A Survey of Climate Responsive Design Strategies in Cambodian Residential Architecture

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Abstract. Energy conservation is a crucial concern for every household in Cambodia, as it plays a significant role in mitigating environmental issues. Residential architecture that combines a climate-responsive design has been attracting increasing attention due to its recognized energy-saving capabilities. This study aims to investigate the climate-responsive design features of single-family houses in two regions of Cambodia. The applied strategy involves a survey of the bioclimatic techniques from six houses in each region. These houses are qualitatively analyzed on the architectural styles, type of materials used, and 17 aspects of climate-responsive design strategies found in tropical climatic design. This study's findings reveal that comparable climatic conditions in both regions often lead to the application of similar design strategies. These strategies include high thermal mass, natural lighting techniques, natural ventilation, passive cooling through color, rainwater discharge, solar shading, and thermal insulation by material. These factors significantly contribute to sustainable living by reducing energy usage. This research finding emphasizes the fundamental proof of design strategies that had been integrated in Cambodian houses for low energy consumption. The findings of this study could potentially guide future architects in Cambodia to implement these strategies on a broader scale nationwide, resulting in more energy-efficient housing designs.

Keywords: Climate-responsive design, Cambodia residential architecture, Design Techniques, Energy saving.

1 Introduction

In 2021, residential housing in Cambodia consumed 35% of the total final energy sources for heating and cooling homes [1]. In the early 2020s, reducing energy consumption has become a crucial topic in the state of environmental pollution and energy shortage. In tropical climates like that of Cambodia, achieving optimal thermal comfort poses significant challenges due to high temperatures and humidity prevail throughout the year, which made the emergence of climate-responsive design in contemporary architecture gain widespread recognition for its efficiency in reducing artificial energy.

Many architectural buildings were fond of the design using climate-responsive strategy concepts, starting from the New Khmer architecture of the 1950s. Due to the

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internal war Lok Nol period (1975-1979), most of the buildings were destroyed and have undergone significant transformation, marked by efforts to rebuild, restore, and redefine the country's architectural identity amidst the devastation caused by the regime's policies. The reconstruction process has been influenced by cultural heritage preservation, urban development, tourism, and contemporary design trends. [2]. Those remaining buildings are very important for new wave architects to get inspired and identify the identity of Cambodian architecture. The study objective aims to: (a) explore the design features that have been integrated in Cambodian single-family houses across two regions in terms of architectural style, type of materials used, and design features that respond to the local climate; (b) analyze the most frequently employed techniques of climate-responsive design solutions in Cambodian residential architecture that help to respond to the local climatic condition.

2 Literature Review

Tropical climates create distinct environmental challenges due to high humidity, intense solar radiation, and heavy rainfall. Integrating climate-responsive design techniques seeks to harmonize built environments with local climatic conditions, minimizing energy consumption on mechanical systems for thermal comfort and artificial lighting [3].

2.1 Principles of Climate-Responsive Design in Tropical Climates

Key principles of climate-responsive design in tropical regions are building orientation, natural ventilation, shading, thermal insulation, and the use of appropriate building materials in the need to mitigate heat gain, maximize airflow, and maintain indoor thermal without relying on air-conditioning systems [4]. Building orientation helps regulate internal temperature by minimizing direct sun exposure, while shading devices such as overhangs and louvres reduce heat penetration into the building [5]. Design strategies such as cross ventilation and stack effect ventilation for passive cooling are commonly employed to harness prevailing winds and promote natural air exchange [6]. The integration of vegetation, water bodies, and shaded outdoor spaces can enhance the microclimate, contributing to cooler, more comfortable living environments [7].

