216	\$23	\$14
5	ELECTRIC	61	53	\$40	\$4,403	\$24	\$16
5	GAS	59	49	\$33	\$3,896	\$21	\$12

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

APPENDIX A: DETAILED COST ESTIMATING TABLES FOR 8 MODELS

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

SCENARIO: CLIMATE ZONE 3; ALL ELECTRIC; 2009 IECC BASELINE						
Baseline Home:	2200 SF prototype, compliant with 2009 IECC (prescriptive)					
Design Home:	2200 SF prototype, compliant with DOE Challenge Home (performance)					
Foundation Type:	Slab on Grade					
City:	Ft. Worth , TX					
Climate Zone:	3					
Space & Water Fuel:	Electric					
Cost						
INCREMENTAL COSTS						\$7,291
MONTHLY PAYMENT						\$39.14
MONTHLY UTILITY SAVINGS						\$66
ASSUMED INTEREST RATE (same as V3 analysis)						5.00%
NET MONTHLY CASHFLOW						\$26.49
DOE Challenge Home Mandatory Requirements: Exhibit 1						
Measure	2009 IECC Baseline	DOE Challenge Home(Rev. 03)	UNIT COST	UNIT QTY	UNIT	Marginal Cost for Challenge Home
Home is ENERGY STAR V3 Qualified	N/A	V3 Cost Impacts Reflected in Items Below	-	-	-	-
Fenestration meets ENERGY STAR criteria	U=0.50; SHGC=0.30	U=0.30; SHGC=0.27 BEDs: R-38 Attic Assembly: 1.5" of CCSPF over R-8 Duct Work and 2" of CCSPF over R-6 Duct Work, encapsulating duct work with R-8 of blownin FG added to the existing R-30.	\$0.91	330	Window Area (ft ²)	\$301
Ceiling/Attic Insulation (2012 IECC)	Ceiling: R30 blown-in				Buried Encapsulated Ducts (BEDs)	\$1,148
Above Grade Wall Insulation (2012 IECC)	Wall: R13	Wall: R13+5	\$0.83	1531	Sq. Ft.	\$1,271
Floor Insulation (2012 IECC)	Floor: n/a	Floor: n/a	-	-	-	-
Foundation Insulation, Slab (2012 IECC)	Slab: 0	Slab: 0	-	-	-	-
Foundation Insulation, Wall (2012 IECC)	n/a	n/a	-	-	-	-
Duct location	Attic (100% of supply & return)	Ducts inside conditioned space	-	-	-	-
Total duct leakage	Total Leakage ≤ 12 cfm per 100 SF of CFA	Total Leakage < 8 cfm per 100 SF of CFA	\$0.17	814	Duct Surface Area Structured	\$138
Water Efficiency	N/A	Meets EPA Water Sense Requirements for Hot Water Distribution	\$193.00	1	Plumbing System	\$193
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$40.00	1	Refrigerator	\$40
Clothes Washer	Not Provided by Builder	Not Provided by Builder	-	-	-	-
Lighting	50% of lighting is high efficacy	80% of lighting is high efficacy	\$2.80	10.00	Lamps	\$28
Bath Fans (WHMV)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan w/controller	\$94.00	1	Bath Fan	\$94
Bath Fan (Local Exhaust)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan	\$31.00	2	Bath Fan	\$62
EPA Indoor airPLUS Verification Checklist	-	Comply with EPA Indoor airPLUS	\$1,000.00	1	IAPlus Home	\$1,000
Consolidated Renewable Energy Ready Checklist	-	-	\$350.00	1	Homes with Checklists Applied	\$350
DOE Challenge Home PERFORMANCE PATH						
Cooling	-	-	-	-	-	-
Heating	7.7 HSPF / 13 SEER / 11 EER ASHP; Electric Backup	9.0 HSPF / 16 SEER / 13 EER ASHP; Electric Backup	\$384.00	2	Tons	\$768
Radiant Barrier	None	None	-	-	-	-
Ceiling Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Ceiling Insulation Installation	Grade II	Grade I	\$0.07	2750	Insulated Ceiling SF	\$193
AGW Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
AGW Insulation Installation	Grade III	Grade I	\$0.09	1531	Insulated AGW SF	\$138
Foundation Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Foundation Insulation Installation	Grade II	Grade I	-	-	-	-
Infiltration	7.0 ACH50	2.5 ACH50	\$0.44	2200	CFA	\$968
Windows	see Energy Star fenestration above	see Energy Star fenestration above	-	-	-	-
Doors	R-2.0	R-2.9	\$2.17	2	Door	\$4
Water Heater	0.92 EF electric storage; 50 gal.	0.95 EF electric storage; 50 gal.	\$1.20	50	Gallons	\$60
Thermostat	Programmable	Programmable	-	-	-	-
Duct Sealing	See Total Duct Leakage above	See Total Duct Leakage above	-	-	-	-
Duct Insulation	supplies R-8; returns R-6	supplies R-8; returns R-6	-	-	-	-
ENERGY STAR CHECKLISTS						
Thermal Enclosure System - Rater	Cost includes reduced lumber from Advanced Framing & Rater Verification; Other associated costs listed elsewhere include the home's insulation, windows and door improvements.					-\$25
HVAC Sys. Quality Install. - Contractor	Cost includes Credential Fee, HVAC Commissioning, Contractor Completion of Checklist. Other costs associated with the requirement are reflected above in the WHMV system and in reduced capacity for HVAC Equipment.					\$200
HVAC Sys. Quality Install. - Rater	Cost includes Document Collection & Review, Bedroom Pressure Balancing, Rater Verification. Other cost associated with the requirement are reflected in Duct Sealing and Duct Insulation.					\$350

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

SCENARIO: CLIMATE ZONE 3; GAS SPACE & WATER HEATING; 2009 IECC BASELINE						
Baseline Home:	2200 SF prototype, compliant with 2009 IECC (prescriptive)					
Design Home:	2200 SF prototype, compliant with DOE Challenge Home (performance)					
Foundation Type:	Slab on Grade					
City:	Ft. Worth , TX					
Climate Zone:	3					
Space & Water Fuel:	Gas					
Cost						
INCREMENTAL COSTS						\$6,868
MONTHLY PAYMENT						\$36.87
MONTHLY UTILITY SAVINGS						\$66
ASSUMED INTEREST RATE (same as V3 analysis)						5.00%
NET MONTHLY CASHFLOW						\$29.02
DOE Challenge Home Mandatory Requirements: Exhibit 1						
Measure	2009 IECC Baseline	DOE Challenge Home(Rev. 03)	UNIT COST	UNIT QTY	UNIT	MARGINAL COST FOR Challenge Home
Home is ENERGY STAR V3 Qualified	N/A	V3 Cost Impacts Reflected in Items Below	-	-	-	-
Fenestration meets ENERGY STAR criteria	U=0.50; SHGC=0.30	U=0.30; SHGC=0.27 BEDS: R-38 ATTIC Assembly: 1.5" of CCSPF over R-8 Duct Work and 2" of CCSPF over R-6 Duct Work, encapsulating duct work with R-8 of blownin FG added to the existing R-30.	\$0.91	330	Window Area (ft ²)	\$301
Ceiling/Attic Insulation (2012 IECC)	Ceiling: R30 blown-in		\$1,148.40	1	Buried Encapsulated Ducts (BEDs)	\$1,148
Above Grade Wall Insulation (2012 IECC)	Wall: R13	Wall: R13+5	\$0.83	1531	Sq. Ft.	\$1,271
Floor Insulation (2012 IECC)	Floor: n/a	Floor: n/a	-	-	-	-
Foundation Insulation, Slab (2012 IECC)	Slab: 0	Slab: 0	-	-	-	-
Foundation Insulation, Wall (2012 IECC)	n/a	n/a	-	-	-	-
Duct location	Attic (100% of supply & return)	Ducts inside conditioned space	-	-	-	-
Total duct leakage	Total Leakage ≤ 12 cfm per 100 SF of CFA	Total Leakage < 8 cfm per 100 SF of CFA	\$0.17	814	Duct Surface Area	\$138
Water Efficiency	N/A	Meets EPA Water Sense Requirements for Hot Water Distribution	\$193.00	1	Structured Plumbing System	\$193
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$40.00	1	Refrigerator	\$40
Clothes Washer	Not Provided by Builder	Not Provided by Builder	-	-	-	-
Lighting	50% of lighting is high efficacy	80% of lighting is high efficacy	\$2.80	10.00	Lamps	\$28
Bath Fans (WHMV)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan w/controller	\$94.00	1	Bath Fan	\$94
Bath Fan (Local Exhaust)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan	\$31.00	2	Bath Fan	\$62
EPA Indoor airPLUS Verification Checklist	-	Comply with EPA Indoor airPLUS	\$1,000.00	1	IAPlus Home	\$1,000
Consolidated Renewable Energy Ready Checklist	-	-	\$350.00	1	Homes with Checklists Applied	\$350
DOE Challenge Home PERFORMANCE PATH						
Cooling	13 SEER A/C	15 SEER A/C	\$156.00	2	Tons	\$312
Heating	80 AFUE	90 AFUE	\$6.60	24	kBtu/hr	\$158
Radiant Barrier	None	None	-	-	-	-
Ceiling Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Ceiling Insulation Installation	Grade II	Grade I	\$0.07	2750	Insulated Ceiling SF	\$193
AGW Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
AGW Insulation Installation	Grade III	Grade I	\$0.09	1531	Insulated AGW SF	\$138
Foundation Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Foundation Insulation Installation	Grade II	Grade I	-	-	-	-
Infiltration	7.0 ACH50	2.5 ACH50	\$0.44	2200	CFA	\$968
Windows	see Energy Star fenestration above	see Energy Star fenestration above	-	-	-	-
Doors	R-2.0	R-2.9	\$2.17	2	Door	\$4
Water Heater	0.59 EF (0.71 RE) gas storage; 50 gal.	0.67 EF (0.76 RE) gas storage; 50 gal.	\$0.70	50	Gallons	\$35
Thermostat	Programmable	Programmable	-	-	-	-
Duct Sealing	See Total Duct Leakage above	See Total Duct Leakage above	-	-	-	-
Duct Insulation	supplies R-8; returns R-6	supplies R-8; returns R-6	-	-	-	-
ENERGY STAR CHECKLISTS						
Thermal Enclosure System - Rater	Cost includes reduced lumber from Advanced Framing & Rater Verification; Other associated costs listed elsewhere include the home's insulation, windows and door improvements.					-\$25
HVAC Sys. Quality Install. - Contractor	Cost includes Credential Fee, HVAC Commissioning, Contractor Completion of Checklist. Other costs associated with the requirement are reflected above in the WHMV system and in reduced capacity for HVAC Equipment.					\$200
HVAC Sys. Quality Install. - Rater	Cost includes Document Collection & Review, Bedroom Pressure Balancing, Rater Verification. Other cost associated with the requirement are reflected in Duct Sealing and Duct Insulation. Elimination of R-Vent					\$250

