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Comparative Analysis of Energy Efficiency: Insulated Concrete Form vs. Wood-Framed Residential Construction

Somik Ghosh * **and Ben Bigelow**

Haskell and Irene Lemon Construction Science Division, University of Oklahoma, Norman, OK 73019, USA; bigelow@ou.edu
* Correspondence: sghosh@ou.edu

Abstract: Wood is the most commonly used material for framing single-family houses in the USA, yet alternative materials like Insulated Concrete Forms (ICFs) offer potential advantages in energy efficiency and thermal performance. This study evaluates ICFs as a viable alternative by analyzing the energy performance and indoor temperature stability of five single-family houses in Oklahoma, USA, monitored over 12 months. The sample included a total of five single-family houses: two wood-framed houses with blown fiberglass insulation, one wood-framed house with spray foam insulation in the attic, and two houses with ICF exterior walls. Results demonstrated that ICF houses consumed up to 41% less electricity and at least 5% less natural gas compared to wood-framed houses, with improved indoor temperature stability. Occupants also saved approximately USD 270 annually on energy costs, highlighting the advantage of ICF's efficiency. This study provides empirical evidence of the benefits of ICF construction, which previously relied heavily on simulations or anecdotal claims. However, findings are limited by the specific geographic focus of the study. Future research should expand on these findings by incorporating a wider range of climates and housing designs to better understand the broader applicability of an ICF as an alternative to conventional wood-framed construction.

Keywords: insulated concrete form (ICF); wood-framing; energy efficiency

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Academic Editors: Cinzia Buratti and Adrian Pitts

Received: 31 December 2024
Revised: 19 February 2025
Accepted: 23 February 2025
Published: 2 March 2025

Citation: Ghosh, S.; Bigelow, B. Comparative Analysis of Energy Efficiency: Insulated Concrete Form vs. Wood-Framed Residential Construction. *Buildings* **2025**, *15*, 804. https://doi.org/10.3390/buildings15050804

1. Introduction

Wood is widely regarded as the most common building material when framing walls for single-family houses in the USA [1]. Although other options for wall construction, like masonry, concrete, or earth, offer more comfort, energy efficiency, and sturdiness, the USA construction industry has widely adopted wood and wood-framing as the most common options. However, several factors, such as the shortage of skilled workers as well as the projected increase in demand for houses in recent times, suggest that there is a need for alternative options that require smaller working crews without increasing construction time. Hence, this study investigated the efficacy of Insulated Concrete Forms (ICFs) as an alternative building material. Additionally, the evaluation of thermal performance of building envelopes is a key area of interest in construction and building research. Thus, examining the energy efficiency of ICFs compared to wood-framed construction was also a major objective of this study. ICF walls are typically composed of hollow blocks or panels stacked like Legos® to form a wall. Steel rebar is then inserted into the hollow cores, which are subsequently filled with concrete. This process creates a wall with two layers of Expanded Polystyrene (EPS) insulation, reinforced with steel and concrete in between (Figure 1a,b). ICF systems are characterized by two main features: the shape of the EPS and the form of the concrete after pouring. EPS may come in the form of blocks, planks, or panels, with blocks being the most widely used type [2].

(a) (b)

Figure 1. (**a**) Typical ICF block. (**b**) ICF block with concrete poured.

The Integration of EPS within the ICF wall has several advantages. The EPS layer delivers superior thermal insulation, effectively retaining heat during colder conditions and maintaining cooler interior environments in warmer climates. Also, the use of EPS eliminates the necessity for conventional formwork materials, such as wood, thereby contributing to the conservation of natural resources. Unlike conventional wall assemblies, ICF walls do not require curing, resulting in reduced water consumption and simplified construction processes. Collectively, these features make ICFs more sustainable than conventional wall assemblies [3].

ICFs have been widely adopted in developed countries and integrated into their building codes due to their advantages, such as their lightweight construction and energy efficiency. Experimental studies have demonstrated that an ICF serves as a superior alternative to conventional walls [4]. The study further indicated that using ICF in place of conventional materials improves overall building comfort. Further, the thermal mass of the ICF wall and its thermal resistance offer a significant advantage over conventional wall assemblies [5]. Several studies, particularly at the Oak Ridge National Laboratory [3,6,7], have explored the benefits of thermal mass. Saber et al. analyzed energy efficiency and thermal comfort for three adjacent houses with identical design parameters, including orientation, window areas, roof designs, and heating and air conditioning systems. The houses featured different wall systems: an ICF block, an ICF plank, and conventional wood-framed walls. Air leakage tests revealed no significant differences; however, the ICF houses demonstrated approximately 20% higher energy efficiency due to superior R-values and full wall insulation coverage [8]. Another study in Tennessee, USA, compared seven structurally similar houses differing only in wall construction. The house with ICF walls demonstrated energy consumption reduced by 7.5% compared to its wood-framed counterparts, emphasizing the role of thermal mass in maintaining indoor thermal stability during wide outdoor temperature fluctuations [9].

