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Case Study: Low Energy building in developing country

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Abstract: *Low energy building is a challenge for the developing countries. Due to lack of knowledge of the professionals about the low energy building is a barrier to construct low energy buildings. So to make understand the difference between a conventional building and converted low energy building in this study taken a model and applied different changes. On the same building and by simulation extracting the result so that the professionals and as well as the developer, contractor to understand the difference.*

Keyword: *low energy building, sustainable development, construction management, site management, energy evaluation, case study*

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I. Introduction

This is a case study based on a real conventional project. For the study the design is modified to make it as low energy building. So both the design is modeled in BIM application to check the different results and aspect to clarify the benefits to have a low energy building in developing countries and countries like Bangladesh which is situated in hot humid climate.

1.1 Case Study building overview

The case study site is on Baridhara. In detail it is beside new Apollo Road, it offers connectivity with Baridhara, Gulshan, banana and Uttara Residential zone. It is near to one of the largest shopping mall in South Asia, Jamuna City.

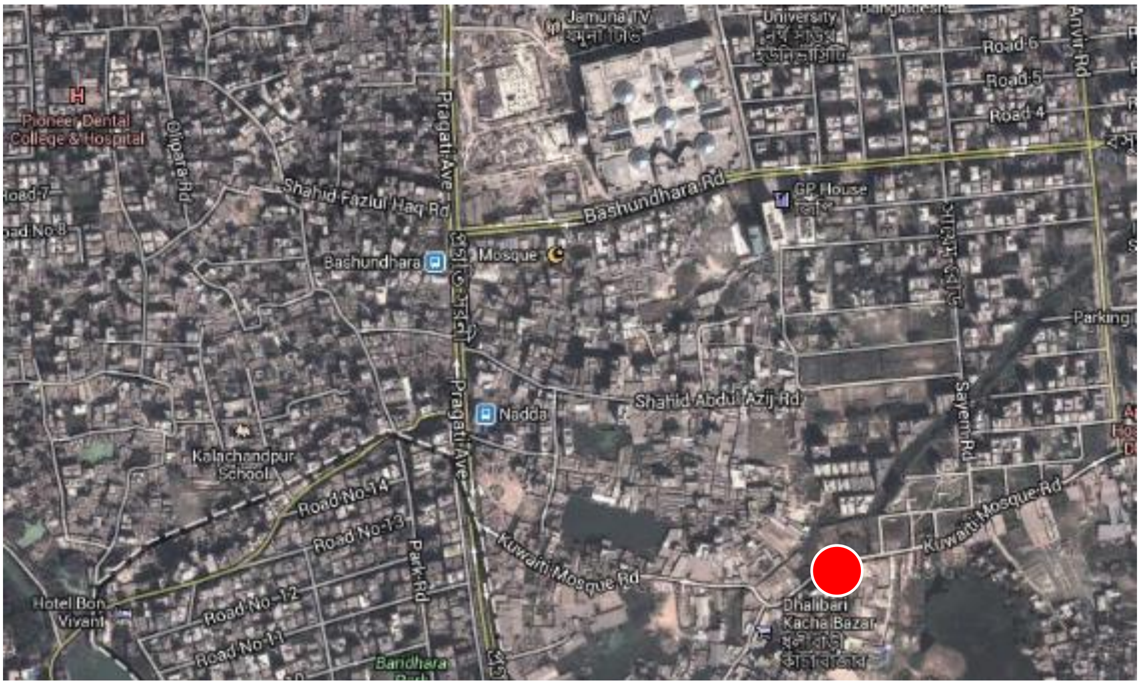


Figure 1: Site location of case study building, Source: Google map

The case study building is a typical nine storied real estate residential apartment building with four units on each floor. Total thirty six apartments are in the design. The multi storied residential apartment building is very common and popular in Dhaka city. This is because of the extreme pressure on city land and the dynamic chance of urban lifestyle and behaviour. Because of the increased pressure on land, most of the single storied building or a duplex is being demolished and these multi storied residential apartment building took place on that site. The process of the real estate developer is the owner of the particular land goes into a deal for the land value of the particular plot. As in the return of the land value developer offers the land owner 50-60% of the flat of the building. If that is not equivalent to the land price than the real estate developer give the land owner cash money to balance the price. And the rest 50% flat real estate developer keep for the company. The company sells the flats and takes back their investment. For the reason of profit both parties want to facilitate more functions and facilities to confirm the flats are attractive for the client. So that both parties can sell the apartment is a good price.

In this particular design there are 4 different types of units. Type: A, Type: B, Type: C and Type: D; the size of the apartment A is 1820 sft (170 sqm), B is 1590 sft (148 sqm), C is 1875 sft (175 sqm) and D is 1850 sft (172 sqm). Type A and B front side faces to the North side road, Type D faces both North side and East side road and Type D longer façade faces on East side. In openness context type C is in the best location as it is in a corner.

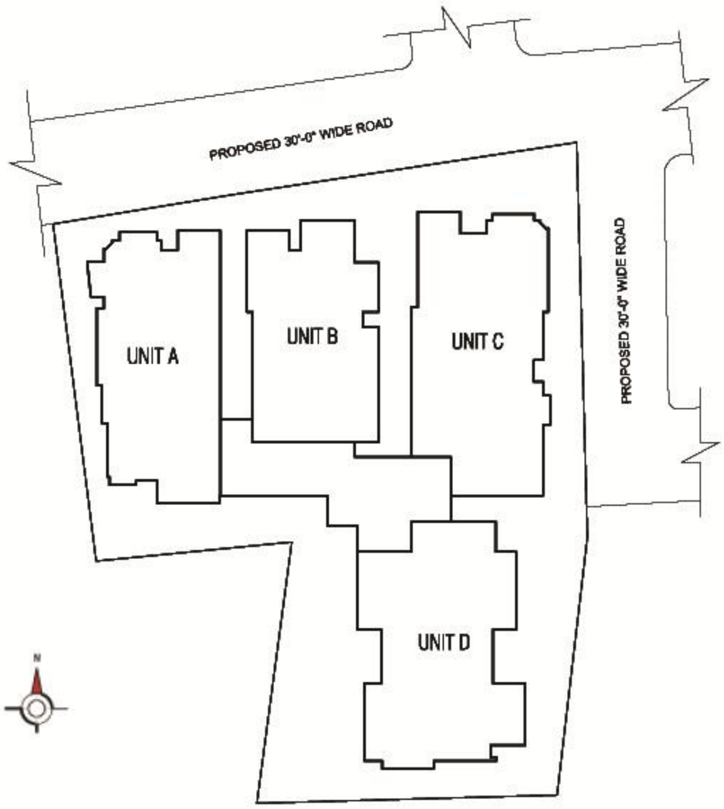


Figure 2: Unit plan of the case study building, (BrainTrain, 2013)

1.2 Present feature and proposal for low energy building

1.2.1 Planning aspects

1.2.1.1 Site analysis

As the building is situated in Dhaka, and Dhaka is densely populated so most of the building has only one side open and that is road side. But for the particular case study the plot is a corner plot so the buildings have two one side and the other two sides is surrounded by 2 buildings. In this particular case study the Type C is facing north and east side road. Both of the roads are 30 feet (10m) wide (as a proposal). One road is a highway, so there is huge traffic all the time. In west side and south side is surrounded by residential multi-storied building. As west is partly shaded by a building so in the design of shading in the particular study is not that much important. But the south side is blocked; this is a negative issue for this site. The gap between the west and south side building and case study proposed building is 10 feet (3m). The negative issue that usually faced here the chance is less because the gap is 10 feet (3m) this is a good gap for air ventilation and privacy.

Figure 3: 30 feet (10m) wide road in North and East side, (BrainTrain, 2013)

1.2.1.2 Building form

It is a compact form. Except the Type D unit other 3 units organized very compactly. According to Gut the building form should be spread out for warm humid climate(Gut & Ackerknecht, 1993). Givoni stated that compact shape is good when the building is considered as air conditioned(Givoni, 1998). Real estate developer and the land owner make a decision that the building will be air conditioned. . By interviewing both of them the observation is both of them want an air conditioning space that is why they asked architect to make the block compact. And in developer’s point of view they want to utilize the maximum space that is why they want compact planning.

1.2.1.3 Orientation of the building

The façade on north and east is bigger. Both of the façade are oriented to the road as well. As the site is an irregular shape so it is very difficult to identify which site is getting maximum priority. Designing in an irregular shape site is also very challenging. Gut and Wong recommended for the tropical climate is, the east west side should be less to avoid the solar radiation(Gut & Ackerknecht, 1993)(Wong & Li, 2007).

In the design the orientation doesn't consider for solar radiation. It follows the site outline and to utilize the maximum useable and salable are selling. The design is all about to utilize every square millimetre. But here the architects are using a proper sunshade on the east side. The research found that most of the buildings of Dhaka city have the same consideration when designing the building. So the findings are in the future as well the building is going to be designed like that. Only the basis of site outline and maximum saleable area the real estate developer will ask the architects to design.

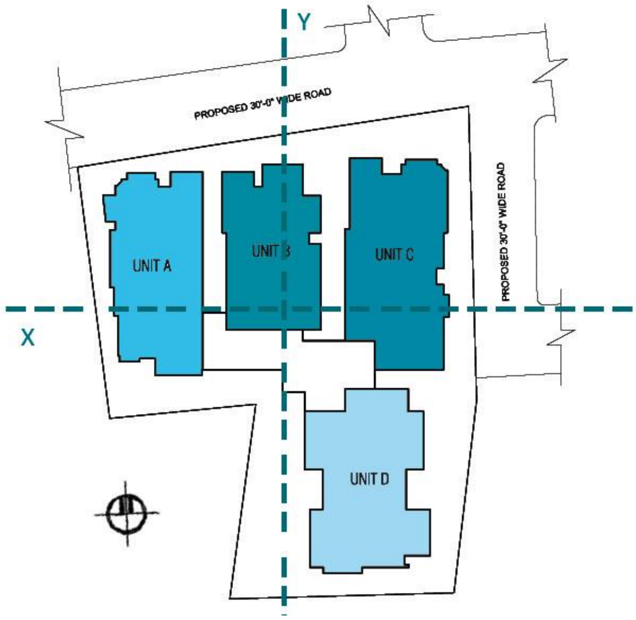


Figure 4: Typical floor plan for showing the orientation, (BrainTrain, 2013).

1.2.1.4 Arrangement of the room

Gut in his journal said the room arrangement depends on the functions. It depends on the user functions according to the usage pattern in different time of day. (Gut & Ackerknecht, 1993) In this thesis case study it is done on a new project, so there are no occupants to interview. The architects design the apartment on the experience of the general use pattern of different functions what is general in Dhaka city. Because in real estate development they have to design on the generalized usage pattern. When they are designing the building then there was no occupant to interview. After finishing the design they go for advertisement to sell the apartment. So this is difficult for any developer to have a specific use pattern of the apartment. In this building there are thirty six apartments and nobody knows is going to buy it and what would be his occupation or number of family members. The main focus of designing this apartment is target group. In this apartment the target group is higher middle class people. And small family because the entire apartment have only two bedrooms, one is for the household owner and second bed is for the kids. There is another bed for the guest. So by the size of the apartment and the client is choosing the apartment to buy.

General use pattern of an apartment in Dhaka city: there is a culture to have housekeepers in the apartment to serve the owner of that apartment. All the household work is done by the housekeeper like cooking, washing, maintaining. Dining space is the best place to supervise all these types of works, from dining space the visibility and accessibility is easy. In higher middle income group dining space is the most favourable or desired space because most of the family member meets hare, chats over here with each other. So this is the most functional space of the apartment. The master bedroom is the second most used room and in third position is the living room. These rooms are used very frequently. In Dhaka's culture most of the apartment places their television in the living room, so the room is being occupied by the occupants for entertainment. Watching television is the common entertainment among all classes of people in Bangladesh because of lack of public place for recreation. So when the occupant came home from the office or school they watch the television for relaxation.

Below the different types of apartment and its room layout is shown.

