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A Sustainable Residential Building Model in North Iraq by Considering Occupant Behaviour, Sociocultural Needs, and the Impact on Energy Use

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Abstract: Sustainable design, which aims to reduce energy consumption and mitigate climate change, is a primary concern of developing countries. Hence, it reduces CO_2 emissions. Residential buildings in North Iraq account for approximately 69% of all electricity consumed. To mitigate this issue, this article investigates the design of a sustainable model by considering the local climate, building design occupant behaviour, and sociocultural needs in the region and their impact on energy use. This study used mixed research methods to develop a sustainable single-family house model in semi-arid climates, specifically Erbil (North Iraq), the process consisted of three phases. Phase One saw the collection of all data from analysed literature, observation, worship, case study simulations of the base, and an improved model. Phase Two defined the guidelines for creating sustainable model dwellings based on the main findings in Phase One. Phase Three created a prototype to evaluate the sustainable model, primarily focusing on meeting people's design preferences while avoiding privacy concerns. In addition, DesignBuilder Software simulation was used to examine the impact of occupancy behaviour (based on local culture and traditions) on the building's energy performance throughout two phases. In the first step, three occupancy profile types are compared with real-life study bills. These profiles were the base case, which came from an actual case; the statistical profile from surveys; and the international standard ASHRAE 90.1, which was used as the default. The second phase compared the base model with an improved model and developed a sustainable prototype that satisfies local climate and sociocultural needs. The result indicated that the standard occupant profile significantly differs from the actual bill by 40%, whereas the statistical profile and base case reduce the gap to 11% and 4%, respectively. The sustainable prototype model can enhance operative temperature by 4 °C and decrease total energy use by 50% compared to the base case model. Data also showed that occupants keep lights on even when rooms are unoccupied. Therefore, when designing sustainable dwellings, it is crucial to consider occupant behaviour and their sociocultural needs, as they have a significant impact on energy use as a result of their activity patterns and schedules. These factors should be considered in the local code.

Keywords: sustainable model; single-family house; sociocultural needs; occupant behaviour; energy use; building's energy performance

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1. Introduction

1.1. Building and Sustainability

Globalisation and urbanisation in developing nations have given rise to various social, cultural, and economic transformations, necessitating rapid and innovative construction techniques to address growing housing demand [1,2]. The vital concerns mentioned previously underscore the necessity of pursuing sustainable development and the need to fostering a more sustainable built environment with reduced resource use and energy expenditure. Research on sustainable green-certification labels has been a longstanding area of interest [3], with particular attention given to creating frameworks for evaluating and categorising various aspects of building sustainability such as energy efficiency, water consumption, and waste management [4]. Many different assessment tools are used to check the measurable parts of a building's thermal and energy performance [5]. These include Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan, Leadership in Energy and Environmental Design (LEED) in the US, Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, Green Star in Australia, and Green Mark in Singapore [3]. Most building evaluation systems prioritise environmental considerations more than economic factors, paying less attention to the sociocultural dimension [6]. There is a growing imperative to situate environmental concerns within a more comprehensive cultural and social framework, encompassing both human influence and building environmental dimensions to enhance the overall quality of life [7].

Moreover, to facilitate the transition towards a low-carbon future, it is imperative to provide housing options that are both environmentally friendly and socially and culturally suitable [8]. Culture is significant in sustainable development because it influences social and economic activities determined by inhabitant behaviour, cultural values, and decision-making processes [9,10]. Hence, sustainable solutions will likely be rooted in cultural contexts. Measuring and identifying sociocultural indicators is crucial in addressing deficiencies and gaps within sustainability assessment. The lack of social and cultural considerations in the development of buildings and communities poses a risk to sustainability. This creates risks of disruption and disturbance of both established ways of life and senses of place. To effectively navigate an increasingly interconnected global society, it is imperative to adopt a holistic strategy that encompasses both sociocultural and environmental sustainability [11].

The Paris Agreement is an additional internationally binding agreement in the global effort to address climate change. The pact came into force in 2016 following its adoption by 196 countries at COP21 in Paris, France. Furthermore, a climate agreement to activate nations' commitment to the Paris Agreement was developed at the most recent United Nations Climate Change Conference (COP28), which was held in Dubai in December 2023, which aims to restrict and limit the increase in mean global temperature to over 1.5 °C the pre-industrial benchmark and mitigate greenhouse gas emissions as stated in the Paris Agreement. Achieving this target necessitates all nations' efforts to curtail greenhouse gas releases expeditiously [12]. In light of the Paris Agreement, North Iraq acknowledges the pressing necessity to combat climate change and adopt a low-energy and resilient urban approach. The region committed to decreasing greenhouse gas emissions to a minimum of 40% below the levels recorded in 2015 by 2030 [13]. These results emphasise the crucial significance of including energy conservation in buildings as a primary focus of this work.

1.2. Energy Consumption and Comfort in the Building Sector

The construction sector has a significant impact on climate change globally, as it accounts for 36% of the overall energy consumption and 39% of the carbon dioxide (CO_2) emissions associated with energy usage and industrial operations [14]. At the same time, North Iraq has a particularly high electricity consumption per capita (MWh/capita)—about 7.5 MWh/capita—compared to developed and neighbouring countries in the context of buildings. It has been observed that energy consumption during the operational phase constitutes a considerable proportion, exceeding 80% of the lifespan [14,15]. However, building operations utilise several energy sources, including electricity, coal, natural gas, and more. Additionally, it is widely recognised that the primary objective of energy usage in buildings is to ensure the occupant's comfort [16–18]. Residential buildings in North Iraq account for the most significant proportion of energy consumption within the building sector, constituting approximately 69% of the total electricity consumption [13,19]. Electric demand to supply is more than double that, leading to power outage for 12 h a day.

However, it is a significant environmental issue as fossil fuels (gasoline, diesel, and natural gas) account for approximately 85% of electricity demand and are notably absent from the energy mix [19]. Accordingly, electricity consumption produces a high rate of greenhouse gases, which consequentially have adverse effects on the climate. The residential sector represents the core element in producing greenhouse gas emissions and is responsible for 59% of the greenhouse gas emissions of North Iraq [13]. Hence, it is imperative to employ energy-saving management strategies in residential buildings to effectively reduce greenhouse gas emissions. Nevertheless, there needs to be a more comprehensive elucidation of the factors that influence household energy usage, which is crucial for enhancing energy conservation efforts and reducing emissions [20].

Many terms have been introduced globally to mitigate energy consumption in buildings, such as ultra-low-energy buildings, energy-efficient buildings, green buildings, eco-houses, and low-carbon energy buildings. Low-carbon buildings include the implementation of design strategies to mitigate the environmental impact of construction processes [21,22]. In addition, there are other energy efficiency measures linked to this goal. According to the European Union (2009), implementing integrated design principles in low-energy buildings can reduce operating costs by up to 80% [23].

A building's energy performance describes how well it manages energy use. Quantitative measurements can be taken to evaluate energy efficiency using energy performance indicators (EPI). Energy usage intensity (EUI), measured in kilowatt-hours per square meter, is the most widely adopted EPI for various building types, such as net-zero buildings [24]. According to the IEA Annex 53 project, six main factors influence the energy performance and use of a building. These factors are divided into two groups: physical factors, such as building envelope, climate, and building systems or equipment, and human influence, such as occupant behaviour, indoor environmental conditions, and building operations and maintenance [23,25,26].

Controlling the energy used in the home is a crucial consideration for policymakers. Many advanced nations have followed suit, adopting a uniform definition of energy consumption that considers (a) local climate, (b) local population demands, and (c) local building material availability. Each country's severity of environmental problems determines how much it practices low energy use [21,22]. The defining standard cannot be used internationally because of varying climates in different locations [27,28].

1.3. Sociocultural and Behavioral Context in Building Efficiency

Another relevant aspect that must be considered in the architectural design of energy-efficient buildings is the sociocultural dimension. Woodcraft et al. demonstrate the importance of social elements in successfully implementing sustainable housing development [29]. According to [30–32], occupant behaviour significantly impacts building energy consumption. According to a study by Hong et al., occupant behaviour is a significant source of uncertainty when predicting the energy performance of buildings through thermodynamic simulations [33]. This uncertainty arises from the complexity and unpredictability of occupant behaviour within a building. Previous research has indicated that energy consumption resulting from the behaviour of building occupants is comparable to that of mechanical cooling systems and appliances [34]. Studies on occupant behaviour have shown that the default load schedules do not accurately reflect the behaviour of actual occupants in their respective regions or nations. To address this, they conducted time-use data (TUD) surveys to create new occupancy pattern schedules and obtain more accurate behavioural data [33–35]. According to the results of Mahdavi et al., implementing effective building design and operational practices can significantly reduce energy consumption in buildings [35]. The behaviour of residents can significantly affect the energy consumption of buildings in several ways, including the opening and closing of windows, operating electrical equipment, managing heating and cooling systems, and regulating heating and cooling set points. According to a study by Hong and Lin, altering occupant behaviour inside buildings could reduce energy demand by 5–30% [36]. Promoting and attaining energy-conscious behaviour among households is undeniably a pivotal concern for reducing energy consumption in the residential sector [36]. The results obtained from domestic behavioural change programs conducted at national and global levels [37,38] has demonstrated a significant energy-saving potential of approximately 15–18% through enhancing occupants' awareness in residential buildings. Privacy can be considered a factor that directly and indirectly affects energy use in residential buildings through the influence of spatial layout arrangements and space use. For example, using a courtyard, roof terrace, indoor and outdoor balcony, outdoor gardens, guest segregation, open-and-close curtain, and architectural forms, such as the location of windows, windows, and shading design [39,40], are all factors that can influence energy use in residential buildings.

1.4. Influence of Sociocultural Needs on Housing Development

Cultural traditions include social and economic norms, comfort, personal preferences and attitudes, an individual's background, and household characteristics have all been identified as factors that may influence occupancy patterns [41,42]. Research conducted in China has examined the relationship between behaviour and energy consumption in the context of the washing of clothes. The findings suggest that introducing foreign technology and technical standards without considering their alignment with local cultural norms may lead to unforeseen energy usage and environmental effects [43]. To compare cultural disparities between Japan and Norway regarding energy consumption, several factors were considered, including infrastructure, climate conditions, pricing and income levels, residential dimensions, employment patterns, and gender norms. The findings suggest a correlation between energy usage and regional cultural trends and habits exists.

Consequently, one potential approach to mitigating energy consumption is to advocate for technology that offers equivalent cultural services while requiring less energy. Hence, methods of saving energy can be integrated into various lifestyles without compromising cultural traditions. Furthermore, enhancing users' understanding of energy flow within residential settings is crucial for the implementation of improved billing methods and conducting energy audits [44]. Following the objective of the cross-cultural analysis, comparative research was undertaken in Denmark and Belgium, with a specific focus on examining the energy policies implemented in each respective region. A comparison of individual factors was also conducted. Data on building characteristics, ownership, utilisation of appliances, washing and drying habits, lighting, personal computers, and televisions were gathered. Bartiaux and Gram-Hanssen [45] concluded that despite similar cultural backgrounds, notable variations in patterns and lifestyles exist, emphasising the importance of differences in energy usage.

Furthermore, ensuring occupant satisfaction is a crucial objective in sustainable design since it involves connecting and balancing the physiological and psychological well-being of home dwellers [46]. Comfort considerations encompass intangible parameters, such as the provision of privacy and individual control over the comfort of one's personal space, and tangible parameters, such as building orientation, layout, and special organization [11]. The many aspects mentioned above have a reciprocal relationship and influence how occupants utilise their building. Therefore, it is imperative to consider these factors during the architectural design process [47]. Multiple studies have substantiated that preserving privacy and providing comfort for occupants within buildings are crucial factors in attaining sustainability. Privacy in residential buildings tends to be weighted higher than in other building typologies such as office buildings, due to the difference in function [6,48]. Moreover, the architectural design of buildings can significantly improve the privacy and comfort of occupants. However, there are various obstacles to ensuring that residents are satisfied with both their internal and external environments [49,50].

Incorporating Western design and construction methods has presented particular challenges in building development across cities in North Iraq. One issue arises with the need for more sociocultural features in contemporary homes. Numerous authors have posited that the spatial arrangement of modern residences must align with the conventional family life model and daily living requirements. Several issues commonly found in contemporary houses include inadequate privacy, excessive noise, and insufficient space for family activities [51]. According to Morad et al. [19], the challenges associated with contemporary houses can be attributed to the influence of Westernization, which is gradually altering the visual landscape of cities in North Iraq. One of the aims of this study is to mitigate the sociocultural challenges commonly encountered in contemporary residential areas such as Erbil.