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

SCENARIO: CLIMATE ZONE 5; ALL ELECTRIC; 2009 IECC BASELINE						
Baseline Home:	2200 SF prototype, compliant with 2009 IECC (prescriptive)					
Design Home:	2200 SF prototype, compliant with DOE Challenge Home (performance)					
Foundation Type:	Conditioned Basement					
City:	Indianapolis, IN					
Climate Zone:	5					
Space & Water Fuel:	Electric					
Cost						
INCREMENTAL COSTS						\$5,590
MONTHLY PAYMENT						\$30.01
MONTHLY UTILITY SAVINGS						\$101
ASSUMED INTEREST RATE (same as V3 analysis)						5.00%
NET MONTHLY CASHFLOW						\$71.07
DOE Challenge Home Mandatory Requirements: Exhibit 1						
Measure	2009 IECC Baseline	DOE Challenge Home(Rev. 03)	UNIT COST	UNIT QTY	UNIT	MARGINAL COST FOR Challenge Home
Home is ENERGY STAR V3 Qualified	N/A	V3 Cost Impacts Reflected in Items Below	-	-	-	-
Fenestration meets ENERGY STAR criteria	U=0.35; SHGC=0.45	U=0.30; SHGC=0.27	\$0.69	330	Window Area (ft ²)	\$227
Ceiling/Attic Insulation (2012 IECC)	Ceiling: R38 blown-in	Ceiling: R38 blown-in	\$3.50	92	Top Plate Area (SF)	\$322
Above Grade Wall Insulation (2012 IECC)	Wall: R21	Wall: R21	-	-	-	-
Floor Insulation (2012 IECC)	Floor: n/a	Floor: n/a	-	-	-	-
Foundation Insulation, Slab (2012 IECC)	Slab: 0	Slab: 0	-	-	-	-
Foundation Insulation, Wall (2012 IECC)	R-10	R-15	\$0.22	1501	Material Cost (SF)	\$330
Duct location	Ducts in conditioned space: basement and interior walls	Ducts inside conditioned space	-	-	-	-
Total duct leakage	Total Leakage ≤ 12 cfm per 100 SF of CFA	Total Leakage < 8 cfm per 100 SF of CFA	\$0.19	1221	Duct Surface Area Structured	\$232
Water Efficiency	N/A	Meets EPA Water Sense Requirements for Hot Water Distribution	\$193.00	1	Plumbing System	\$193
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$40.00	1	Refrigerator	\$40
Clothes Washer	Not Provided by Builder	Not Provided by Builder	-	-	-	-
Lighting	50% of lighting is high efficacy	80% of lighting is high efficacy	\$2.80	10.00	Lamps	\$28
Bath Fans (WHMV)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan w/controller	\$94.00	1	Bath Fan	\$94
Bath Fan (Local Exhaust)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan	\$31.00	2	Bath Fan	\$62
EPA Indoor airPLUS Verification Checklist	-	Comply with EPA Indoor airPLUS	\$1,000.00	1	IAPlus Home	\$1,000
Consolidated Renewable Energy Ready Checklist	-	-	\$350.00	1	Homes with Checklists Applied	\$350
DOE Challenge Home PERFORMANCE PATH						
Cooling	-	-	-	-	-	-
Heating	7.7 HSPF / 13 SEER / 11 EER ASHP; Electric Backup	9.2 HSPF / 15 SEER / 13 EER ASHP; Electric Backup	\$345.84	2	Tons	\$692
Radiant Barrier	None	None	-	-	-	-
Ceiling Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Ceiling Insulation Installation	Grade II	Grade I	\$0.07	2200	Insulated Ceiling SF	\$154
AGW Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
AGW Insulation Installation	Grade III	Grade I	\$0.04	1531	Insulated AGW SF	\$61
Foundation Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Foundation Insulation Installation	Grade II	Grade I	\$0.15	1501	Insulated Foundation Wall SF	\$225
Infiltration	7.0 ACH50	2.0 ACH50	\$0.48	2200	CFA	\$1,056
Windows	see Energy Star fenestration above	see Energy Star fenestration above	-	-	-	-
Doors	R-2.9	R-3.1	\$2.17	2	Door	\$4
Water Heater	0.92 EF electric storage; 50 gal.	0.95 EF electric storage; 50 gal.	\$1.20	50	Gallons	\$60
Thermostat	Programmable	Programmable	-	-	-	-
Duct Sealing	See Total Duct Leakage above	See Total Duct Leakage above	-	-	-	-
Duct Insulation	R-0	R-0	-	-	-	-
ENERGY STAR CHECKLISTS						
Thermal Enclosure System - Rater	Cost includes reduced lumber from Advanced Framing & Rater Verification; Other associated costs listed elsewhere include the home's insulation, windows and door improvements.					-\$100
HVAC Sys. Quality Install. - Contractor	Cost includes Credential Fee, HVAC Commissioning, Contractor Completion of Checklist. Other costs associated with the requirement are reflected above in the WHMV system and in reduced capacity for HVAC Equipment.					\$200
HVAC Sys. Quality Install. - Rater	Cost includes Document Collection & Review, Bedroom Pressure Balancing, Rater Verification. Other cost associated with the requirement are reflected in Duct Sealing and Duct Insulation.					\$350