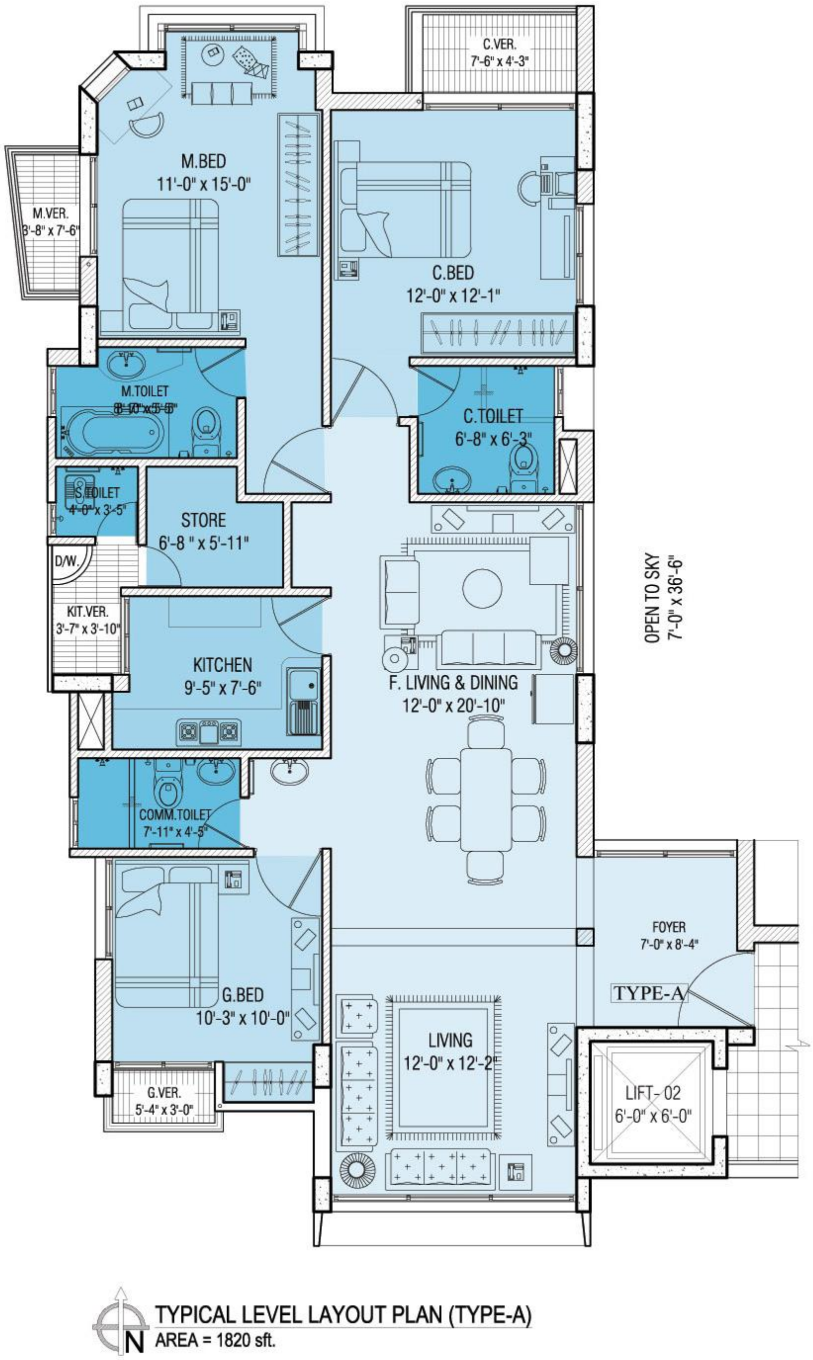


Figure 5: Typical floor plan (Type: A), 1820 sft (170 sqm),(BrainTrain, 2013).

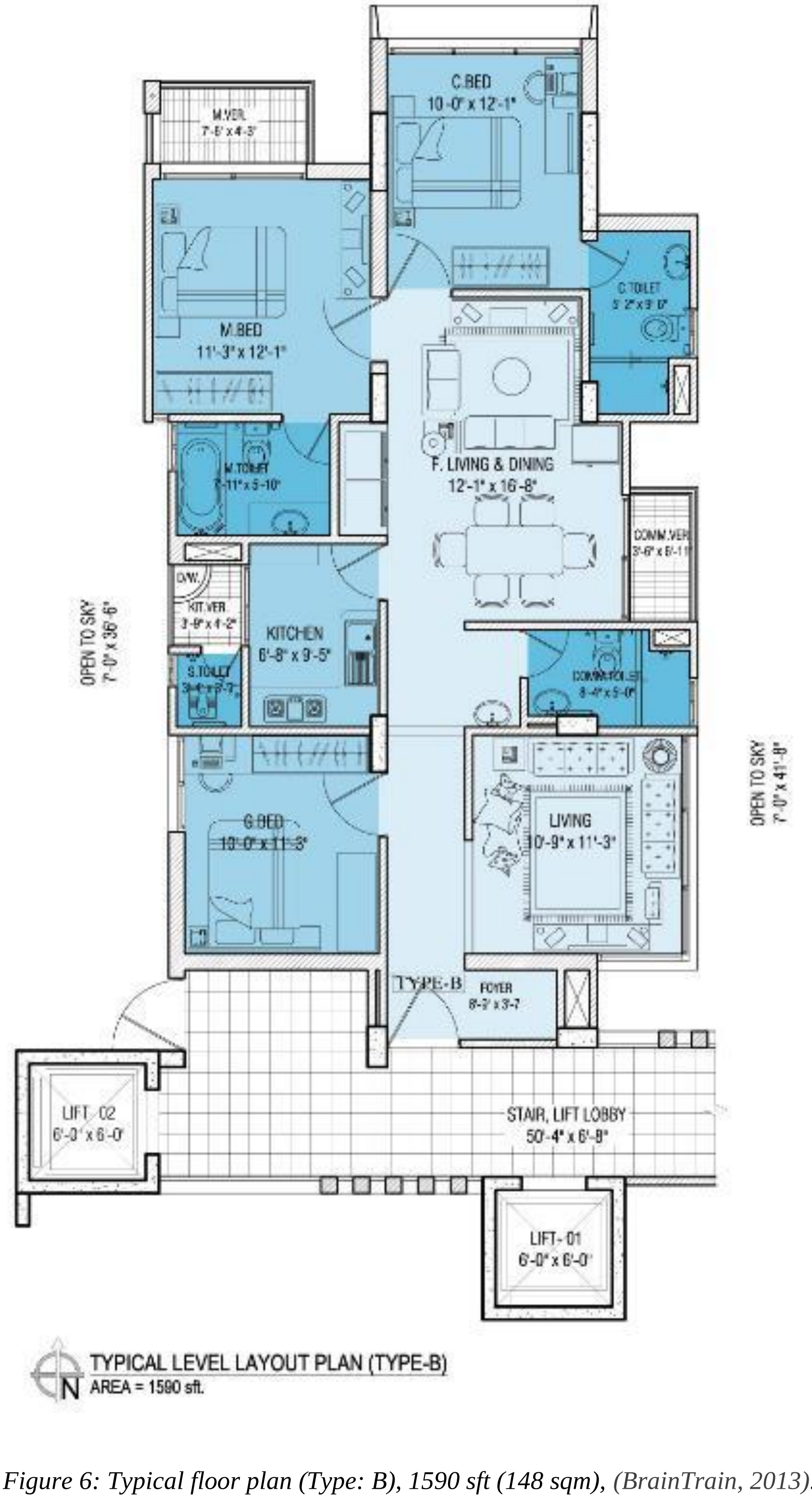


Figure 6: Typical floor plan (Type: B), 1590 sft (148 sqm), (BrainTrain, 2013).

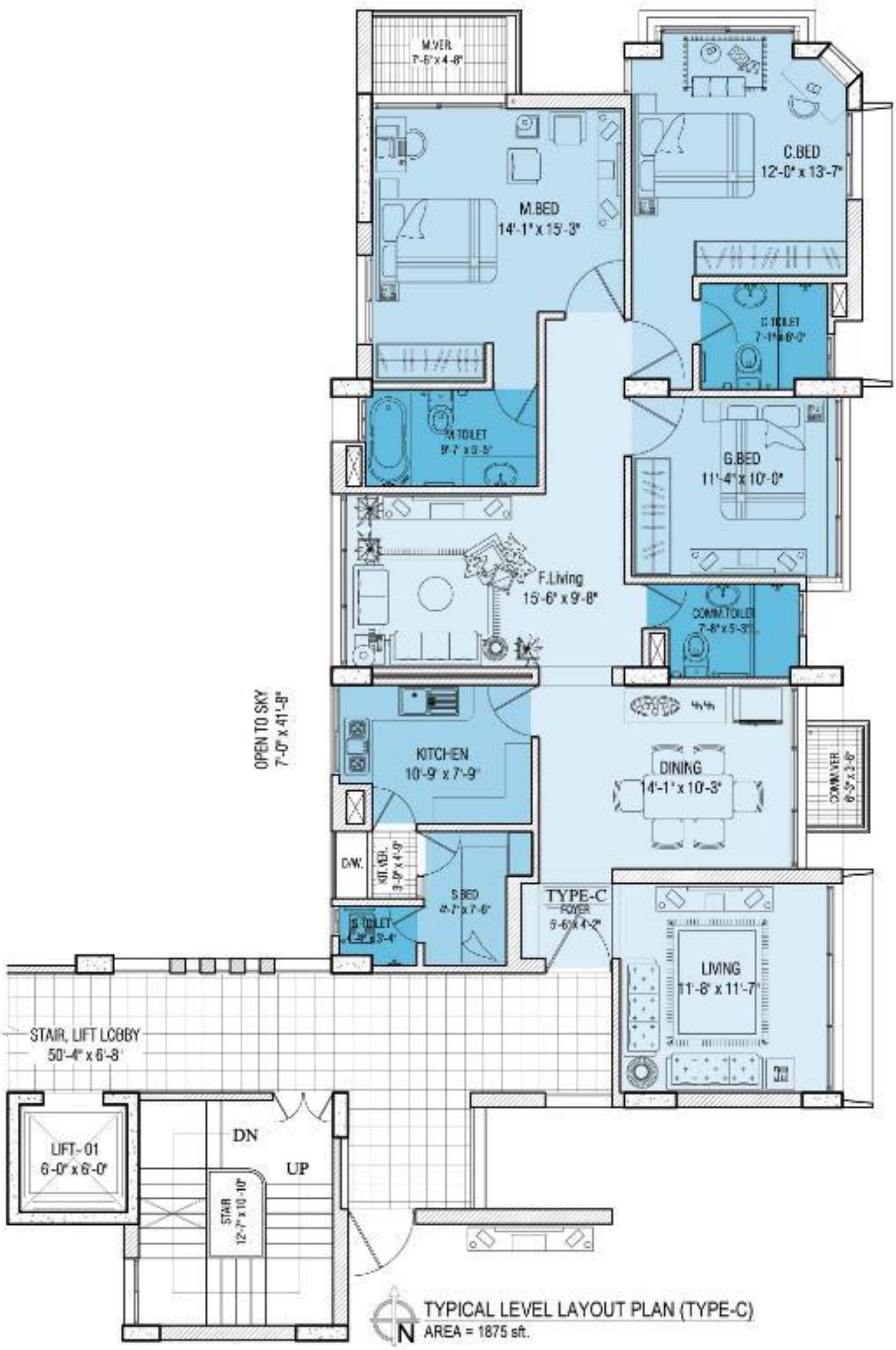


Figure 7: Typical floor plan (Type: C), 1875 sft (175 sqm), (BrainTrain, 2013).