1.5. Research Objectives and Addressing a Knowledge Gap

Most recent articles in North Iraq highlight energy efficiency through building envelope design, mainly through orientation [13,51–54], window glazing type [13], Window-to-wall ratio [13,55], construction materials for walls and roofs [13,52,54], shading [13,52], and insulation [13,52]. In contrast, sociocultural behaviour such as privacy and its effect on the occupant lifestyle using space and building layout [56], has not been studied as a variable for energy efficiency. In addition, no studies have focused on evaluating the primary stage of buildings to satisfy sociocultural needs in North Iraq. However, a comprehensive study has yet to be conducted on building optimisation considering building envelopes, design layout, occupant behaviour profiles, and sociocultural needs in semi-arid regions. Most papers focus on a single objective and function, such as cooling demand, to optimise buildings, while a few concentrate on thermal comfort and energy demand for heating conditions. Therefore, this study attempts to close this knowledge gap by developing guidelines as a sustainable model for future dwellings that also consider social and cultural needs of residents. The following aspects are the aims of this paper:

- The main objective of this study is to gain insight into the energy consumption patterns of residents in Erbil (North Iraq) and analyse how social, cultural, and physical characteristic factors of dwellings impact their behaviour in relation to energy usage. The collected data will enhance the accuracy of predicting energy performance.
- To find the primary relationship between energy usage, architecture design, and the sociocultural context in the residential building to create sustainable housing in North Iraq and compare it to existing standards in developed countries.
- To develop a sustainable model for the new housing projects in the region that is appropriate for the social and cultural needs of the residents.

2. Materials and Methods

The increasing housing demand by North Iraq government causes a high energy demand in the housing sector. Building design characteristics, together with occupant behaviour based on sociocultural needs, significantly influence the energy performance of contemporary buildings. To investigate this issue, this study used a mixed-methods strategy combining concurrent and sequential designs [57]. A mixed-methods approach was applied to analyze the demographic pattern and family structure to understand the occupant behaviour profile of the households as well as the design characteristics of contemporary dwellings concerning energy consumption. Snowball sampling was used to obtain, as close as possible, a cross-section of participants for access to their surveys and interviews [58]. The chosen methodological technique is considered suitable for generating significant data that can be utilised to construct the proposed framework in this study [59,60]. For a typical case, the energy consumption has been numerically and graphically modelled using quantitative methods in DesignBuilder Energy Software v6.1. Different behaviour profiles and energy consumption of building models were compared using comparative methods.

Figure 1 illustrates the research methodology. The initial stage involved the utilisation of household questionnaires, workshops (semi-structured interviews) with professionals, field survey observations, and on-site data measurement in single-family houses as a preliminary method. The subsequent section examines the surveys, which were conducted using statistical techniques to establish the occupant’s behaviour profile and building design characteristics concerning Phase Three. The analytical findings were then entered into the DesignBuilder Energy Software v6.1 to produce a model representing the initial scenario, with the results obtained in two phases. In Phase One, three distinct occupancy profiles are compared to actual case study bills. These profiles include the base case (obtained from real cases), statistical profile (obtained from surveys), and international standard ASHRAE 90.1 as the default. In the Phase Two, a comparison was made between the base model and an improved model, and a prototype was developed that satisfied the local climate and sociocultural needs.

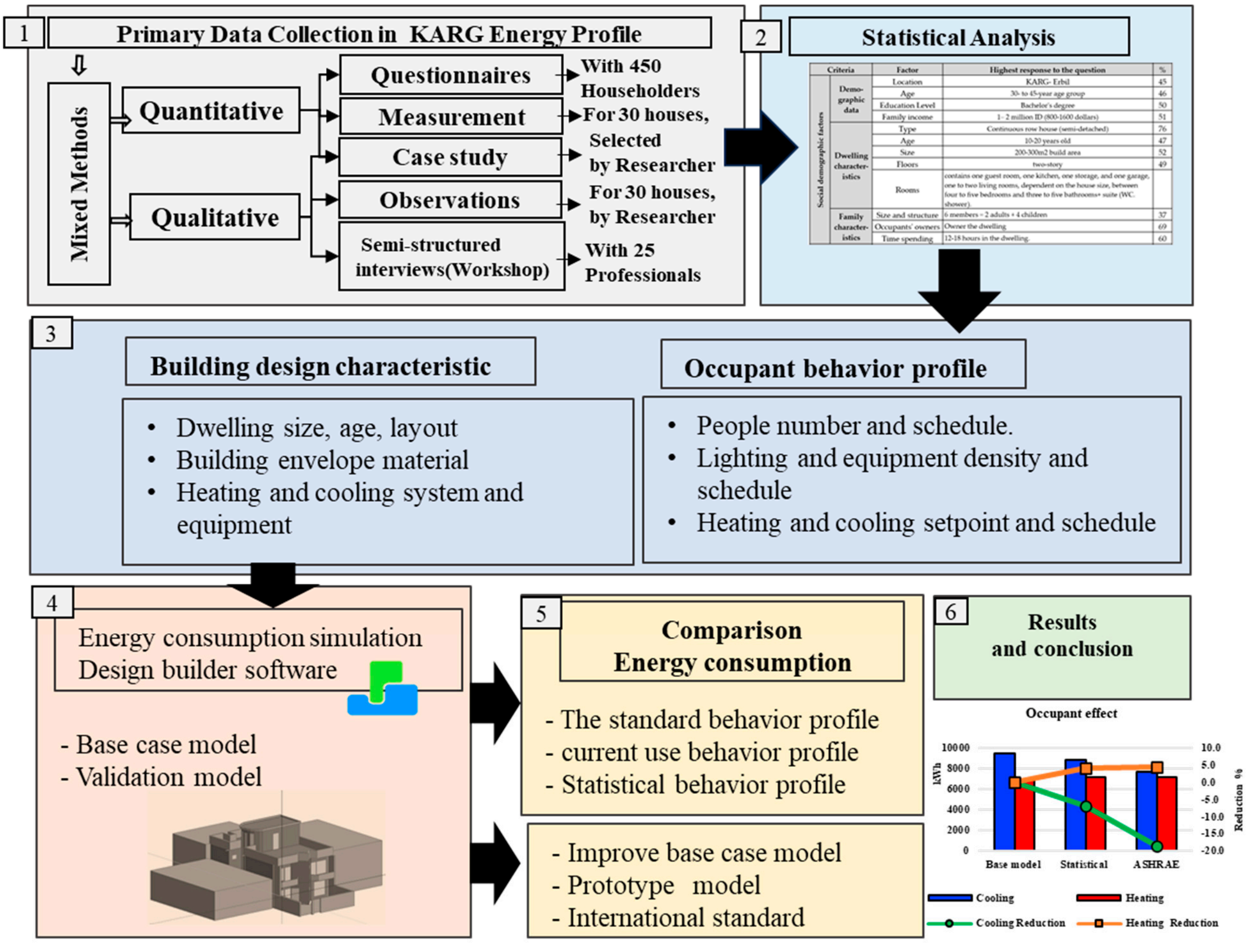


Figure 1. Research methodology.

2.1. Observations and Measurement

Since there is no specific number in the literature regarding observation, the study observed 30 individual single-family dwellings in this investigation. Observational features that were photographed and noted included a cultural occupant behaviour pattern (lifestyle), the overall layout of the house, space-specific arrangement, functionality, and building envelope materials. This contributed to assessing the influence of privacy on the building layout, envelope, sociocultural behaviour pattern (lifestyle), and presence related to energy consumption. The research monitored a real-life case study about the outdoor and indoor temperature and humidity for one month in the summer (21st of June summer solstice) and one month in the winter (21st of December winter solstice), and also observed the occupants' behaviour.

2.2. Semi-Structured Interviews

The workshop, which was conducted by the Department of Architectural Engineering at the University of Duhok examined the interconnections between energy use, architectural design, and the social and cultural context of residential buildings in Erbil (North Iraq). It was made up of 20 academic professionals specialising in several fields of design and engineering, as well as 5 governmental representatives from different directorates. The interview was conducted with a group of professionals and lasted nearly 2 h. The objectives encompassed identifying issues about the energy consumption of contemporary residential dwellings and proposing novel energy-efficient housing projects that meet sociocultural and environmental requirements. The main predefined question is whether current housing is impacted by Western architecture and way of life, and whether it fulfils the local people's needs, regional climate conditions, and sustainable development. It is possible to reformulate and employ the traditional architectural elements in the contemporary dwelling in a way that suits those local to the region.

2.3. Household Survey (Sociocultural Survey)

A comprehensive study collected data on occupants' behaviour and knowledge, dwelling layout, and building envelope related to energy use in North Iraq. Homeowners completed a survey to assess house design characteristics, user behaviours, and attributes, and their impact on determining energy consumption. The dataset was analysed statistically to identify physical and behavioural characteristics influencing energy use [61]. A sample of 450 households was surveyed in North Iraq. The survey was comprised of 52 questions, categorised into 6 distinct sets of criteria.

1. Householders' general information
2. Dwelling characteristics
3. Occupants' behaviour patterns and periods related to the use of appliances, cooling and heating systems, lighting, and domestic hot water systems (DHWS).
4. Occupants' thermal comfort depends on the building envelope construction.
5. Social culture needs and satisfaction for current and future houses.
6. Occupant awareness and education about building energy efficiency and sustainability.

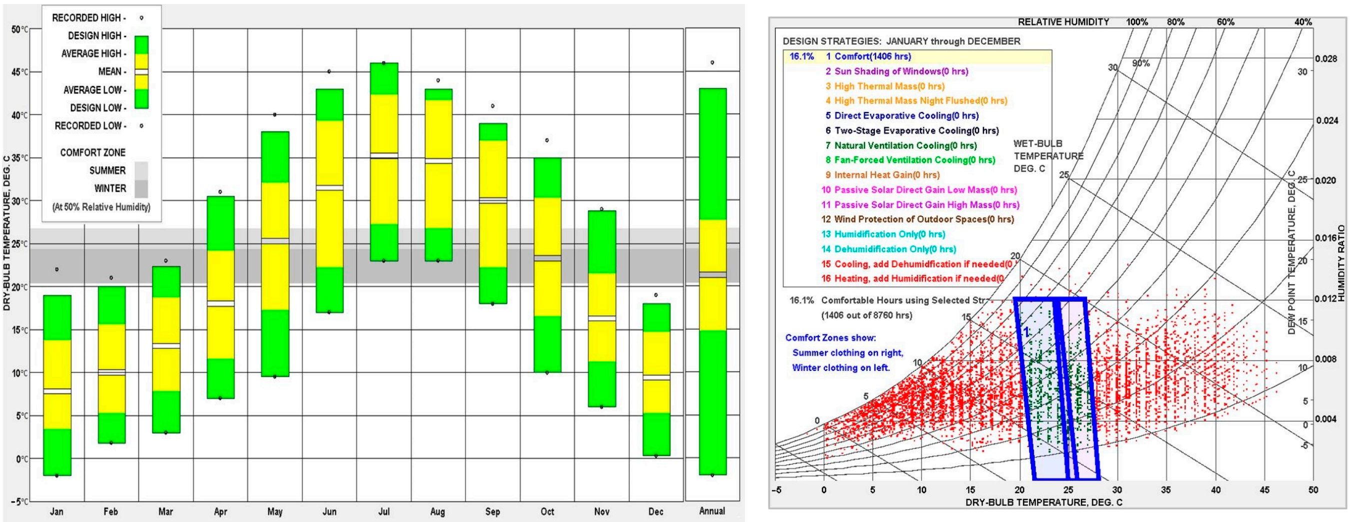
Questionnaire results assisted in selecting a typical residence as the case study for this investigation. The case study was modelled and simulated with the help of data gathered from the workshop, including semi-structured interviews, household questionnaires, and observational surveys, which informed the creation of a new framework. All inquiries were translated into Kurdish and Arabic languages to facilitate an easy survey process and obtain accurate outcomes.

2.4. Case Study Module and Simulation

A real-life case study was chosen based on the results of a questionnaire to investigate how important it is to consider detailed social and cultural profiles of occupants, as well as the design and physical features of a dwelling, when figuring out how much energy a building needs. This was conducted using DesignBuilder Software [62], which leverages EnergyPlus as the simulation engine to assess housing performance in terms of energy demands for heating, cooling, lighting, and thermal comfort [63]. To determine the requirements under optimal conditions, the initial step was conducting a simulation of the case study house. Then, various envelope configurations were assessed to determine the optimal thermal comfort and energy efficiency. The simulations' findings guided the design process and established the framework for constructing energy-efficient residences in semi-arid regions to satisfy sociocultural needs such as privacy.

2.5. Weather Data

The base case study was located in Erbil (North Iraq). Erbil has a semi-arid climate (Bash). Summer has high temperatures and low humidity, and usually lasts from June to September, with July and August being the hottest months. The average temperature is 34 degrees Celsius, with the highest ever recorded temperature being 48 degrees Celsius [19]. The average temperature drops to 7 °C from December to February during the winter season, which features low temperatures and precipitation, with the lowest ever recorded temperature being −3 degrees Celsius [52,64]. Hourly air temperature data for Erbil International Airport (WMO:406356) uses EWP-TMY2 meteorological data from the https://climate.onebuilding.org/ website for energy simulation. These weather data files were constructed using historical records from 2007 to 2021 (Figure 2A). The psychometric chart of Erbil shows only 16% of people being in the comfort zone, and both heating and cooling strategies are needed to achieve thermal comfort in buildings (Figure 2B).