Due to limited field investigations, several studies have employed numerical simulations to evaluate the performance of ICF envelopes in residential construction. These simulations consistently indicate a nonsignificant increase in initial construction costs while demonstrating substantial savings in energy-use [9–11]. Despite the simulations showing substantial energy savings in the houses built with ICFs in comparison to wood-framed houses, using ICFs is not very common due to a lack of awareness. Specifically, Ochsendorf et al. [10] simulated the performances of ICF envelopes for single-family houses, multifamily units, as well as commercial structures and found that over the total life cycle, ICF construction adds to the cost by less than 5%, but the benefit in energy savings is considerable. Mallay and Wiehagen [12] compared ICF walls with standard walls and found a lower whole-house infiltration rate in the house with ICF exterior walls, thus making it a more energy-efficient option for above-grade applications. Similar findings based on simulations were reported by a few other studies [9,11], where energy savings in houses with ICF exterior walls ranged from 4% to 10% over conventional wood-framed houses, depending on the climatic region. Gajda and his colleagues tested several thermally massive materials such as autoclaved concrete block walls, concrete masonry units, and cast-in-place concrete panels along with ICFs in different locations across the USA. They concluded that ICF walls saved the most energy across all locations [13,14]. Additionally, several studies have evaluated the hygrothermal performance of various exterior wall systems and have found that thermal mass directly influences energy efficiency by reducing space heating and cooling demands [15–20].

Despite the documented benefits, the low level of adoption of ICFs can be attributed to a lack of empirical data highlighting the improved energy performance of the houses using them in comparison to conventional wood-framed houses. While previous studies have highlighted the benefits of ICFs using simulated data, there is a lack of research that has collected and analyzed empirical field data to provide more accurate and informed conclusions. To date, only a few studies have gathered such data, including one by Saber et al. [8], which collected data from three houses, and another by Petrie et al. [9], which gathered data from seven houses in Tennessee, USA. This paper presents a comparative analysis of energy usage data collected from multiple houses with wood-framed exterior walls and ICF walls located in Oklahoma, USA.

This study employed a case study approach to address two objectives: (1) comparing the energy performance of ICF and wood-framed houses, and (2) assessing variations in indoor temperature stability between the two construction types in single-family houses in central Oklahoma, USA. Five single-family houses with different exterior wall materials were selected, and their actual energy consumption data were analyzed to identify performance variations.

The remainder of the document is organized as follows: the next section provides the methodology followed by the Results and Conclusion. The Results present two key analyses: a comparison of energy consumption between ICF and wood-framed houses, along with an analysis of indoor temperature fluctuations in response to outdoor temperature variations for the two construction types. The document concludes by discussing the implications of these findings and offering recommendations for future research in this field.

2. Materials and Methods

The primary aim of this study was to provide empirical evidence on the energy performance of houses with varying exterior wall assemblies and insulation types, beyond anecdotal claims of monetary savings associated with energy-efficient construction practices. The specific objectives of the research were as follows:

- To compare the energy performance of houses with ICF exterior walls against those with wood-framed exterior walls in central Oklahoma, USA.
- To determine whether houses with ICF exterior walls exhibit better indoor temperature stability in response to changes in outdoor temperatures.

2.1. Research Method

A quantitative research approach was employed to analyze and compare data from houses with wood-framed and ICF exterior walls. Energy performance was evaluated using actual energy consumption data, while indoor temperature stability was assessed by measuring variations in indoor temperatures in response to outdoor temperature changes.

2.1.1. Selection of Houses

A major challenge in conducting studies of this nature lies in securing homeowner consent to access energy usage data and to permit the collection of temperature and moisture data from within their houses. For this study, data were collected from five houses built in 2022 under the 2015 International Residential Code (IRC). Among these, two houses had a floor area of 181 m^2 (1950 ft^2) and three houses had a floor area of 192 m^2 (2070 ft^2). The control group consisted of two wood-framed houses with blown fiberglass (BFG) insulation in the walls and attics, and one wood-framed house with BFG insulation in the walls and spray foam (SF) insulation in the attic. The experimental group included two houses with ICF walls, one with SF insulation in the attic and the other with BFG insulation in the attic. All houses were located within the same neighborhood, less than one kilometer apart. This proximity minimized variability in external environmental conditions, such as temperature, humidity, and solar exposure. Floor plans and orientations of the houses are shown in Figure 2. The typical wall sections for the wood-framed houses and the houses with ICF exterior walls are provided in Figure 3a,b.