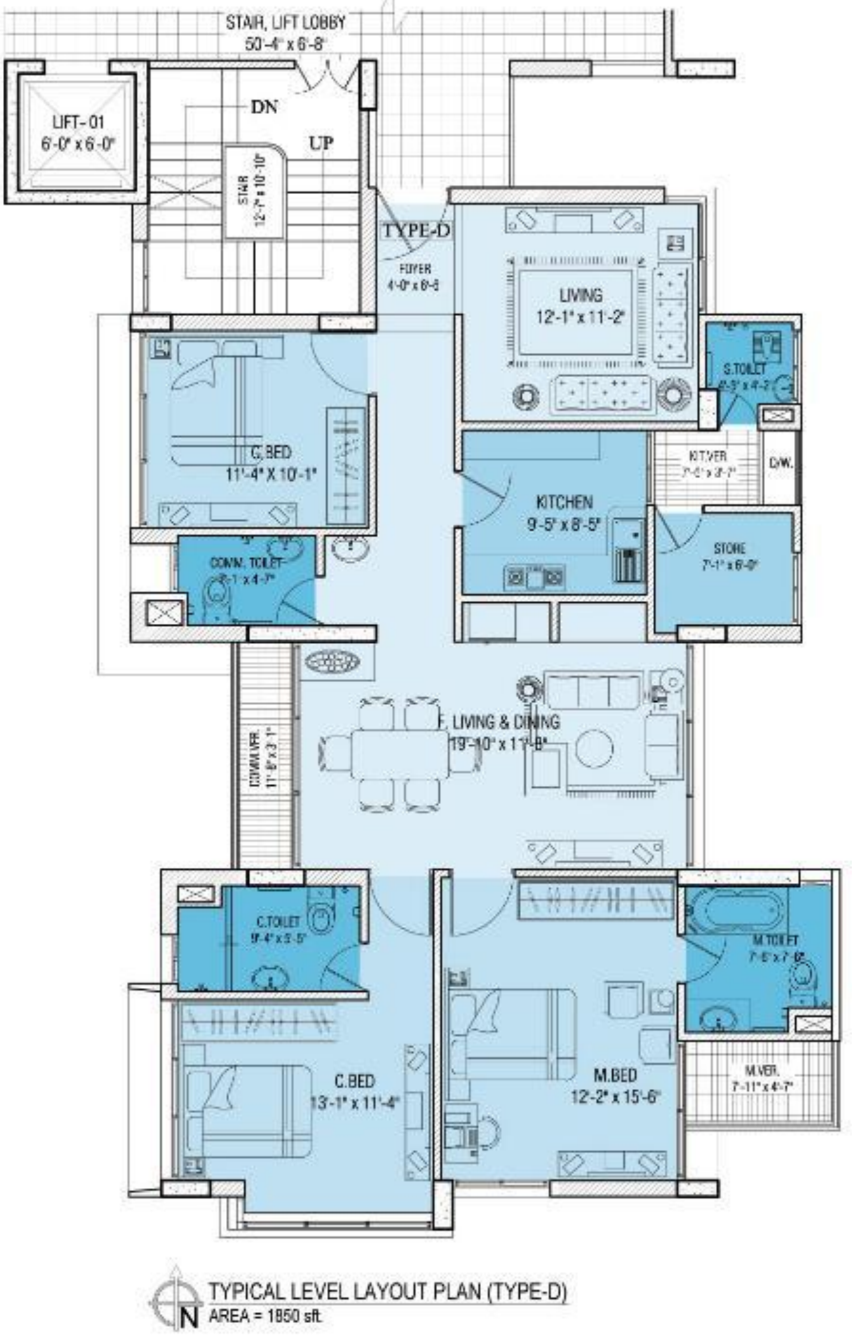


Figure 8: Typical floor plan (Type: D), 1850 sft (172 sqm), (BrainTrain, 2013).

In room arrangement the other important issue to be taken care they are separate important spaces or rooms with internal heat generated rooms such as kitchens. The heat generated from the kitchen is transmitted to the bedrooms or living room. So if the kitchen is not designed and position correctly then the other space like a bedroom, living room internal temperature go higher. This is not good for the indoor air climate. The occupant will feel discomfort. And to avoid this discomfort they will use the air conditioner and the energy consumption load would be high. As in the thesis study look forward for the external heat it is also considered here to work about the internal heat gain.

1.2.1.5 Orientation of rooms

In this section we will look forward the individual room position and orientation. In the theses case study project there are four types of units. In the below chart the main functions are listed with the orientation.

	Master Bed	Bedroom 2	Bedroom 3	Living	Dining	Kitchen
Type A	North-West	North-East	South-West	South	East	West
Type B	North-West	North-East	West	East	East	West
Type C	North-West	North-East	East	East	East	West
Type D	South-East	South-West	West	East	West	East

Table 1: Orientation of rooms in different types of apartments, (BrainTrain, 2013).

Apartment Type: A

In this flat most of the room's orientation is good if considered in the previous study. The master bedroom is located in North West direction. In the west the opening is covered with a verandah. The verandah has a roof on top, so it will work as the shading device, and for the depth of the verandah, the heat transmission will be low because of the depth of the verandah. Second bed is in North East direction. The east side is not totally exposed, this is partly shaded by the building another block. Third bedroom is south oriented and opening on the west side as well. The opening has the proper shading device. That part is also partly shaded by another building. In this apartment three bedrooms have cross ventilation. Living room is on the south side, so good orientation. The dining and family living is attached and in east oriented which is partly shaded by the side block of the building. The kitchen is on the west side and also segregated with the main functions by toilet and store room but attached to the dining room. This is a common design policy for residential apartments in Dhaka.

Apartment Type: B

Master bedroom of this apartment oriented on North West. But in west side there is no opening. And that part is blocked by the apartment type "A" block. The child bed is oriented in North East. East side is also blocking, there is no opening. The guest bed is situated on the west side. This bedroom is in the worst position. Because the room opening is on the west side but the side is partly shaded by another block. In this apartment the most annoying thing is none of the bedroom has cross ventilation option due to compact planning.

Apartment Type: C

The master bedroom of this unit is in North West orientation. West is partly shaded by another block. So this is not a problem in the room. The north opening is with large verandah. Child bed is in North East orientation. These two bedrooms have cross ventilation. But the guest bed is oriented in east but the room does not have any cross ventilation except secondary cross ventilation. Family living is in west direction which is partly shaded and dining is in east direction with a large verandah. Formal living room is also in East orientation. The kitchen is in West orientation but attached with family living space, it can be a problem.

Apartment Type: D

In this unit the master bed is oriented in South East side. In east there is large verandah and toilet to block the extra solar radiation. In South West direction the child bed is located. On the west side the shading device is designed in such way so treat it can protect the West solar radiation. Guest bed is oriented on west side with the extended shading device but without cross ventilation. The kitchen is on the east side and attached wall with the living room, so the living room can be heated by the heat emission of the kitchen. Living room is East orientated. Dining is west direction with extended verandah, positive sight is the cross ventilation is direct over here because family living is in the East side opposite of dining and they is no barrier in between these two spaces. More or less all the rooms are in good position in this unit.

1.2.1.6 Landscape of the project

Raeissi and Taheri suggested doing proper plantation to save energy and for other advantages(Raeissi & Taheri, 1999). In this thesis project design we can see the landscape in ground floor, Both the North side and east side road. The boundary is designed with multiple level of plantation. It enhances the aesthetical beauty as well as plantation purpose. Teemusk and Mander suggested the construction system of green roof. They suggested the green roof should consist with the following layers. Waterproofing membrane not to damage the concrete roof, drainage layer for passage through the water so that they can stay over the roof, filter membrane then a layer of plants(Teemusk & Mander, 2009). In this project the architect did the green room on top floor. The architect is also suggested for this project to plant trees and shrubs in those verandahs where solar radiation is high. The architect is also design plantation area in the parking area; these areas are under the roof, so he suggested the plants who can survive without direct sunlight. Below computer generated images of plantation are given:

Figure 9: Green roof (Computer generated render), (BrainTrain, 2013).

*Figure 10**Error! Unknown switch argument.**: Plantation is in the parking, (Computer generated render), (BrainTrain, 2013)*

1.2.2 Walls

1.2.2.1 External Wall

In the case study design project the present situation is all the external wall is 10 inch solid brick. But by the previous study the thesis study will examine 10 inch composite walls with air gap. Because the U value of solid wall is bigger than the U value with the same thickness but composite wall and with air cavity. Wong on his journal stated that 50mm air cavity can reduce solar radiation and it can save 7-10% cooling energy. In the experimental composite wall the composite layers are plaster, brick and air cavity. The solid 250mm brick walls have the U value of 1.76 whereas the 10 inch composite walls have the U value of 0.22. In present design 10 inch wall composition is like ¾ inch outer plaster, 8 ¾ inch Brick and then ½ inch inner plaster. On the other hand the proposed composite wall composition is like ¾ inch outer plaster, 3 inch brick work, 2¾ inch of air cavity, 3 inch brick work and ½ inch inner plaster. Some of the exterior walls have face brick cladding; they are not taken into consideration. Outer façade is light colour painted. According to Cheung it is possible to reduce 12% cooling consumption energy by using a light colour finish at the external envelope(Cheung, et al., 2005). In below picture you can see the difference between the normal wall and proposed composite wall.

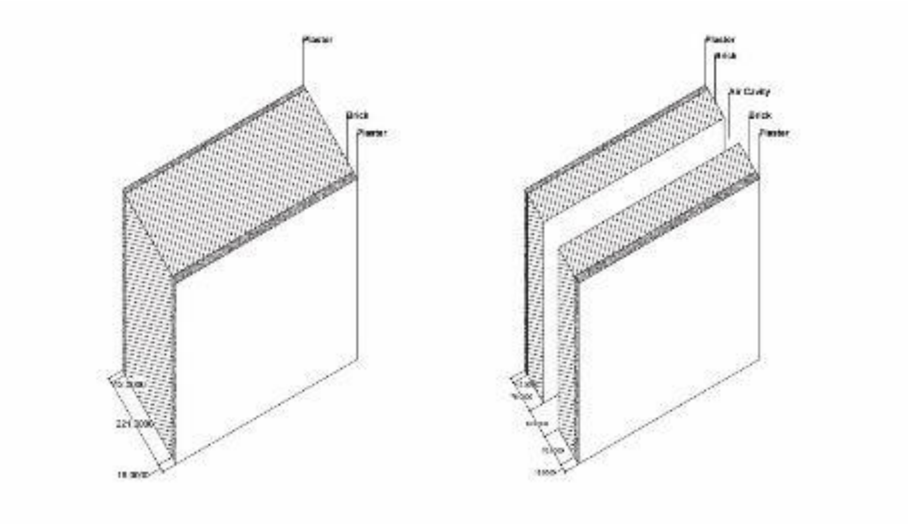


Figure 11: (Left) Case study designed wall (Right) Proposed Composite wall

1.2.2.2 Internal wall

Internal wall is a 125mm solid brick wall. In the proposal it remains same as they do not have to deal with solar radiation and 125mm (5 inch) is commonly used in residential apartment. This is good for console pipes, sound absorption. In the study it is found that if the wall is thinner than this there is a chance for sound pollution and privacy as well. And the construction cost of composite wall is also much more than the solid wall. So in this study this wall keeps the same as previous. The different layer of this wall is 19mm plaster on one side, 96mm brick and then on the other side of the wall 12mm plaster.

1.2.3 Insulation

Generally in Dhaka's residential building insulation is not being used. From the previous study we can see that the air cavity in the wall is good enough for reducing the solar heat gain. And in windows, double glazing is good enough for this climate. In roof we have green roofing to reduce the solar radiation from the sun. So in this particular case study not in external wall, windows or in roof slab insulation is proposed. As they are expensive and not available I the market so all the solution is thing for alternative of the insulation. But it is also considered to have the same output.

1.2.4 Floor slabs

The floor slabs are 9 inches thick, the ceiling portion is plastered and the floor portion is covered with tiles. The layers of the slabs are 1 inch plaster at bottom and 178mm concrete, mortar for floor finish 5/8" inch and floor finish 3/8" inch. This roof is good enough for sound protection.

1.2.5 Roof

The roof slab is thick, it is 10 inches. And because of green roof treatment there are several layers is added on the top of it. The roof is big enough for making it as a communication area, Architect design pavement, plantation and sitting arrangement as well in this particular area, there is shaded, semi shaded space in the roof. And in the proposal there is an option for renewable energy so some of the portion of roof and at the top of the water reservoir and stair case the solar panels will be placed. Mainly in the Dhaka city room is used for community space and hanging laundry. In this particular design community space is designed into the ground floor, so the roof is only used for recreational purpose. There is also designed the laundry dryer.