(A) **(B)**

Figure 2. Erbil. (**A**) Distribution of monthly air dry-bulb temperature (°C). (**B**) Psychometric chart.

2.6. Occupant Behaviour Simulation

The study aimed to assess the influence of occupancy behaviour by conducting experiments using three distinct models (Figure 3).

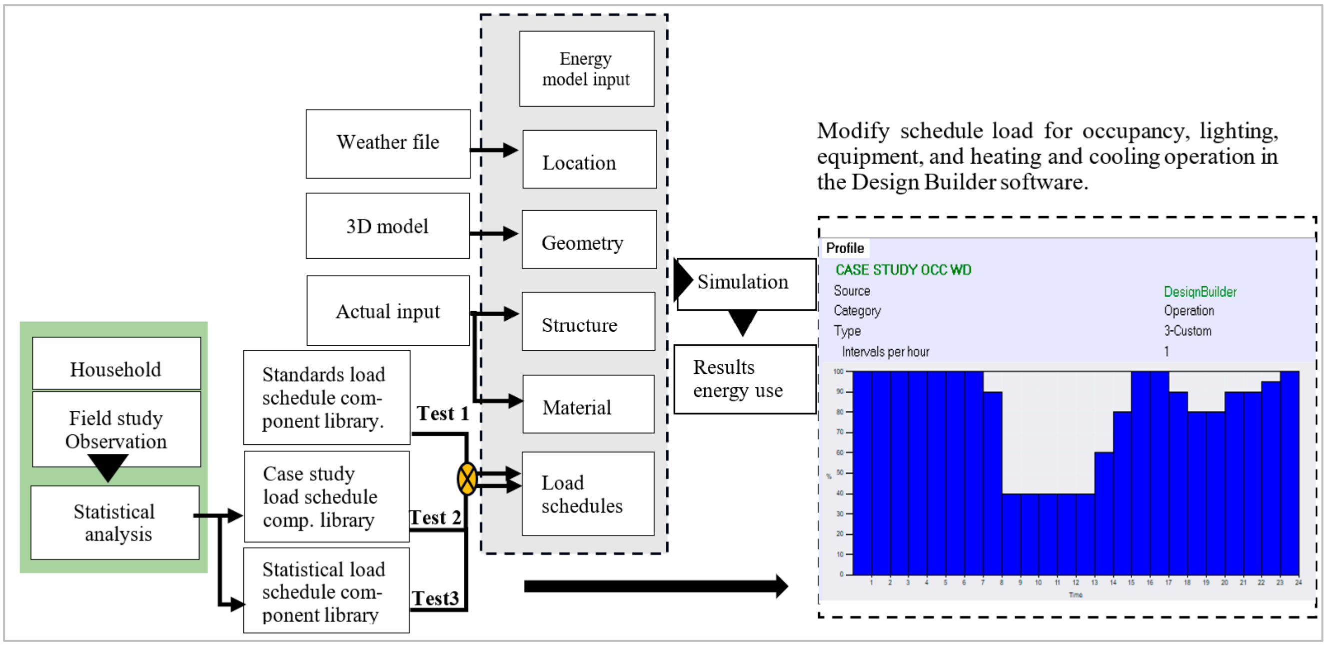


Figure 3. Method for processing model test.

The first model involved building energy models using default data values from the Design-Builder thermal simulation program. These simulations were carried out over one year to determine the consumption patterns associated with standard behaviour based on data obtained from ASHRAE 90.1.

In the second model, the existing time-use schedules are substituted with the expected schedules derived from the typical case study, encompassing eight separate thermal zones (Figure 4). It is important to note that all inputs in this case study are associated with internal heat gains. The parameters, including lighting, occupancy, home occupant's activities, and equipment usage in each zone, were individually established to simulate a typical family's activities and resemble real-life conditions.

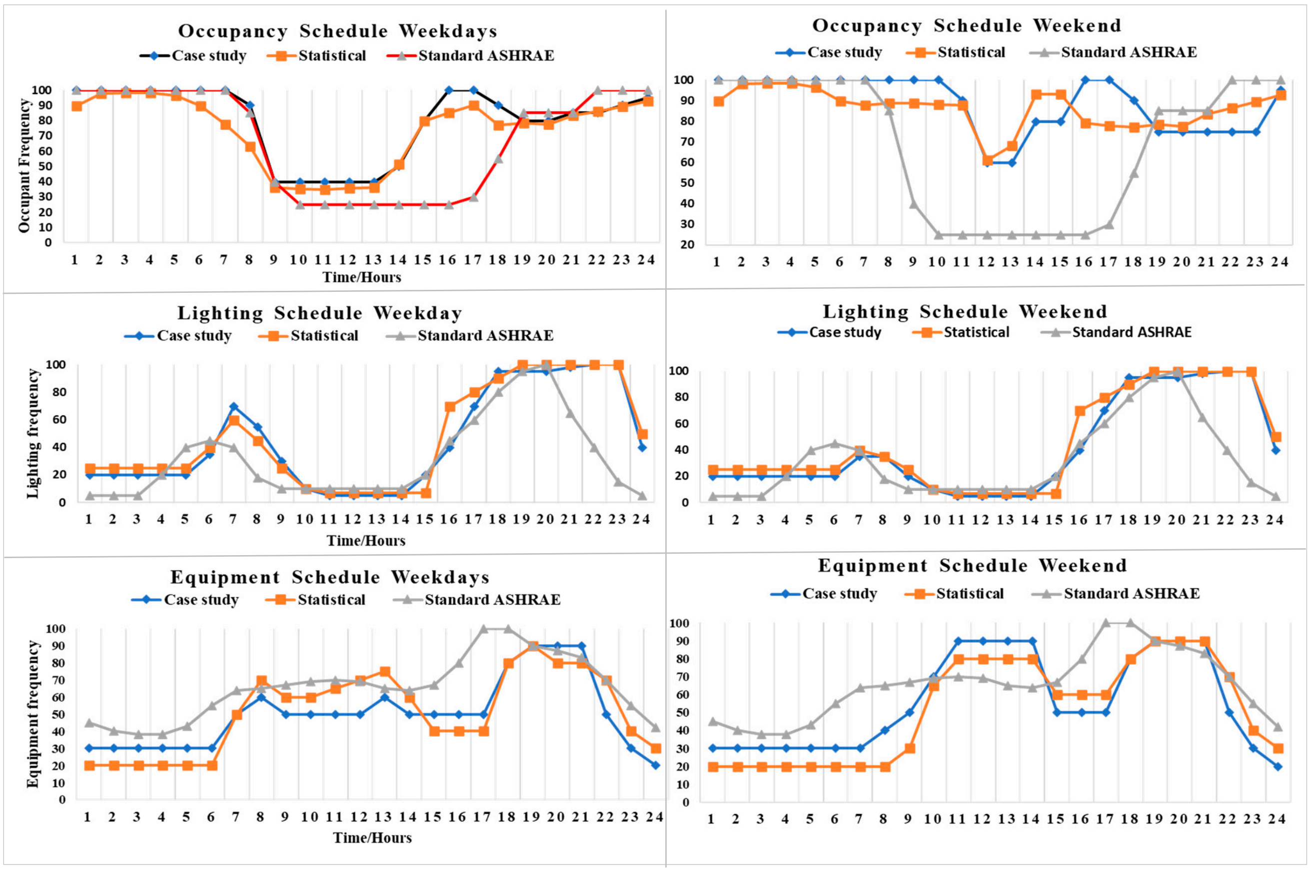


Figure 4. Scheduled load input in simulation.

The third model was created by combining data collected from the household behavioural survey and both the International Organization for Migration (IMO) survey [65] and Harry, H [66] survey into the load schedules. The introduction of load schedules into the simulation program helped determine the consumption pattern for the statistical behaviour of households in North Iraq. The IMO survey is regarded as one of the most extensive statistical endeavours undertaken in the region since 1987. The present sociodemographic study collected data from 12,699 households, encompassing established residents and displaced families residing in the three governorates of Duhok, Erbil, and Sulaymaniyah within the region.

3. Analysis Results

3.1. Household Survey Result Data

The results of the household questionnaire, as summarised in Table 1, had a significant influence on the development of energy-efficient homes in North Iraq by providing information about the physical features of the building as well as its operating systems and applications, in addition to the occupant behaviour and habit in energy use and sociocultural satisfaction in the current dwelling.

The statistical study discovered components that are impacting energy usage. By employing Spearman’s rank correlation coefficient approach, which summarises the intensity and direction (positive or negative) of a link between two variables, the results showed that energy consumption is positively correlated with dwelling size and age, family salary, occupancy numbers (especially children), air conditioner numbers, and education levels.

Table 1. Summary of data obtained through analysis of household questionnaire.

Criteria		Factor	Highest Response to the Question	%
Social demographic factors	Demographic data	Location	KARG-Erbil	45
		Age	30- to 45-year age group	46
		Education Level	Bachelor’s degree	50
		Family income	1–2 million ID (800–1600 dollars)	51
	Dwelling characteristics	Type	Continuous row house (semi-detached)	76
		Age	10–20 years old	47
		Size	200–300 m^2 build area	52
		Floors	Two-story	49
		Rooms	Contains one guest room, one kitchen, one storage, and one garage, one to two living rooms, dependent on the house size, between four to five bedrooms and three to five bathrooms+ suite (WC. shower).	
	Family characteristics	Size and structure	6 members = 2 adults + 4 children	37
		Occupants’ owners	Owner the dwelling	69
		Time spending	12–18 h in the dwelling.	60
Occupants’ behavior Energy consumption & usage Occupants’ behavior		Electricity sources	100% national grid, 99% from public generators, usually 4–6 Amperes (69%) due to a power cut 9–12 h (84%)	
		Cooling Devices and numbers	98% used evaporative coolers (350–500 w), and 95% used air conditioning (1.5–2 tons). Owning two to three evaporative coolers and air conditioners accounted for 66% and 50%, respectively.	
		Heating Devices and numbers	100% kerosene (oil) heaters (daily 5–8 L), 99% electric heaters (1200–1800 w). Owning two to three kerosene (oil) and electric heaters represent 81% and 70%, respectively.	
		Air conditioning utilization	It is used 7–12 h daily in the summer and winter, 66% and 61%, respectively. Moreover, primarily used in the bedroom (94%) and living room (76%).	
		Water heater	In winter, it is used daily	95
		Artificial lighting	using Artificial lighting in the daytime in their house	92
		Electricity bill	Half of the participants know the household electricity bill, while almost half do not. The reason may be that people in KARG have two electricity bills for the national grid and public generator electricity. The average payment is nearly 110000ID (80 Us dollars), representing 10% of income.	50
Occupant thermal comfort		Thermal comfort Level	In summer, it felt hot (+3) In winter, it felt cold (−3)	77 72
		Air-conditioning set point	In summer, air conditioning was set below 23 °C In winter, air conditioning was set above 22 °C	77 62
Building envelope construction		Thermal insulation	Not have thermal insulation in their homes	87
		External wall	Used Solid block in the construction and plaster	76
		Roof	Used Reinforced concrete in the floor and roof construction	98
		Windows	Used PVC frame	69
		Glazing	Used Double glazing panel with air gap 6 mm (handmade)	47

Table 1. *Cont.*

Criteria			Factor	Highest Response to the Question	%
Social-cultural indicators	Current dwelling	Satisfaction	Usage needs	Yes, they are satisfied	71
			Keeping privacy	No, they are not satisfied	83
			Accessible for disabled elderly	No, they are not satisfied	55
			Safety and security conditions	Yes, they are satisfied	69
			Room size	The people were satisfied with the bedroom, guest room, toilet, WC, bathroom, outdoor space (garden), balcony, and kitchen, representing 60%, 71%, 90%, 81%, 61%, 60%, and 58%, respectively. They are not satisfied with the living room and the area of the house and storage that should be bigger at 56%, 57% and 51%, respectively.	
		Refurbishment		(55%) made changes, such as changing the house's interior and exterior decoration only for renovation and beauty, or changed window frames from iron to PVC and glazing types from single glazing to double glazing to make their home more thermally comfortable, or added bedrooms or another floor because their son is married and needed more space, or added one room on the roof as a store	55
		Gender segregation		58% separate male and female guests. Most of them host the guest in the guest room and living room at 98% and 78%, respectively,	58
				Do not have separate entrances for males and females	65
		Gardens utilization		35% Used outdoor space gardens only in summer. 25% Do not have one. Usually, the garden is used for installing air conditioners and air coolers 42%. and 38% used it for spreading clothes to dry. Unfortunately, just 35 were used for social interaction	35
		Balconies utilization		62.5% were not always used. 75% used it to install air conditioners and air coolers, and 69% used it for their clothes to dry. Unfortunately, just 7% were used for social interaction	63
		Roof utilization		Beas on observation, 100% roof was not always used; it was usually used for storage and installing air conditioners and coolers and water tank.	
	Future dwelling need	Extension		48% want to enlarge their house. Wants to add bedrooms at 90.4%, then storage and a living room at 21.2% and 15.4%, respectively. Regarding outside space, respondents want to add a balcony at 69.2%, followed by an enclosed garage and storage at 30.8% and 25.6%, respectively.	
		Dwelling type		want to live in a villa (detached house)	73
		Residents Expectation	Thermal comfort and well-being of the users in different seasons, such as winter and summer		94
			Safety and security of the house		91
			Affordability of the house		81
			The need for visual contact with the public using appropriate apertures (window, door size and orientation)		80
			The use of a garden as a private indoor space invisible to the public		72
			The use of a garden as an outdoor space visible to the public (accessible for guests)		69
			The aesthetical design quality of the building envelope (external appearance of the entrance elevation)		68
			Separation of the kitchen (cold/hot)		67
			Master bedroom with own bathroom or WC/shower		66
			The use of the balcony, for instance, in summer only for family social interaction.		64
			Additional guest room with own bathroom or WC/shower		62
			Clear Separation between private spaces and semi-open spaces as space arrangement of the residential		62

3.2. Existing Case Study Modeling and Simulation

The study utilised survey data analysis from Table 1 which considered various factors such as house type, layout design, construction year, area, number of floors, envelope material, heating, cooling, and domestic hot water systems (DHWS). These factors were chosen to align with the significant features of the sample. The case study's residents, who demonstrated a willingness to collaborate and share building plans, details about daily routines, and reports of their electricity consumption, also impacted the choice of the case study house.