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

SCENARIO: CLIMATE ZONE 5; GAS SPACE & WATER HEATING; 2009 IECC BASELINE						
Baseline Home:	2200 SF prototype, compliant with 2009 IECC (prescriptive)					
Design Home:	2200 SF prototype, compliant with DOE Challenge Home (performance)					
Foundation Type:	Conditioned Basement					
City:	Indianapolis, IN					
Climate Zone:	5					
Space & Water Fuel:	Gas					
Cost						
INCREMENTAL COSTS						\$5,083
MONTHLY PAYMENT						\$27.29
MONTHLY UTILITY SAVINGS						\$70
ASSUMED INTEREST RATE (same as V3 analysis)						5.00%
NET MONTHLY CASHFLOW						\$42.77
DOE Challenge Home Mandatory Requirements: Exhibit 1						
Measure	2009 IECC Baseline	DOE Challenge Home(Rev. 03)	UNIT COST	UNIT QTY	UNIT	MARGINAL COST FOR Challenge Home
Home is ENERGY STAR V3 Qualified	N/A	V3 Cost Impacts Reflected in Items Below	-	-	-	-
Fenestration meets ENERGY STAR criteria	U=0.35; SHGC=0.45	U=0.30; SHGC=0.27	\$0.69	330	Window Area (ft²)	\$227
			\$3.50	92	Top Plate Area (SF)	\$322
Ceiling/Attic Insulation (2012 IECC)	Ceiling: R38 blown-in	Ceiling: R38 blown-in				
Above Grade Wall Insulation (2012 IECC)	Wall: R21	Wall: R21	-	-	-	-
Floor Insulation (2012 IECC)	Floor: n/a	Floor: n/a	-	-	-	-
Foundation Insulation, Slab (2012 IECC)	Slab: 0	Slab: 0	-	-	-	-
Foundation Insulation, Wall (2012 IECC)	R-10	R-15	\$0.22	1501	Material Cost (SF)	\$330
Duct location	walls	Ducts inside conditioned space	-	-	-	-
Total duct leakage	Total Leakage ≤ 12 cfm per 100 SF of CFA	Total Leakage < 8 cfm per 100 SF of CFA	\$0.19	1221	Duct Surface Area	\$232
		Meets EPA Water Sense Requirements for Hot Water Distribution	\$193.00	1	Structured Plumbing System	\$193
Water Efficiency Dishwasher	N/A	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$40.00	1	Refrigerator	\$40
Clothes Washer	Not Provided by Builder	Not Provided by Builder	-	-	-	-
Lighting	50% of lighting is high efficacy	80% of lighting is high efficacy	\$2.80	13.00	Lamps	\$36
Bath Fans (WHMV)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan w/controller	\$94.00	1	Bath Fan	\$94
Bath Fan (Local Exhaust)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan	\$31.00	2	Bath Fan	\$62
EPA Indoor airPLUS Verification Checklist	-	Comply with EPA Indoor airPLUS	\$1,000.00	1	IAPlus Home Homes with Checklists Applied	\$1,000
Consolidated Renewable Energy Ready Checklist	-	-	\$350.00	1	Checklists Applied	\$350
DOE Challenge Home PERFORMANCE PATH						
Cooling	13 SEER	13 SEER	-	-	-	-
Heating	80 AFUE	95 AFUE	\$7.17	42	kBtu/hr	\$301
Radiant Barrier	None	None	-	-	-	-
Ceiling Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Ceiling Insulation Installation	Grade II	Grade I	\$0.07	2200	Insulated Ceiling SF	\$154
AGW Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
AGW Insulation Installation	Grade III	Grade I	\$0.04	1531	Insulated AGW SF	\$61
Foundation Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Foundation Insulation Installation	Grade II	Grade I	\$0.15	1501	Insulated Foundation Wall SF	\$225
Infiltration	7.0 ACH50	2.0 ACH50	\$0.48	2200	CFA	\$1,056
Windows	see Energy Star fenestration above	see Energy Star fenestration above	-	-	-	-
Doors	R-2.9	R-3.1	\$2.17	2	Door	\$4
Water Heater	0.59 EF (0.71 RE) gas storage; 50 gal.	0.67 EF (0.76 RE) gas storage; 50 gal.	\$0.70	50	Gallons	\$35
Thermostat	Programmable	Programmable	-	-	-	-
Duct Sealing	See Total Duct Leakage above	See Total Duct Leakage above	-	-	-	-
Duct Insulation	R-0	R-0	-	-	-	-
ENERGY STAR CHECKLISTS						
Thermal Enclosure System - Rater	Cost includes reduced lumber from Advanced Framing & Rater Verification; Other associated costs listed elsewhere include the home's insulation, windows and door improvements.					-\$100
HVAC Sys. Quality Install. - Contractor	Cost includes Credential Fee, HVAC Commissioning, Contractor Completion of Checklist. Other costs associated with the requirement are reflected above in the WHMV system and in reduced capacity for HVAC Equipment.					\$200
HVAC Sys. Quality Install. - Rater	Cost includes Document Collection & Review, Bedroom Pressure Balancing, Rater Verification. Other cost associated with the requirement are reflected in Duct Sealing and Duct Insulation. Elimination of B-Vent					\$250

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

SCENARIO: CLIMATE ZONE 3; ALL ELECTRIC; 2012 IECC BASELINE						
Baseline Home:	2200 SF prototype, compliant with 2012 IECC (prescriptive)					
Design Home:	2200 SF prototype, compliant with DOE Challenge Home (performance)					
Foundation Type:	Slab on Grade					
City:	Ft. Worth , TX					
Climate Zone:	3					
Space & Water Fuel:	Electric					
Cost						
INCREMENTAL COSTS						\$4,663
MONTHLY PAYMENT						\$25.03
MONTHLY UTILITY SAVINGS						\$37
ASSUMED INTEREST RATE (same as V3 analysis)						5.00%
NET MONTHLY CASHFLOW						\$12.44
DOE Challenge Home Mandatory Requirements: Exhibit 1						
Measure	2012 IECC Baseline	DOE Challenge Home(Rev. 03)	UNIT COST	UNIT QTY	UNIT	MARGINAL COST FOR Challenge Home
Home is ENERGY STAR V3 Qualified	N/A	V3 Cost Impacts Reflected in Items Below	-	-	-	-
Fenestration meets ENERGY STAR criteria	U=0.35; SHGC=0.25	U=0.30; SHGC=0.27	\$0.63	330	Window Area (ft²)	\$208
		BEDs: R-38 Attic Assembly: 1.5" of CCSPF encapsulating supply side and 2" of CCSPF on return side.	\$708.40	1	Buried Encapsulated Ducts (BEDs)	\$708
Ceiling/Attic Insulation (2012 IECC)	Ceiling: R38 blown-in	Wall: R13+5	-	-	-	-
Above Grade Wall Insulation (2012 IECC)	Wall: R13+5	Floor: n/a	-	-	-	-
Floor Insulation (2012 IECC)	Floor: n/a	Slab: 0	-	-	-	-
Foundation Insulation, Slab (2012 IECC)	Slab: 0	n/a	-	-	-	-
Foundation Insulation, Wall (2012 IECC)	n/a	Attic (100% of supply & return)	-	-	-	-
Duct location	Total Leakage ≤ 4 cfm per 100 SF of CFA (Not applicable-ducts are in conditioned space) Assume	Total Leakage < 8 cfm per 100 SF of CFA (Met via encapsulated duct work, see above)	-	-	-	-
Total duct leakage						
Water Efficiency	N/A	Meets EPA Water Sense Requirements for Hot Water Distribution	\$193.00	1	Structured Plumbing System	\$193
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$40.00	1	Refrigerator	\$40
Clothes Washer	Not Provided by Builder	Not Provided by Builder	-	-	-	-
Lighting	75% of lighting is high efficacy	80% of lighting is high efficacy	\$2.80	10.00	Lamps	\$28
Bath Fans (WHMV)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan w/controller	\$94.00	1	Bath Fan	\$94
Bath Fan (Local Exhaust)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan	\$31.00	2	Bath Fan	\$62
EPA Indoor airPLUS Verification Checklist	-	Comply with EPA Indoor airPLUS	\$1,000.00	1	IAPlus Home	\$1,000
Consolidated Renewable Energy Ready Checklist	-	-	\$350.00	1	Homes with Checklists Applied	\$350
DOE Challenge Home PERFORMANCE PATH						
Cooling	-	-	-	-	-	-
Heating	7.7 HSPF / 13 SEER / 11 EER ASHP; Electric Backup	9.0 HSPF / 16 SEER / 13 EER ASHP; Electric Backup	\$384.00	2	Tons	\$768
Radiant Barrier	None	None	-	-	-	-
Ceiling Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Ceiling Insulation Installation	Grade II	Grade I	\$0.07	2750	Insulated Ceiling SF	\$193
AGW Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
AGW Insulation Installation	Grade III	Grade I	\$0.09	1531	Insulated AGW SF	\$138
Foundation Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Foundation Insulation Installation	Grade II	Grade I	-	-	-	-
Infiltration	3.0 ACH50	2.5 ACH50	\$0.13	2200	CFA	\$286
Windows	see Energy Star fenestration above	see Energy Star fenestration above	-	-	-	-
Doors	R-2.9	R-2.9	-	-	-	-
Water Heater	0.92 EF electric storage; 50 gal.	0.95 EF electric storage; 50 gal.	\$1.20	50	Gallon	\$60
Thermostat	Programmable	Programmable	-	-	-	-
Duct Sealing	See Total Duct Leakage above	See Total Duct Leakage above	-	-	-	-
Duct Insulation	supplies R-8; returns R-6	supplies R-8; returns R-6	-	-	-	-
ENERGY STAR CHECKLISTS						
Thermal Enclosure System - Rater	Cost includes reduced lumber from Advanced Framing & Rater Verification; Other associated costs listed elsewhere include the home's insulation, windows and door improvements.					-\$25
HVAC Sys. Quality Install. - Contractor	Cost includes Credential Fee, HVAC Commissioning, Contractor Completion of Checklist. Other costs associated with the requirement are reflected above in the WHMV system and in reduced capacity for HVAC Equipment.					\$200
HVAC Sys. Quality Install. - Rater	Cost includes Document Collection & Review, Bedroom Pressure Balancing, Rater Verification. Other cost associated with the requirement are reflected in Duct Sealing and Duct Insulation.					\$350