1.2.6 Windows

In the present design the window is sliding window made of aluminium section and 5mm clear glass. As it is sliding the window can be open only 50%. So the size what we got from the plan in air ventilation aspect is only 50% efficient. For lighting as the glass is clear that is considerable. Inside of the window frame there is an MS bar grill for security. The grill is a very common feature in Bangladesh. Most of the windows are floor to lintel height to have more opening in favour to air ventilation and light. The kitchen windows have a sill height of 762 mm, and the toilet window sill heights are 1525 mm. The window design for this apartment is shown in the picture below. This is the typical design that is followed all over Dhaka by the real estate developer in case of window.

Figure 12: Typical photo of window (Tahmina, 2009).

Here in this thesis study for window the proposal is to use not this typical aluminium section. The joints between this aluminium section and the plaster of the wall, is not good enough to prevent the heat transmission. And the U value of this aluminium section is also not good. Instead of this section the suggestion is to use the newly imported aluminium section which is good in the joint. The sections have the option for use double glazing. Another reason is the typical aluminium sections have the option or sliding, when theses aluminium section is used to swing then they become more ineffective. There are gaps between every joint. And for sliding option the effectiveness of air flow becomes 50% of the total window aperture. Because sliding window can open only 50% another 50% is covered by another part. On the other hand these swing windows can open 100% and the room can avail 100% of the window aperture. Most of the windows are being full height to have more ventilation to make the indoor climate comfortable. The Verandas doors become connected with side window and create a big aperture so that this opening can serve both as window and door. Kitchen windows are not full height in case if the counter is placed on the opening wall, otherwise the kitchen which does not have direct opening and connected with veranda for a passive opening they have a full height opening for ventilation. The below image shows the image of proposed window:

Figure 13: Proposed window (VELFAC, 2013).

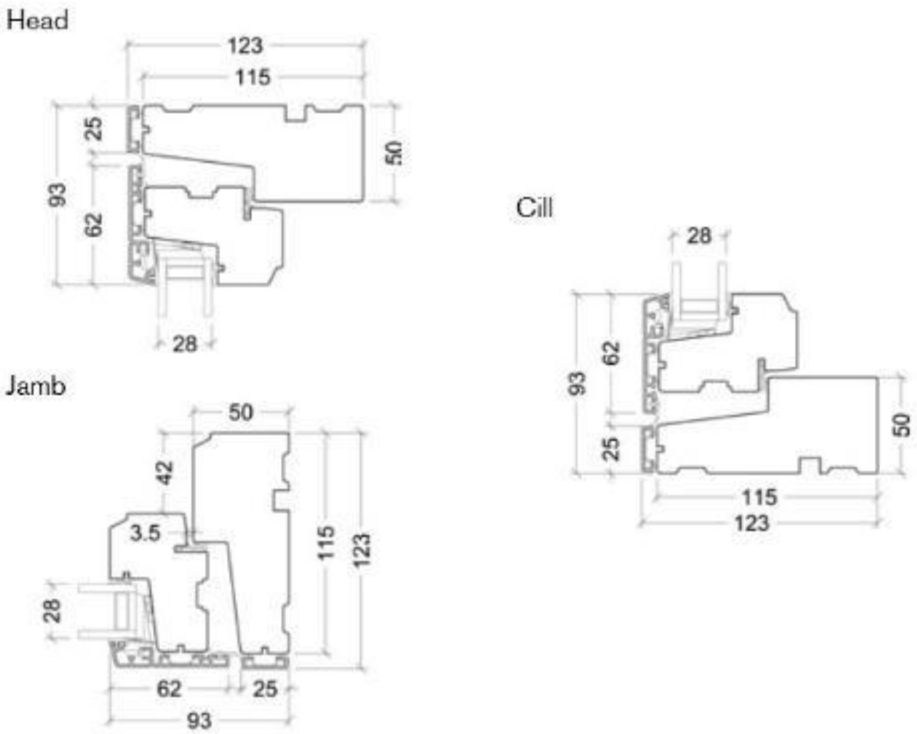


Figure 14: Sectional drawing of the window frame (VELFAC, 2013).

1.3 Use proper applications

1.3.1 Architectural design and model: ArchiCAD

For modelling the two case study types this study used ArchiCAD application. This is a BIM application to do architectural modelling. As the output is a universal IFC format so it can be used any other BIM application and utilized for development. As the IFC model of these studies can be used for mechanical, plumbing and electrical BIM model(Graphisoft, n.d.).

1.3.2 Structural design and model: Tekla

In this study the structural model is built in Tekla, the design used the original design provided by the consultant. The model is done over here to take the quantity from the model and to integrate with the architectural model(Tekla, n.d.).

1.3.3 Energy analysis: ArchiCAD

The energy simulation of the case study two models is done in the ArchiCAD energy simulator, but for doing that the study puts all the relevant information from the theoretical study and the recommendation given by different expertise(Graphisoft, n.d.).

1.3.4 BIM model check: Solibri

After doing model in ArchiCAD and intrigued with Tekla model the study needs to check the flaws and errors in BIM model, if there is an error then the simulation is not going in a proper way, and also for quantity takes off the study need an absolute perfect model. To make it a perfect study needs to check the model error. This task is done by another application name Solibri. The application also shows the architectural design error recommendation as well(Solibri, n.d.).

1.3.5 Quantity takeoff: ArchiCAD and Tekla

For cost estimation the study need the quantity of each and every item. For quantity the study used quantity take option in ArchiCAD and Tekla and got detailed information from these two applications. It is very easy to get the data as per required(Graphisoft, n.d.)(Tekla, n.d.).

1.4 Energy analysis though BIM application

In this thesis study two BIM model is being analysed in energy simulation to understand the difference between these two models. One model is the design that is done without considering the energy consumption or low energy solution and another model is done with the same project with a low energy solution in material and technology. From the computer simulated analysis the thesis can find some statistics. Under section all the data will be described with a specification that has been used in these two models. The factor that is considered in doing the energy simulation of these two models they are:

U value: In thesis study one of the major tasks is to identify the u value of different material in tropical climates like Dhaka. In Bangladesh there is no authorized standard material. So the study has to focus on other researcher work and their study result. In the study it is also calculated through the formula to determine the u value. The ArchiCAD application also calculates the U value according to the thickness of different material and condition. The conditional survey is not for one type of model, in the study the conditional survey is for two types of models. So all the U values are collected before doing the energy simulation. The application required all these data to do the energy simulation.

Environment setting: In the thesis study the location coordinate is taken from google map and insert them into the application to have exact environmental condition of the models. The project is coordinated is 23° 48' 0" N, 90° 25' 0" E.

Ground level offset distance: Due to the semi basement the project is lifted 30 inches above the ground level but that part is not elevated by column, the part is elevated by the semi basement.

Soil type: In Dhaka most of the soil is clay or normal soil. There is no rock content in Dhaka.

Surrounding: From site the study finds that there are two roads adjacent to the plot. One is on the south side and another one is on the west side. Most of the surrounding is paved for this specific project.

Wind protection: North, North-East, East, South-East and North-West are partly shaded by other buildings. South, South-West, and West sides are unprotected for wind protection.

External shading: Means tress or buildings to block the wind. East, South-East and South have external shading.

Climate Data: The climate data is taken from IWEC file: Dhaka 2007, this data is taken from an online data source.

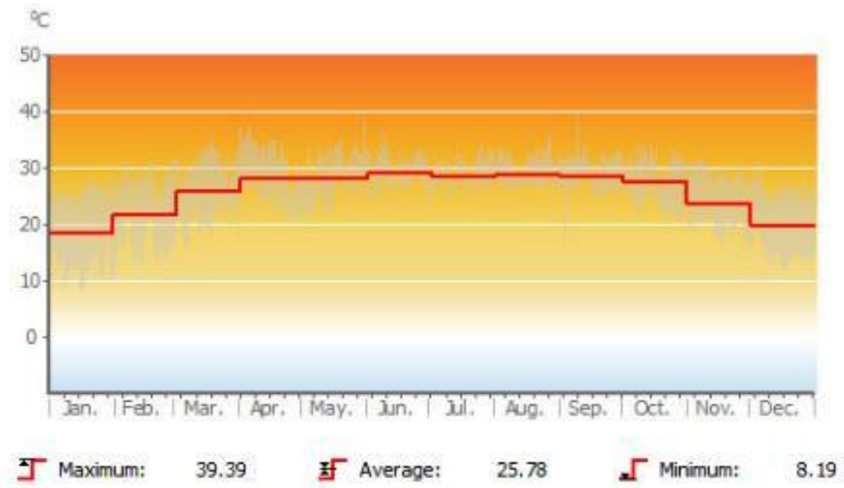


Figure 15: Climate data by IWEC, Source: ArchiCAD.

Climate type: The tropical climate, typical in Dhaka. It is hot and humid. The moisture content is high.

Primary building function: The primary function of this building is residential. 10% is for parking another 90% is for residential and it's supporting amenity services.

Interior lighting: In interior lighting the study has different lighting solution. The existing design model has typical fluorescent light. This is commonly used in residential apartments. And in low energy model the thesis study proposed different light and that is compact fluorescent.

Habitation:

Daily Schedules	Recurrence	Date Range	In use [hours]
habitation	Every Day	1/1 - 31/12	8760

Table 2: Habitation chart, Source: ArchiCAD.

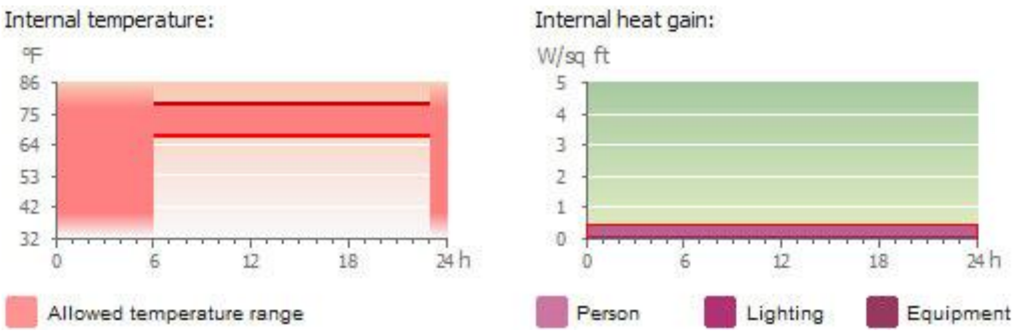


Figure 16: Temperature and internal heat gain chart, Source: ArchiCAD.

Building system and energy:

		Existing model	Low energy model
Heating type		Natural	Natural
Cooling Type		Natural	Natural
Ventilation type		Natural	Natural
Air exchange rate		1/Hour	1/Hour
Service Hot water	Hot Water	10^0 c	50^0 c
	Cold Water	10^0 c	50^0 c

Table 3: Energy System Chart, Source: ArchiCAD.

Green System:

	Existing model	Low energy model
Solar thermal collector	4000 sft	250 sft
Solar energy target	Hot water	Hot water
Heat pump	Ground water	Ground water
Heat pumps capacity	170 kBtu/hr	170 kBtu/hr

Table 4: Green system chart, Source: ArchiCAD.

Electricity produced: The main electricity that the national grid supplies to these buildings are generated from natural gas. Some of the plants have different fuel. Some of them are based on water dam as well. The newly nuclear power plant is also signed to establish.

Electricity cost: Bangladesh power development board has different rates for different types of user. From their tariff rate up to 100 unit residential building per unit electricity cost is 3.33 Taka (Bangladesh Power Development Board, 2013).

By all the above specific data and from the BIM models the energy simulations simulate the information's and generates the data and makes a report for each model. Below all the data's between these two models is being shown.

1.4.1 Key Values

In Key value section all the important data of the BIM model are shown, the building data as well as the energy data. General project data, building geometry data, building shell performance data, heat transfer data, and also specific annual demand of the energy is shown here. The operation cost is also addressed over here.

