

## OFFICE BUILDING ENERGY SIMULATION FOR SEVEN CLIMATIC REGIONS OF BANGLADESH USING BIM

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### ABSTRACT

*Building energy consumption depends on many factors such as climate, occupant's behavior, building size and orientation. Analysis of building energy performance at the early phase of the project is crucial for sustainable building design. The purpose of this paper is to determine the energy performance of an office building located in the various climatic region of Bangladesh. A ten story high and circular shape office building conceptual model was developed by incorporating BIM tools Autodesk Revit® 2015. The whole building conceptual energy simulation was performed by Autodesk Green Building Studio (GBS). From the energy simulated results by Autodesk Revit, it was observed that the analyzed office building located in Dhaka which is the main city of South central zone of Bangladesh consumed more energy than the others zones. On the contrary, the same office building located in Jessore which is the main city of the South Western region of Bangladesh consumed less energy than that from other zones.*

**Keywords:** Energy, climatic zones, office building, simulation, performance

### 1. INTRODUCTION

Globalization, changing of living standard and lifestyle as well as increasing industrialization raise energy demand. Globally, around 40% of the total annual energy consumed by buildings (Barua & Billah). Bangladesh has the lowest per capita primary energy consumption within the Indian subcontinent. In 2011, per capita primary energy consumption in Bangladesh was about 205 kilogram oil equivalent (kgoe) whereas it was 614 kgoe in India, 482 kgoe in Pakistan, 383 kgoe in Nepal, and 499 kgoe in Sri Lanka. The primary energy utilization in Bangladesh was increased to 26.7 Mtoe in 2013 that is almost double from 14.8 Mtoe in 2002 (Halder, Paul, Joardder, & Sarker, 2015). Moreover, residential sector in Bangladesh is responsible for around 47% of total energy consumption in Bangladesh (Alam, Islam, & Biswas, 2014).

Nowadays, building, energy and environment are the fundamental issue for the building industry worldwide because there are possible environmental impacts on ambient air conditions and fresh water supply (Fong & Lee, 2017). It is very much important to consider carefully the energy and environmental performance of building (Alrashed & Asif, 2015). However, building energy demand varies with respect to the outdoor weather conditions of a country. Therefore, selection of appropriate passive concept for building design with respect to the local climatic condition is one of the important factor (Panchabikesan, Vellaisamy, & Ramalingam, 2017). Energy simulation at the conceptual stage of a building plays an important role to design energy efficient building because energy efficiency is a key factor for a high quality building.

A climatic zone may be defined as an area for which common outdoor conditions for calculating the energy demand are defined by using a few parameters (Carpio, Jódar, Rodríguez,

&Zamorano, 2015).Building design consultants and energy researchers could get a better idea about the possible impacts on the thermal performance of the office buildings in the different climates from energy analysis and its findings (Eskin & Türkmen, 2008).In order to examined the influences of diverse climate conditions on the thermal and energy performance of office buildings in China(H. J. Wu, Yuan, Zhang, & Bi, 2012),Thailand (Kunchornrat, Namprakai, & du Pont, 2009)and Europe (Tsikaloudaki, Laskos, & Bikas, 2011)were conducted through climatic data analysis to improve the thermal performance of buildings. Research have shown that total energy demand can be reduced more than 50% by identifying and implementing sensitive climatic design parameter(Zhao, Künzelt, & Antretter, 2015).Moreover, climatic zoning for building energy efficiency applications is an important parameter in many programs and policies (Walsh, Cóstola, & Labaki, 2017).

There are many types research has been conducted on the effect of the climatic zone on building energy performance; however, there is no research conducted in the context of Bangladeshi climatic zones. The main objective of this study is to analyze the effect of Climatic zones on the energy performance of building including life cycle cost, carbon emissions, and renewable energy potential.