2.2 Bioclimatic Design and Housing in The Tropics

Bioclimatic design emphasizes the relationship between a building and its surrounding environment, aiming to optimize energy efficiency by responding to the specific climate characteristics of a region [8]. In tropical housing, bioclimatic strategies often include roof design optimized for rainwater management and high ceilings for air circulation [9]. In countries with high humidity and frequent rainfall, roofing solutions such as steep slopes and wide overhangs are necessary to manage water runoff while also providing shade to ensure the buildings remain functional, comfortable, and energy-efficient [10]. The popular climatic strategies used in tropical buildings were categorized into 17 architectural solutions: building orientation and shape, solar shading, natural ventilation, natural lighting techniques, light weight construction, high thermal mass, evaporative cooling, earth cooling, passive cooling by using color, thermal insulation by material, thermal insulation by design, passive solar energy, storm prevention, flood prevention, rainwater discharge, moisture and condensation prevention, and others [11].

3 Research Methodology

3.1 Site and Setting: Phnom Penh and Siem Reap

Two different regions of Cambodia are chosen to examine climate-responsive design techniques in residential architecture due to the fact that they represent different socio-cultural and environmental contexts. The Phnom Penh region, located in the southern part of Cambodia, experiences a tropical wet and dry climate characterized by high temperatures, high humidity, and distinct wet and dry seasons with average temperatures ranging from 25°C to 35°C. Heavy rainfall during the monsoon season (May to October) and high humidity levels, especially during the rainy season. Siem Reap region, located in the northern part of Cambodia, shares similar climatic conditions with Phnom Penh but has slightly cooler average temperatures due to its inland location, though rainfall is often less intense than in Phnom Penh with the average temperature ranging from 24°C to 35°C [12].

The climatic similarities of the two regions, combined with their distinct architectural histories and current development pressures, make them important case studies. By examining both regions, this research can gain an understanding of how climate-responsive design strategies can be applied across Cambodia's diverse built environment, from its dense urban area to its culturally significant and rural landscape.

3.2 Unique Cultural and Architectural Characteristics

The unique cultural and architectural characteristics of Cambodia, particularly in areas like Phnom Penh and Siem Reap, have a significant impact on how climate-responsive design approaches are adopted. Although the two regions share the high temperatures, high humidity, and seasonal rains that characterize tropical climates, the cultural and historical architecture of each location includes distinctive components that react differently to these environmental characteristics.

Phnom Penh's Urban Characteristics. New Khmer architecture left an indelible mark on the evolution of architecture in Phnom Penh; the new architecture also responds to the high density of the city as well as its hot tropical climate. In this case, the urban dwellings often incorporate:

Natural ventilation and sunlight optimization without the use of artificial devices is made possible by large windows that encourage ventilation and reduce cooling requirements. These values are in harmony with the traditional ideas of open space and air transfer in crowded zones.

Solar shading by vertically protruding sunshades and horizontal roof overhangs reduces the heat gain by exclusion of direct sunlight to the indoors. These solar shading devices are very important for this type of building.

Construction materials with local resources such as ceramic and terracotta tiles. This type of tiles is of great importance to indoors since they are thermally resistants and are also representative of the art of tap and tile in Cambodia.

Siem Reap's Cultural Heritage and Vernacular style. In Siem Reap, there is an especially rich vernacular architectural tradition and proximity to historic sites such as the temple complex of Angkor Wat sees a greater degree of traditional materials and layouts that respond to culture and climate:

High thermal mass materials, often with thicker walls and natural stone or brick, which absorb heat during the day and release it at night, supporting passive cooling.

Steeply sloped roofs and large eaves, adapted from traditional Khmer housing, help manage rainfall and provide shade, key for both climate responsiveness and cultural aesthetics.

Courtyards and open spaces integrated into the design not only serve as cultural symbols of community but also promote natural ventilation and cooling.

Both Phnom Penh and Siem Reap benefit from bioclimatic design principles common to tropical areas but implemented in culturally resonant ways. These include:

Cross-ventilation and stack effect ventilation, facilitated by large windows and strategic building orientation, to promote passive cooling in both urban and rural settings.

Rainwater management through angled roofs and integrated drainage, ensuring homes remain functional and comfortable during heavy monsoon rains.