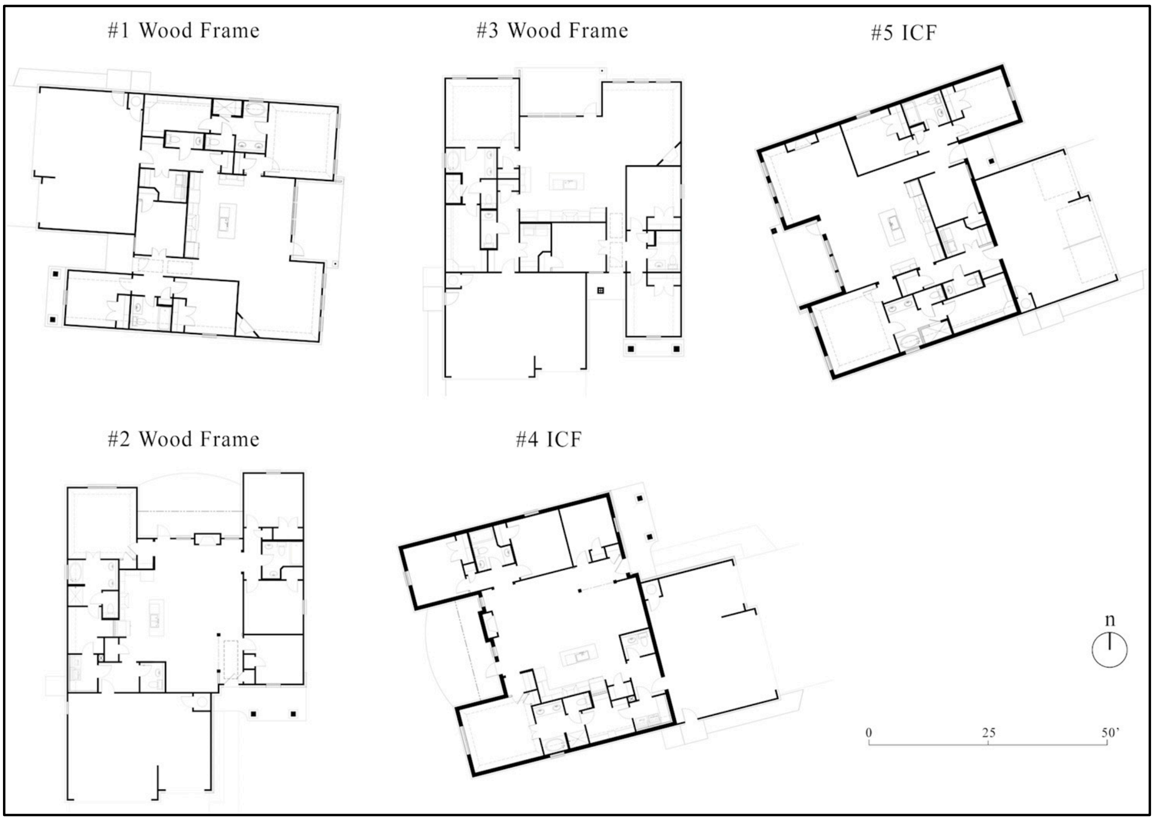

Figure 2. Orientations of the houses.