General Project Data		
Location:	Dhaka	
Primary Operation Profile:	Residential (90%)	
Evaluation Date:	6/3/2013 6:25 PM	
Building Geometry Data		
Gross Floor Area:	**60081.99**	sq ft
Building Shell Area:	**74358.28**	sq ft
Ventilated Volume:	**537694.29**	cu ft
Glazing Ratio:	**4**	%
Building Shell Performance Data		
Air Leakage:	**1.50**	ACH
Outer Heat Capacity:	**9.86*10^-4**	Btu/sq ft,F

Heat Transfer	U value	[Btu/sq ft,F,hr]
Building Shell Average:	**0.48**	
Floors:	-	
External:	**0.19 - 0.80**	
Underground:	-	
Openings:	**0.76 - 0.87**	
Specific Annual Demands		
Net Heating Energy:	**0.00**	kBtu/sq fta
Net Cooling Energy:	**52.01**	kBtu/sq fta
Total Net Energy:	**52.01**	kBtu/sq fta
Energy Consumption:	**110.59**	kBtu/sq fta
Fuel Consumption:	**36.24**	kBtu/sq fta
Primary Energy:	**108.73**	kBtu/sq fta
Operation Cost:	**120.69**	Taka/sq fta
CO_2 Emission:	**7.83**	lb/sq fta

Figure 17: The existing model, BIM energy simulation, Source: ArchiCAD.

General Project Data		
Location:	Dhaka	
Primary Operation Profile:	Residential (90%)	
Evaluation Date:	6/3/2013 5:52 PM	
Building Geometry Data		
Gross Floor Area:	**60081.99**	sq ft
Building Shell Area:	**74358.28**	sq ft
Ventilated Volume:	**537694.29**	cu ft
Glazing Ratio:	**4**	%
Building Shell Performance Data		
Air Leakage:	**1.83**	ACH
Outer Heat Capacity:	**10.99*10^-4**	Btu/sq ft,F

Heat Transfer	U value	[Btu/sq ft,F,hr]
Building Shell Average:	**0.32**	
Floors:	-	
External:	**0.12 - 0.63**	
Underground:	-	
Openings:	**0.52 - 0.69**	
Specific Annual Demands		
Net Heating Energy:	**0.00**	kBtu/sq fta
Net Cooling Energy:	**29.59**	kBtu/sq fta
Total Net Energy:	**29.59**	kBtu/sq fta
Energy Consumption:	**63.96**	kBtu/sq fta
Fuel Consumption:	**10.48**	kBtu/sq fta
Primary Energy:	**31.45**	kBtu/sq fta
Operation Cost:	**34.91**	Taka/sq fta
CO_2 Emission:	**2.26**	lb/sq fta

Figure 18: Low energy model, BIM energy simulation, Source: ArchiCAD.

1.4.2 Energy consumption by source

In this section it shows the energy consumption ratio from different sources. From which source how much energy is consumed by different source? Also shown here is the cost that is spent in the energy. CO^2 emission is also shown in below comparison. Below chart is the representation of two models energy consumption by the source.

Source Type		Source Name	Energy Quantity kBtu/a	Energy Cost Taka/a	CO_2 Emission lb/a
Renewable		Solar Collector	111415	NA	0
		Environment	3648916		0
Secondary		Electricity	1633107	1788978	255828
		Total:	5593439	1788978	255828*

Figure 19: The existing model, Consumption by source, Source: ArchiCAD

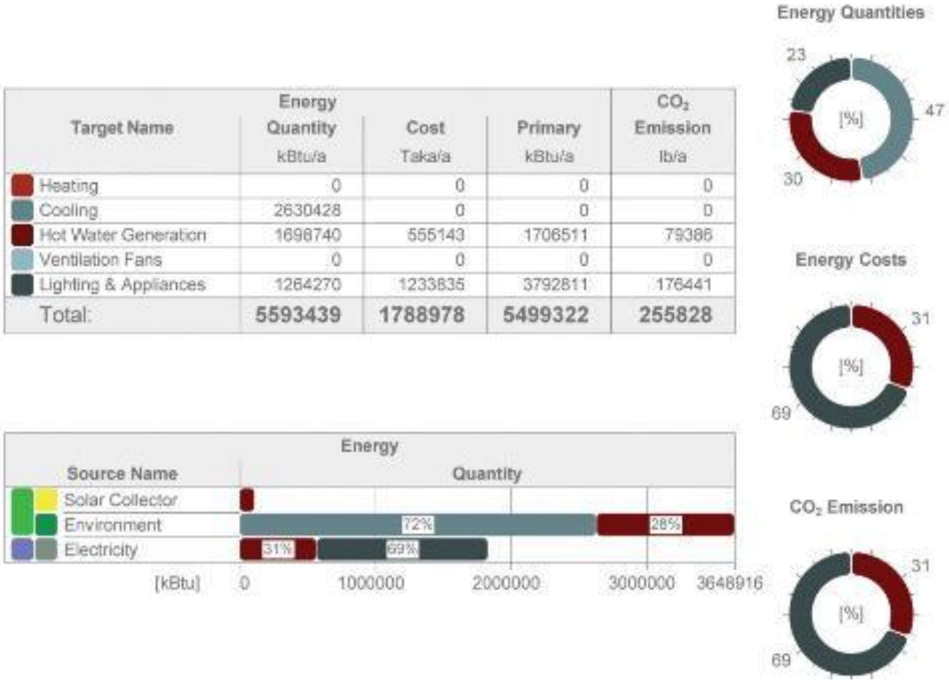
Source Type		Source Name	Energy Quantity kBtu/a	Energy Cost Taka/a	CO_2 Emission lb/a
Renewable		Solar Collector	299595	NA	0
		Environment	597832		0
Secondary		Electricity	175913	585792	83769
		Total:	1073341	585792	83769*

Figure 20: Low energy model, Consumption by source, Source: ArchiCAD.

From the existing design the source is consuming 67% from renewable energy. In this 67% only 2% achieved from the solar collector. As the Bangladesh RAJUK (RajdhaniUnnayonKortipokkho) has the rules to use mandatory solar collector, so nowadays the real estate install the minimum solar collector not to violate the rules. In this project of 250 square feet solar collectors are installed. On the other hand from the low energy building model the data show that 84% energy is achieved from the renewable energy, among them 28% energy is collected from solar panel. Only 16% energy is consumed from the national grid. CO^2 emission rate is also high in the existing design whereas low in low energy building solution. In existing model annual CO^2 emission is equal to 14 acres (which is equal to 1.1 football fields) of tropical forest. And in low energy building solution annual CO^2 emission is 0.5 acres (which is roughly equivalent to 7 tennis courts) of tropical forest. The annual cost of energy in existing model is 1,788,978 Taka and in low energy building model the annual cost is 585,792 Taka.

1.4.3 Energy consumption by target

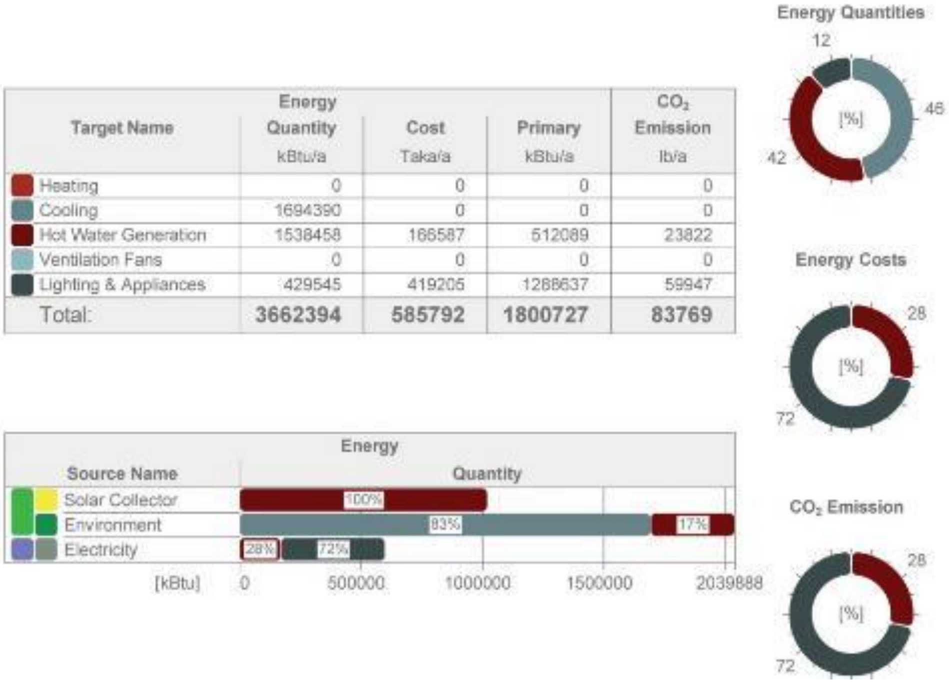
The chart will represent the difference overview of energy consumption by the targets. In below charts it is also stated the target energy consumption is fulfilled by which source and what is the percentage.



Target Name	Energy Quantity kBtu/a	Cost Taka/a	Primary kBtu/a	CO_2 Emission lb/a
Heating	0	0	0	0
Cooling	2630428	0	0	0
Hot Water Generation	1698740	555143	1706511	79386
Ventilation Fans	0	0	0	0
Lighting & Appliances	1264270	1233835	3792811	176441
Total:	5593439	1788978	5499322	255828

Table 5: Consumption by target (Existing model), *Source: ArchiCAD.*

From the chart it is stated that most of the energy is consumed by cooling and hot water generation. For lighting and other appliances the energy consumption rate is not that much comparing to hot water generation and cooling. 47% of total consumers are for cooling and 30% of total consumers are for hot water generation, and only 23% of total consumption is for other appliances like light, TV, fridge etc. For Dhaka's climate heating and ventilation fan is not being used. In the second chart we can see the CO^2 emission from the source. From cost it is observed that 31% cost is spent for hot water generation and rest 69% cost is for lighting and appliances.



Target Name	Energy Quantity kBtu/a	Cost Taka/a	Primary kBtu/a	CO_2 Emission lb/a
Heating	0	0	0	0
Cooling	1694390	0	0	0
Hot Water Generation	1538458	166587	512089	23822
Ventilation Fans	0	0	0	0
Lighting & Appliances	429545	419205	1288637	59947
Total:	3662394	585792	1800727	83769

Table 6: Consumption by target (Low energy model), *Source: ArchiCAD.*

From the chart it is stated that most of the energy is consumed by cooling and hot water generation. For lighting and other appliances the energy consumption rate is not that much comparing to hot water generation and cooling. 46% of total consumers are for cooling and 42% of total consumers are for hot water generation, and only 12% of total consumption is for other appliances like light, TV, fridge etc. For Dhaka's climate heating and ventilation fan is not being used. In the second chart we can see the CO^2 emission from the source. From cost it is observed that 28% cost is spent for hot water generation and rest 72% cost is for lighting and appliances.

1.4.4 Monthly energy balance

In these charts it is reflected over the year in which month from which source energy is consumed. This is overall ratio or graphical chart.

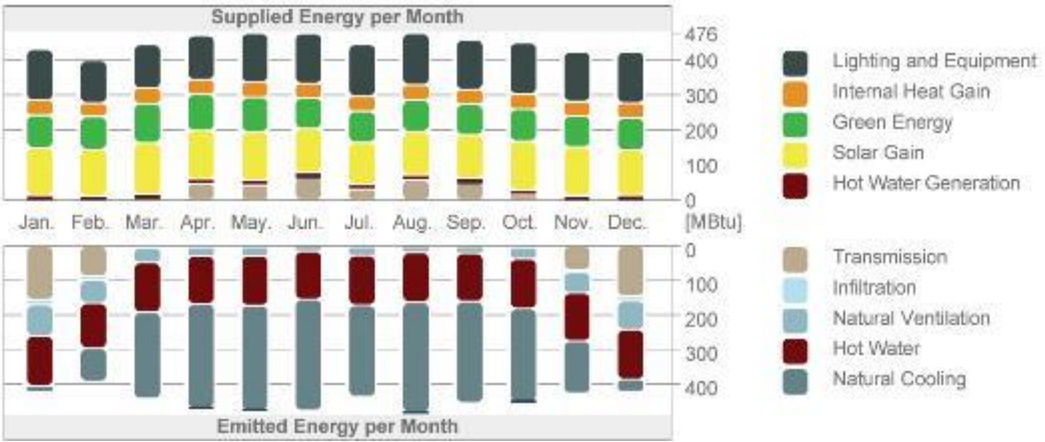


Table 7: Energy balance (Existing model), Source: ArchiCAD.