3.3 Scope and Limitation

Six single-family houses were selected from each region due to the capability of design features that could respond to the local climate condition. All of the twelve houses are in good condition in terms of style and size. The purpose of this selection is to understand the architectural design of each house, which includes the architectural style, type of materials used, and frequently used design features that are responsive to the local climate. Information of the physical features of houses was studied and recorded by photographing the residential houses from the outside, due to the limitations of accessing the interior of the residential units. The exterior of the residents helps us to understand the connection of the interior. Some of the selected houses will be analyzed based on the general observation of residential exteriors and detailed photographs inside the residential houses. Various researchers have used a similar approach to do architectural analysis. Chris King examines the structural and architectural elements of a group of preserved houses [13]. It is important to mention that it seems impossible to identify the exact date of when the houses were built and by whom. Conversely, House D will conduct a two-day survey to evaluate the operational costs and energy savings associated with the climate-responsive design strategies implemented in House D. On the first day, the manual controls for the air conditioner and artificial lighting are activated to function regularly in accordance with the owner's everyday activities. On the next day, the air conditioning system is completely deactivated for the whole day, and artificial lighting operates solely throughout the nighttime. The indoor thermometer is use during day 2 operation, to test out the indoor temperature and humidity as well.

4 Measurement, Analyze and Results

4.1 Selected Sides of the Survey

Fig. 1. Twelve selected houses from both regions of Cambodia.

The figure above illustrates the selected houses from two regions of Cambodia. Each region contains six houses, four of which are designed by private owners and two by Borey community housing. Since the current style of living for Cambodian residences is divided into two ways of living, the intention for choosing both ways of living is to explore every aspect of housing development in Cambodia. The Borey community housing's is typically mass-produced by developers; the building orientation does not always prioritize climate sensitivity. The selected houses from Borey community housing will be examined in the south-facing direction of each individual home. The purpose of all house selection is to find the climate-responsive design corresponding to all climate types in Cambodia. Architectural details of these selected houses are presented in (Fig. 1), and their specific data is listed in (Table 1).

Table 1. General information about the houses

Code	Location	Cli-mate region	Year cons	Architectural style	Function	Construc-tion method
House A	Phnom Penh	Central	1960s	Traditional urban style	Residential	Local constructor

House B	Phnom Penh	Central	1960s	Contemporary style	Residential	Local constructor
Phno	Phnom Penh	Central	1960s	Contemporary style	Residential	Local constructor
House D	Phnom Penh	Central	2000s	Contemporary style	Residential	Local constructor
House E	Phnom Penh	Central	2020s	Contemporary style	Residential	Urbanland Constructor
House F	Phnom Penh	Central	2020s	Contemporary style	Residential	Samraong village Con-structor
House G	Siem Reap	North	2010s	Traditional urban style	Residential	Local skilled worker
House H	Siem Reap	North	2020s	Contemporary style	Residential	Local constructor
House I	Siem Reap	North	2020s	Contemporary style	Residential	Local constructor
House J	Siem Reap	North	2020s	Contemporary style	Residential	Local constructor
House K	Siem Reap	North	2020s	Contemporary style	Residential	Bakong vil-lage Constructor
House L	Siem Reap	North	2020s	Contemporary style	Residential	Borey Tour-ism Constructor

4.2 Types of Material Used in the Investigated Houses

All houses are built with solid bricks and plaster on both sides, except House A, which utilizes wooden panels for the walls. 200mm thick wall in average for high thermal mass can significantly increase comfort and reduce energy use in their home. This works by absorbing heat during the day and, during the cold season, releasing it at night as the temperature lowers, resetting the cycle. In the warmer season, this works well since overnight temperatures drop enough to take the heat out of the walls [14]. All of the houses used concrete foundations, distributing the building's weight to the ground. The beam and column structures of all houses were constructed from concrete. Expect House G to combine with the wooden structure support for the roof overhang. The window openings of all houses are constructed from glass with metal frames; expect House A to utilize a wooden panel. The roof style is various, as shown in (Table 2). Among the material types mentioned in (Table 3), they were widely used in housing construction in Cambodia in the 20th century.