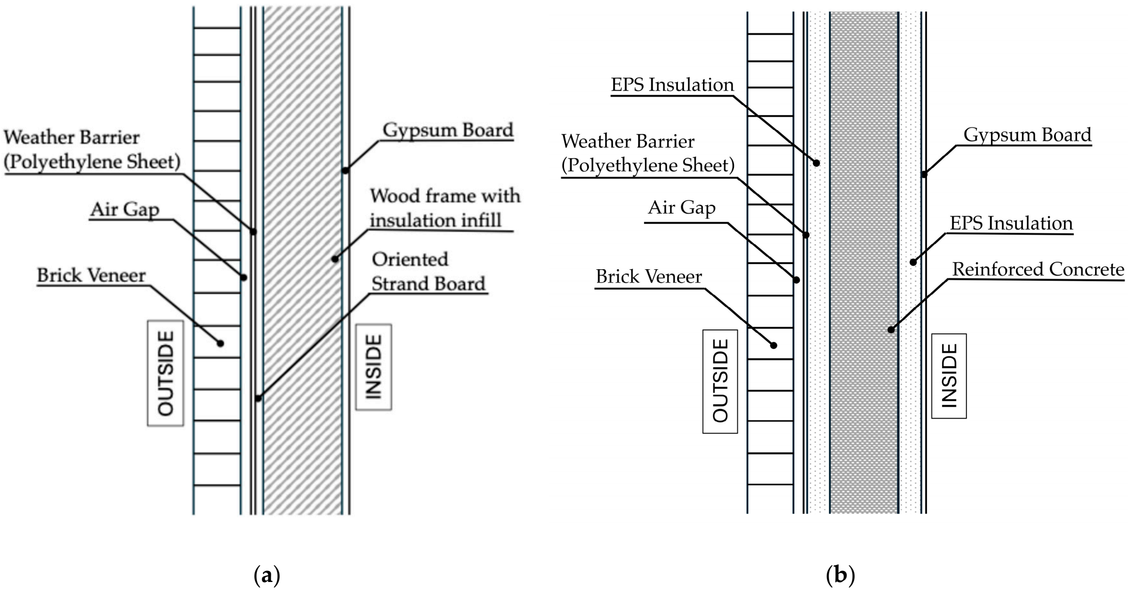

Figure 3. (**a**) Exterior wall section of a wood-framed house. (**b**) Exterior wall section of an ICF house.

Table 1 below provides the details of the walls and insulation types of each house. In addition, the window-to-wall ratios (shown as %) of the houses are provided in Table 2. The ratios are provided by north, east, west, and south walls, although some houses are not perfectly oriented. Houses #4 and #5, featuring ICF exterior walls, exhibit higher window-to-wall ratios and higher percentages of windows on the west elevation, possibly increasing the heating load during the summer months, compared to the other houses. The floor plans of the houses with similar floor areas have minor variations in the window sizes.

Table 1. Wall and insulation details of the houses.

House	Floor Area [m^2]	Wall Type	Wall Insulation	Attic Insulation	HVAC System
#1	192	Wood Frame	BFG—R15	BFG—R30	Single, SEER 16.0
#2	181	Wood Frame	BFG—R15	BFG—R30	Single, SEER 15.0
#3	192	Wood Frame	BFG—R15	SF > R30	Single, SEER 16.0
#4	181	ICF	Rigid Foam > R15	BFG—R30	2 stage, SEER 15.0
#5	192	ICF	Rigid Foam > R15	SF > R30	2 stage, SEER 16.0

Table 2. Window-to-wall ratios (shown as %) of the houses.

Direction of Ext Wall	House #1	House #2	House #3	House #4	House #5
East	33.4%	3.0%	3.2%	9.4%	6.4%
South	3.2%	9.5%	10.8%	1.8%	1.9%
West	10.8%	1.7%	1.8%	31.5%	34.5%
North	1.8%	34.0%	33.4%	2.7%	3.3%

Note: The gross exterior wall is measured horizontally from the exterior surface; it is measured vertically from the top of the floor to the bottom of the roof. The gross exterior wall area includes below-grade as well as above-grade walls. It includes walls, doors, and windows.

2.1.2. Data on Actual Energy Usage and Temperature/Moisture

The researchers collaborated with the builder of the test houses to include a provision in the sale contract allowing for the collection of actual electricity and natural gas usage data. Energy consumption data, provided by the utility companies, was recorded in 60 min intervals over a 12-month period. This ensured that the analysis accounted for energy use during both peak heating and cooling seasons, providing a comprehensive dataset for analysis.

With the consent of the homeowners, indoor sensors were installed in each house to collect temperature and moisture data. Two sensors were placed in each house: one in the living area and the other in the master bedroom, both positioned at a height of four feet above the floor to capture representative temperature and moisture readings at locations where they were exposed to unrestricted air circulation that was representative of the average humidity and/or temperature of the indoor environment. This was per the installation guideline provided by the sensor manufacturer. Additionally, outdoor sensors were installed throughout the neighborhood to gather localized temperature data, ensuring accurate comparisons between indoor and outdoor conditions.

3. Results

The findings presented in this section focus on comparing the energy performance of wood-framed and ICF houses based on actual consumption. Additionally, variations in indoor temperature and moisture levels are analyzed to understand the impact of construction methods on the indoor environment.

3.1. Energy Performance of Houses Based on Actual Consumption

The average electricity consumption for the wood-framed houses with BFG insulation in both walls and attics (houses #1 and #2) was 16.4 MJ/month/m^2 (Table 3). In comparison, the other houses had significantly lower amounts of energy consumption: house #3 (wood-framed with BFG insulation in the walls and SF insulation in the attic) consumed 19% less electricity, house #4 (ICF exterior walls with BFG insulation in the attic) consumed 41% less, and house #5 (ICF exterior walls with SF insulation in the attic) consumed 17% less electricity than the average of houses #1 and #2. Table 3 provides a detailed breakdown of the monthly electricity consumption for each house. The comparative assessment of energy consumption among the five houses highlights the influence of different exterior wall assemblies on energy efficiency. Houses #1 and #2, featuring conventional wood-framed constructions with BFG insulation in both walls and attics, exhibited the highest average electricity consumption at 16.4 MJ/month/m^2. The total annual consumption for house #1 was 40,248 MJ, with noticeable peaks during summer, indicating substantial cooling demands. House #2 followed with a stable but high annual usage of 33,300 MJ.