Typical units were constructed in 2008 on a 200 m^2 (10 m $\times$ 20 m) plot size with a total built area of 265 m^2 (adjacent from three sides), including a 240 m^2 (ground + first) and 25 m^2 (second) floor plan. The unit plan includes an entrance, reception, four bedrooms, three bathrooms, a hall, living room, kitchen, and penthouse (Figure 5). There are seven members of the extended family living in the dwelling. The two parents have three adult children; one is married and has a 10-year-old child. The homeowner and his married son are away from home for five days a week (Sunday–Thursday) from 8:00 a.m. to 2:00 p.m. In the meantime, the daughter-in-law—a primary school teacher—goes to school five days a week from 8:00 a.m. to 1:00 p.m. with her child. In contrast, one adult child finishes her bachelor's degree and stays home. At the same time, the mother assumes the role of homemaker, dedicating a significant portion of her time to domestic responsibilities inside the household. The thermal transmittance of the building components was calculated according to EN ISO 6946 [67]. Table 2 presents a brief overview of the construction aspects of the case study and the occupant and internal load parameter input data in the case study specified in Table 3 and Figure 6.

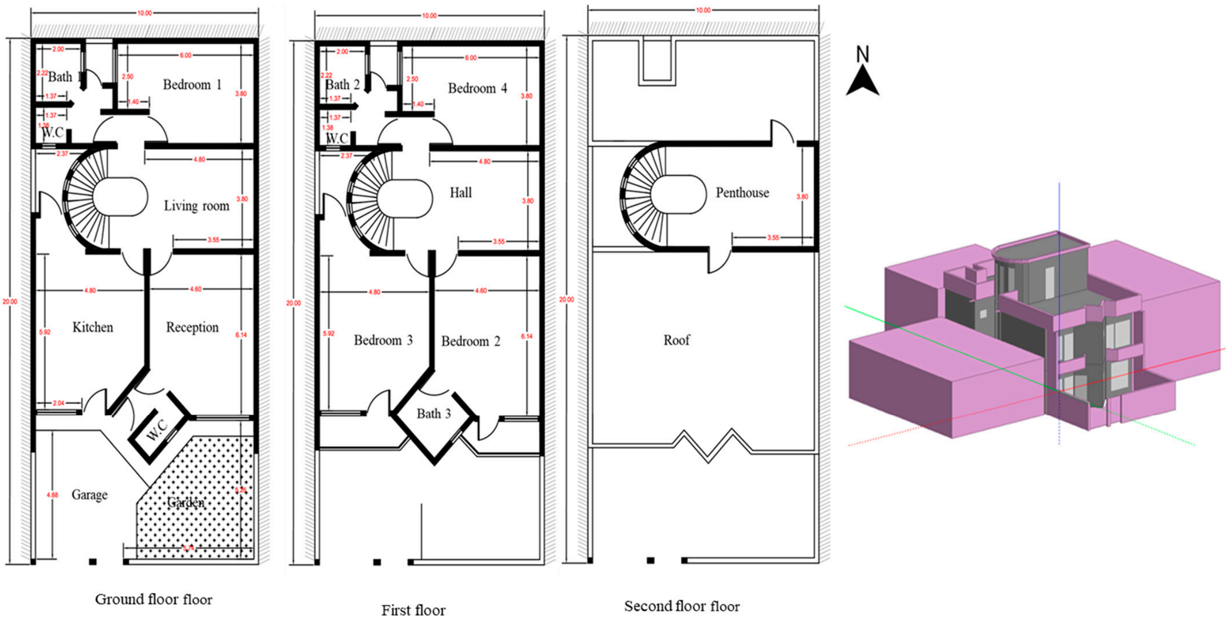


Figure 5. Case study plans and 3D model.

Table 2. Typical house construction details.

House Module	Construction Details	U-Value
Roof	Gypsum boards (2 cm), air gap (10 cm), reinforced concrete (20 cm)	2.45 (W/m^{2}K)
External wall	Gypsum-plaster interior rendering (2 cm), solid concrete block (20 cm), cement plastering external rendering (2 cm)	2.70 (W/m^{2}K)
Internal partitions	Gypsum plaster rendering (2 cm), solid concrete block (20 cm), gypsum plaster rendering (2 cm)	2.55 (W/m^{2}K)
Ground floor	Soil + crushed rock layer (10 cm), plain concrete (10 cm), sand and cement mix (5 cm), porcelain tile (2 cm)	1.69 (W/m^{2}K)
Internal floor	Gypsum boards (2 cm), air gap (10 cm), reinforced concrete (20 cm), cement mortar (5 cm), porcelain tile (2 cm)	2.0 (W/m^{2}K)
Windows	PVC (polyvinyl chloride) with double clear glass (3 mm/air 6 mm)	3.2 (W/m^{2}K)
Façade or direction	South	
Door	Indoor: wood and PVC (polyvinyl chloride) Outdoor: metal steel	3.48–3.1 (W/m^{2}K)

Table 3. Input data of case study model.

Zone	Metabolic	Number of Occupants during Occupancy	Lighting W/m^2	Equipment W/m^2	Zone Cooling/ Heating Set Temp. °C
Bedroom 1	Sleep/Rest	1	3.6	2	
Bedroom 2	Sleep/Rest	2	3.6	2	
Bedroom 3	Sleep/Rest	2	3.6	2	
Master bedroom	Sleep/Rest children life care	2	3.7	8	
Living room	Sitting, reclining, watching TV, conversation and communication	5	4	8	21 °C–24 °C
Kitchen	Cooking and eating/drinking	4	3.5	30	
Penthouse	Walking	1	3.5	0	
Guest room	Seated quietly	6	3.8	2	
Store and bathrooms. WC		0 1	5 7	0 10	

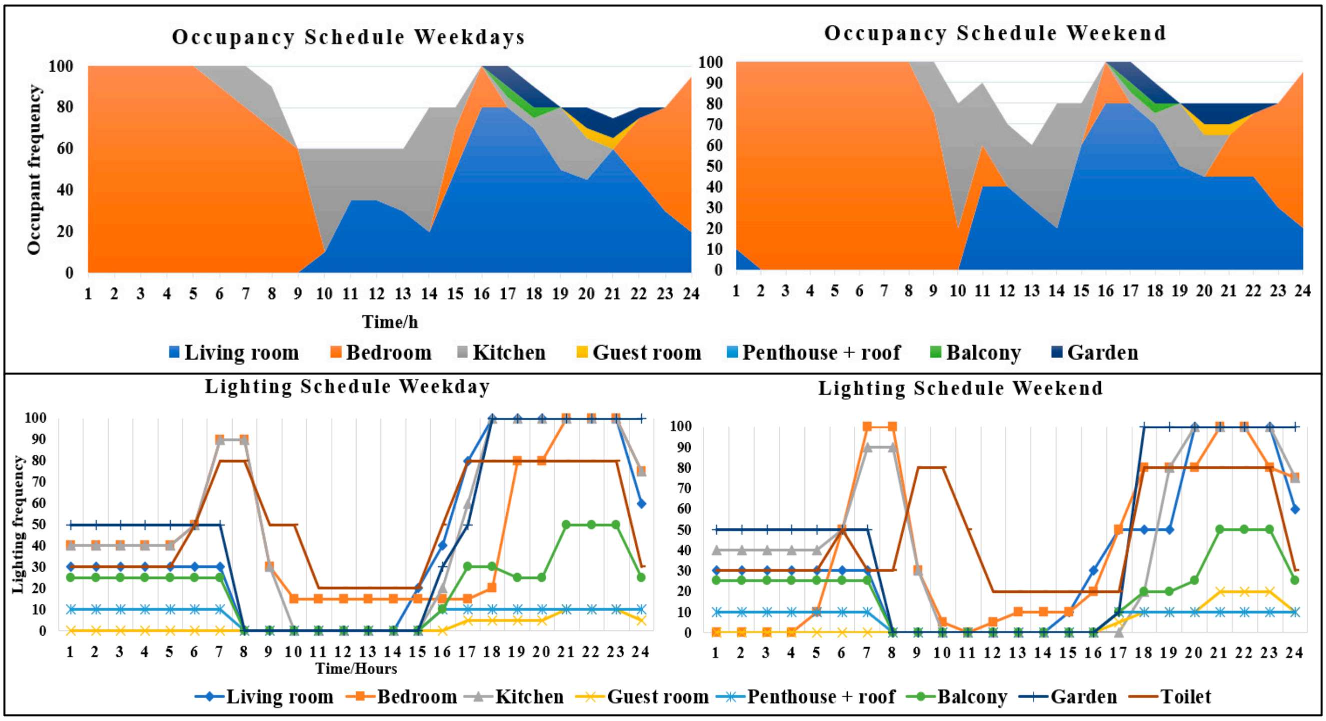


Figure 6. Internal load schedules based on user survey.

3.3. Energy Consumption Base Case

Data on actual energy consumption was gathered from 2020 to 2022. National graduate and public generators' average electricity generation capacity is 23,258 kilowatt-hours. The annual electricity energy consumption of the base model was determined to be 24,198 kilowatt-hours (kWh). Another way to quantify the annual energy use is as an energy use intensity (EUI), measured in kWh/m^2/year, which is 135 kWh/m^2 per year. Figure 7 provides a complete depiction of the aggregate energy use across many applications, encompassing lighting, heating, cooling, room electricity, and domestic hot water. The computer simulation accurately illustrated that the biggest energy consumption is attributed to cooling needs, accounting for around 39% (9455 kWh). Following this comes heating needs, which account for 29% (6926 kWh) of energy consumption. Room or internal lighting, exterior lighting and equipment, and domestic hot water (DHW) account for approximately 11% (2750 kWh), 11% (2685 kWh), and 10% (2452 kWh), respectively. Data demonstrate that heating and cooling loads play significant roles in semi-arid climates, which must be considered during the design process to achieve energy-efficient buildings and sustainable design.

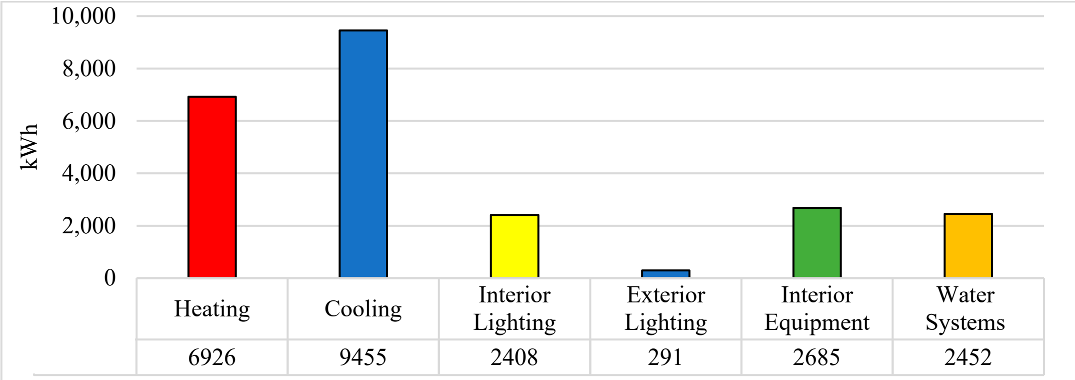


Figure 7. Total electricity consumption for indoor load base model simulation.