Table 2. Types of roof style used in the houses investigated

Phnom Penh re-gions	**House A**	**House B**	**House C**	**House D**	**House E**	**House F**
Architec-tural	Cross hipped:	Parabolic roof: fired	Clere-story/A	Double gable	Concrete flat roof	Concrete flat roof

style (roof)	fired clay tile	clay tile with insulation	Frame roof: fired clay tile with ceiling plywood	roof: fired clay tile with insulation	with roof coating	with roof coating
Floor	Wooden floor	Reinforced concrete with terracotta tiles	Reinforced concrete with cement tiles	Reinforced concrete with ceramic tiles	Reinforced concrete with matt ceramic tiles	Reinforced concrete with ceramic tiles
Siem Reap regions	**House G**	**House H**	**House I**	**House J**	**House K**	**House L**
Architectural style (roof)	Cross gable roof: fired clay tile with insulation	Concrete slab roof: green roof garden	Concrete slab roof with roof coating	Concrete slab roof with roof coating	Concrete slab roof with roof coating	Cross hipped roof: fired clay tiles
Floor	Reinforced concrete with hard wood floor	Reinforced concrete with terrazzo floor	Reinforced concrete with matt ceramic tiles	Reinforced concrete with matt ceramic tiles	Reinforced concrete with ceramic tiles	Reinforced concrete with matt ceramic tiles

Table 3. Most used material and their properties

Materials name	Advantages	Note
Wood	Renewable, low carbon emission due to locally availability, durable & resilient	Sensitive to fire
Terracotta tiles	Durability and strength, natural cooling tile, anti-slip, does not absorb moisture	Fire proof
Ceramic tiles	Durability, heat resistance, water resistance which have the ability to resist moisture	Fire proof
Fired clay roof tile	Resilient to rust, rot, decay and water damage	Fire proof
Roof coating	White colors reflect sun heating. Waterproofing can help seal cracks and holes that lead to leaks and extensive damage.	Maintain is require accordingly
Natural stone	Resistant to scratches, clips, stains, locally, availability, sound insulation	Only available in some region

4.3 Investigation of Climate-Responsive Design Strategies Integrated Into Each Selected House

Popular climatic strategies used in the built environment in tropical regions were categorized and numbered as 17 architectural solutions as follow: 1. building orientation and shape, 2. earth cooling, 3. evaporative cooling, 4. flood prevention, 5. high thermal mass, 6. lightweight construction, 7. moisture and condensation prevention, 8. natural lighting techniques, 9. natural ventilation, 10. passive cooling by using color, 11. passive solar energy, 12. rainwater discharge, 13. solar shading, 14. storm prevention, 15. thermal insulation by design, 16. thermal insulation by material, 17. other.

Table 4. Investigation of climate-responsive design strategies on each house

	Phnom Penh						Siem Reap					
	A	B	C	D	E	F	G	H	I	J	K	L
1	✓	✓	-	-	-	-	✓	✓	✓	✓	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	✓	✓	-	-	-	-
4	✓	-	-	-	-	-	-	-	-	-	-	-
5	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11	-	-	-	-	-	-	-	-	-	-	-	-
12	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
13	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
15	-	✓	✓	✓	-	-	✓	✓	-	✓	-	-
16	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
17	-	-	-	-	-	-	✓	-	-	-	-	-

(Table 4.) shows the survey of climate-responsive design solutions from 12 houses according to two regions. *Natural lighting techniques and* indoor lighting are fairly good for all houses due to the large glass window placement as shown in (Fig. 2). *Natural ventilation* for all residences had many window openings that allowed air to circulate in interior space, as shown in (Fig. 2). Additionally, houses H, I, and J incorporated the design of a little open courtyard adjacent to the dwelling as a pocket garden to facilitate air exchange in stack ventilation in order to enhance indoor air quality (Fig. 3). *Rainwater discharge*, as mentioned in (Table. 2). Each house had a various roof style with a degree-angled sloped roof, and the deep eaves helped drain away the rain to the roof. The gutter on the roof helped to discharge the rainwater directly to the sewage system. For *storm prevention*, all of the selected houses are built with a strong structure for the roof that is capable of withstanding the heavy storm.

