Joint CSCE Construction Specialty & CRC Conference 2025
Conférence conjointe spécialisée en construction de la SCGC et CRC-2025

Montreal, Quebec
July 28-31, 2025 / *28-31 juillet 2025*

Building Efficiency: A Comparative Analysis of Sustainable Building Materials and Existing Green Energy Technologies-A Simulation-Based multi-Climate Approach

Kennedy, Evan.[1], Cai, Yilin.[1], Aryal, Ashrant.[1], and Hartell, Julie.[1]
[1] Department of Construction Science, Texas A&M University, 574 Ross St., College Station, Texas

ABSTRACT:

This study presents a comparative analysis of market available sustainable building materials and green energy technologies aimed at improving energy efficiency and resilience in residential structures. Current construction materials and alternative, sustainable options were evaluated in accordance with their adherence to specified energy codes and standards. However, the actual impact of such technologies on energy consumption depends on the specific climate zone they are implemented in. To provide a realistic comparison, detailed energy simulation models were developed in EnergyPlus, capturing the energy consumption and performance impact of each material and technology on two bedrooms / two bathrooms (2B2B) floor plan. Comparative simulations across three Texas climate zones were conducted to quantify annual realistic net energy consumption and regional performance impacts. The energy savings of each alternative are discussed.

Alternative materials used in common home construction were modeled based on data from publicly accessible specifications and manufacturer sources. This method ensured accurate parameters for simulations relative to baseline models. In parallel, green energy production technologies, such as home wind turbines, photo voltaic (PV) panels, solar roofing, etc., were assessed for cost-efficiency, resilience, and community acceptability. Quantitative assessments of the simulation data were used to accurately address each of the parameters. To highlight the effects of the potential of these energy efficient alternatives, a simulation was developed culminating the highest performing parameters from each building component discussed. By providing a simulation-based overview of sustainable building alternatives, this analysis aims to support decision-making in energy-efficient construction within diverse climate conditions.

1. INTRODUCTION

The increasing accessibility of energy-efficient technologies and sustainable building materials has created significant opportunities to reduce energy consumption and operational costs in residential construction. However, the diverse range of available alternatives, each with unique performance characteristics, costs, and climatic suitability, presents challenges for stakeholders in making informed decisions. This challenge is further complicated by the lack of available consolidated guidance on evaluating the costs, benefits, and practicality of implementing these alternatives (Hafez et al., 2023). To address this gap, this study investigates both market available and increasing common innovative building materials, and energy systems. Focus was on their ability to enhance energy efficiency while maintaining cost-effectiveness, resiliency, and compatibility with regional climatic conditions for the state of Texas.

The need for this research is evident through the growing energy demand from residential buildings especially during summer months in the United States (EPA, 2025) and the increasing frequency of extreme climatic events, both of which strain power grids (Stone et al., 2021) (NOAA, 2023). Additionally, a survey conducted by *Gillespie & Rubloff, 2023,* found that 81% of Americans expressed that extreme weather events such as heat waves or drought have increased their energy consumption resulting in higher monthly monetary impacts. By identifying and evaluating energy-efficient solutions, this study aims to provide homeowners and stakeholders with actionable insights into reducing energy dependence and achieving long-term cost savings. The materials assessed are analyzed across key criteria, including installation and maintenance costs, energy performance, resilience (energy efficiency, fire resistance, flood mitigation, and wind durability), community acceptability as evident by code adoption, and implementation efficiency. Green energy technologies are assessed upon their market availability, cost-effectiveness, community acceptance as evident by code adoption, and their energy production capabilities.

The study focuses on five major Texas population centers—Austin, Amarillo, El Paso, Dallas, and Houston—representing three diverse climate zones as defined by the 2021 International Energy Conservation Code (IECC) (IECC, 2021). Energy simulation tools, such as EnergyPlus, are utilized to evaluate the energy-saving potential of various alternatives within these regions. Factory testing data, manufacturer specifications, and reviews of the current literature are incorporated to ensure a robust and regionally relevant analysis.