3.4. Validation Building Model

The simulation model was validated with on-site measurement data. Data collection was conducted for one month in the summer of 2023 and one month in the winter of 2023 to assess the outdoor and indoor thermal environments. The living space and bedroom were chosen on the ground and first floors. Elitech GSP-6 temperature and humidity sensors were used for data collection. The sensors were placed at a height of 1.8 m in the corner of the room and conducted at intervals of 10 min, consistent with earlier studies on monitoring [68,69]. The precision of the temperature measurement has a tolerance of ±0.5 °C (−20 °C–40 °C), while the RH measurement is reported to have a tolerance of ±3% (at 25 °C, 20–90% RH). According to Nicol et al., this level of accuracy is reasonable [70]. The validation process involved collecting data from a real-life case study and evaluating the outcomes of the base-case model simulation to verify the reliability of the model's behaviour and results. The house owners provided the building's electricity bills. The process of validation was examined in two distinct stages. In the first stage, the researcher obtained the necessary EnergyPlus Weather (EPW) files from the Climate OneBuilding database. To verify their precision, researchers compared the recorded outside temperatures during four weeks of summer 2023. However, the EPW weather data files were constructed using historical records from 2007 to 2021 (Figure 8, Table 4), meaning some disparity could have occurred.

Table 4. Comparison between mean outdoor temperatures and humidity from EPW files and in situ measurements for August 2023.

Location	Period	In Situ Measurements	Energy Plus Weather Data
Erbil	Mean °C (August)	33.36 °C	34.3 °C
	Mean % (August)	19.2%	17.3%
	Mean Absolute Error	1.9 °C for (10-min intervals)	

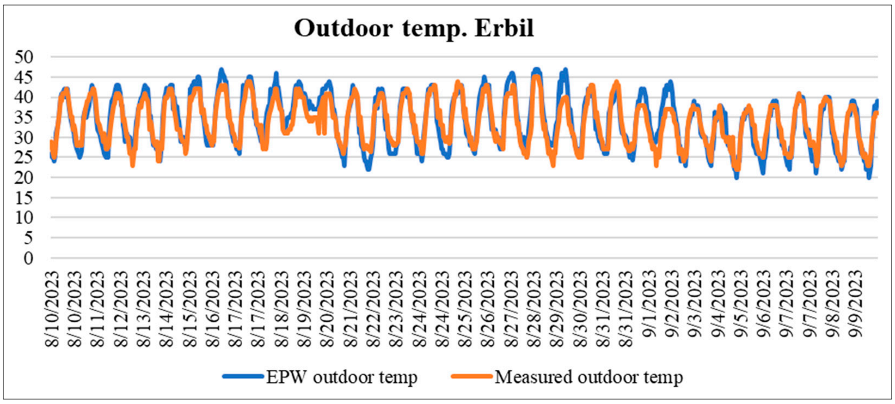


Figure 8. Comparison between outdoor temperatures from EPW files and in situ measurements.

In the second stage, the calibration methodology employed in this study consisted of multiple phases derived from the ASHRAE Standard 140-2017 [71] that was aligned with earlier research [72–74]. Subsequently, the simulation was executed, and the obtained outcomes were compared and extracted with the measured data. The calibrated data was visually represented to analyse the measured and simulated data disparity. Subsequently, suitable adjustments were made to the model. The process involved using a manual calibration method in conjunction with statistical techniques, including the normalised mean bias error (NMBE) and root mean square error (RMSE) CV. To account for the variability between the measured and simulated data, NMBE and RMSE were used, as stated in ASHRAE 140-2017. For calibration against air temperature, many writers have employed a threshold of 10% for the MBE and 30% for the RMSE. When comparing hourly data, it is expected that both the NMBE and the RMSE should be below 10% and 30%, respectively [75–77]. The manual calibration method was chosen, and multiple iterations were conducted for the calibration goal. The simulated outcomes were compared to the observed outdoor and indoor air temperatures. The values for the base model (NMBE) and CV (RMSE) were 7.3% and 22%, respectively, for outdoor air temperature and indoor air temperature (Table 5 and Figure 9). The obtained indexes fell within an acceptable range of values.

Table 5. Validation summary of calibration criteria of simulation model. Legend: NMBE, normalized mean bias error; CV RMSE, coefficient of variation of root square mean error.

Validation Criteria	Threshold ASHRAE 140-2017	Summer Outdoor Air Temperature	Summer Indoor Air Temperature Living
NMBE (%)	0–10%	7.3%	5.24%
CV(RMSE) (%)	0–30%	22%	16%

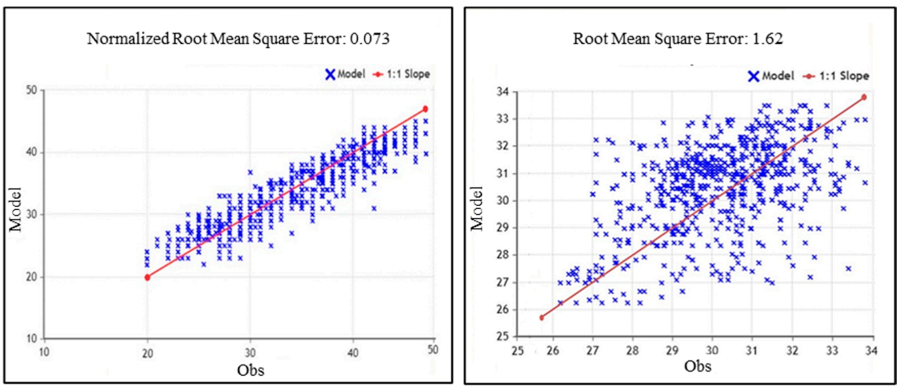


Figure 9. NMBE (%), CV RMSE (%) comparison between monitored and simulated outdoor and indoor air temperatures.

3.5. Comparison between Occupancy Profiles

To define the sociocultural impact on occupant behaviour, a comparison between the real bill, base model, statistical model, and default model standard ASHRAE 90.1 has been carried out during the research process. Figure 10 shows the difference between the real bill, base model, and default model standard ASHRAE of about 40%, respectively, while the statistical model closes the gap to 11%. In contrast, the base model, which considers occupant behaviour, closes the gap to 4%. This indicates that the international standards and the occupancy profile adopted for design and performance analysis are specifically unrelated to the local region, which provides incorrect outcomes and impact assumptions regarding energy usage and occupant comfort.

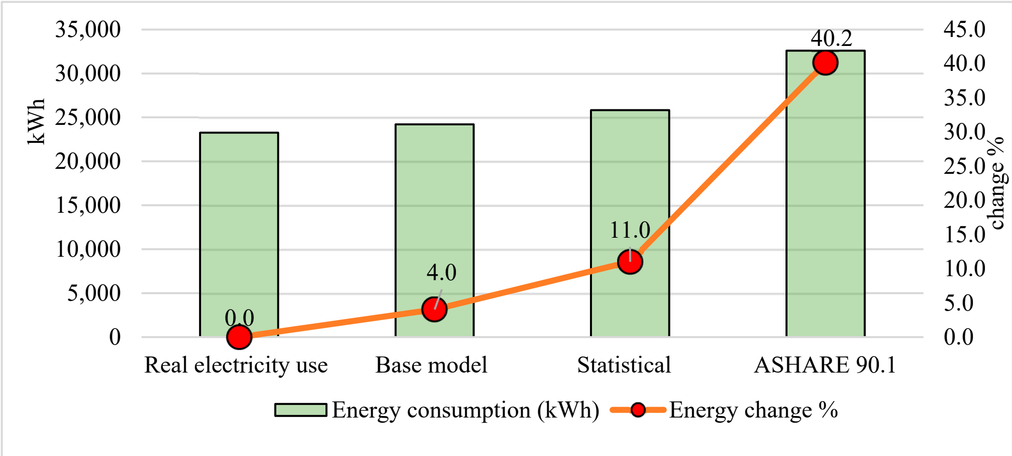


Figure 10. Annual electricity consumption difference between real bill, base model, statistical, and default standard model simulation.

3.6. Impact of Occupant Behavior on Energy Use

The actions of a building's occupants impact its energy consumption significantly because of their occupancy patterns, lighting choices, appliance use, and HVAC adjustments.

Applying the statistical and ASHRAE 90.1 occupant schedule instead of the base model and not changing the power load or any other parameter, the heating load could go up by up to 4.4% and the cooling load could go down by 18% (Figure 11A). When equipment schedules are changed, there is a noticeable change of 30% in energy consumption compared to the standard schedule. However, the statistics are close to the base model (difference of 1.7%) (Figure 11B). The opposite of the previous variable lighting schedule shows an increase of 26% in lighting use with the standard schedule and a reduction of 8% with the statistical schedule (Figure 11C). This is due to residents frequently turning on lights even when rooms are empty. This practice can be explained by no particular cultural factor other than the fact that national grid electricity is cheap.

3.7. Improved Case Study Envelopes and Operation-Related Behaviour of the Occupants

Two standards were selected for improving envelopes due to unavailable codes for building envelopes in the region. The study selected the Turkish Standard (TS 825) as a local standard because it is on the border with North Iraq and has similar climatic factors and sociocultural conditions [78]. In addition to TS 825, ASHRAE 90.1 2007, as an international standard, is suitable for the local climate and its characteristics [79,80]. To improve the operation-related behaviour of the occupants, this study considered lighting, equipment, and air conditioning (Table 6).

The outcome demonstrates the potential to reduce heating and cooling energy use by up to 37% and 55%, respectively, with a potential reduction in total primary energy of up to 30% (Figure 12A). However, by improving the operation-related behaviour of the occupants related to heating and cooling, energy use can be reduced by up to 65%, with a total primary energy reduction of up to 44% (Figure 12B). That means that operating variables can reduce 14% of total energy.

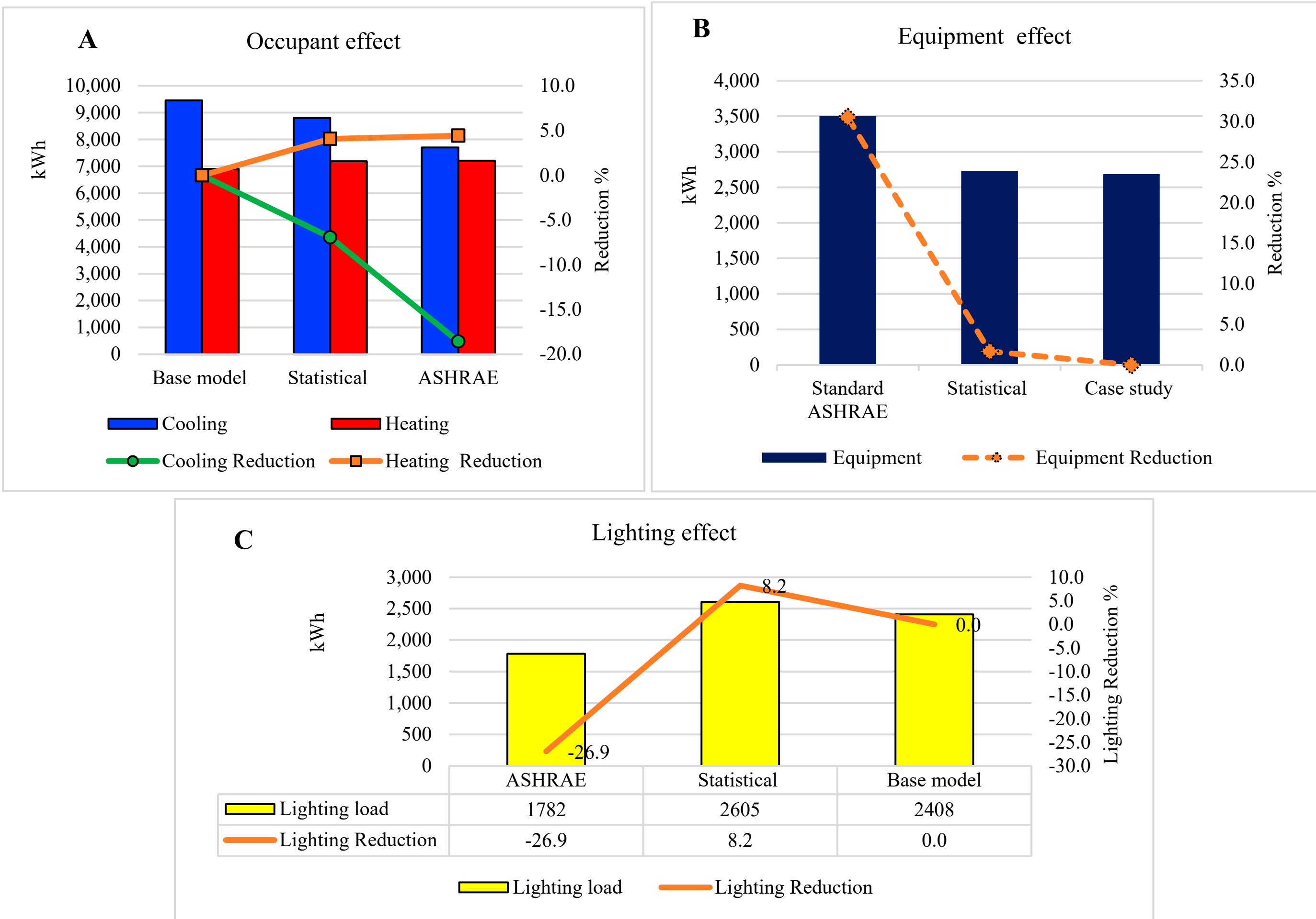


Figure 11. Heating and cooling consumption and difference between real bill, base model, statistical, and default standard model simulation. (**A**) Impact of occupant pattern, (**B**) impact of equipment pattern, and (**C**) impact of lighting pattern.