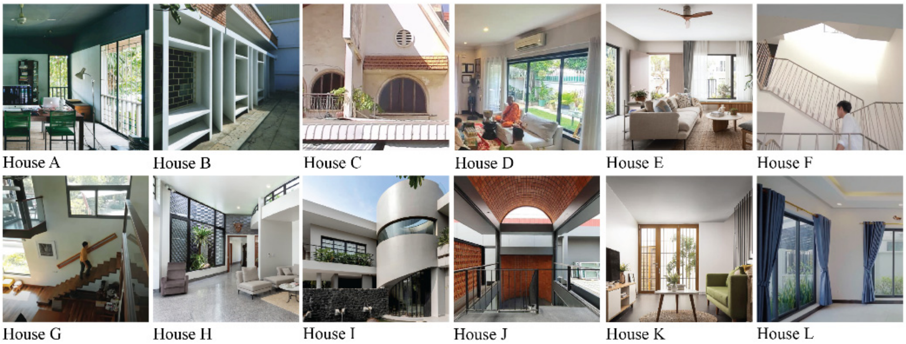

Fig. 2. Window placement for natural lighting and ventilation. Source: The gentry, UAD architects, Bakong village, A+U magazine.

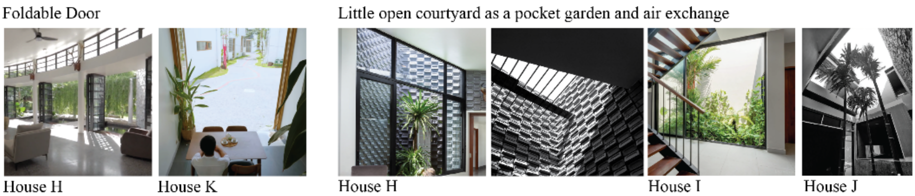

Fig. 3. Foldable door and little open courtyard for air exchange. Source: UAD architects

There are 4 design solutions with the exception of one house from each of the design solutions. *High thermal mass*, except for house A. All of the dwellings have a thick wall, average 200 mm, to help absorb heat during the daytime and release the stored heat at night, especially the double-layer brick wall (house B) on the first floor, which helps to promote air intake through the gap. *Passive cooling by using color*; except for House A, all of the dwellings mentioned above are all painted in white for interior and exterior to help to reflect the sunlight, which minimizes the heat gain inside the dwelling. *Thermal insulation by material*, expect for house A. Houses B use terracotta tile on the outer surface of the roof, which gives a temperature buffer in both hot and cold climates due to their insulation properties. Houses B, C, D, G, and L had roof insulation covered underneath the roof structure. Additionally, houses E, F, I, J, and K use roof coating paint to reflect the sunlight, helping to minimize heat absorption into the space. House H uses a special feature of a green roof for thermal insulation. *Solar shading*, except for House L, deep eaves presence for Houses A, B, C, D, and G, and the slab overhang for Houses E, F, H, I, J, and K approximately 1.2 to 1.5 meters offer effective shade to reduce direct sunlight. Special vertical shading devices are also found in Houses E and I. House J, also equipped with red brick, was placed in a unique pattern in order to provide shading from direct sunlight.

4.4 Energy Saving and Operation Costs

Two days field examination assessment on energy consumption at House D, conducted during the Khmer New Year visit on April 14-15, 2024 due to the facts that it is the hottest month of Cambodia. On April 14, the energy operation was conducted manually by activating electrical devices such as air conditioning and artificial lighting for daily activities. On April 15, all indoor energy operations, including air conditioning, were completely shut down for the whole day, with artificial lights functioning only at night. The results demonstrate a considerable difference between the 2 days of evaluation of the operational costs and energy savings associated with the climate-responsive design strategies implemented in House D. Only the air conditioner, fan, and artificial lighting are being examined in this experiment; the use of air purifiers, refrigerator, laptop and phone chargers is not being included.