The alternatives discussed in this study represent components essential to a home's exterior envelope and systems responsible for significant energy demand such as HVAC systems. Also, resilient and energy-efficient wall system solutions such as SIPs are simulated. In addition, green energy technologies, such as solar panels, solar roofing, and high albedo roof coatings, are evaluated for their potential to further enhance energy performance aspects of existing homes. While this study aims to further inform homeowners, it does not include an exhaustive or comprehensive list of alternatives. Rather, an emphasis is placed on market available solutions to increase the applicability of each of the solutions simulated. Capabilities to comply with energy efficiency standards such as ENERGY STAR, LEED, Enterprise Green Communities, and ICC 700: Nation Green Building Standard are considered in the considerations for inclusion of energy efficient technologies.

The objective of this study is to conduct a simulation-based evaluation of both market available and innovative building materials, along with green energy technologies, in the aim of assisting homeowners and builders in making informed decisions tailored to regional needs. Building categories and components chosen for intervention were selected by assessing market available alternatives to aspects of a home observed as relevant towards decreasing energy consumption, while also increasing potential resiliency. The criteria for selecting building component categories for substitution is informed by FEMA’s Technical Bulletin 2 (FEMA, 2008) along with market available alternatives for energy generation. This targeted approach allowed for unbiased evaluation of alternative materials and technologies through results based on pinpointed simulations set in five distinct city centers in Texas. Net energy consumption metrics serves as the primary tool for analysis on the applicability of each substitution in accordance with specified climate zones. By consolidating essential information into an accessible format, homeowners and builders can make informed decisions about implementing resilient and energy-efficient solutions tailored to individual climate zones in Texas. Through this analysis, actionable options are provided to optimize energy efficiency and decrease reliance on energy grids for residential construction.

2. LITERATURE REVIEW

Despite the abundance of standing literature on energy efficient alternatives for home implementation, many homeowners might feel overwhelmed (Rezaie et al., 2010). Rezaie et al., 2010 suggests that the final decision begins and ends with the owner’s perspective at the forefront. Challenges remain in the implementation of energy-efficient construction practices. Knowledge gaps, policy limitations, and resource constraints continue to hinder the widespread adoption of these technologies (Hafez et al., 2023). Studies further support the use of simplified simulation-based analyses to select optimal building components, which reinforces the methodology employed in this research (Jannat et al., 2020). This review supports the methodology of this study, highlighting the need to evaluate energy solutions in a comparative, climate-driven framework to assist homeowners in making informed decisions.

2.1 Energy Efficient Components

One area explored is the role of insulation and building envelope design in enhancing energy efficiency. Research has emphasized that insulation materials with higher thermal resistance are more cost-effective in heating-dominated regions, whereas materials with lower thermal resistance tend to perform better in cooling-dominated climates (Kumar et al., 2020). The selection of insulation material, its thickness, and placement are among some of the factors in optimizing energy savings. However, additional considerations, such as sound insulation, fire resistance, and environmental impact, have also be considered (Schiavoni et al., 2016), insisting that there is no single solution for every case or building type. Interestingly, studies have found that increasing insulation thickness does not always yield significant energy savings; for instance, in one study conducted by *Iqbal & Al-Homoud* a 50% increase in polyurethane insulation thickness led to only a 2% reduction in annual energy consumption (Iqbal & Al-Homoud, 2007).

Another commonly studied component of residential energy consumption is the heating, ventilation, and air conditioning (HVAC) system. Research has shown that optimizing set-point temperatures can lead to notable energy savings. Specifically, maintaining summer and winter set-point temperatures, resulted in a 3% reduction in annual energy use for some climates, while implementing nighttime setbacks yielded a 4% reduction respectively (Iqbal & Al-Homoud, 2007). This suggests that simple behavioral changes in energy management can be as effective as physical retrofits, but at a significantly lower cost. Additionally, comparative studies on HVAC systems have highlighted the energy-saving potential of variable refrigerant flow (VRF) systems. One study found that VRF systems offer energy savings ranging from 52.7% to 57.9% over variable air volume (VAV) systems with reheat boxes, all while maintaining similar indoor thermal comfort (Aynur et al., 2009). The selection of air conditioning systems, particularly in regions with high demand, could be perceived as a key determinant of overall energy consumption.