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

SCENARIO: CLIMATE ZONE 3; GAS SPACE & WATER HEATING; 2012 IECC BASELINE						
Baseline Home:	2200 SF prototype, compliant with 2012 IECC (prescriptive)					
Design Home:	2200 SF prototype, compliant with DOE Challenge Home (performance)					
Foundation Type:	Slab on Grade					
City:	Ft. Worth , TX					
Climate Zone:	3					
Space & Water Fuel:	Gas					
Cost						
INCREMENTAL COSTS						\$4,216
MONTHLY PAYMENT						\$22.63
MONTHLY UTILITY SAVINGS						\$37
ASSUMED INTEREST RATE (same as V3 analysis)						5.00%
NET MONTHLY CASHFLOW						\$13.95
DOE Challenge Home Mandatory Requirements: Exhibit 1						
Measure	2012 IECC Baseline	DOE Challenge Home(Rev. 03)	UNIT COST	UNIT QTY	UNIT	MARGINAL COST FOR Challenge Home
Home is ENERGY STAR V3 Qualified	N/A	V3 Cost Impacts Reflected in Items Below	-	-	-	-
Fenestration meets ENERGY STAR criteria	U=0.35; SHGC=0.25	U=0.30; SHGC=0.27	\$0.63	330	Window Area (ft ²)	\$208
		BEDs: R-38 Attic Assembly: 1.5" of CCSPF encapsulating supply side and 2" of CCSPF on return side.	\$708.40	1	Buried Encapsulated Ducts (BEDs)	\$708
Ceiling/Attic Insulation (2012 IECC)	Ceiling: R38 blown-in					
Above Grade Wall Insulation (2012 IECC)	Wall: R13+5	Wall: R13+5	-	-	-	-
Floor Insulation (2012 IECC)	Floor: n/a	Floor: n/a	-	-	-	-
Foundation Insulation, Slab (2012 IECC)	Slab: 0	Slab: 0	-	-	-	-
Foundation Insulation, Wall (2012 IECC)	n/a	n/a	-	-	-	-
Duct location	Attic (100% of supply & return)	Ducts inside conditioned space	-	-	-	-
Total duct leakage	Total Leakage ≤ 4 cfm per 100 SF of CFA (Not applicable-ducts are in conditioned space) Assume	Total Leakage < 8 cfm per 100 SF of CFA (Met via encapsulated duct work, see above)	-	-	-	-
Water Efficiency	N/A	Meets EPA Water Sense Requirements for Hot Water Distribution	\$193.00	1	Structured Plumbing System	\$193
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$40.00	1	Refrigerator	\$40
Clothes Washer	Not Provided by Builder	Not Provided by Builder	-	-	-	-
Lighting	75% of lighting is high efficacy	80% of lighting is high efficacy	\$2.80	10.00	Lamps	\$28
Bath Fans (WHMV)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan w/controller	\$94.00	1	Bath Fan	\$94
Bath Fan (Local Exhaust)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan	\$31.00	2	Bath Fan	\$62
EPA Indoor airPLUS Verification Checklist	-	Comply with EPA Indoor airPLUS	\$1,000.00	1	IAPlus Home	\$1,000
Consolidated Renewable Energy Ready Checklist	-	-	\$350.00	1	Homes with Checklists Applied	\$350
DOE Challenge Home PERFORMANCE PATH						
Cooling	13 SEER A/C	15 SEER A/C	\$144.00	2	Tons	\$288
Heating	80 AFUE	90 AFUE	\$6.60	24	kBtu/hr	\$158
Radiant Barrier	None	None	-	-	-	-
Ceiling Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Ceiling Insulation Installation	Grade II	Grade I	\$0.07	2750	Insulated Ceiling SF	\$193
AGW Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
AGW Insulation Installation	Grade III	Grade I	\$0.09	1531	Insulated AGW SF	\$138
Foundation Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Foundation Insulation Installation	Grade II	Grade I	-	-	-	-
Infiltration	3.0 ACH50	2.5 ACH50	\$0.13	2200	CFA	\$286
Windows	see Energy Star fenestration above	see Energy Star fenestration above	-	-	-	-
Doors	R-2.9	R-2.9	-	-	-	-
Water Heater	0.59 EF (0.71 RE) gas storage; 50 gal.	0.67 EF (0.76 RE) gas storage; 50 gal.	\$0.70	50	Gallons	\$35
Thermostat	Programmable	Programmable	-	-	-	-
Duct Sealing	See Total Duct Leakage above	See Total Duct Leakage above	-	-	-	-
Duct Insulation	supplies R-8; returns R-6	supplies R-8; returns R-6	-	-	-	-
ENERGY STAR CHECKLISTS						
Thermal Enclosure System - Rater	Cost includes reduced lumber from Advanced Framing & Rater Verification; Other associated costs listed elsewhere include the home's insulation, windows and door improvements.					-\$25
HVAC Sys. Quality Install. - Contractor	Cost includes Credential Fee, HVAC Commissioning, Contractor Completion of Checklist. Other costs associated with the requirement are reflected above in the WHMV system and in reduced capacity for HVAC Equipment.					\$200
HVAC Sys. Quality Install. - Rater	Cost includes Document Collection & Review, Bedroom Pressure Balancing, Rater Verification. Other cost associated with the requirement are reflected in Duct Sealing and Duct Insulation. Elimination of R-Vent					\$250

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

SCENARIO: CLIMATE ZONE 5; ALL ELECTRIC; 2012 IECC BASELINE						
Baseline Home:	2200 SF prototype, compliant with 2012 IECC (prescriptive)					
Design Home:	2200 SF prototype, compliant with DOE Challenge Home (performance)					
Foundation Type:	Conditioned Basement					
City:	Indianapolis, IN					
Climate Zone:	5					
Space & Water Fuel:	Electric					
Cost						
INCREMENTAL COSTS						\$4,403
MONTHLY PAYMENT						\$23.64
MONTHLY UTILITY SAVINGS						\$40
ASSUMED INTEREST RATE (same as V3 analysis)						5.00%
NET MONTHLY CASHFLOW						\$15.99
DOE Challenge Home Mandatory Requirements: Exhibit 1						
Measure	2012 IECC Baseline	DOE Challenge Home(Rev. 03)	UNIT COST	UNIT QTY	UNIT	MARGINAL COST FOR Challenge Home
Home is ENERGY STAR V3 Qualified	N/A	V3 Cost Impacts Reflected in Items Below	-	-	-	-
Fenestration meets ENERGY STAR criteria	U=0.32; SHGC=0.45	U=0.30; SHGC=0.27	\$0.44	330	Window Area (ft ²)	\$144
			\$3.50	92	Top Plate Area (SF)	\$322
Ceiling/Attic Insulation (2012 IECC)	Ceiling: R38 blown-in	Ceiling: R38 blown-in				
Above Grade Wall Insulation (2012 IECC)	Wall: R21	Wall: R21	-	-	-	-
Floor Insulation (2012 IECC)	Floor: n/a	Floor: n/a	-	-	-	-
Foundation Insulation, Slab (2012 IECC)	Slab: 0	Slab: 0	-	-	-	-
Foundation Insulation, Wall (2012 IECC)	R-15	R-15	-	-	-	-
Duct location	walls	Ducts inside conditioned space	-	-	-	-
Total duct leakage	Total Leakage ≤ 4 cfm per 100 SF of CFA (Not applicable-ducts are in conditioned space) Assume	Total Leakage < 8 cfm per 100 SF of CFA	\$0.19	1221	Duct Surface Area	\$232
Water Efficiency	N/A	Meets EPA Water Sense Requirements for Hot Water Distribution	\$193.00	1	Structured Plumbing System	\$193
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$40.00	1	Refrigerator	\$40
Clothes Washer	Not Provided by Builder	Not Provided by Builder	-	-	-	-
Lighting	75% of lighting is high efficacy	80% of lighting is high efficacy	\$2.80	10.00	Lamps	\$28
Bath Fans (WHMV)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan w/controller	\$94.00	1	Bath Fan	\$94
Bath Fan (Local Exhaust)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan	\$31.00	2	Bath Fan	\$62
EPA Indoor airPLUS Verification Checklist	-	Comply with EPA Indoor airPLUS	\$1,000.00	1	IAPlus Home	\$1,000
Consolidated Renewable Energy Ready Checklist	-	-	\$350.00	1	Homes with Checklists Applied	\$350
DOE Challenge Home PERFORMANCE PATH						
Cooling	-	-	-	-	-	-
Heating	7.7 HSPF / 13 SEER / 11 EER ASHP; Electric Backup	9.2 HSPF / 15 SEER / 13 EER ASHP; Electric Backup	\$345.84	2	Tons	\$692
Radiant Barrier	None	None	-	-	-	-
Ceiling Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Ceiling Insulation Installation	Grade II	Grade I	\$0.07	2200	Insulated Ceiling SF	\$154
AGW Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
AGW Insulation Installation	Grade III	Grade I	\$0.04	1531	Insulated AGW SF	\$61
Foundation Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Foundation Insulation Installation	Grade II	Grade I	\$0.15	1501	Insulated Foundation	\$225
Infiltration	3.0 ACH50	2.0 ACH50	\$0.13	2200	Foundation CFA	\$286
Windows	see Energy Star fenestration above	see Energy Star fenestration above	-	-	-	-
Doors	R-3.1	R-3.1	-	-	-	-
Water Heater	0.92 EF electric storage; 50 gal.	0.95 EF electric storage; 50 gal.	\$1.20	50	Gallons	\$60
Thermostat	Programmable	Programmable	-	-	-	-
Duct Sealing	See Total Duct Leakage above	See Total Duct Leakage above	-	-	-	-
Duct Insulation	R-0	R-0	-	-	-	-
ENERGY STAR CHECKLISTS						
Thermal Enclosure System - Rater	Cost includes reduced lumber from Advanced Framing & Rater Verification; Other associated costs listed elsewhere include the home's insulation, windows and door improvements.					-\$100
HVAC Sys. Quality Install. - Contractor	Cost includes Credential Fee, HVAC Commissioning, Contractor Completion of Checklist. Other costs associated with the requirement are reflected above in the WHMV system and in reduced capacity for HVAC Equipment.					\$200
HVAC Sys. Quality Install. - Rater	Cost includes Document Collection & Review, Bedroom Pressure Balancing, Rater Verification. Other cost associated with the requirement are reflected in Duct Sealing and Duct Insulation.					\$350