Table 3. Monthly electricity consumption (MJ) of houses.

Month	#1	#2	#3	#4	#5
February	1867.72	2375.10	1257.94	976.15	1214.09
March	2040.00	2874.20	1265.01	1306.30	1441.53
April	2259.22	2216.91	1510.24	1417.09	1516.21
May	3521.47	2214.48	2326.64	2135.19	2436.28
June	4641.67	3530.63	3919.32	3478.77	3829.69
July	5971.36	4591.20	5385.74	4334.97	4865.03
August	5943.71	5075.47	5009.97	4130.29	4819.55
September	4588.21	3407.05	3833.68	2491.60	4048.97
October	2817.80	1999.77	2482.34	1316.68	2509.91
November	2137.05	1434.84	1591.76	992.87	1863.66
December	2296.08	1618.29	1660.03	1109.04	2305.84
January	2164.04	1962.06	1487.01	1635.00	1591.80
TOTAL	40,248.32	33,300.01	31,729.69	25,323.95	32,442.55
Monthly Average Per m^2	17.47	15.33	13.77	11.66	14.08
Delta			−19.1%	−40.7%	−16.5%

In contrast, house #4, which had ICF exterior walls and BFG insulation in the attic, demonstrated the best energy performance, consuming only 25,323 MJ annually, 41% less electricity than the average of houses #1 and #2. This finding aligns with previous studies, such as those conducted at the Oak Ridge National Laboratory, which reported that ICF walls improve energy efficiency due to their superior thermal resistance and thermal mass properties [4,5,7]. The finding is also consistent with that of Gajda and colleagues, who noted that among thermally massive materials, ICF consistently achieved the highest energy savings [13,14].

House #3, a wood-framed structure with SF insulation in the attic, achieved a moderate 19% reduction in energy use compared to houses #1 and #2. This outcome reinforces the thermal advantages of using improved insulation methods, even within conventional wood-framed assemblies. House #5, an ICF structure with SF insulation in the attic, consumed 32,442 MJ annually—17% less than the average of the wood-framed houses. Despite the better performance of ICF systems, house #5 exhibited elevated relative humidity levels, likely attributable to the increased airtightness of the ICF envelope. Previous research [21] has documented higher airtightness in ICF envelopes as a characteristic of this construction method. However, the increased airtightness in house #5 resulted in more frequent operation of the heating ventilation and air conditioning (HVAC) system to maintain indoor comfort, leading to higher electricity consumption compared to both the other ICF and wood-framed houses.

The variation in average electricity consumption among the houses decreased during the summer months (June through September). This reduction could be due to the increased cooling loads experienced during this period in Oklahoma, USA. Notably, house #5 demonstrated improved energy performance relative to house #3 during the summer months, which is different from the trends observed in the 12-month average electricity consumption. Table 4 presents a detailed comparison of the monthly actual electricity consumption of the houses during the summer months, highlighting the seasonal variations.

Table 4. Monthly electricity consumption (MJ) of the houses during the summer months.

Month	#1	#2	#3	#4	#5
June	4641.67	3530.63	3919.32	3478.77	3829.69
July	5971.36	4591.20	5385.74	4334.97	4865.03
August	5943.71	5075.47	5009.97	4130.29	4819.55
September	4588.21	3407.05	3833.68	2491.60	4048.97
TOTAL	21,144.95	16,604.34	18,148.72	14,435.63	17,463.24
Monthly Average Per m^2	27.53	22.93	25.07	19.94	22.87
Delta			−0.7%	−26.6%	−10.3%

The wood-framed houses with BFG insulation in both walls and attics (houses #1 and #2) exhibited the highest average natural gas consumption at 0.737 m^3/month/unit floor area (Table 5). Seasonal fluctuations were evident, with house #1 peaking at 285 m^3 in February and decreasing to 30 m^3 by July, reflecting the increased heating demand during colder months.

Table 5. Monthly natural gas consumption (m^3) of the houses.