The role of windows and building geometry in energy performance has also been extensively studied. Low-emissivity, double-glazed windows have been recommended for hot climates to improve energy efficiency (Iqbal & Al-Homoud, 2007). In addition, the geometric properties of buildings, such as surface area and volume, have been shown to significantly influence energy consumption. Generally, larger surface areas and volumes correlate with higher energy demand, indicating that both material selection and structural design play crucial roles in determining overall energy efficiency (Jannat et al., 2020).

2.2 Integration of Energy Generation and Energy Modeling

Renewable energy integration, particularly through photovoltaic (PV) technology, has been identified as a promising, cost-effective solution for energy generation. Hybrid systems that combine PV panels with other renewable technologies, such as ground-source heat pumps, offer advantages in efficiency, cost reduction, and emissions control (Rezaie et al., 2010). While the initial installation and maintenance costs of such systems are notable, the long-term benefits they offer homeowners, particularly in reducing reliance on conventional energy sources, can be substantial if implemented properly. One instance would be through the implementation of a range of PV's coupled with batteries for optimized storage during peak load hours (Koskela et al., 2019).

In addition to individual technologies, comprehensive approaches that integrate multiple energy conservation measures have been found to significantly reduce energy demand. One study indicated that combining several energy-efficient strategies can lead to overall energy savings of up to 36% based on their input parameters (Iqbal & Al-Homoud, 2007). However, the selection of appropriate materials and technologies must be tailored to regional climate conditions and homeowner priorities. The final decision on the optimal energy-saving solutions ultimately depends on cost considerations and personal goals (Rezaie et al., 2010). The literature reviewed emphasized the importance of climate-specific material selection, operational efficiency improvements, and renewable energy integration in reducing residential energy consumption. While no single approach is universally optimal, a combination of strategies—

including high-performance insulation, efficient HVAC systems, advanced window technologies, and hybrid renewable energy solutions—can lead to significant energy savings.

3. METHODOLOGY

The study focused on five Texas cities—Houston, Austin, Dallas, El Paso, and Amarillo—as illustrated in Figure 1. Each city was selected to represent distinct geographical locations and climate characteristics while also providing regional insights for five diverse major population centers within Texas. Houston, Austin, and Dallas fall under the IECC 2A climate zone, characterized as hot and humid. El Paso is categorized as 3B, warm and dry, while Amarillo falls within the 4A climate zone, which is mixed humid (IECC, 2021). For baseline energy consumption levels, refer to Appendix A.

Figure 1: Texas Cities Used for Energy Modeling

A typical 2-bedroom, 2-bathroom unit (2B2B) model with a total area of 1,297 sq ft as shown in Figure 2 was developed for energy simulation purposes. The model utilized for simulations came from the Department of Energy (DoE) Prototype Building Model (USDOE, 2021). The model geometry accounts for three occupants and a range of household electronic devices. Specifications for individual building components were adjusted according to regional climate variations. Components within each category to be supplemented were chosen from FEMA Technical Bulletin 2's acceptable materials for resilient materials (FEMA, 2008). It should be noted that no additional calibration was necessary, as the baseline model used for this study consistently aligned with the U.S. Energy Information Administration's (EIA) metrics for the average annual household consumption in the United States (EIA, 2025). Acceptable alternatives to be substituted were classified classes 4 or 5 in Table 2 of FEMA Technical Bulletin 2 (FEMA, 2008). By isolating these sections and systems that are imperative for the resilience of a residence, more targeted results were achieved. Aspects of resiliency were assessed by flood, fire, wind, and energy resiliency. To gather this data, manufacturer specific data was synthesized on selected components pertaining to FEMA' Technical Bulletin 2. Detailed building construction compositions are listed in Appendix B.