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

SCENARIO: CLIMATE ZONE 5; GAS SPACE & WATER HEATING; 2012 IECC BASELINE						
Baseline Home:	2200 SF prototype, compliant with 2012 IECC (prescriptive)					
Design Home:	2200 SF prototype, compliant with DOE Challenge Home (performance)					
Foundation Type:	Conditioned Basement					
City:	Indianapolis, IN					
Climate Zone:	5					
Space & Water Fuel:	Gas					
Cost						
INCREMENTAL COSTS						\$3,896
MONTHLY PAYMENT						\$20.92
MONTHLY UTILITY SAVINGS						\$33
ASSUMED INTEREST RATE (same as V3 analysis)						5.00%
NET MONTHLY CASHFLOW						\$11.97
DOE Challenge Home Mandatory Requirements: Exhibit 1						
Measure	2012 IECC Baseline	DOE Challenge Home(Rev. 03)	UNIT COST	UNIT QTY	UNIT	MARGINAL COST FOR Challenge Home
Home is ENERGY STAR V3 Qualified	N/A	V3 Cost Impacts Reflected in Items Below	-	-	-	-
Fenestration meets ENERGY STAR criteria	U=0.32; SHGC=0.45	U=0.30; SHGC=0.27	\$0.44	330	Window Area (ft ²)	\$144
Ceiling/Attic Insulation (2012 IECC)	Ceiling: R38 blown-in	Ceiling: R38 blown-in	\$3.50	92	Top Plate Area (SF)	\$322
Above Grade Wall Insulation (2012 IECC)	Wall: R21	Wall: R21	-	-	-	-
Floor Insulation (2012 IECC)	Floor: n/a	Floor: n/a	-	-	-	-
Foundation Insulation, Slab (2012 IECC)	Slab: 0	Slab: 0	-	-	-	-
Foundation Insulation, Wall (2012 IECC)	R-15	R-15	-	-	-	-
Duct location	walls	Ducts inside conditioned space	-	-	-	-
Total duct leakage	Total Leakage ≤ 4 cfm per 100 SF of CFA (Not applicable-ducts are in conditioned space) Assume	Total Leakage < 8 cfm per 100 SF of CFA	\$0.19	1221	Duct Surface Area Structured	\$232
Water Efficiency	N/A	Meets EPA Water Sense Requirements for Hot Water Distribution	\$193.00	1	Plumbing System	\$193
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$40.00	1	Refrigerator	\$40
Clothes Washer	Not Provided by Builder	Not Provided by Builder	-	-	-	-
Lighting	75% of lighting is high efficacy	80% of lighting is high efficacy	\$2.80	13.00	Lamps	\$36
Bath Fans (WHMV)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan w/controller	\$94.00	1	Bath Fan	\$94
Bath Fan (Local Exhaust)	Standard Efficiency Bath Fans	ENERGY STAR Bath Fan	\$31.00	2	Bath Fan	\$62
EPA Indoor airPLUS Verification Checklist	-	Comply with EPA Indoor airPLUS	\$1,000.00	1	IAPlus Home	\$1,000
Consolidated Renewable Energy Ready Checklist	-	-	\$350.00	1	Homes with Checklists Applied	\$350
DOE Challenge Home PERFORMANCE PATH						
Cooling	13 SEER	13 SEER	-	-	-	-
Heating	80 AFUE	95 AFUE	\$7.17	42	kBtu/hr	\$301
Radiant Barrier	None	None	-	-	-	-
Ceiling Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Ceiling Insulation Installation	Grade II	Grade I	\$0.07	2200	Insulated Ceiling SF	\$154
AGW Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
AGW Insulation Installation	Grade III	Grade I	\$0.04	1531	Insulated AGW SF	\$61
Foundation Insulation	see 2012 IECC insulation above	see 2012 IECC insulation above	-	-	-	-
Foundation Insulation Installation	Grade II	Grade I	\$0.15	1501	Insulated Foundation Wall SF	\$225
Infiltration	3.0 ACH50	2.0 ACH50	\$0.13	2200	CFA	\$286
Windows	see Energy Star fenestration above	see Energy Star fenestration above	-	-	-	-
Doors	R-3.1	R-3.1	-	-	-	-
Water Heater	0.59 EF (0.71 RE) gas storage; 50 gal.	0.67 EF (0.76 RE) gas storage; 50 gal.	\$0.70	50	Gallons	\$35
Thermostat	Programmable	Programmable	-	-	-	-
Duct Sealing	See Total Duct Leakage above	See Total Duct Leakage above	-	-	-	-
Duct Insulation	R-0	R-0	-	-	-	-
ENERGY STAR CHECKLISTS						
Thermal Enclosure System - Rater	Cost includes reduced lumber from Advanced Framing & Rater Verification; Other associated costs listed elsewhere include the home's insulation, windows and door improvements.					-\$100
HVAC Sys. Quality Install. - Contractor	Cost includes Credential Fee, HVAC Commissioning, Contractor Completion of Checklist. Other costs associated with the requirement are reflected above in the WHMV system and in reduced capacity for HVAC Equipment.					\$200
HVAC Sys. Quality Install. - Rater	Cost includes Document Collection & Review, Bedroom Pressure Balancing, Rater Verification. Other cost associated with the requirement are reflected in Duct Sealing and Duct Insulation. Elimination of B-Vent					\$250

DOE Zero Energy Ready Home Savings & Cost Estimate Summary - Appendices

APPENDIX B: DATA SOURCES

System	Cost Estimating Data Source(s)
Fenestration	NREL National Residential Efficiency Measures Database*
Ceiling/Attic Insulation	RS Means Residential Cost Data 2013
Ceiling Insulation Installation	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Above Grade Wall Insulation	RS Means Residential Cost Data 2013
AGW Insulation Installation	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Foundation Insulation, Wall	RS Means Residential Cost Data 2013
Foundation Insulation Installation	RS Means Residential Cost Data 2013
Total duct leakage	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Water Efficiency	Toolbase.org; Topic areas; PEX water supply; manifold distribution systems; accessed online June 2013.
Dishwasher	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Refrigerator	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Clothes Washer	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Lighting	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Whole House Mechanical Ventilation	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Bath Fan (Local Exhaust)	Based on Internet pricing for intermittent timer controls (5 Manufacturers, Averaged cost); Completed 9/12/2013.
EPA Indoor airPLUS Verification Checklist	DOE Estimate
Renewable Energy Ready Checklist	DOE Estimate
Cooling	NREL National Residential Efficiency Measures Database *(equipment only)
Heating	NREL National Residential Efficiency Measures Database* (equipment only) + Additional estimate for elimination of B-vent flue
Radiant Barrier	Not used
Infiltration	NREL National Residential Efficiency Measures Database (equipment only)*
Doors	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
Water Heater	NREL National Residential Efficiency Measures Database*
Thermal Enclosure System - Rater	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
HVAC Sys. Quality Install. - Contractor	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.
HVAC Sys. Quality Install. - Rater	ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary." November 2013.

*Because this database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction

Cost of Constructing a Home

www.nahb.org

Special Studies January 2, 2020

By Carmel Ford

NAHB Economics and Housing Policy Group

Introduction

Over the years, NAHB has periodically conducted “construction cost surveys” to collect information from builders on the various components that go into the sales price of a typical single-family home. NAHB’s most recent Construction Cost survey (conducted in the fall of 2019) shows that, on average, 61.1 percent of the sales price goes to construction costs and 18.5 percent to finished lot costs. On average, builder profit is 9.1 percent of the sales price.

Of the major stages of construction, interior finishes, at 25.4 percent, accounts for the largest share of construction costs, followed by framing at 17.4 percent. These percentages cover all costs paid by a builder, including labor, materials, and the cost of hiring subcontractors.