Table 6. Improved base case study parameters [70,79,80].

		U-Value Wall (W/m^{2}K)	U-Value Roof (W/m^{2}K)	U-Value Window (W/m^{2}K)
Envelope parameters	Region 1	0.70	0.45	2.4
	Region 2	0.60	0.40	2.4
	ASHRAE (B2)	0.70	0.27	3.9
	ASHRAE (A3)	0.59	0.27	3.4
Operation parameters	Lighting	Occupant control	Developed schedule load based on occupant presence.	
		Efficient lighting	Change to 15 W	
	Equipment	Efficient equipment	Efficient applications are available in the market.	
	Air condition set point and coefficient	Setpoint	Cooling 25 °C–Heating 20 °C recommended by ASHRAE	
		COP	3	

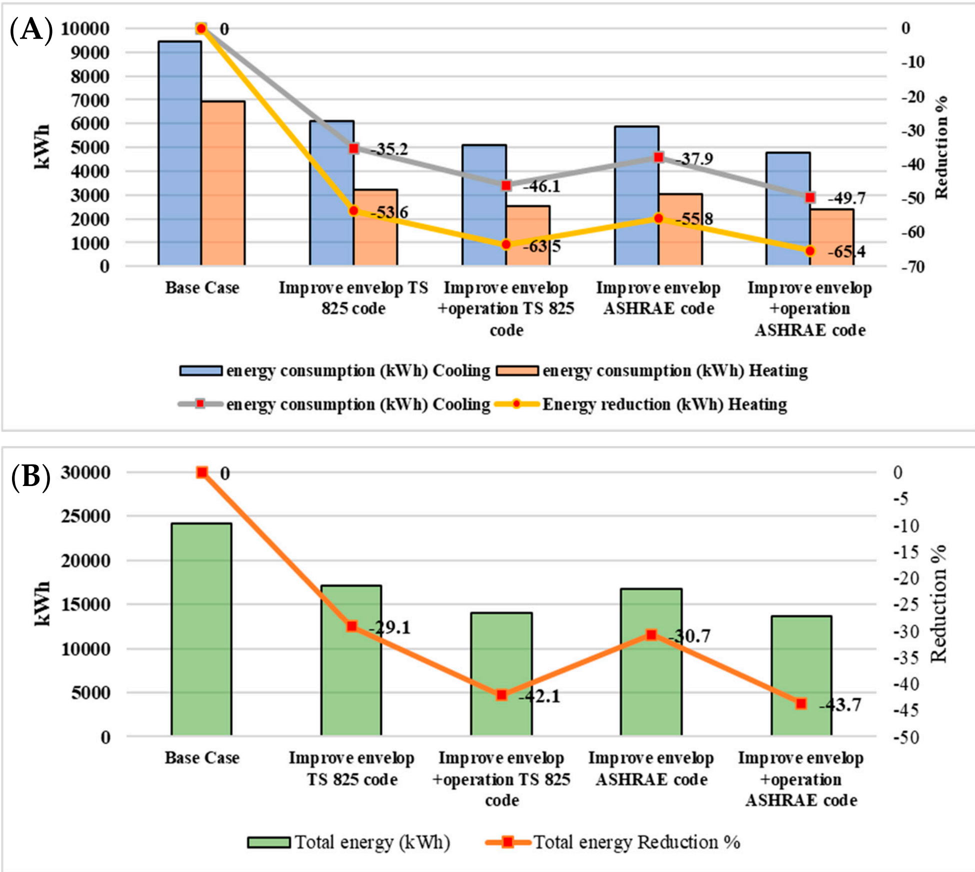


Figure 12. Energy-use reduction comparing base case and improved case in term of (**A**) heating and cooling and (**B**) total energy use.

4. Sustainable Model for Housing Requirements by Considering Sociocultural Needs

According to the available literature, the workshop, and the results of the semi-structured interviews, it was unanimously acknowledged that privacy and gender segregation are the primary issues that should be considered during the design process. The interviewees emphasised that adopting contemporary designs is a crucial aspect to consider throughout the design process, and people like to imitate facades and plans from the media. Hence, contemporary architecture has emerged as the dominant trend in North Iraq, driven by the conviction that new architecture consistently outperforms previous constructions. Moreover, the main reason that led to the emergence of contemporary housing design is the small and limited residential plots due to the new urban planning and theories established by foreign specialists, which ignored the people's behaviour and social relations because of new policies and concepts (international or post-modernist styles) in planning and architectural levels.

4.1. Contemporary Housing Development and Its Impact on Sociocultural Values of Occupants

It was noted through direct observation that nearly all homes in North Iraq had large openings in the main entrance façade, which did not grant any privacy to the occupants and caused overheating in the summer and underheating in the winter, as well as the poor location of the windows and the height difference between the houses, which caused neighbours' windows to invade privacy. In contrast, the interior windows are small. This results in occupants being unsatisfied with the lighting and ventilation provided to the rooms because they are directed to the lighting shaft. Generally, the lighting shaft width and length are 80–100 cm and 100–140 cm, respectively (Figure 13). The fence walls are short or transparent, exposing the ground floor windows outward and denying residents any sense of privacy because individuals on the street can see them. The inner entrance for the guest room and kitchen faces the main entrance, meaning that if both entrances are open simultaneously, this will provide a direct view from outside (public street) into the heart of the home, which impacts the occupants' privacy. Based on the questionnaire, most participants do not utilise the open roof space, balcony, and garden for social interaction because they want to maintain privacy, which cannot occur with the neighbour overlooking.

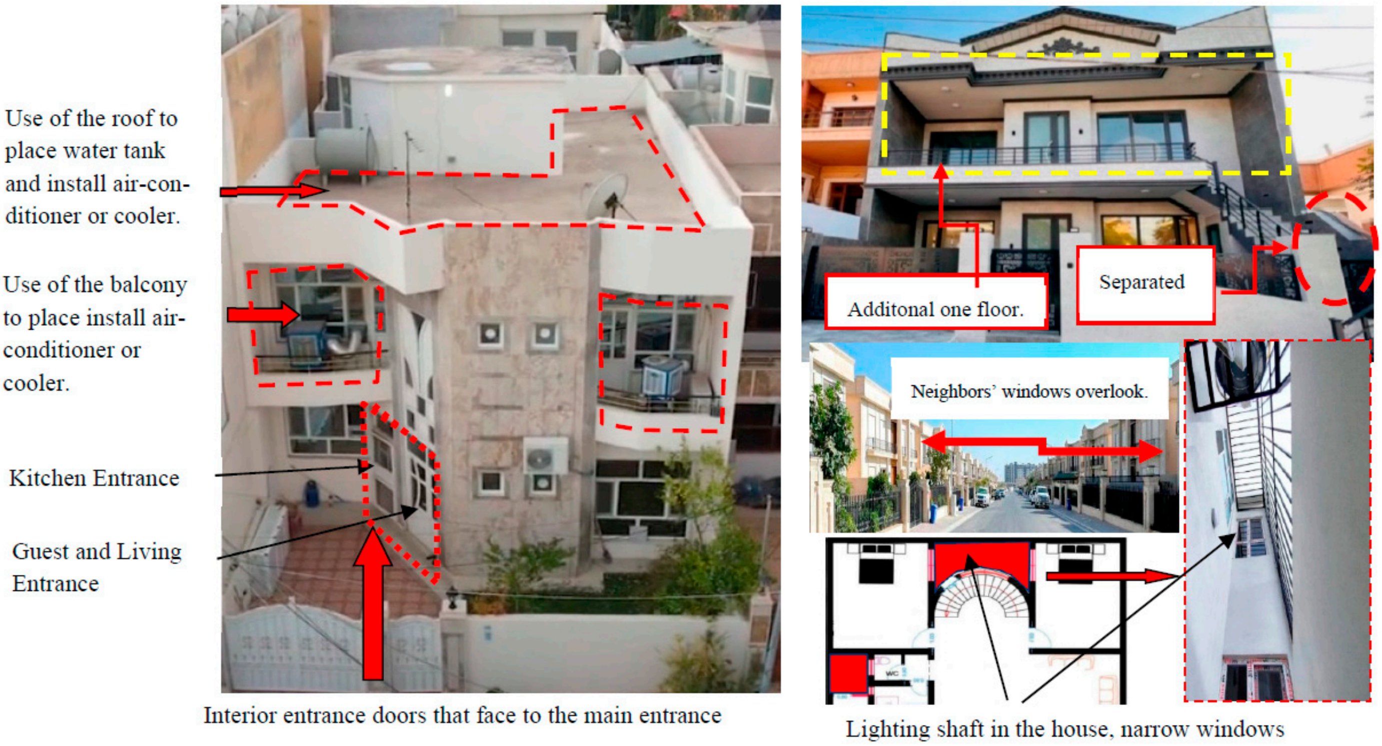


Figure 13. Contemporary architectural design characteristics of single-family house in Erbil.

4.2. Developing a Sustainable Model for Future Housing Development Considering Sociocultural Needs

Contemporary housing development made crucial changes in social interactions and house layout, mainly in terms of functionality. For example, replacing the courtyard with an outdoor garden (the living room became the main space for activity), rooms outward looking to the garden, an indoor balcony with an outdoor balcony, and a roof without a terrace. People need more space because they want their children to continue living with them at home even after marriage. This has led to the construction of dwellings with inappropriate features not only for the location's climatic conditions but also for the sociocultural needs of the natives.

Creating a sustainable model can be broken down into three steps (Figure 14): collecting and analysing data, developing energy-efficient building designs that consider social and cultural factors, and testing the design by making a prototype model. The suggested sustainable model consists of successive stages that are anticipated to result in the development of energy-efficient dwellings that are well-suited for semi-arid climatic regions. Architects may initiate the design process by gathering data on the specific geographical area in which the dwelling is going to be built and having an in-depth understanding of the location. These activities include gathering data about sociocultural norms, local environmental factors, case studies of pre-existing residences, and building laws. If there is a need to modify the study context, adhering to the stages while making appropriate alterations to align with the objectives is advisable. The second stage pertains to the specifications of energy-efficient buildings, encompassing aspects such as building design and layout and the materials and construction methods employed in the building process. The third step demonstrates the prototype of the building design that aligns with the sociocultural requirements within the study environment.

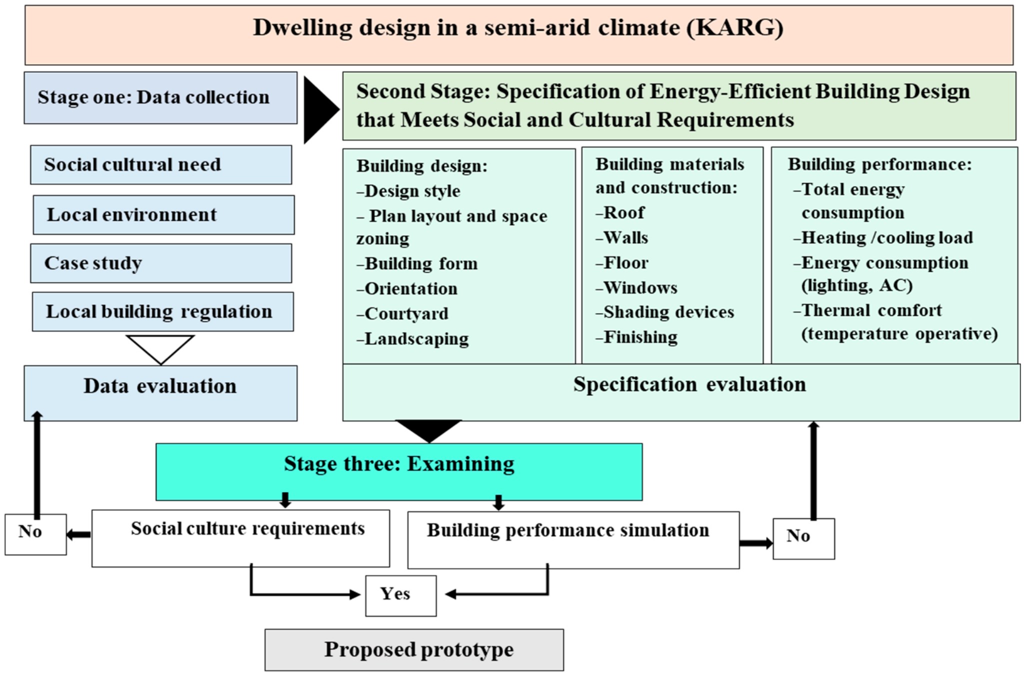


Figure 14. Sustainable model based on housing requirements and considering sociocultural needs.