Month	#1	#2	#3	#4	#5
February	285.60	229.60	263.20	254.80	268.80
March	218.40	162.40	196.00	190.40	210.00
April	179.20	117.60	156.80	154.00	168.00
May	78.40	39.20	67.20	56.00	61.60
June	36.40	30.80	33.60	28.00	42.00
July	30.80	30.80	30.80	30.80	33.60
August	28.00	30.80	25.20	28.00	25.20
September	30.80	25.20	28.00	28.00	28.00
October	30.80	30.80	25.20	36.40	36.40
November	81.20	84.00	84.00	72.80	78.40
December	232.40	204.40	204.40	170.80	182.00
January	411.60	400.40	352.80	369.60	336.00
TOTAL	1643.60	1386.00	1467.20	1419.60	1470.00
Monthly Average Per m^2	0.7782	0.6961	0.6947	0.7130	0.6960
Delta			−6.1%	−3.4%	−5.9%

In contrast, as shown in Table 5, the other houses demonstrated improved efficiency relative to this baseline. House #3, a wood-framed house with BFG insulation in the walls and SF insulation in the attic, recorded a 6% reduction in gas consumption, maintaining the most stable usage patterns throughout the year. Houses #4 and #5, both featuring ICF exterior walls, showed reductions of 3% and 6%, respectively, when compared to the baseline wood-framed houses. House #5, which had ICF walls with SF insulation in the attic, maintained consistent consumption levels throughout the year despite the reduced natural ventilation typically associated with tightly sealed ICF envelopes.

The thermal mass properties of ICF walls likely contributed to the observed efficiency gains by mitigating sharp fluctuations in indoor temperature and reducing space heating demands. Previous studies have emphasized this advantage, highlighting the role of thermal mass in moderating temperature swings and lowering energy usage [15–20]. These findings align with research conducted by Oak Ridge National Laboratory and Gajda et al., which demonstrated significant energy savings attributable to the thermal mass effect in ICF walls [4,7,13].

A similar trend in the average consumption of gas among the houses was observed during the winter months (December through March), with differences from the baseline houses (#1 and #2) that were slightly more than the 12-month averages. This indicates that the use of ICFs in exterior wall and attic insulation systems had a greater impact during colder months. However, it is important to note that the observed differences in gas consumption could have been larger if the heating loads were higher; Oklahoma experienced a relatively mild winter during 2023–2024. House #5 (ICF exterior walls with SF insulation in the attic) demonstrated better performance than house #3 (wood-framed with BFG insulation in walls and SF insulation in the attic) during the winter months, which is different from the 12-month average consumption trends. Table 6 provides a detailed breakdown of the monthly actual gas consumption for the five houses during the winter months.

Table 6. Monthly natural gas consumption (m^3) of houses during the winter months.

Month	#1	#2	#3	#4	#5
Jane	411.60	400.40	352.80	369.60	336.00
February	285.60	229.60	263.20	254.80	268.80
March	218.40	162.40	196.00	190.40	210.00
December	232.40	204.40	204.40	170.80	182.00
TOTAL	1148.00	996.80	1016.40	985.60	996.80
Monthly Average Per m^2	1.99	1.84	1.76	1.82	1.73
Delta	-	-	−8.5%	−5.5%	−10.6%

3.2. Indoor Temperature Fluctuations with Variations in Outdoor Temperatures

Dew point temperature and relative humidity data, for both indoors and outdoors, were collected using two indoor sensors installed in each house and localized outdoor sensors. Temperature differences between indoor and outdoor conditions were computed for each house, accounting for their unique set-point temperatures. The variability of these differences was quantified using the coefficient of variation, facilitating a standardized comparison across datasets. A higher coefficient of variation indicates greater variability, while a lower coefficient of variation signifies more consistent data. Table 7 presents the coefficient of variations for all five houses over a 12-month post-occupancy period.

Table 7. Variations (coefficients of variation) in the differences between indoor/outdoor temperatures of the houses.

Month	#1	#2	#3	#4	#5
January	0.49	0.38	0.27	0.19	0.28
February	0.47	0.30	0.20	0.17	0.21
March	0.58	0.42	0.21	0.2	0.17
April	0.56	0.42	0.25	0.2	0.27
May	0.48	0.38	0.34	0.21	0.22
June	0.59	0.43	0.25	0.26	0.28
July	0.67	0.49	0.30	0.19	0.21
August	0.63	0.42	0.33	0.20	0.22
September	0.55	0.38	0.38	0.25	0.27
October	0.58	0.41	0.39	0.25	0.28
November	0.67	0.39	0.40	0.25	0.26
December	0.59	0.44	0.40	0.22	0.27
Mean (Std. Dev.)	0.57 (0.067)	0.41 (0.046)	0.31 (0.074)	0.22 (0.030)	0.25 (0.037)