The following sections describe the methodology of the survey and discuss the results in more detail.

Methodology

NAHB’s 2019 Construction Cost survey was conducted by emailing a questionnaire to a representative sample of 6,516 home builders. The sample was stratified by the size of the builder (based on the number of 2018 single-family starts) and by region of the country (the sample being proportional to housing starts in each of the four principal Census regions).

Over the years, NAHB has modified the survey and its methodology. In 2009, the survey methodology changed to provide a better, more representative sample of single-family construction across the country. In 2013, NAHB developed a different construction cost breakdown that more closely resembles the steps that builders take when building a home. Prior to 2013, the breakdown had 29 sections. In 2013, we created eight subcategories for each of the major stages of construction, with a total of 36 sections grouped under the appropriate construction stage. The new format simplified data collection, greatly reducing the number of follow-up calls needed to clarify and verify builder responses.

Respondents were asked to provide information about the typical single-family home built by their firms during 2019. Usable responses were received from 49 builders. Table 1 shows the detailed results of the 2019 Construction Cost survey.

**Table 1. Single Family Price and Cost Breakdowns
2019 National Results**

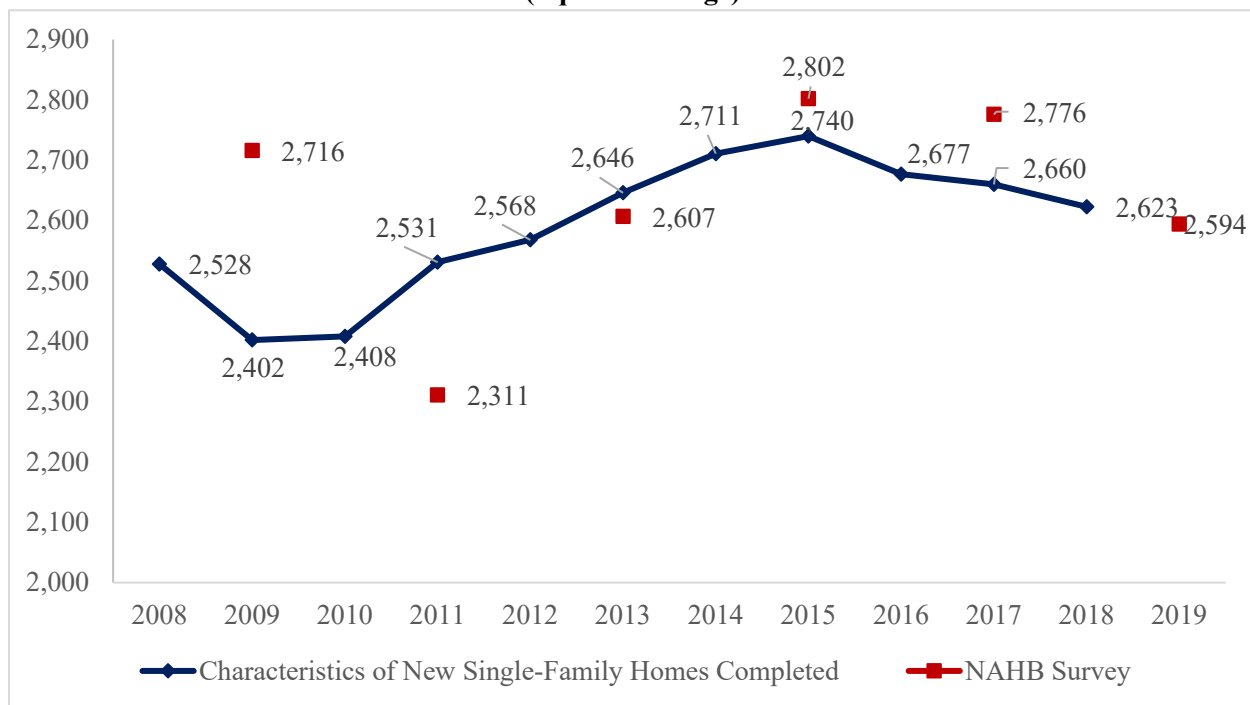
Average Lot Size:		22,094
Average Finished Area:		2,594
I. Sale Price Breakdown	Average	Share of Price
A. Finished Lot Cost (including financing cost)	\$89,540	18.5%
B. Total Construction Cost	\$296,652	61.1%
C. Financing Cost	\$8,160	1.7%
D. Overhead and General Expenses	\$23,683	4.9%
E. Marketing Cost	\$4,895	1.0%
F. Sales Commission	\$18,105	3.7%
G. Profit	\$44,092	9.1%
Total Sales Price	\$485,128	100.0%
II. Construction Cost Breakdown	Average	Share of Construction Cost
I. Site Work (sum of A to E)	\$18,323	6.2%
A. Building Permit Fees	\$5,086	1.7%
B. Impact Fee	\$3,865	1.3%
C. Water & Sewer Fees Inspections	\$4,319	1.5%
D. Architecture, Engineering	\$4,335	1.5%
E. Other	\$719	0.2%
II. Foundations (sum of F to G)	\$34,850	11.8%
F. Excavation, Foundation, Concrete, Retaining walls, and Backfill	\$33,511	11.3%
G. Other	\$1,338	0.5%
III. Framing (sum of H to L)	\$51,589	17.4%
H. Framing (including roof)	\$40,612	13.7%
I. Trusses (if not included above)	\$6,276	2.1%
J. Sheathing (if not included above)	\$3,216	1.1%
K. General Metal, Steel	\$954	0.3%
L. Other	\$530	0.2%
IV. Exterior Finishes (sum of M to P)	\$41,690	14.1%
M. Exterior Wall Finish	\$19,319	6.5%
N. Roofing	\$9,954	3.4%
O. Windows and Doors (including garage door)	\$11,747	4.0%
P. Other	\$671	0.2%
V. Major Systems Rough-ins (sum of Q to T)	\$43,668	14.7%
Q. Plumbing (except fixtures)	\$14,745	5.0%
R. Electrical (except fixtures)	\$13,798	4.7%
S. HVAC	\$14,111	4.8%
T. Other	\$1,013	0.3%
VI. Interior Finishes (sum of U to AE)	\$75,259	25.4%
U. Insulation	\$5,184	1.7%
V. Drywall	\$10,634	3.6%
W. Interior Trims, Doors, and Mirrors	\$10,605	3.6%
X. Painting	\$8,254	2.8%
Y. Lighting	\$3,437	1.2%
Z. Cabinets, Countertops	\$13,540	4.6%
AA. Appliances	\$4,710	1.6%
AB. Flooring	\$11,998	4.0%
AC. Plumbing Fixtures	\$4,108	1.4%
AD. Fireplace	\$1,867	0.6%
AE. Other	\$923	0.3%
VII. Final Steps (sum of AF to AJ)	\$20,116	6.8%
AF. Landscaping	\$6,506	2.2%
AG. Outdoor Structures (deck, patio, porches)	\$3,547	1.2%
AH. Driveway	\$6,674	2.2%
AI. Clean Up	\$2,988	1.0%
AJ. Other	\$402	0.1%
VIII. Other	\$11,156	3.8%
Total	\$296,652	100.0%

Home and Lot Size

The average single-family home size in the 2019 NAHB Construction Cost Survey is 2,594 square feet of finished floor space, the smallest square footage since 2011. Historically, average square footage in the NAHB survey has tended to move in the same direction as in the Census Bureau's series with a lag, and with wider fluctuations, as you would expect from the smaller sample size.

The average home size dropped from 2,716 square feet in 2009 to 2,311 square feet in 2011, as demand eroded after the Great Recession. As the economy recovered, it rose steadily and peaked at 2,802 square feet in 2015. Since then, the average square footage has trended downward, dropping to 2,776 in 2017 and to 2,594 in 2019 (Graph 1). Data from the Census Bureau corroborates this trend: the average size of all new homes peaked in 2015 at 2,740 square feet, but has declined every year since then. The smaller square footage in recent years is evidence that builders are shifting toward the production of more entry-level homes to meet demand for more affordable homes.