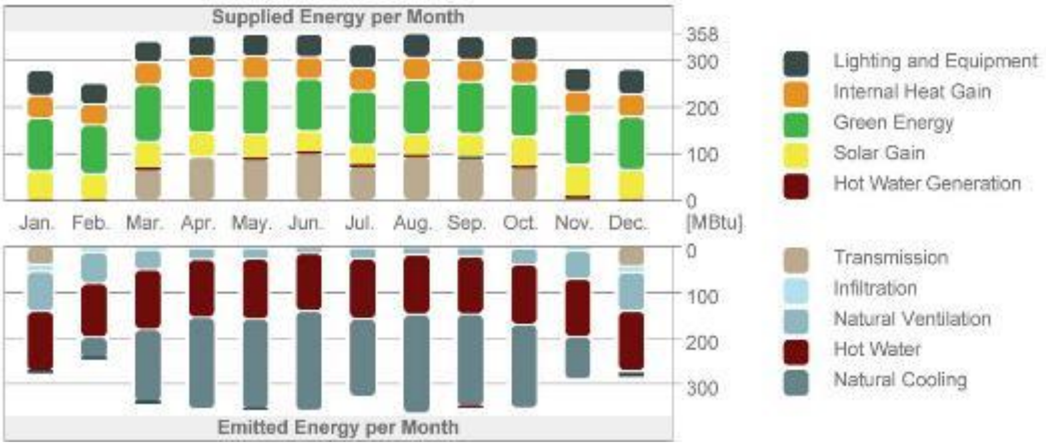


Table 8: Energy balance (Low energy model), Source: ArchiCAD.

1.5 Quantitative analysis and construction cost

The main purpose of the thesis is to make the comparison between the two types of architecture and construction to determine the energy cost. For that reason the thesis study is focused on the construction cost, interest on that cost and the selling price for unit space. To determine all these factors the study has to focus on the quantity and unit cost for those individual items. So the study concentrates on different items. The ArchiCAD, the BIM application determines the quantity of each item and from the developer the thesis study collects the data of the construction cost of items item. The thesis is concentrating only on the building outer shell and civil construction, so the other cost and quantity is taken from the original bill of quantity made by the architectural consultant on the particular case study project. The consultant on this project is Brain Train Limited.

Quantity take off by ArchiCAD and rates

By the archived data from previous studies and by the help of BIM models in this section the study will incorporate all these data and try to find out the overall cost of the construction of the building. In both cases the study uses the BIM model. One model is the existing design with all the recommendation that is done by the architects, and other model which is modelled by this thesis study with all the recommendation found from the theoretical study. Below all the quantity take from the ArchiCAD BIM model is shown, by floor wise and material wise. Because of the information flood of the materials and their compositions the study is only showing the summary taken from models. Few things are taken directly from the bill of quantity provided by the real estate developer. Just like the electric, plumbing cost.

1.5.1.1 Up to Basement roof (for both models same)

Sl. No	Item of Works	QTY	Unit	Mat. Cost	Labour Cost	Total Cost (Taka)
1	Earth Cutting	110000	Cft.		770000	770000
2	Earth back fills	20000	Cft.		40000	40000
3	Solid filling with viti sand	10000	Cft.	120000	25000	145000
4	Single layer brick soling	8200	Sft.	239850	12300	252150
5	Cement concrete works	1400	Cft	209370	16800	227170
6	I-Joist fitting & fixing	10900	Rft.		3270000	3270000
7	Polythene laying	10000	Sft.	10000	10000	20000
8	Piling work	9200	Rft.	6810650	2576000	9386650
9	Reinforced cement concrete work	21600	Cft.	5034960	324000	5358960
10	Grade beam	4700	Cft.	1059615	70500	1130115
11	1.5” Patent stone	600	Sft.	8784	3000	11784
12	3/4" plaster inside wall and ceiling	15900	Sft	89040	127200	216240
13	1/2" Patent stone	500	Sft.	7350	2500	9850
14	Plaster with NCF	2500	Sft.	18563	12500	31063
15	Reinforcement works	1430	Cwt.	5320000	306000	5626000
16	Loading, unloading, caring	76.5	Ton		11475	11475
17	Paving works	8000	Sft	528000	120000	648000
18	Shuttering works	22500	Sft.		510000	510000
	Total			**19456182**	**7697275**	**27154457**

Table 9: BOQ of basement

1.5.1.2 Floor wise reinforcement quantity (for both models same)

Bar Dia	Unit	8 mm	10 mm	12 mm	16 mm	20 mm	25 mm	Total
For pile	CWT	160	140	200	320			820
Basement roof	CWT	22	455	550	135	330	40	1532
Up to G.F roof	CWT	32	255	47	122	100	15	571
First- Second	CWT	30 x 2	265 x 2	44 x 2	130 x 2	88 x 2	5 x 2	1124
Third	CWT	33	208	40	135	75	1	492
Fourth	CWT	33	208	40	140	69	1	491
Fifth	CWT	33	212	30	158	29	1	463
Sixth	CWT	33	212	30	158	29	1	463
Seventh-Ninth	CWT	33 x 3	218 x 3	25 x 3	161 x 3	17 x 3	1 x 3	1365
Roof top	CWT	5	40	10	10	5	-	70
Total	**CWT**	**513**	**2857**	**1106**	**1917**	**866**	**72**	**7331**
	CWT	**7331**		**Kg**	**366550**		**Ton**	**366.55**

Table 10: Reinforcement quantity of the project

1.5.1.3 Plinth to ground floor (Existing)

Sl. No	Item of Works	QTY	Unit	Mat. Cost	Labor Cost	Total Cost (Taka)
1	Column RCC	1800	Cft.	419580	27000	446580
2	Slab, beam, lintel, drop wall RCC	5200	Cft.	1195740	78000	1273740
3	Fare face concrete work	1500	Cft.	476850	75000	551850
4	Reinforcement work	575	Cwt.	1966500	109250	2075750
5	Loading, unloading, caring	28.75	Ton		4313	4313
6	10” Brickwork	2050	Cft.	270190	30750	300940
7	5” Brickwork	4900	Sft	284690	39200	323890
8	3” Brickwork	500	Sft	25050	4000	29050
9	Door chowkat frame	165	Rft.	52800		52800
10	Door shutter	175	Sft	30625	1750	32375
11	Door frame fixing	10	Nos	725	1000	1725
12	3/4" plaster inside wall	18900	Sft	105840	151200	257040
13	3/4" plaster outside wall	3000	Sft	16800	24000	40800
14	Chipping RCC surface	19500	Sft		29250	29250
15	Plastic paint on wall and ceiling	18900	Sft	114421	56700	171121
16	Mater coat	3000	Sft	12616	10500	23116
17	Tiles on wall	700	Sft	45990	9800	55790

18	Tiles on floor	3000	Sft	402375	60000	462375
19	Enamel paint	2000	Sft	6250	6000	12250
20	Paving works	2100	Sft	138600	31500	117100
21	Aluminum window	960	Sft	230400		230400
22	Column guard	800	Rft	56000		56000
23	M.S Grill in window	1250	Sft	137500		137500
24	Railing in stair	60	Sft	16800		16800
25	Cat door	5	Nos	17500		17500
26	Shuttering work	19500	Sft	1178452	390000	390000
27	Ponding work for curing	1000	Rft		5000	5000
28	Green at ground floor	L.S.	L.S			200000
29	Reception lobby	L.S	L.S			800000
30	Main gate	L.S	L.S			100000
31	Door lock	10	Nos	5000	400	5400
	Total			**7207294**	**1144613**	**8220455**

Table 11: BOQ of existing design-Ground floor

1.5.1.4 Plinth to ground floor (Low energy design)

Sl. No	Item of Works	QTY	Unit	Mat. Cost	Labor Cost	Total Cost (Taka)
1	Column RCC	1800	Cft.	419580	27000	446580
2	Slab, beam, lintel, drop wall RCC	5200	Cft.	1195740	78000	1273740
3	Fare face concrete work	1500	Cft.	476850	75000	551850
4	Reinforcement work	575	Cwt.	1966500	109250	2075750
5	Loading, unloading, caring	28.75	Ton		4313	4313
6	10” Brickwork	1435	Cft.	245728	30750	276478
7	5” Brickwork	4900	Sft	284690	39200	323890
8	3” Brickwork	500	Sft	25050	4000	29050
9	Door chowkat frame	165	Rft.	52800		52800
10	Door shutter	175	Sft	30625	1750	32375
11	Door frame fixing	10	Nos	725	1000	1725
12	1/2" plaster inside wall	18900	Sft	70560	151200	221760
13	1/2" plaster outside wall	3000	Sft	11200	24000	35200
14	Chipping RCC surface	19500	Sft		29250	29250
15	Plastic paint on wall and ceiling	18900	Sft	114421	56700	171121
16	Mater coat	3000	Sft	12616	10500	23116
17	Tiles on wall	700	Sft	45990	9800	55790
18	Tiles on floor	3000	Sft	402375	60000	462375
19	Enamel paint	2000	Sft	6250	6000	12250
20	Paving works	2100	Sft	138600	31500	117100
21	Aluminum window	960	Sft	576000		576000
22	Column guard	800	Rft	56000		56000
23	M.S Grill in window	1250	Sft	137500		137500
24	Railing in stair	60	Sft	16800		16800
25	Cat door	5	Nos	17500		17500
26	Shuttering work	19500	Sft	1178452	390000	390000
27	Ponding work for curing	1000	Rft		5000	5000
28	Green at ground floor	L.S.	L.S			200000
29	Reception lobby	L.S	L.S			800000
30	Main gate	L.S	L.S			100000
31	Door lock	10	Nos	5000	400	5400
	Total			**7487552**	**1144613**	**8500713**

Table 12: BOQ of Low energy design model-Ground floor

1.5.1.5 First to ninth floor (Existing design)

Sl. No	Item of Works	QTY	Unit	Mat. Cost	Labor Cost	Total Cost (Taka)
1	Slab and beam	3800	Cft	292600	68400	933850
2	Fare face front facade	800	Sft	254320	40000	294320
3	False slab, lintel, drop wall	500	Cft	89125	9000	98125
4	Reinforcement works	482	Cwt	1638000	110860	1748860
5	Loading, unloading reinforcement	24.1	Ton		3615	3615
6	10” Brickwork	2200	Cft	289960	22000	311960
7	5” Brickwork	6400	Sft	371840	51200	423040
8	3” Brickwork	500	Sft	18300	4000	22300
9	Door chowkat frame	596	Rft	210450		210450
10	Door shutter	656	Sft	196800	9840	206640
11	Door frame fixing	35	Nos	2538	5250	7788

12	Main door frame molding boat	71	Rft		5325	5325
13	Internal door frame molding boat	525	Rft		18375	18375
14	Door clamp	280	Nos	2940	1400	4340
15	Door chain	4	Nos	480	60	540
16	Magnetic door stopper	20	Nos	600	100	700
17	Rubber door stopper	15	Nos	225	45	270
18	Door hinge	140	Nos	12600	2800	15400
19	3/4" plaster inside wall	6400	Sft	49440	51200	100640
20	3/4" plaster outside wall	17900	sft	100240	143200	243440
21	1" cement plaster	4000	Sft	31060	36000	67060
22	Decorative ceiling edge	400	Rft	4240	16000	20240
23	Plaster with NFC	800	Sft	5940	8000	13940
24	Grove is cutting over plaster	2200	Rft		11000	11000
25	Chipping of RCC surface	16000	Sft		24000	24000
26	Plastic paints on wall & ceiling	24200	Sft	146507	72600	219107
27	Master coat	4000	Sft	16821	14000	30821
28	Tiles on wall	2900	Sft	206045	40600	246645
29	Tiles on floor	5800	Sft	777925	116000	893925
30	Tiles in Bath floor	600	Sft	41955	9600	51555
31	Tiles in kitchen floor	110	Sft	33215	7600	40815
32	Granite kitchen top	110	Sft	59835	4400	64235
33	Marble on basin counter	40	Sft	21758	1600	23358
34	Facing brickwork	1500	Sft	158925	90000	248925
35	Enamel paint	3000	Sft	9375	12000	21375
36	French polish	1650	Sft		41250	41250
37	Aluminum Window	2530	Sft	632500		632500
38	Fly proof net	1200	Sft	132000		132000
39	M.S. Louvre	90	Sft		27000	27000
40	Verandah railing	270	Sft	162000		162000
41	Railing in stair	60	Sft	18000		18000
42	Cat door	12	Nos	42000	600	42600
43	Plastic door	4	Nos	11200	600	17800
44	Shuttering work	17800	Sft		534000	534000
45	Ponding work for curing	1000	Sft		5000	5000
46	Door lock	25	Nos	27500	1790	29290
	Total			**6069259**	**1620310**	**8268419**
	1st to 9th floor total cost			**54623331**	**14582790**	**74415771**