Houses #4 and #5 (ICF exterior walls with BFG insulation and ICF exterior walls with SF insulation, respectively) showed smaller coefficients of variation in comparison to houses #1 and #2 (wood-framed houses with BFG walls and attics). The coefficients of variation for houses #4 and #5 ranged from 0.17 to 0.26 and from 0.17 to 0.28, respectively, whereas those of houses #1 and #2 were 0.47–0.67 and 0.30–0.49. This showed that there were more fluctuations in the indoor temperatures in houses #1 and #2 with the change in outdoor temperatures. House #3 showed less variation with the change in outdoor temperature (coefficient of variations ranged from 0.20 to 0.40). The lower coefficients of variation observed in houses #4 and #5 (ICF exterior walls with BFG and SF insulation) suggest that the thermal mass of the concrete in ICF walls could have played a role in moderating heat flow into the interior spaces. This reduced temperature fluctuations and helped stabilize indoor conditions, leading to decreased peak heating and cooling demands. By comparison, houses #1 and #2 (wood-framed houses) exhibited greater temperature fluctuations due to the lack of thermal mass in the exterior walls, resulting in a less stable indoor thermal environment. The existing literature identifies thermal mass and airtightness as key factors contributing to the superior energy performance of houses constructed with ICFs. Several studies have evaluated the hygrothermal performance of various exterior wall systems and have found that thermal mass directly influences energy efficiency by reducing space heating and cooling demands [15–20]. Given the higher thermal mass of an ICF, it can be inferred that houses with ICF exterior walls may benefit from more stable indoor temperatures. The more stable indoor temperatures in houses with ICF walls could contribute to increased occupant comfort and improved energy efficiency. These lower coefficients of variation suggest that the houses with ICF walls will be more comfortable to occupants than wood-framed houses.

3.3. Energy Usage Behaviors of Occupants of the Houses

A homeowner survey was conducted to assess the energy usage behaviors across the five houses. The number of occupants, including adults and children, ranged from two to four per house. Occupancy duration was similar for houses #1 through #4, with residents present for 11–15 h per day, while house #5 had a slightly lower occupancy duration of 6–10 h per day. The duration of lighting use was consistent across all houses, indicating uniform energy usage behavior in this aspect. Notably, occupants of houses #3 and #4 exhibited a higher level of energy consumption monitoring compared to the other houses. This heightened awareness, coupled with lower thermostat set points, likely contributed to the reduced electricity and natural gas consumption observed in house #4. Table 8 provides a summary of the number of occupants and the corresponding energy usage behaviors for each house.

Table 8. Energy usage behaviors of occupants of the houses.

Criteria		**#1**	**#2**	**#3**	**#4**	**#5**
Number of occupants	Adults	2	2	2	2	3
	Children	1	0	1	1	1
Number of hours each person occupies the house	Adults	11–15	11–15	11–15	11–15	6–10
	Children	11–15		11–15	11–15	6–10
Number of hours lights are on in the main living area		<12	13–16	<12	<12	<12
How often do you rely on natural ventilation?		Never	Half the time	Never	Sometimes	Never
Set point temperature (°C)		21–22	25	20–21	20–22	21–22
Do you utilize ceiling fan?		Yes	Yes	Yes	Yes	No
Do you take advantage of Smart hour Program?		Yes	No	No	No	No
How closely do you monitor your energy consumption (1 = never; 5 = always)?		1	2	4	4	1

3.4. Analysis of Utility Expenses

Utility expenses for each house were calculated based on the actual consumption of natural gas and electricity, as shown in Table 9. For natural gas, monthly rates were obtained from the utility provider, with a fixed fee of USD 39 per month. Usage-based costs varied significantly, ranging from over USD 100 during the winter months to less than USD 10 during the summer months. Electricity costs included a fixed residential charge of USD 13 per month, along with additional surcharges for fuel costs and past winter events in the region. The rate per megajoule (MJ) also varied beyond the first 2160 MJ consumed. On average, houses with ICF exterior walls demonstrated notable energy cost savings, with occupants paying approximately USD 270 less annually in energy bills compared to those in wood-framed houses. The range of annual savings for ICF houses relative to wood-framed houses was between USD 141 and USD 396, highlighting the economic advantages of ICF construction in reducing utility expenses.

Table 9. Utility expenses of the houses.