**Graph 1. SIZE OF SINGLE-FAMILY HOMES
(Square Footage)**

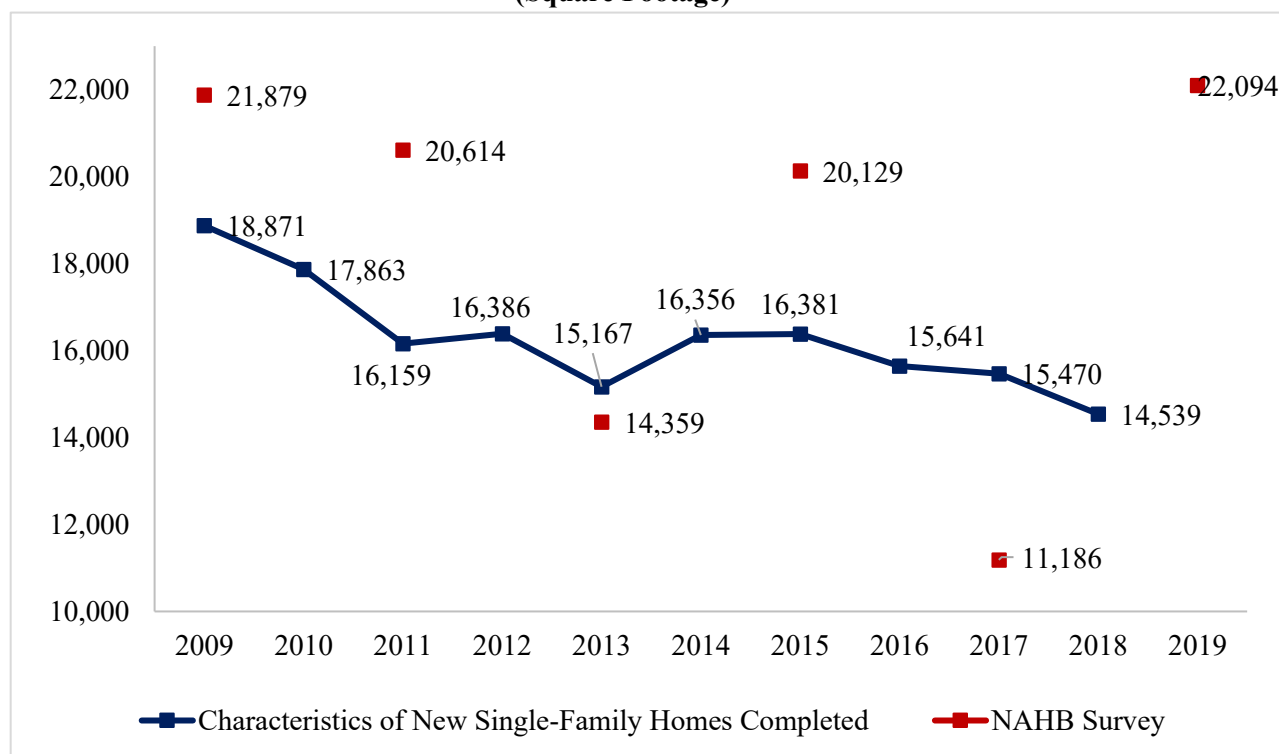


The average lot size in the 2019 NAHB Construction Cost Survey is 22,094 square feet, or about a half-acre (1 acre is equivalent to 43,560 square feet). This is the highest average lot size recorded in the survey's history. The average lot size was in the territory of 20,000 to 22,000 square feet in 2009 and 2011, but dropped to 14,359 sq. ft. in 2013. It rebounded to 20,129 sq. ft. in 2015, but dropped again to 11,186 sq. ft. in 2017, the smallest lot size since the inception of the survey.

In general, lot size in the NAHB survey has tended to move in the same direction as the Census series, but again with more volatility from year to year (Graph 2). The Census data show a downward trend in lot size between 2009 and 2013, dropping from an average of 18,871 sq. ft. to a low of 15,167 sq. ft. in 2013. It rebounds to 16,381 sq. ft. in 2015, but falls again to another low of 14,539 sq. ft. in 2018.

The NAHB survey shows a significant increase in lot size in 2019, which deviates from the downward trend exhibited by the Census data. Again, this may reflect the Construction Cost survey's small sample size.

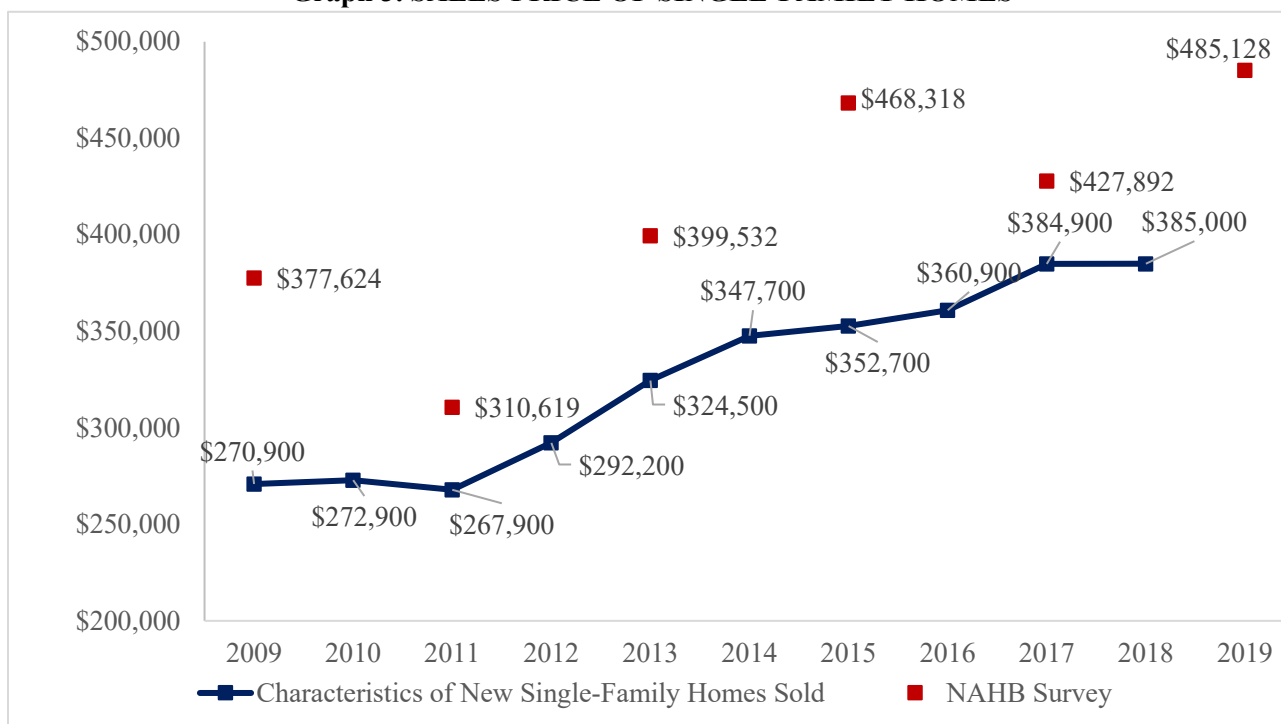
**Graph 2. LOT SIZE OF SINGLE-FAMILY HOMES
(Square Footage)**



Sales Price

The average single-family home sales price in the 2019 NAHB Construction Cost Survey is \$485,128, the highest average sales price (not adjusted for inflation) in the survey's history. The Census Bureau's series shows the average price for new single-family homes sold increasing steadily after the Great Recession, going from \$267,900 in 2011 to \$384,900 in 2017, and leveling off at \$385,000 in 2018 (Graph 3). It is important to note that [home price appreciation](#) slowed in 2018 as higher mortgage interest rates softened demand for housing. [Price growth reaccelerated](#) in 2019, however, as mortgage rates dropped to record lows and the labor market continued to expand.

Compared to the Census series, the NAHB survey data show a similar upward trend, but with bigger jumps in the average price. Again, the larger fluctuations in the NAHB surveys are most likely due to the smaller sample size. The relatively simple geographic stratification (four Census regions) may also be a factor.

Graph 3. SALES PRICE OF SINGLE-FAMILY HOMES

Sales Price Breakdown

A key feature of the NAHB survey is that it asks builders to break down the sales price of their homes into seven categories: finished lot cost; total construction cost; financing cost; overhead and general expenses; marketing costs; sales commission; and profit. Table 2 contains historical information on the sales price breakdown of a single-family home. It is important to remind readers to use caution when comparing data across years in Table 2, as trends may be affected by the survey's sample size limitations and the fact that a different set of builders responds to the survey each time.

On average in the 2019 NAHB survey, 61.1 percent of the final house price was attributable to construction costs, 18.5 percent to the cost of the finished lot, 4.9 percent to overhead and general expenses, 3.7 percent to sales commissions, 1.7 percent to financing costs, 1.0 percent to marketing costs, leaving 9.1 percent for profit (prior to taxes).

As a share of the average sales price, construction costs rose significantly, going from 55.6 percent in 2017 to 61.1 percent in 2019. At the same time, the finished lot cost share decreased from 21.5 percent to 18.5 percent, and the average profit margin fell from 10.7 percent to 9.1 percent.