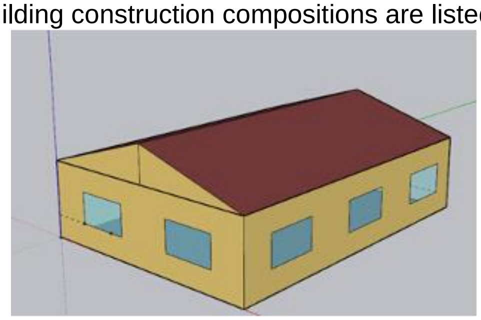

Figure 2: Building Model Geometry of Simulations Conducted (2B2B) (USDOE, 2021)

To better provide targeted comparisons to the baseline model, individual alternatives listed in Table 1 were subjected to independent integrative energy modeling. This was conducted by simply replacing a single baseline material parameter with alternative values for testing (e.g. market available insulated foundation parameters replaced the baseline model foundation values) while no other changes were made to the energy model for each corresponding simulation. This methodology assured uniform simulation conditions to gain comparative data for analysis. In total, 180 independent energy simulations were conducted to systematically assess individual component impact against the baseline model. From here, a review of each model performance was conducted.

Table 1: Alternatives Simulated in Substitution to the Baseline

Components	**Building Components Alternative**			
Alternative Energy Generation	PV1	Solar Roof	Solar Window	Wind Turbine
	PV + Battery	Solar Roof + Battery	Solar Window + Battery	Wind Turbine + Battery
Roofing	High Albedo			
Siding	Brick	Fiber Cement Board	Aluminum (metal)	
Flooring	Wood	Tile	Carpet	
Windows	Double Pane Low-E[3]	Triple Pane	FEFA[6], Low-E Triple-Pane	
Doors	1-Hour Fire Rated	Glass Pane	Steel Plated	
Insulation	High Density Fiber Glass	Closed Cell Spray Foam	EPS[5]	
Foundations	Insulated SoG[2]	Crawl Space		
Drywall	Mold & Moisture Resistant	Fire Resistant (Type C)	High Impact	
SIPs[7]	Wood SIPs	Steel SIPs	MgO[8] SIPs	
HVAC	Window AC	High SEER[4] Rating		

1 - Photovoltaic (PV) / 2 – Slab-on-Grade / 3 – Low emissivity / 4 - Seasonal energy efficiency ratio / 5 – Expanded Polystyrene / 6 - Foam Enhanced Frame & Argon / 7 – Structural Insulated Panels / 8 – Magnesium Oxide

The best performing alternative from each building component category was then substituted collectively within a model to simulate the combined effects of each building component substitution. These new simulation values were integrated based on their ability to net the least yearly purchased energy in each climate zone. It is important to note that not all alternatives implemented on the new model were the same for each climate zone. This decision to nonuniformly implement alternatives across all climate zones was derived from their varying ability to reduce net energy consumption within each climate zone further supporting the focus on climate specific resilient solutions.

4. DISCUSSIONS

The simulation-based results of this study largely align with existing literature around energy-efficient building materials, HVAC systems, and renewable energy integration, reaffirming traditional strategies—such as improving insulation, optimizing HVAC systems, and upgrading windows—remain the most significant contributors to energy savings. Notably, results from this simulation largely align with standing literature surrounding the linkage between climatic data and alternative performance. For instance, in climate zones characterized by consistently favorable wind speeds (Amarillo), wind turbines yielded the most notable reductions of other alternatives addressed. Specific net energy consumptions can be noted against the baseline in Tables 2 and 3 below. As observed in prior studies, residential energy consumption is largely influenced by these components (Aynur et al., 2009; Hafez et al., 2023; Iqbal & Al-Homoud, 2007) though their effectiveness varies based on climate conditions and building configurations. A case study by *Fikru* found that the effectiveness of implementing even one alternative could reduce the energy consumption of a residence noticeably (Fikru, 2019). This observation is further supported by the findings of this study which point to commonly implemented energy efficient alternatives as the most impactful.