Table 13: BOQ of existing design-1st to 9th floor

1.5.1.6 First to ninth floor (Low energy design)

Sl. No	Item of Works	QTY	Unit	Mat. Cost	Labor Cost	Total Cost (Taka)
1	Slab and beam	3800	Cft	292600	68400	933850
2	Fare face front facade	800	Sft	254320	40000	294320
3	False slab, lintel, drop wall	500	Cft	89125	9000	98125
4	Reinforcement works	482	Cwt	1638000	110860	1748860
5	Loading, unloading reinforcement	24.1	Ton		3615	3615
6	10" Brickwork	1870	Cft	253908	28000	335908
7	5" Brickwork	6400	Sft	371840	51200	423040
8	3" Brickwork	500	Sft	18300	4000	22300
9	Door chowkat frame	596	Rft	210450		210450
10	Door shutter	656	Sft	196800	9840	206640
11	Door frame fixing	35	Nos	2538	5250	7788
12	Main door frame molding boat	71	Rft		5325	5325
13	Internal door frame molding boat	525	Rft		18375	18375
14	Door clamp	280	Nos	2940	1400	4340
15	Door chain	4	Nos	480	60	540
16	Magnetic door stopper	20	Nos	600	100	700
17	Rubber door stopper	15	Nos	225	45	270
18	Door hinge	140	Nos	12600	2800	15400
19	1/2" plaster inside wall	6400	Sft	32960	51200	84160
20	1/2" plaster outside wall	17900	sft	66800	143200	210000
21	1" cement plaster	4000	Sft	31060	36000	67060
22	Decorative ceiling edge	400	Rft	4240	16000	20240
23	Plaster with NFC	800	Sft	5940	8000	13940
24	Grove is cutting over plaster	2200	Rft		11000	11000
25	Chipping of RCC surface	16000	Sft		24000	24000
26	Plastic paints on wall & ceiling	24200	Sft	146507	72600	219107
27	Master coat	4000	Sft	16821	14000	30821

28	Tiles on wall	2900	Sft	206045	40600	246645
29	Tiles on floor	5800	Sft	777925	116000	893925
30	Tiles in Bath floor	600	Sft	41955	9600	51555
31	Tiles in kitchen floor	110	Sft	33215	7600	40815
32	Granite kitchen top	110	Sft	59835	4400	64235
33	Marble on basin counter	40	Sft	21758	1600	23358
34	Facing brickwork	1500	Sft	158925	90000	248925
35	Enamel paint	3000	Sft	9375	12000	21375
36	French polish	1650	Sft		41250	41250
37	Aluminum Window	2530	Sft	1518000		1518000
38	Fly proof net	1200	Sft	132000		132000
39	M.S. Louvre	90	Sft		27000	27000
40	Verandah railing	270	Sft	162000		162000
41	Railing in stair	60	Sft	18000		18000
42	Cat door	12	Nos	42000	600	42600
43	Plastic door	4	Nos	11200	600	17800
44	Shuttering work	17800	Sft		534000	534000
45	Ponding work for curing	1000	Sft		5000	5000
46	Door lock	25	Nos	27500	1790	29290
	Total			**6868787**	**1620310**	**9073947**
	1st to 9th floor total cost			**60019083**	**14582790**	**81665523**

Table 14: BOQ of Low energy design model-1st to 9th floor

1.5.1.7 Rooftop (for both models same)

Sl. No	Item of Works	QTY	Unit	Mat. Cost	Labor Cost	Total Cost (Taka)
1	Column	600	Cft	134820	12000	146820
2	Overhead water reservoir	1000	Cft	184950	20000	204950
3	Reinforcement work	70	Cwt	234500	16800	251300
4	Loading, unloading	3.5	Ton		525	525
5	10” Brickwork	1900	Cft	250420	20900	271320
6	5” Brickwork	900	Sft	52290	8100	60390
7	3/4" cement plaster outside wall	3500	sft	19600	31500	51100
8	Plaster with NCF	10001	Sft	7425	10000	17425
9	Lime terracing	6500	Sft	242840	78000	320840
10	Master coat	3500	Sft	14104	12250	26354
11	Enamel paint	1000	Sft	2625	3000	5625
12	Shuttering work	4000	Sft		100000	100000
13	Cloth drying stand	15	Nos		75000	75000
14	Roof top railing	250	Sft		150000	150000
15	Ladder	2	Nos		10000	10000
16	Steel door	75	Sft		18500	18500
17	Ponding work for curing	1000	Cft		5000	5000
18	Roof top landscape	L.S			1000000	1000000
	Total			**1143575**	**1571575**	**2715149**

1.5.1.8 Total construction cost (Existing design)

	Saleable are	**64000**	**sft**
Sl.No	**Floor**	**Amount (Taka)**	**Cost per sft**
1	Foundation works up to the basement	27154457	424
2	Plinth to ground floor roof	8220455	128
3	From 1st floor to 9th floor	74415771	1163
4	Roof top including lime terrace	2715149	42
5	Cost for safety, security and fencing	1000000	16
6	Sanitary works @100 tk/Sft	6300000	98
7	Electrical works @110 tk/Sft	6930000	108
8	Intercom	200000	3
9	Lift 2 nos (8 passengers)	4000000	63
10	Generator	2000000	31
11	Fire hydrant and fire alarm	900000	14
12	Water sprinkler at semi basement	1200000	19
	Sub-total 1	**135035832**	**2110**
13	Substation equipment cost	1200000	19
14	L.T/H.T meter, cable, demand note, R&D for connection	900000	14
15	Solar panel	200000	3
	Sub-total 2	**2300000**	36
	Total	**137135832**	**2143**
16	Material price increases (10% of total cost	**150849415**	**2357**
17	Cost per sft including project overhead 5% of total cost	**157706206**	**2464**

18	Cost per sft including office overhead 5% of total cost	**164563000**	**2571**
		Total	**2571**

Table 15: Total construction cost of existing design model

So cost per sft per **saleable area is 2571 Taka**

1.5.1.9 Total construction cost (Low energy design)

	Saleable are	**64000**	**sft**
Sl. No	**Floor**	**Amount (Taka)**	**Cost per sft**
1	Foundation works up to the basement	27154457	424
2	Plinth to ground floor roof	8500713	133
3	From 1st floor to 9th floor	81665523	1276
4	Roof top including lime terrace	2715149	42
5	Cost for safety, security and fencing	1000000	16
6	Sanitary works @100 tk/Sft	6300000	98
7	Electrical works @110 tk/Sft	6930000	108
8	Intercom	200000	3
9	Lift 2 nos (8 passengers)	4000000	63
10	Generator	2000000	31
11	Fire hydrant and fire alarm	900000	14
12	Water sprinkler at semi basement	1200000	19
	Sub-total 1	**142565842**	**22128**
13	Substation equipment cost	1200000	19
14	L.T/H.T meter, cable, demand note, R&D for connection	900000	14
15	Solar panel	2000000	31
	Sub-total 2	**2300000**	**36**
	Total	**144865842**	**2264**
16	Cost per sft for future material price increase (10% of total cost	**159352427**	**2490**
17	Cost per sft including project overhead 5% of total cost	**166595718**	**2603**
18	Cost per sft including office overhead 5% of total cost	**173839010**	**2716**
		Total	**2760**

Table 16: Total construction cost of low energy design model

So cost per sft per **saleable area is 2716 Taka**

1.6 Real saleable cost of real estate developer

1.6.1 Land owner's portion

In Bangladesh the land for real estate project development is almost same for the city context. The real estate developers do not have their own land. So they always rely on others land. First they do a feasibility study and market study about the land they want to develop. Then after doing all the study the real estate developer went for a meeting with the landowner.

In this case the real estate developers do not buy the land by cash price. The offer the landowner to give him 40% -50% flat on the land owner's name. If the land owner felt that the flat is not enough comparing to land value then land owner demand extra cash to make a deal with the real estate developer. If a real estate developer found the deal profitable then the landowner gives the real estate developer power of attorney to develop project on his site.

Why the landowner did not develop a project on his own land? This is the common question for common people. The study finds the answer like this, most of the time the landowner do not have enough cash to invest in the project, the bank is not going to finance for total cost, land owner should have his own investment to start the project. On the other hand most of the land owners do not want to take the hassle to develop a multi storied residential project. And after the project is finished the landowner is going to own 50% apartment of the building. The land owner can use for his/her own and rest of the units he can sale or rent. Without investing money on investing the land owner avail the opportunity. For these reasons most of the time in Dhaka city, the real estate developer deals with the land owner in the following way. And this is another reason to for market competition and saleable price.

The landowner will have:

1. 50% of the flat (total 36 flats) 18 flats
2. Cash deal for signing 12000000 Taka
3. Car parking 50% of total car parking (total 42) 21 car parking

1.6.2 Real estate developer cost per unit

From the above chapter it is clear that the land owner 50% of the saleable area. So the real estate developer can sale only 50% of the total built area. And also he has to add 12000000 Taka as building cost. The real estate developer also has to give the interest on the loan they take in developing the project. So bank loan interest would be also added for the period of time they utilized the money until they pay back to the bank. Here the developer can sale 64000/2 = 32000 sft (from the apartment area) and there is will be another salable thing that is the parking, each of the parking they will sell on 400000 Taka and developer has to make profit from that sale. That part is presented on next chart where the study shows the profit. So in a short the study can see the comparison between two models in the below chart:

	Existing Design	**Low Energy Design**
Total construction cost	164563000	173839010
Cash deal with land owner	12000000	12000000
Bank interest for loan (70% of total construction cost, for 2 years at interest rate of 16%)	39165994	41373684
Profit 15% of the construction cost	24684450	26075852
Total cost	**240413444**	**253288546**
So the saleable area per sft is	**7513**	**7915**

Table 17: Saleable cost per square feet with profit

1.6.3 Real estate developer profit from the project

The thesis will show the investment of the real estate developer and the profit rate in both of the cases. The chart below will show the several cost involvement and the profit rate.

	Existing Design	**Low Energy Design**
30% of the construction cost	49368900	52151703
Cash deal with land owner	12000000	12000000
Total investment	**61368900**	**64151703**

Table 18: Total investment by the real estate developer

	Existing Design	**Low Energy Design**
Investment	61368900	64141703
15% profit from the construction cost	24684450	26075852
21 car parking sale (21 x 400000)	8400000	8400000
Total profit	**33084450**	**34475852**
Interest rate on investment (flat interest per year)	**27%**	**27%**

Table 19: Total profit on investment

This is not the least; the developer is going to have more interest, but not to make the study to complicate in this particular study try to avoid those things. But the other profits are:

The interest rate of the instalment: The real estate developer start sale the apartments before construction, most of the cases when the design drawing is approved them start advertising to sale those apartments. So the buyer of those apartments starts paying instalment against their apartment. So in these cases the real estate developer is in a chance to earn the interest rate against the instalment money.

The square feet rate is also not same for all apartments; the study is showing the minimum square foot rate or average square foot rate. From the first floor to third floor the square feet rate is higher than the other floors. The demand on those floors is higher than the upper floors. There are several reasons for high demand, the people of Dhaka is used to live in low rise buildings so they do not feel comfortable to live in upper stories. Another reason is accessibility, if the elevator is not working by chance then it would be very difficult for the occupant to use the stair and go up.