Based on the household questionnaire, field survey (observational and on-site measurement), research, and workshop interviews, the following guidelines should be followed to build an energy-efficient house that satisfies sociocultural criteria in semi-arid climates:

Building layout: the most favourable orientation is 130–220° [13,52,54]. The form ratio of width–depth in a house layout should not exceed 1.7 for optimal cross ventilation and natural lighting while considering flexibility as it is conventional for a male adult to stay with his parents after marriage. Therefore, future extensions to the house layout should be considered. The local population favours open-plan designs, which can improve airflow (ventilation) and natural light, but it may put more strain on mechanical ventilation systems during the warmer months. Therefore, architects should consider incorporating movable space partitions. Most homeowners prefer two-story dwellings.

Additionally, two-story houses are the best for private spaces. Semi-private and public rooms can be found on the ground floor, and entirely private spaces can be found on the first story. A typical floor plan includes the main entrance, guest room, one or two living rooms, one kitchen (a cold kitchen for light cooking and a hot kitchen for heavy cooking) with a food store, at least three bedrooms and one bathroom, at least two toilets, one for guests near the guest room and one for residents, and at least one garage or parking spot for vehicles. The outdoor area should possess visual elements that provide shelter, enabling unrestricted utilisation by the female inhabitants. The entry to the house must be designed in such a way that it does not allow direct exposure of the living room to the external environment.

Courtyard: according to the household questionnaire and specialists, having a courtyard is important, and using a side courtyard is more suitable due to limited plot area. It can provide various benefits to its residents, such as privacy and enhancing natural lighting and ventilation, as well as gathering family, especially in the summer, which leads to reduced energy use.

Vegetation: in North Iraq, using plants in residential spaces has become uncommon due to the occupants' preference for substituting any green areas with concrete porcelain or porcelain floors. This is due to expanding indoor space, and these locations require ongoing care. Excessive utilisation of hard surface flooring leads to a significant accumulation of heat in the outside environment, causing elevated air temperatures during the day and subsequent dissipation of heat during the night. Therefore, vegetation can provide shade, privacy, and reduce heat absorption and reflection on buildings.

Balcony: in the context of the study, the design of a residential balcony can be tailored to ensure privacy for the residents while also preventing external observers, such as pedestrians on the street, from having a direct line of sight into the balcony area. According to the household questionnaire, a significant proportion of households do not utilise their balconies, primarily due to privacy concerns. Therefore, boosting the functionality of balconies for leisure purposes can potentially lead to energy conservation by lowering the need for mechanical ventilation systems within internal spaces.

Roofs: commonly, dwellings are provided with flat roofs for many reasons. The main reason is the minimal precipitation, eliminating the need for specialised roof structures. Another factor is sociocultural choices, where roofs are prominent in traditional dwellings. Roofs are utilised for various activities, such as hosting meetings, sleeping, weddings, and other social events. Despite the decline in house roofs for social gatherings in contemporary society, the survey questionnaire indicated that a flat roof is not used due to privacy issues and the availability of a mechanical ventilation system. Despite this, a flat roof remains the most favoured option, which is mainly attributed to the possibility of expanding the house's floors in the future. The subsequent factors are the primary aspects that architects should adhere to when designing a roof. The insulation material's thickness significantly impacts its performance. According to the simulation, there is a positive correlation between the thickness of the insulation material and its energy performance.

- Materials with effective insulation and low U-values are considered the most suitable for mitigating solar radiation's impact in semi-arid climates. According to the findings, the suitable U-value is 0.45 W/m^2K by a total energy reduction of 9.6% (17% cooling, 10% heating), and the maximum recommended U-value is 0.26 W/m^2K by a total energy reduction10.9 (19.3% cooling, 11.9% heating). It can be determined that the appropriate U-value has been identified. No significant energy savings are associated with exceeding the recommended level of insulation.
- The incorporation of space within the roof design to accommodate renewable energy applications such as solar panels should be considered.
- It is advisable to utilize materials with light colours and reflecting finishes to mitigate surface heat accumulation. This method can reduce energy usage by up to 45% [81].
- Roof shading is strongly recommended as it can mitigate surface heat gain, reducing cooling demand. Additionally, installing a roof enclosure will afford a heightened level of privacy. This enhanced privacy may serve as an incentive for the occupants of the dwelling to engage in various activities on the roof, reminiscent of the cultural practices observed in traditional Kurdish residences.

Wall: it was noted that adherence to insulation in North Iraq dwellings is not mandatory, leading residents to avoid using such materials to minimise construction costs as supported by the survey. Furthermore, the researcher conducted a study to evaluate the effectiveness of implementing optimal wall suggestions recommended by ASHRAE and TS825. The study's findings indicate potential total energy savings of about 15% by international standards (29% heating, 17% cooling). Nevertheless, according to the literature, there are many options for improving the wall for an instant cavity wall, which has an excellent opportunity to reduce energy consumption. However, according to the architects interviewed, locals are unlikely to select cavity walls as an alternative as they would require them to reduce the room size, which would result in cost issues. Considering the following factors while designing and constructing a wall is essential:

- In semi-arid regions, using materials with high thermal mass to construct walls is advisable.

- Light-colored paint is advised for exterior walls to reflect solar radiation and minimise solar gains.
- In semi-arid regions, the recommended U-value for external walls is 0.7 W/m^2K and the maximum is 0.6 W/m^2K.
- Energy savings can be significantly increased by improving external wall insulation with a maximum U-value of 0.26 W/m^2K.
- Uninsulated walls for interior walls are advised since they are shielded from sunlight.
- Window (glazing type): in the context of the study, it is noticed that window type has the lowest effect on energy reduction, with a maximum reduction of 1.6%.
- According to Ahmed et al. [82], it is recommended that the window-to-wall ratio (WWR) should not surpass 20% in regions characterised by hot and semi-arid climates due to the higher temperature levels.
- Architects should incorporate high openings into their designs as they are an efficient way to let in natural light and discharge warm air while ensuring visual privacy.
- An appropriate inside shade for the windows should be installed, such as curtains with an external shade.
- Including "Mashrabiya" in-house architecture needs consideration due to its capacity to offer privacy, mitigate sun reflections, and facilitate natural ventilation.
- It is advisable to avoid placing windows on the first floor in a manner that immediately faces the exterior street and neighbouring building.
- It is advised that double glazing be used, with a maximum U-value of 2.4 W/m^2K and a gap filled with low-conductivity gases, to increase the homeowners' thermal comfort and acoustic privacy. However, due to the absence of factories that manufacture windows filled with gases, the production of double glass is carried out manually with just air.

4.3. Sustainable Prototype Model Based on Sociocultural Behaviour of Occupants' Behaviour

Design of the prototype was informed by various aspects, including the local climate, preferences of building occupants, land use policy, and other relevant considerations. The plot area is 240 m^2 while adhering to the construction restriction of no more than two stories. It is designed to be occupied by six members (two parents and four children) based on the average family in North Iraq. The floor plan of the proposed detached home is organised into distinct zones, including public, semi-private, and private sections. The public sections of the establishment include the main entrance, guest rooms designated for both males and females, and a guest room with a bathroom and stairway. The semi-private places within the context include the living room, kitchen, dining room, and bathrooms on the ground floor. Keeping one bedroom on the ground floor in the prototype layout was based on various reasons outlined in the case study.

Initially, including a ground floor bedroom provides increased adaptability for the dwelling regarding potential future extension, enabling the ground floor to function independently as a separate apartment unit. Furthermore, it is worth noting that, due to the parents' advanced age, they express their desire to avoid using stairs when reaching their bedroom. The first floor, designed as a private area, comprises two bathrooms and four bedrooms. The master bedroom has an ensuite facility, but the three bedrooms share the bathroom. The initial building features an inside balcony providing a vantage point overlooking the courtyard. The courtyard has been fully transformed with a pergola at the roof level, offering shade for both the inner balcony and the courtyard area.

The placement of trees in the outside garden was hypothesised to enhance the level of privacy for the occupants within the building and offer a source of shade. The courtyard area will function as a space for relaxation during the summer and as a designated play area for children, among other applications. Moreover, covering or shading the roof creates space for gathering during summer, and even allows for it to be used as a sleeping space. Because of this, people living in the house may alter their habits and start spending more time outside, which will decrease energy usage (Figure 15). The input data for the envelope includes the U-values for the roof, wall, and window: 0.45 (W/m^{2}K), 0.6 (W/m^{2}K), and 2.4 (W/m^{2}K), respectively. The schedule load for lighting, occupancy, and equipment use is modified according to the improved model, and enhanced privacy significantly changes occupants' lifestyles by enhancing family gatherings on rooftops, gardens, courtyards, and balconies (Figure 16). Figure 17 illustrates the main improvement in the prototype model by taking advantage of the vernacular architectural elements and modifying the current design.

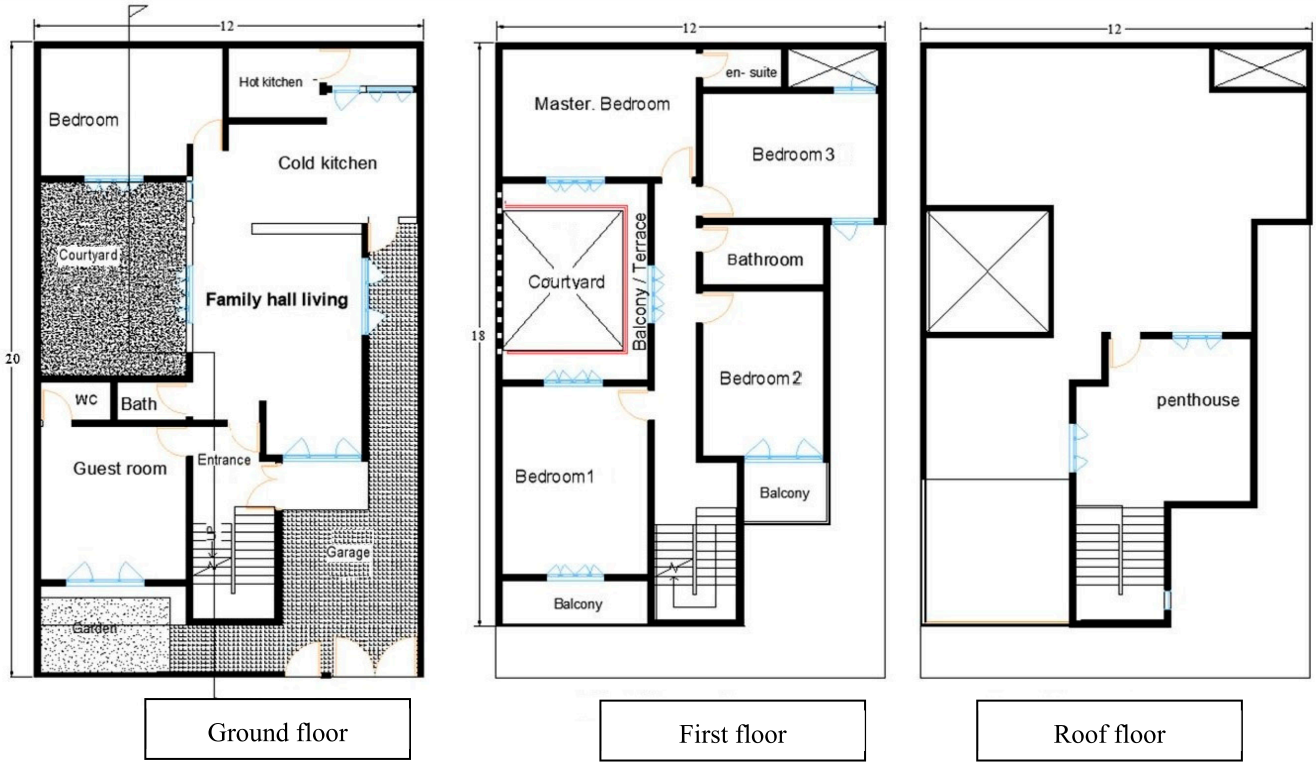


Figure 15. Proposed prototype plans and space distribution for simulation.

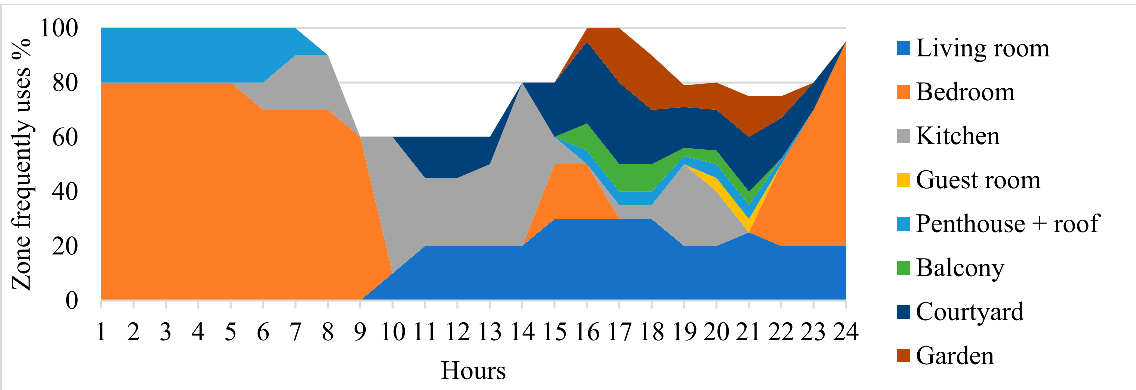


Figure 16. Spaces frequently used in prototype model.