Table 2: Net Energy Consumptions of Alternatives Energy Generation Technologies Integrated to the Baseline by percentage

Alternative Technologies	City Center				
	Amarillo	**Austin**	**Dallas**	**El Paso**	**Houston**
Baseline	0.00%	0.00%	0.00%	0.00%	0.00%
PV	-39.60%	-41.69%	-39.79%	-41.05%	-41.13%
PV + Battery	-68.03%	-68.78%	-64.58%	-72.67%	-69.13%
Solar Roof	-40.38%	-42.56%	-40.65%	-41.76%	-42.00%
Solar Roof + Battery	-69.31%	-70.61%	-66.07%	-73.51%	-70.63%
Solar Window	-19.69%	-16.57%	-16.69%	-22.59%	-16.71%
Solar Window + Battery	-19.71%	-16.59%	-16.71%	-22.69%	-16.72%
Wind Turbines	-60.15%	-28.56%	-38.64%	-29.45%	-30.82%
Wind Turbines + Battery	-72.33%	-33.43%	-45.09%	-36.41%	-35.58%
Window AC	19.46%	8.47%	14.47%	7.57%	6.70%
High SEER HVAC	-12.68%	-12.05%	-13.81%	-10.68%	-11.44%

Table 3: Net Energy Consumptions of Alternatives Building Components Substituted to the Baseline by percentage

Alternative Building Components	City Center				
	Amarillo	**Austin**	**Dallas**	**El Paso**	**Houston**
High Albedo Roof	-0.79%	-1.79%	-1.34%	-2.07%	-1.95%
High Density Fiber Glass	1.44%	-2.27%	-2.99%	1.01%	-2.27%
Closed Cell Spray Foam	0.37%	-3.25%	-4.40%	-0.24%	-3.24%
EPS	0.03%	-3.41%	-4.57%	-0.52%	-3.40%
Brick	-1.57%	-2.88%	-2.78%	-2.58%	-2.94%
Fiber Cement Board	-0.43%	-1.32%	-1.08%	-1.11%	-1.49%
Aluminum (metal)	-1.11%	-3.90%	-3.22%	-3.05%	-4.11%
Mold & Moisture Resistant	0.28%	0.26%	0.27%	0.30%	0.25%
Fire Rated (Type C)	0.27%	0.28%	0.30%	0.29%	0.27%
High Impact	-0.70%	-1.52%	-2.04%	-0.99%	-1.55%
Wood SIPs	-2.97%	-5.69%	-6.99%	-3.75%	-5.47%
Steel SIPs	-2.25%	-4.99%	-6.47%	-2.86%	-5.00%
MgO SIPs	-2.34%	-4.88%	-5.73%	-3.01%	-4.67%
Double Pane Low-E	-5.99%	-1.56%	-3.29%	-1.23%	-1.29%
Triple Pane	-4.45%	0.17%	-1.69%	1.16%	0.56%
FEFA & Low-E triple-pane	-6.57%	-2.11%	-3.84%	-1.92%	-1.86%
Wood	-4.87%	-6.19%	-5.50%	-5.97%	-6.50%
Tile	-4.20%	-5.18%	-4.57%	-5.05%	-5.42%
Carpet	-1.72%	-2.01%	-1.76%	-2.00%	-2.11%
1-Hour Fire Rated	-0.12%	-0.13%	-0.10%	-0.06%	-0.11%
Glass Panel	-0.30%	-0.12%	-0.36%	0.02%	-0.10%
Steel Plated	-0.61%	-0.46%	-0.53%	-0.45%	-0.43%
Insulated SoG	-0.50%	-0.38%	-0.84%	-0.29%	-0.44%
Crawl Space	0.04%	-1.58%	-1.34%	-1.03%	-2.23%

Substitutions of insulation type alone were found to yield diminished energy savings compared to a more comprehensive wall system such as SIP's. This finding supports the conclusion that a multi-faceted approach is desirable to achieve heightened energy reductions. SIPs were identified as a viable alternative solution for increasing energy efficiency. Compared to conventional framing methods, greater energy savings were achieved due to minimized heat loss and increased R-values through the utilization of expanded polystyrene (EPS).