In Toul Kork, Phnom Penh the electricity cost 800 riels (Cambodia currency) for kWh. According to the results, the operating costs for April 14th, 2024, are 65223.2 riles (16.3 USD), and April 15th, 2024, are 3985.6 riels (0.99 USD) (Table 5 & Table 6). The typical inside temperature, measured with an indoor thermometer, is between 24°C and 29°C with 50% to 60% humidity, which is a reasonably comfortable temperature for the tropical climate when the air conditioner is off all day and the stand fan is running.

Table 5. Light unit and energy consumption per hour

Floor	Function	Type of electric device	Unit	Energy use/kWh	Operation 14/04/24	Operation 15/04/24
G Floor	Living Room	LG Air conditioner 1.5 hp	01	1.492 kWh	5h	0
		LED Light bulbs (10W)	10	0.01 kWh	4h	3h
		Tube light bulbs18W 1.5m	01	0.018 kWh	0h	1h
		Stand fan 75W	01	0.075 kWh	0h	5h
	Dining Room	LG Air conditioner 1.5hp	01	1.492 kWh	2h	0h
		LED Light bulbs (10W)	09	0.07 kWh	2h	2h
		Stand fan 75W	01	0.075 kWh	2h	2h
	Guest Room	LG Air conditioner 1.5hp	01	1.492 kWh	9h	0h
		LED Light bulbs (10W)	10	0.07 kWh	4h	5h
		Tube light bulbs18W 1.5m	02	0.018 kWh	0h	1h
		Stand fan 75W	01	0.075 kWh	0h	10h
	Guest Bathroom	LED Light bulbs (10W)	02	0.07 kWh	1h	1h
	Kitchen	LG Air conditioner 1.5 hp	01	1.492 kWh	2h	0
		LED Light bulbs (10W)	09	0.01 kWh	2h	2h
		Tube light bulbs18W 1.5m	01	0.018 kWh	2h	2h
		Stand fan 75W	01	0.075 kWh	0h	2h
	Bathroom	LED Light bulbs (10W)	02	0.01 kWh	0.5h	0.5h
	Car Park	LED Light bulbs (10W)	04	0.01 kWh	11h	11h
1st Floor	Living Room	LG Air conditioner 1.5 hp	01	1.492 kWh	2h	0
		LED Light bulbs (10W)	04	0.01 kWh	2h	1h
		Stand fan 75W	01	0.075 kWh	0h	1h
	Master Bedroom	LG Air conditioner 1.5 hp	01	1.492 kWh	11h	0
		LED Light bulbs (10W)	08	0.01 kWh	5h	4h
		Stand fan 75W	01	0.075 kWh	0h	10h
		LED Light bulbs (10W)	03	0.01 kWh	1h	1h

	Master Bathroom	Tube light bulbs18W 1.5m	01	0.018 kWh	0h	0h
	Bedroom 01	LG Air conditioner 1.5 hp	01	1.492 kWh	11h	0
		LED Light bulbs (10W)	08	0.01 kWh	6h	7h
		Stand fan 75W	01	0.075 kWh	1h	13h
	Bathroom 01	LED Light bulbs (10W)	03	0.01 kWh	1h	1h
		Tube light bulbs18W 1.5m	01	0.018 kWh	0h	0h
	Bedroom 02	LG Air conditioner 1.5 hp	01	1.492 kWh	10h	0h
		LED Light bulbs (10W)	06	0.01 kWh	5h	6h
		Stand fan 75W	01	0.075 kWh	1h	12h
	Bathroom 02	LED Light bulbs (10W)	02	0.01 kWh	1h	1h
		Tube light bulbs18W 1.5m	01	0.018 kWh	0h	0h
	Study Room	LG Air conditioner 1.5 hp	01	1.492 kWh	2h	0h
		LED Light bulbs (10W)	06	0.01 kWh	2h	2h
		Stand fan 75W	01	0.075 kWh	0h	2h
	Ritual Room	LED Light bulbs (10W)	02	0.01 kWh	0h	0h
Other Func-tion	Staircase	LED Light bulbs (10W)	02	0.01 kWh	5h	5h
	Balcony	LED Light bulbs (10W)	04	0.01 kWh	11h	11h