Table 2. SINGLE-FAMILY HOMES SALES PRICE BREAKDOWN HISTORY

Sale Price Breakdown	1998	2002	2004	2007	2009	2011	2013	2015	2017	2019
1. Finished Lot Cost	23.6%	23.5%	26.0%	24.5%	20.3%	21.7%	18.6%	18.2%	21.5%	18.5%
2. Total Construction Cost	54.8%	50.8%	51.7%	48.1%	58.9%	59.3%	61.7%	61.8%	55.6%	61.1%
3. Financing Cost	1.9%	2.1%	1.8%	2.4%	1.7%	2.1%	1.4%	1.3%	1.8%	1.7%
4. Overhead and General Expenses	5.7%	5.5%	5.8%	7.0%	5.4%	5.2%	4.3%	5.6%	5.1%	4.9%
5. Marketing Cost	1.4%	2.4%	1.9%	2.5%	1.4%	1.5%	1.1%	0.8%	1.2%	1.0%
6. Sales Commission	3.4%	3.7%	3.0%	4.3%	3.4%	3.3%	3.6%	3.2%	4.1%	3.7%
7. Profit	9.2%	12.0%	9.8%	11.2%	8.9%	6.8%	9.3%	9.0%	10.7%	9.1%
8. Total Sales Price (\$)	\$226,680	\$298,412	\$373,349	\$454,906	\$377,624	\$310,619	\$399,532	\$468,318	\$427,892	\$485,128

Source: NAHB Construction Cost Surveys, 1998-2019

Construction Costs

The average construction cost of a typical single-family home in the 2019 survey is \$296,652 (Table 3), or about \$114 per square foot. The cost of construction per square foot was \$80 in 2011, \$95 in 2013, \$103 in 2015, and \$86 in 2017.

Of the 8 major stages of construction, interior finishes, at 25.4 percent, accounts for the largest share of construction costs, followed by framing (17.4 percent), major system rough-ins (14.7 percent), exterior finishes (14.1 percent), foundations (11.8 percent), final steps (6.8 percent), site work (6.2 percent), and other costs (3.8 percent) (See Table 3 for a full breakdown).

Each category in Table 3 includes all the costs paid by a builder that go into a particular item, including labor costs paid directly by the general contractor, the cost of hiring subcontractors, and the cost of materials, however they are purchased.

Among the major stages, the share of construction costs that go to interior finishes shifted the most between 2017 and 2019, falling from 28.6 percent to 25.4 percent. Meanwhile, foundations and major system rough-ins had the largest percentage point increases from 2017 to 2019, rising 1.0 point to 11.8 percent and 0.9 points to 14.7 percent, respectively. Rising foundation costs may reflect increases in the cost of [ready mix concrete seen throughout 2019](#).

The cost of framing, on the other hand, remained essentially unchanged between 2017 (17.3 percent) and 2019 (17.4 percent). It is important to point out that [softwood lumber costs stabilized in 2019](#), after rising significantly in 2018.

Of the detailed items in the NAHB survey, framing and trusses remain the largest share of construction costs. Together, they account for 15.8 percent of 2019's construction costs, slightly down from the 16.8 percent they represented in 2017. The share of construction costs going to impact fees rose slightly from 0.9 percent in 2017 to 1.3 percent in 2019. An [Eyeonhousing.org](#) post, which highlights the top challenges for builders in 2019, shows that a significant share of builders (61 percent) continued to report impact/hook-up/inspection fees remain one of their top problems.

Table 3. SINGLE-FAMILY CONSTRUCTION COST BREAKDOWN HISTORY

Construction Cost Breakdown	1998	2002	2004	2007	2009	2011	2013	2015	2017	2019
I. Site Work (sum of A to E)							6.8%	5.6%	6.7%	6.2%
A. Building Permit Fees	0.9%	1.3%	0.8%	1.7%	1.9%	1.7%	1.5%	1.2%	1.7%	1.7%
B. Impact Fee	1.0%	1.6%	1.1%	1.4%	1.4%	1.5%	1.3%	0.6%	0.9%	1.3%
C. Water & Sewer Fees Inspections	1.0%	1.4%	1.2%	1.6%	1.7%	1.6%	1.8%	1.4%	2.0%	1.5%
D. Architecture, Engineering							1.5%	1.6%	1.4%	1.5%
E. Other							0.7%	0.7%	0.7%	0.2%
II. Foundations (sum of F to G)							9.5%	11.6%	10.8%	11.7%
F. Excavation, Foundation, Concrete, Retaining walls, and Backfill	9.6%	6.9%	9.9%	7.0%	7.1%	9.3%	9.3%	11.3%	10.7%	11.3%
G. Other							0.2%	0.3%	0.1%	0.5%
III. Framing (sum of H to L)							19.1%	18.0%	17.3%	17.4%
H. Framing (including roof)	20.2%	18.4%	21.3%	15.8%	15.6%	13.5%	14.8%	15.4%	15.0%	13.7%
I. Trusses (if not included above)							2.2%	1.3%	1.6%	2.1%
J. Sheathing (if not included above)	NA	0.9%	1.4%	1.6%	1.7%	1.2%	0.9%	0.4%	0.3%	1.1%
K. General Metal, Steel	1.1%	0.8%	0.3%	0.8%	0.7%	0.5%	0.7%	0.4%	0.3%	0.3%
L. Other							0.5%	0.3%	0.1%	0.2%
IV. Exterior Finishes (sum of M to P)							14.4%	15.0%	13.9%	14.1%
M. Exterior Wall Finish							6.8%	7.2%	6.5%	6.5%
N. Roofing	2.6%	2.6%	2.2%	3.2%	3.8%	2.9%	3.2%	3.5%	3.3%	3.4%
O. Windows and Doors (including garage door)							4.1%	4.2%	3.9%	4.0%
P. Other							0.2%	0.2%	0.3%	0.2%
V. Major Systems Rough-ins (sum of Q to T)							13.4%	13.1%	13.8%	14.7%
Q. Plumbing (except fixtures)	5.9%	5.4%	5.3%	5.4%	5.3%	6.0%	4.8%	4.3%	4.6%	5.0%
R. Electrical (except fixtures)	3.8%	3.3%	3.4%	3.9%	3.7%	4.4%	4.0%	4.2%	4.2%	4.7%
S. HVAC	4.1%	4.2%	3.7%	3.9%	4.0%	4.8%	4.5%	4.4%	4.7%	4.8%
T. Other							0.1%	0.3%	0.2%	0.3%
VI. Interior Finishes (sum of U to AE)							29.3%	29.6%	28.6%	25.4%
U. Insulation	1.4%	1.6%	1.4%	1.6%	1.5%	1.8%	1.9%	2.2%	2.2%	1.7%
V. Drywall	5.5%	5.3%	4.9%	5.1%	5.1%	4.4%	3.8%	4.1%	4.4%	3.6%
W. Interior Trims, Doors, and Mirrors							4.3%	4.3%	4.6%	3.6%
X. Painting	3.8%	3.6%	3.6%	3.4%	3.4%	3.3%	3.4%	3.1%	3.0%	2.8%
Y. Lighting	1.0%	0.8%	0.9%	1.0%	1.1%	1.2%	1.2%	1.2%	1.3%	1.2%
Z. Cabinets, Countertops	5.0%	4.3%	6.6%	5.7%	5.6%	5.6%	5.2%	5.5%	5.0%	4.6%
AA. Appliances	1.3%	1.2%	1.3%	1.7%	1.6%	2.0%	1.7%	1.5%	1.5%	1.6%
AB. Flooring	4.8%	4.3%	4.2%	5.0%	5.1%	4.5%	5.0%	4.6%	4.3%	4.0%
AC. Plumbing Fixtures							1.7%	1.5%	1.3%	1.4%
AD. Fireplace							0.8%	1.0%	0.6%	0.6%
AE. Other							0.2%	0.5%	0.4%	0.3%
VII. Final Steps (sum of AF to AJ)							6.6%	6.8%	7.0%	6.8%
AF. Landscaping	1.8%	2.5%	2.6%	2.8%	3.2%	3.5%	2.3%	2.1%	2.5%	2.2%
AG. Outdoor Structures (deck, patio, porches)	0.7%	0.7%	1.0%	0.7%	0.9%	1.0%	1.2%	1.5%	1.3%	1.2%
AH. Driveway	1.5%	1.6%	1.3%	1.4%	1.4%	1.5%	1.5%	2.2%	1.9%	2.2%
AI. Clean Up							0.9%	0.7%	1.1%	1.0%
AJ. Other							0.7%	0.3%	0.3%	0.1%
VIII. Other							0.9%	0.5%	2.0%	3.8%

Source: NAHB Construction Cost Surveys, 1998-2019

Caveats

These results are national averages; the survey sample is not large enough for a geographic breakdown. Building practices, the cost of labor, the cost of land, and to some extent the cost of materials can vary from place to place and depend on the nature of the particular home being built. Although the survey can provide a broad idea of construction costs for the average new single-family home, it is not a perfect tool for estimating costs for a particular house. Companies that provide more specific cost estimating, usually for a fee, include RSMeans (<http://rsmeans.reedconstructiondata.com/>) and Marshall & Swift (<http://www.marshallswift.com/>).

It is also important to note that because the NAHB Construction Cost Survey has a small sample size and does not control for differences in the types of homes submitted in builders' responses, users should exhibit caution when comparing results across multiple years. For a more accurate time-series, users should refer to the Census Bureau's Survey of Construction, which is based on a much larger sample size and controls for home type.