Additionally, it was observed that interior components, such as advanced drywall materials or specific foundation choices, had a relatively minor impact on overall energy consumption when compared to building envelope improvements. While these materials may offer benefits in terms of disaster resilience and indoor comfort, their role in reducing heating and cooling loads was found to be limited. This finding highlights the importance of prioritizing exterior interventions, such as high-performance insulation, advanced glazing, and air-tight construction techniques, when seeking to improve a home's energy efficiency.

Furthermore, it was demonstrated that not all alternative materials and technologies were equally effective across all climate zones. Some energy-efficient solutions performed well in a more heating-dominated region (Climate Zone 4A), but they provided less substantial benefits in cooling-dominated climates (Climate Zones 2A & 3B), and vice versa. This finding underscores the importance of a climate-driven approach when selecting materials and technologies, as broadly applied strategies might not yield optimal results.

4.1 Optimized Building Component Combined Simulation

The final component of this study involved simulating the combined impact of multiple building modifications rather than evaluating materials and technologies in isolation. The optimal alternative for each category specific to each city center is outlined in Table 4 below. The results confirmed that the integration of multiple energy-efficient strategies led to significantly greater reductions in energy consumption compared to implementing individual measures alone. These findings support the growing body of research advocating for targeted design approaches that optimize energy savings thus increasing energy resilience of homes. Such design approaches point to savings through implementation of resilient material and system choices. Furthermore, this study suggested that by providing homeowners with accessible and clear energy simulation summaries and clear, climate-specific results, more effective decision-making could be facilitated. This could ultimately encourage broader adoption of sustainable building practices. This is highlighted through the simulation-based approach confirming well established literature around the topics of energy efficiency.

Table 4: Optimized Building Components for the Combined Case Study

Building Components	Texas City Center				
	Amarillo	**Austin**	**Dallas**	**El Paso**	**Houston**
Alternative Energy Generation	Wind Turbine + Battery	Solar Roofing + Battery	Solar Roofing + Battery	Solar Roofing + Battery	Solar Roofing + Battery
HVAC	High Efficiency HVAC	High Efficiency HVAC	High Efficiency HVAC	High Efficiency HVAC	High Efficiency HVAC
Roof	High Albedo Roof	High Albedo Roof	High Albedo Roof	High Albedo Roof	High Albedo Roof
Insulation	Wood-SIP	Wood-SIP	Wood-SIP	Wood-SIP	Wood-SIP
Siding	Brick	Aluminum Siding	Aluminum Siding	Aluminum Siding	Aluminum Siding
Dry Wall	High Impact	High Impact	High Impact	High Impact	High Impact
Window	FEFA LOW-E Triple-Pane	FEFA LOW-E Triple-Pane	FEFA LOW-E Triple-Pane	FEFA LOW-E Triple-Pane	FEFA LOW-E Triple-Pane
Floor	Wood	Wood	Wood	Wood	Wood
Door	1-Hour Fire Rated	1-Hour Fire Rated	1-Hour Fire Rated	1-Hour Fire Rated	1-Hour Fire Rated
Foundation	Insulated Foundation	Insulated Foundation	Insulated Foundation	Insulated Foundation	Insulated Foundation

The net energy consumption of selected building components substituted for the combined case study by percentage can be seen below in Table 5. These findings further serve to strengthen and synthesize well established energy efficient alternatives as potentially viable solutions to an increased strain on existing energy grids.

Although noticeable energy resilience increases can be observed in this study by substituting only one alternative as also stated by Fikru, 2019, the compounded effects for overall residential resiliency as seen in Table 6 are evident through the combined simulation conducted here. Dallas proved to show the lowest net reduction in energy consumption of 83.77%, while El Paso boasted an 88.29% net reduction in energy consumption. By prioritizing energy efficiency, resilience, and cost-effectiveness, informed choices can be made to contribute to the long-term sustainability and affordability of residential construction.