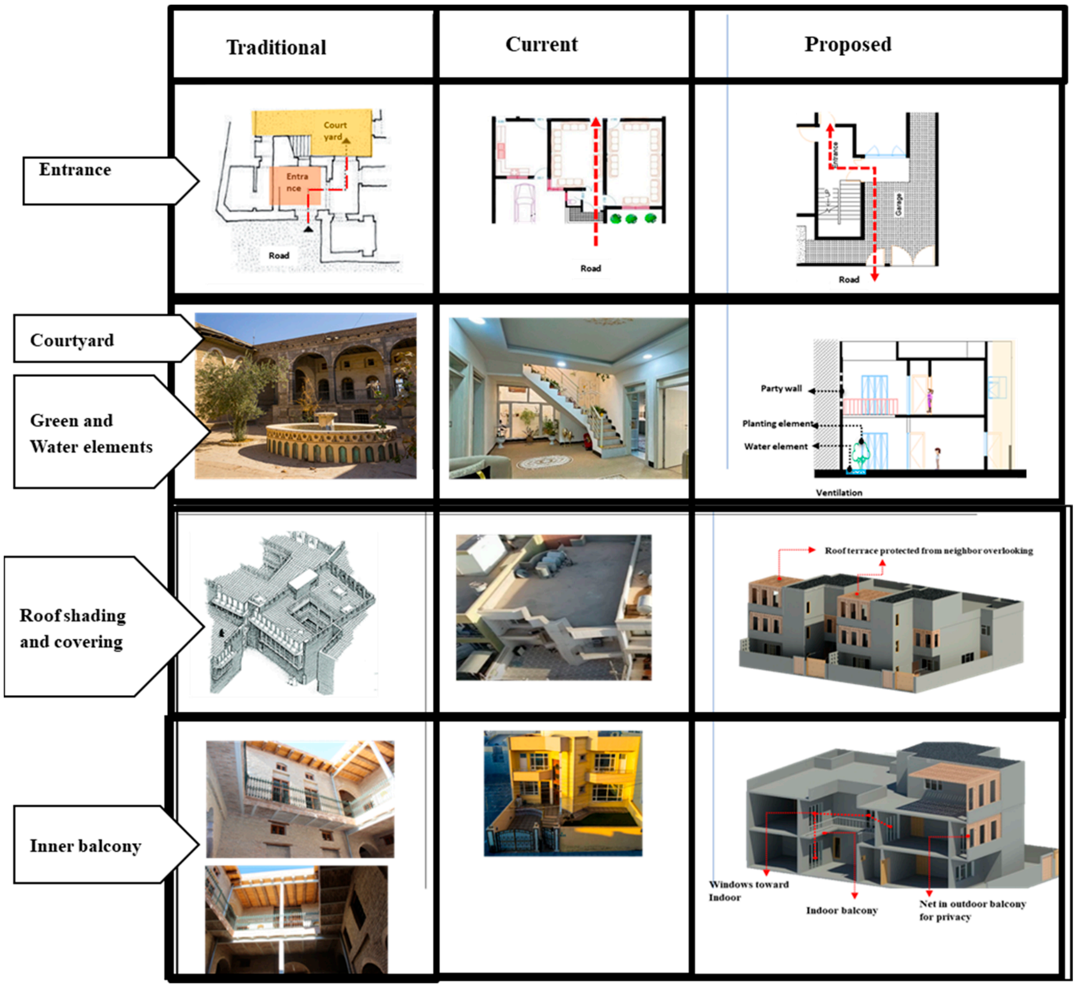


Figure 17. Proposed prototype model for simulation.

4.4. Energy Use and Temperature Performance of Sustainable Prototype Model in Comparison with Base Case, Improved Model, and International Standard

The base case, improved, and prototype models used only natural ventilation (no cooling and heating) to assess each model's performance concerning the annual operative temperature. The simulation's findings demonstrate that the base case model has the maximum operating temperature, followed by the improvised model. In contrast, the prototype had a lower operating temperature, specifically in the summer season when the average temperature in July and August was 31 °C, which was 4 °C lower than the base model (Figure 18). The improved case and prototype have similar average temperatures in the winter months, but the difference is more noticeable during the summer.

However, the split air conditioning system was used in the simulation, and the power and schedule load input were considered for each model to determine the annual energy use performance and the effect of the sociocultural occupant behaviour. The results indicate that the base case study has the highest energy demands, with a total energy consumption of 134 kWh/m^2/y. They were followed by an improved model with a reduction of 43% (76 kWh/m^2/y). Hence, the prototype model showed the lowest energy consumption of 68 kWh/m^2/y with a decrease of 50% (Figure 19). North Iraq is required to develop and update existing regulations and strategies to improve the application of low-energy buildings as the first step to sustainable building. Several European nations have established national benchmarks for low energy usage, taking into account each region's specific environment and demand. Therefore, this study compares the results of the energy patterns with those of some European international criteria for low energy usage [22–83]. The results show that the prototype and improved envelope with operation based on ASHRAE standards are in the European Commission benchmark range for low-energy buildings. They are near to several European national low-energy building standards. Furthermore, there is a favourable potential for adopting TS825 as a standard in residential building envelopes in North Iraq.

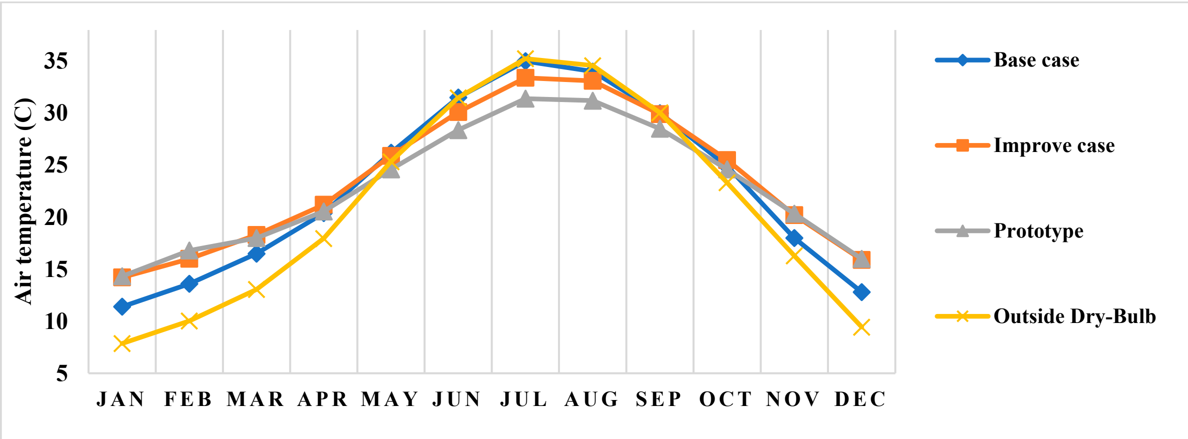


Figure 18. Monthly operating temperatures of prototype model compared to improved and base case model (employing only natural ventilation in simulation).

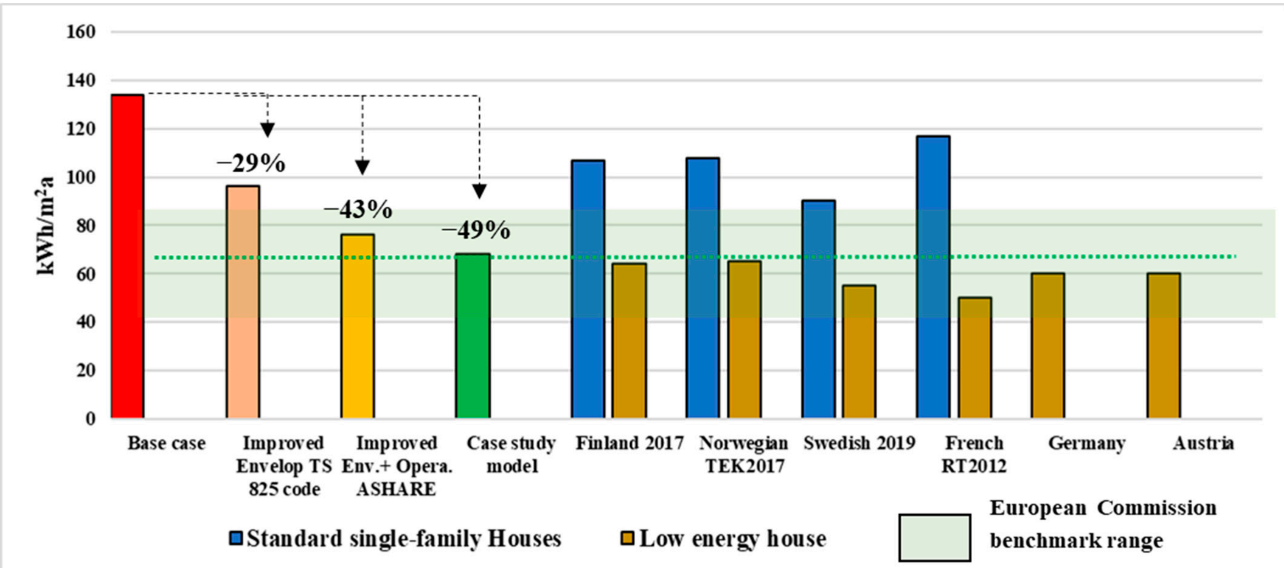


Figure 19. Annual total energy use comparison between prototype, improved, base case model, and international residential standard [22,83].

5. Conclusions

This study indicates that occupant behaviour and sociocultural needs significantly impact the annual energy consumption of residential dwellings. Occupant behaviour significantly influences energy usage through activity patterns and scheduling profiles of air conditioner thermostat settings, electrical equipment, and lights. An analysis of these parameters was undertaken by a survey of a sample of 30 dwellings in North Iraq. The findings were displayed in line and bar graphs for each hour of the day, designed to be used as input information in thermal simulation software as a substitute for the default ones. Based on the simulation results, the energy consumption of a dwelling in North Iraq increased by 42% when the standard (default) parameters were replaced with the local values. This significant outcome suggests that the data concerning the residents' way of life should be highly precise and reflective. Various habits will impact energy usage. Thus, consideration should be used when utilising default or other settings that are not typical of that local culture. Implementing energy-efficient improvements, considering occupant behaviour, and using international codes for building envelopes reduce total energy use by 43%.

The sustainable prototype model simulation shows a 49% decrease in energy consumption and an enhancement in interior thermal comfort (4 °C). Moreover, it fulfilled the sociocultural requirements and the thermal and daylighting performance quite well in the research context compared to the representative case study. Therefore, this will improve households' well-being, quality of life, and productivity.

Furthermore, the research recommends that house's architectural design should provide sufficient privacy to occupants by providing some design elements, such as the placement of trees in the garden, which aims to improve privacy and provide shade for occupants. The courtyard area serves as a summer relaxation and play area for children. The roof can be shaded for gathering and sleeping. This could lead to people spending more time outside, resulting in a more sustainable lifestyle by reducing energy usage and promoting healthier habits.

By examining the survey findings, a comprehensive understanding of the energy consumption patterns of the occupants in North Iraq was gained and evaluated simultaneously. The absence of code and lack of consideration for the current environment in building design are the primary causes of excessive energy use. Housing envelopes are commonly made of thermally inefficient construction materials without thermal insulation.

Similarly, occupant behaviour influences a dwelling's energy usage, particularly in relation to its utilisation of air conditioning equipment. Many people seemingly prefer to run these units constantly at the lowest temperature settings without considering the energy consumption. Another instance is the widespread utilisation of artificial illumination during daylight hours because of low electricity costs and private issues. Simulation tests demonstrated that aligning the light schedules with the occupancy patterns, specifically by turning off the lights when the rooms are unoccupied, is projected to result in a 25% decrease in lighting energy consumption. In addition, occupants spend most of their time in indoor spaces due to private issues and in the large family size (six persons), and the people tend to have more bedrooms for each gender in the residence and for the future when the son is married. This occasionally leads to a situation when a room is inhabited by only one person, resulting in a significant energy demand.

This work has demonstrated that employing a mixed-method approach, which involves analysing data from various building factors together with conducting user surveys, enables the identification of accurate occupancy profiles and their sociocultural behaviour as a sustainable model for future housing development in North Iraq.

Future work should consider diverse types of dwellings and climatic conditions to make a comprehensive study of the region and more detail about domestic hot water supply in terms of time period, temperature setting, power, and schedule load.

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