Top floor is sometime demanding if there is terrace attached to the unit. But most of the cases for roof slab heat radiation the uppermost floor indoor temperature becomes higher rather than other floor, so nobody likes to buy the top most floor apartments. But in this study the study suggested green roof to avoid the heat transmission, so if the real estate developer shows the fact then they are not going to face any problem to sale those apartments.

1.6.4 Energy life cycle cost analysis

When an investor has a satisfactory return on investor's equity then it is considered as attractive investment(Jaffe & Sirmans, 2001). The investment is depending on investor's objectives but good investment determined by using equity models, net present value, and internal rate of return and payback period(Jaffe & Sirmans, 2001). Generally the outcome of real estate development is depending on total investment cost, net operating income on that real estate and required rate of the return and expected holding period(Hoesli & MacGregor, 2000). Net present value can be described by following function:

(Equation: 1)

$$NPV = \sum_{n=1,i=n}^{n} \frac{NOI_i}{(1+R)^n} + \frac{RV_n}{(1+R)^n} - TIC$$

NPV : net present value of equity
No : net operating income through my periods
R : required rate of return
N : expected holding period
RVn : residual value in the nth period TIC: total investment cost
(Equation: 2)

$$0 = \sum_{n=1,i=n}^{n} \frac{NOI_i}{(1+IRR)^n} + \frac{RV_n}{(1+IRR)^n} - TIC$$

IRR : internal rate of return on equity
The data are used in these models are taken from the estimation; as the estimation is accurate the output is more accurate. So it depends on the initial estimation(Hoesli & MacGregor, 2000).
In this study find the investment cost in four types of units and the energy consumption expenses in a year. Then the study will try to find if there is a difference between the payments then when the investor will cover that and when there is a surplus for the apartment investor

1.6.4.1 Apartment type A (1820 sft)

	Existing Design	**Low Energy design**
Investment on flat	13677300 Taka	14405300 Taka
Energy consumption per year	50869 Taka	16653 Taka
The difference between investment	728000 Taka	
The difference between the annual payments	34216 Taka	

Table 20: Apartment Type A comparison

In 23 years the extra investment will be covered by the energy consumption bill. But in 23 years if the study considers the existing design than the investment cost would be 14796418 Tokyo, which is greater than the low energy building investment. The investment cost would be at that time is 14771666 Taka.

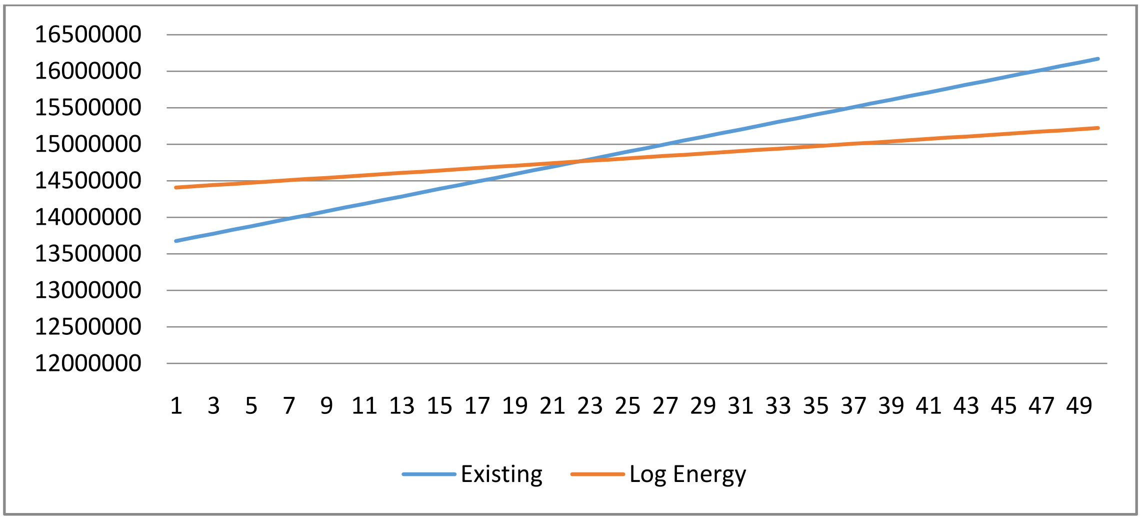


Table 21: Apartment type A-Investment cost progress

1.6.4.2 Apartment type B (1590 sft)

	Existing Design	**Low Energy design**
Investment on flat	11948850 Taka	12584850 Taka
Energy consumption per year	44441 Taka	14549 Taka
The difference between investment	636000 Taka	
The difference between the annual payments	29892 Taka	

Table 22: Apartment Type B comparison

In 23 years the extra investment will be covered by the energy consumption bill. But in 23 years if the study considers the existing design than the investment cost would be 12926541 Taka, which is greater than the low energy building investment. The investment cost would be at that time is 12904917 Taka.

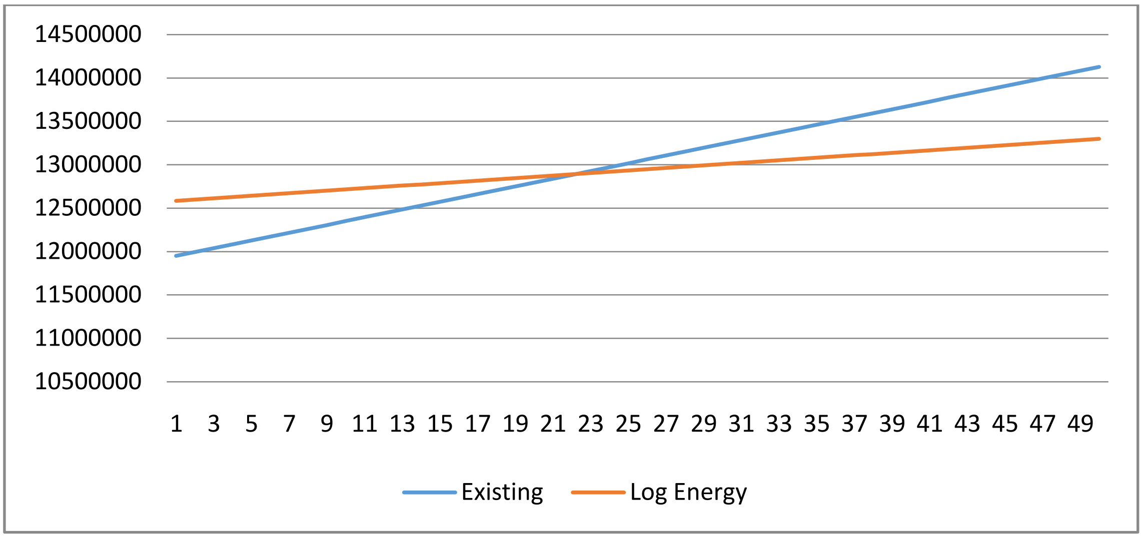


Table 23: Apartment type B-Investment cost progress

1.6.4.3 Apartment type C (1875 sft)

	Existing Design	Low Energy design
Investment on flat	14090625 Taka	14840625 Taka
Energy consumption per year	52406 Taka	17156 Taka
The difference between investment	750000 Taka	
The difference between the annual payments	35250 Taka	

Table 24: Apartment Type C comparison

In 23 years the extra investment will be covered by the energy consumption bill. But in 23 years if the study considers the existing design than the investment cost would be 15243563 Taka, which is greater than the low energy building investment. The investment cost would be at that time is 15218063 Taka.

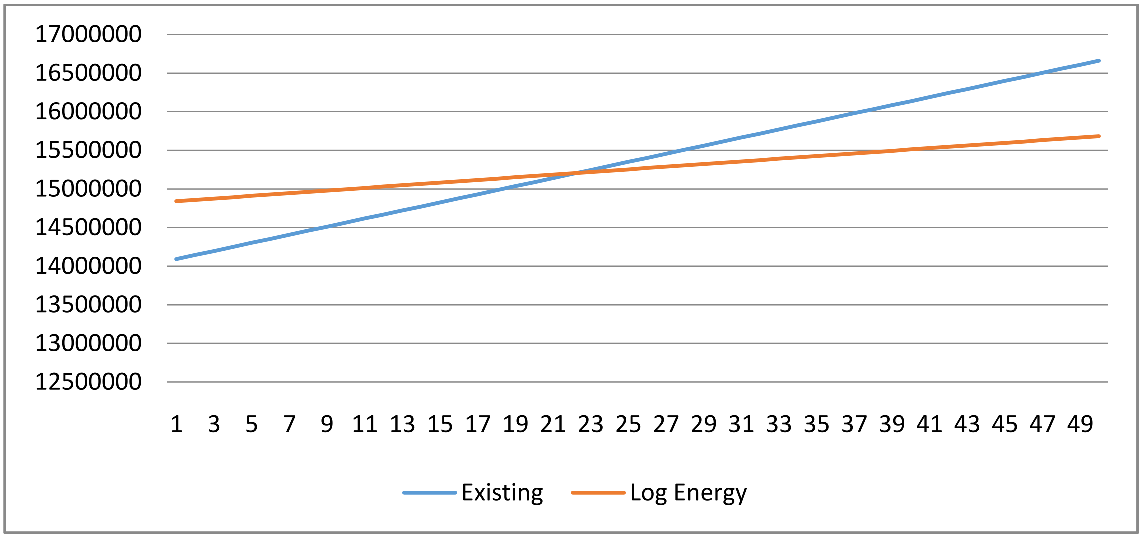


Table 25: Apartment type C-Investment cost progress

1.6.4.4 Apartment type D (1850 sft)

	Existing Design	Low Energy design
Investment on flat	13902750 Taka	14642750 Taka
Energy consumption per year	51708 Taka	16928 Taka
The difference between investment	740000 Taka	
The difference between the annual payments	34780 Taka	

Table 26: Apartment Type C comparison

In 23 years the extra investment will be covered by the energy consumption bill. But in 23 years if the study considers the existing design than the investment cost would be 15040315 Taka, which is greater than the low energy building investment. The investment cost would be at that time is 15015155 Taka.

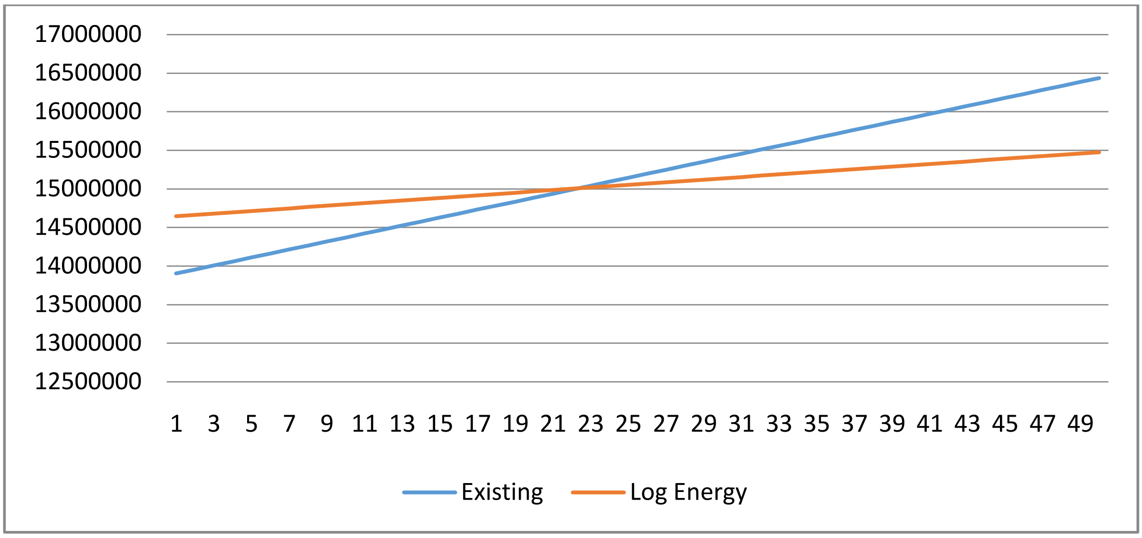


Table 27: Apartment type D-Investment cost progress

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