Table 5: Net Energy Consumption of Selected Building Components Substituted for the Combined Case Study against the Baseline by Percentage

Building Components	Range of Net Reduction	Texas City Center				
		Amarillo	Austin	Dallas	El Paso	Houston
Alternative Energy Generation	66.07%-73.51%	-72.33%	-70.61%	-66.07%	-73.51%	-70.63%
HVAC	10.68%-13.81%	-12.68%	-12.05%	-13.81%	-10.68%	-11.44%
Roof	0.79%-2.07%	-0.79%	-1.79%	-1.34%	-2.07%	-1.95%
Insulation	2.97%-6.99%	-2.97%	-5.69%	-6.99%	-3.75%	-5.47%
Siding	1.57%-4.11%	-1.57%	-3.90%	-3.22%	-3.05%	-4.11%
Dry Wall	0.70%-2.04%	-0.70%	-1.52%	-2.04%	-0.99%	-1.55%
Window	1.86%-6.57%	-6.57%	-2.11%	-3.84%	-1.92%	-1.86%
Floor	4.87%-6.50%	-4.87%	-6.19%	-5.50%	-5.97%	-6.50%
Door	0.06%-0.13%	-0.12%	-0.13%	-0.10%	-0.06%	-0.11%
Foundation	0.29%-0.84%	-0.50%	-0.38%	-0.84%	-0.29%	-0.44%

Table 6: Net Energy Consumption of the Combined Case Study Against the Baseline by Percentage

Simulation Type	City Center				
	Amarillo	Austin	Dallas	El Paso	Houston
Combined Case	-86.86%	-85.55%	-83.77%	-88.29%	-84.77%

5. CONCLUSIONS

In this study, a simulation-based evaluation of both market available and innovative building materials, along with green energy technologies, was conducted to assist homeowners and builders in making informed decisions tailored to regional needs. The analysis was performed across five Texas city centers—Austin, Amarillo, El Paso, Dallas, and Houston—to emphasize the importance of climate-specific solutions in optimizing energy performance. Simulations of energy-efficient solutions outlined in Table 2 mentioned above were carried out and demonstrated varying levels of effectiveness based on environmental conditions simulated. Solar roofing exhibited the highest net energy savings in climate zones 2A and 3B, while wind turbines proved more effective in reducing the net energy reliance in high-wind regions as seen in climate zone 4A. Insulation materials, SIPs, and alternative window systems were found to provide significant energy efficiency benefits, particularly in Describe the areas. The findings emphasized that not all alternatives are universally superior over other solutions in the same climate zone. These instances can be expressed by siding solutions and alternative energy generation solutions seen in this study.

Alternative veins of research to be explored can be seen in in the current findings such as the only slightly greater energy efficiency of the selected window types over other window alternatives in Table 1 (e.g. double pane Low-E windows versus triple pane foam-enhanced frame, Argon, and Low-E windows). Other occurrences of this include crawl-space foundations in Houston, and solar roofing across climate zones 2A and 3B compared to solar panels for the same climate zones. These findings further iterate that there is a need for further cost/benefit analysis on proposed energy efficient alternatives and technologies for residences. Currently, many of the alternatives presented herein are novel in their design approach. As these emerging technologies and construction methods continue to evolve and gain market share, further financial analyses will be essential to better inform occupants about which solutions are most viable for broad, sustainable implementation. As such, further research investigating a pay-back period analysis should be conducted for each of the alternatives discussed in this study. As research around both energy efficient and resilient building materials and technologies gains in prevalence, a more robust reliance on statistical analysis to determine significance towards an impact on energy reduction should be explored.