Month	#1	#2	#3	#4	#5
February	USD 210.25	USD 206.43	USD 182.11	USD 169.75	USD 182.47
March	USD 193.13	USD 194.76	USD 159.45	USD 159.02	USD 170.04
April	USD 190.36	USD 167.84	USD 158.30	USD 154.17	USD 162.43
May	USD 170.51	USD 134.08	USD 141.91	USD 135.24	USD 143.27
June	USD 227.82	USD 185.25	USD 200.29	USD 182.83	USD 198.37
July	USD 276.55	USD 224.86	USD 254.62	USD 215.26	USD 235.59
August	USD 275.96	USD 244.00	USD 240.43	USD 208.04	USD 233.29
September	USD 225.82	USD 180.44	USD 196.99	USD 146.72	USD 205.05
October	USD 159.38	USD 129.12	USD 145.70	USD 106.13	USD 149.00
November	USD 131.33	USD 111.93	USD 116.41	USD 96.82	USD 122.91
December	USD 157.69	USD 134.95	USD 136.14	USD 114.41	USD 148.84
January	USD 191.55	USD 183.72	USD 161.19	USD 168.58	USD 161.01
TOTAL	USD 2410.35	USD 2097.38	USD 2093.53	USD 1856.98	USD 2112.28
Summer Total	USD 1006.15	USD 834.55	USD 892.32	USD 752.85	USD 872.30
Winter Total	USD 752.62	USD 719.86	USD 638.89	USD 611.76	USD 662.36

4. Conclusions

This study analyzed the energy consumption patterns of five houses built in 2022 in Oklahoma, USA under the 2015 IRC, comparing wood-framed and ICF constructions. By evaluating two distinct floor plans (181 m^2 and 192 m^2) and varying insulation configurations, the study provides empirical insights into the impact of construction methods on residential energy performance.

The analysis of actual energy consumption data over a 12-month period revealed significant energy performance differences between wood-framed and ICF houses. Baseline wood-framed houses (#1 and #2) exhibited the highest electricity consumption, whereas the wood-framed house with SF insulation in the attic (#3) consumed 19% less electricity, and the two ICF houses (#4 and #5) consumed 41% and 17% less, respectively. Seasonal trends showed that differences in electricity consumption among the houses diminished during the summer months (June through September) due to high cooling loads across all houses. Similarly, houses with ICF exterior walls demonstrated consistently lower natural gas consumption, using at least 5% less natural gas during the winter months compared to wood-framed houses.

Houses with ICF walls also exhibited greater indoor temperature stability, as indicated by lower coefficients of variation in indoor temperature differences relative to outdoor conditions. For houses with ICF walls (#4 and #5), the coefficients of variation ranged between 0.17–0.26 and 0.17–0.28, respectively, compared to significantly higher ranges of 0.47–0.67 and 0.30–0.49 in the baseline wood-framed houses (#1 and #2). This suggests that houses with ICF walls experienced fewer indoor temperature fluctuations due to outdoor temperature changes.

In terms of cost savings, occupants of houses with ICF exterior walls paid approximately USD 270 less per year in energy bills compared to those in wood-framed houses. This study contributes to the growing body of research on energy-efficient residential construction by providing real-world performance data on ICF systems. The results reinforce the potential of ICF as a cost-effective and sustainable alternative to traditional wood-framed construction, particularly in regions with significant heating and cooling demands.

Despite these promising results, this study has limitations. The sample was restricted to five houses within a single neighborhood, limiting the generalizability of the findings to other climates and construction contexts. Additionally, the analysis did not account for occupant behavior, which can significantly impact energy consumption. To build on the findings of this research, future studies should address the following areas:

- Investigate diverse climate zones: Examine the energy performance of ICF and wood-framed houses across a broader range of climatic conditions to assess the adaptability of ICF construction in varying environments.
- Explore varied construction types: Include a wider array of building designs and insulation configurations to better understand the versatility of ICF systems.
- Account for occupant behavior: Conduct studies that control for or model the influence of occupant activities and preferences on energy usage patterns.

By addressing these areas, future research can provide a more comprehensive understanding of the role that innovative construction techniques like ICFs play in achieving energy-efficient and sustainable housing solutions.

Author Contributions: Conceptualization, methodology, validation, formal analysis, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision, project administration, funding acquisition, S.G. and B.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Concrete Advancement Foundation, USA and the Program for Research Enhancement of the College of Architecture at the University of Oklahoma, USA.

Data Availability Statement: The data used to support the findings of this study will be made available by the corresponding authors upon request.

Acknowledgments: The authors would like to thank R&R Homes, LLC, USA and Dolese Bros. Co., USA for providing some of the data used in this study.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

BFG	Blown Fiberglass
C	Centigrade
cubic m/m^3	Cubic Meter
EPS	Expanded Polystyrene
F	Fahrenheit
Ft/ft	Feet
HVAC	Heating Ventilation and Air Conditioning
ICF	Insulated Concrete Form
MJ	Megajoule
OSB	Oriented Strand Board
sq ft/ft^2	Square Feet
SF	Spray Foam
sq m/m^2	Square Meter
USA	United States of America
USD	United States Dollar

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