Table 6. Cost estimation

Types of electric devices	**Total Opera-tion 14/04/24**	**Cost 14/04/24**	**Total Operation 15/04/24**	**Cost 15/04/24**
LG Air conditioner 1.5 hp	54h x 1.492= 80.568kWh	800 riels x 80.568 = 64454.4 riels	0h x 1.492= 0kWh	800 riels x 0= 0 riels
LED Light bulbs (10W)	63.5h x 0.01= 0.635kWh	800 riels x 0.635= 500 ri-els	63.5h x 0.01= 0.635 kWh	800 riels x 0.635= 508 riels
Tube light bulbs18W 1.5m	2h x 0.018kWh= 0.036 kWh	800 riels x 0.036= 28.8 riels	4h x 0.018= 0.072 kWh	800 riels x 0.072= 57.6 riels
Stand fan 75W	4h x 0.075 kWh= 0.3 kWh	800 riels x 0.3= 240 riels	57h x 0.075 kWh= 4.275 kWh	800 riels x 4.275= 3420 riels
Total		65223.2 riels ≃ **16.30 USD**		3985.6 ≃ **0.99 USD**

5 Result and Discussion

In order to withstand the climatic condition of Cambodia, choosing the type of material, type of roof style, and design solution that are responsive to the local climate are very important to each house to minimize energy consumption and enhance thermal comfort within the interior space of the dwelling. Types of material that are chosen, such as terracotta tiles and ceramic tiles, which help to cold down the indoor temperature due to it natural cooling properties of the material. The type of roof plays an important role in protecting against direct solar heat gain, providing rainwater shading, and withstanding wind and storms.

As mentioned in the site and setting above, both regions likely share similar climatic conditions, which resulted in climate-responsive design solutions being largely the same. The most frequently used design solutions are natural lighting techniques, natural ventilation, rainwater discharge, and storm prevention, which are occupied in all investigated houses in both regions. Then, high thermal mass, passive cooling by using color, and thermal insulation by material were occupied in all houses except House A, which was constructed with wooden panels. Additionally, solar shading was occupied in all houses except House L, which didn't have any proposed installation of shading around the house façade.

New housing developments in Cambodia can be considered through the lens of climate-oriented design as a number of the issues of sustainability arise. One of the major constraints are the financial resources, because elements that would enable passive cooling and thermal insulation such as terracotta tiles and fin style devices tend to be costly and may discourage application in low cost constructions. In addition, there is quite often a market demand for designs that are heavily Western influenced and often do not incorporate climatic features so it does not become easy to incorporate these features such as open courtyards or extended roof eaves for natural ventilation and shading. Further, the ability and knowledge of originators and authors of dominant buildings i.e. developers and architects in climate sensitive construction is low surpassing such factors as a presence of corresponding official legal mechanisms to motivate Green building methods, which would normally favour widespread use. Most of Cambodian cities including Phnom Penh are characterized by a rapid urbanization and spatial imbalance and makes it difficult to visualize how these strategies can be effectively pursued as high density dwelling units often seek to be space efficient and ignore environmental principles thereby making the inclusion of climate responsive practices difficult. Lastly, the presence of the unpredictable effects of climate change in the tropical climate of the country of Cambodia is yet another challenge so there is need to optimally design.

6 Conclusion

Overall, single family houses in Cambodia, designed with climate responsiveness in mind, has effectively adjusted to various climatic conditions through the application of low energy consumption. Strategies such as natural ventilation, natural lighting, rainwater discharge, storm prevention, high thermal mass, passive cooling by using color, thermal insulation by material and solar shading are frequently utilized while methods like earth cooling, moisture and condensation prevention are found to be less suitable.

In conclusion, this study highlights the significance of environmental on residential design in creating sustainable living that minimize the consumption of natural resources. The presence of climate-responsive housing in Cambodia serves as tangible proof of humanity's potential to coexist harmoniously with the environment, affirming the imperative to safeguard and the further integrate such design strategies into architectural practices.

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