Through energy simulation models and data gathered from manufacturers and scientific literature, the necessity of integrating multiple solutions to create sustainable, energy-efficient homes capable of withstanding both environmental and economic challenges was reinforced. This was showcased through an optimized simulation combining each of the lowest netting alternatives to work together in reducing net reliance on the existing energy grid. Total reductions ranged from 83.77% (Dallas, climate zone 2A) –

88.29% (El Paso, climate zone 3B). While no single solution was identified as universally optimal, the findings highlighted the importance of selecting technologies and materials that align with regional climate conditions. By prioritizing energy efficiency, resilience, and cost-effectiveness, informed choices can be made to contribute to the long-term sustainability and affordability of residential construction.

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APPENDIX A

The baseline energy consumption for the model across five Texas cities—Amarillo, Austin, Dallas, El Paso, and Houston—is shown in Figure 3. Energy consumption values range from 37.26 GJ/year (El Paso) to 41.94 GJ/year (Dallas). Notably, Dallas exhibits the highest energy consumption. These baseline figures highlight regional variations influenced by climate, forming the foundation for further energy efficiency analysis.

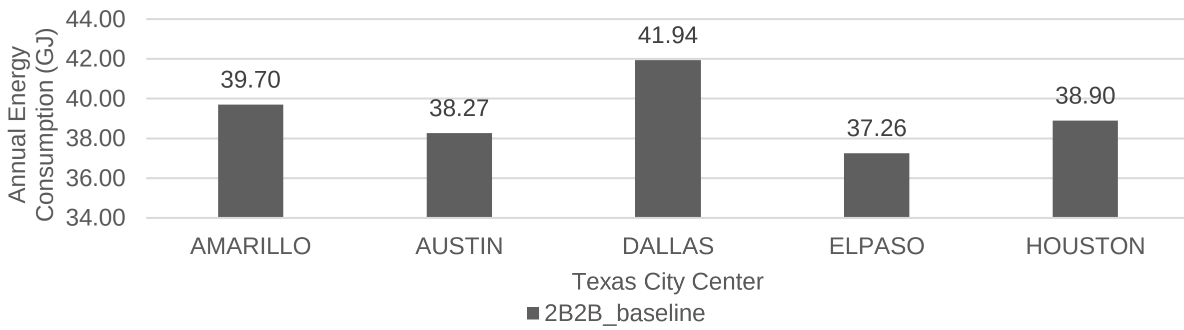

Figure 1: Yearly Energy Consumption for Baseline Models (GJ/Year)

APPENDIX B

Table 1: Baseline Model Parameters for Climate Zone 2A Cities-Austin, Dallas, and Houston

Building items	Construction composition*	Thickness(mm)*	Conductivity(W/m·K)*
Foundation-slab	Concrete	100.00	0.90
Floors	Plywood 3/4in	19.05	0.12
	Carpet Padding	25.40	0.06
Walls-Exterior	Synthetic Stucco	3.05	0.09
	Sheathing Layer	12.70[1]	0.09[1]
	OSB 7/16in	11.11	0.12
	Wall Insulation Layer	88.90[2]	0.06[2]
	Drywall 1/2in	12.70	0.16
Ceiling	Ceiling Insulation Layer	444.46	0.06
	Drywall 1/2in	12.70	0.16
Attic-Roof	Asphalt Shingles	6.34	0.08
	OSB 1/2in	12.70	0.12
Windows	Glass	-	U-2.27
Doors	Consolidated Door	31.70[3]	0.07[3]

Note: *All layer values came from the Department of Energy (DoE) Prototype Building Model in compliance with the 2021 IECC in reference to Chapter 4 (Residential Energy). The specific material was unknown, but the recommended insulative value was achieved.

1. For climate zone 3B (El Paso), the sheathing layer thickness and conductivity were 12.70 mm & 0.09 (W/m K) respectively. For climate zone 4A (Amarillo), the sheathing layer thickness and conductivity were 31.12 mm & 0.04 (W/m K) respectively.
2. For climate zone 3B (El Paso) & 4A (Amarillo), the wall insulation layer thickness and conductivity were 139.70 mm & 0.06 (W/m K) respectively.
3. For climate zone 3B (El Paso) & 4A (Amarillo), the consolidated door layer thickness and conductivity were 42.27 mm & 0.07 (W/m K) respectively.