## **2. GEOGRAPHICAL AND CLIMATIC CONDITION OF BANGLADESH**

Bangladesh, a south-Asian low-income country is located between 20°40' and 26° 38' north latitude and 88° 01' and 92° 41' east longitude with an area of 147,570 km<sup>2</sup>.The country is surrounded by India on the west, north, and northeast while by Myanmar on the south-east and the Bay of Bengal on the south. The density of population in the country has increased dramatically from 704.75 peoples /km<sup>2</sup> in 1990 to 1074.07 peoples /km<sup>2</sup> in 2014. The country has 32.1 million households distributed in over 59,229 mauzas (Halder et al., 2015).Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures, and humidity. There are three distinct seasons in Bangladesh: a hot, humid summer from March to June; a cool, rainy monsoon season from June to October; and a cool, dry winter from October to March. In general, maximum summer temperatures range between 30°C and 40°C. April is the warmest month in most parts of the country. January is the coldest month when the average temperature for most of the country is about 10°C(Alam et al., 2014).Bangladesh has been divided into seven climatic sub-regions that have indicated in figure1 and these seven climatic sub-regions are South-Eastern (Chittagong), North-Eastern (Sylhet), Northern part of the north region (Panchagarh), North- western region (Rajshahi), Western dry region (Bogra), South-western region (Jessore) and South-central region (Dhaka).

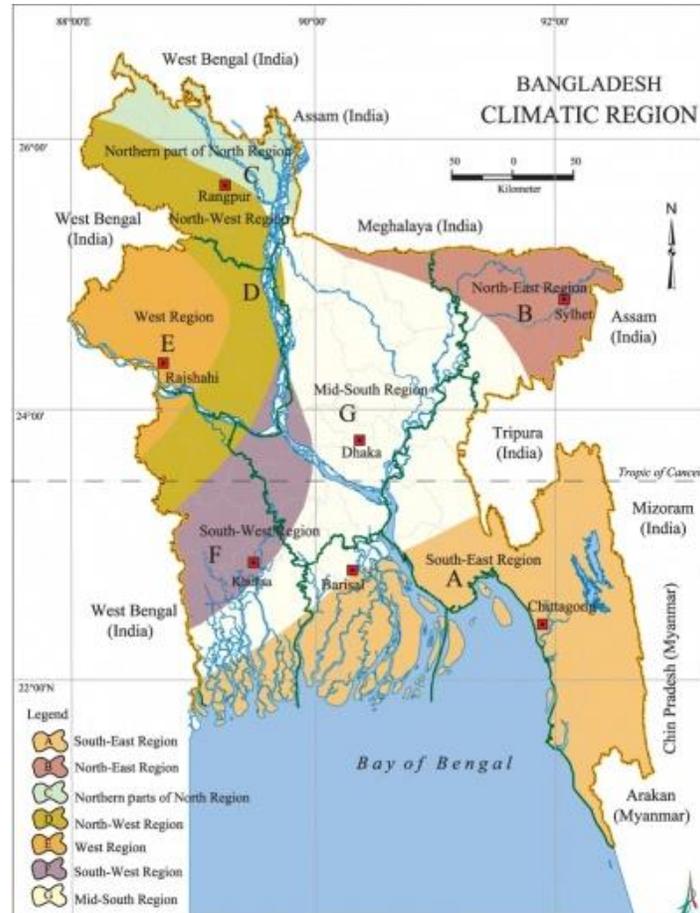


Figure 1: The climatic zones of Bangladesh

### 3. BUILDING INFORMATION MODELING (BIM)

The building information modeling is a digital representation of the physical and functional characteristics of a building project & its life cycle (D. Wu, 2013). BIM is currently the most common denomination for a new way of approaching the design, construction, and maintenance of buildings (Abanda & Byers, 2016). In order to conduct building energy simulation during design and construction phases, various types of information such as building materials, labor force, and facilities are needed and BIM able to provide that information. Various tools are needed in order to generate BIM models (Che, Gao, Chen, & Nguyen, 2010). Many software assists the designers to create a 3D digital model of a building while also providing 4D information, 5D information and other related performance analysis such as costing, scheduling, structural analysis, energy analysis, etc. The most popular and powerful BIM software is Autodesk Revit® that has been used in this study.

### 4. METHODOLOGY

#### 4.1 Design Parameters

A ten-storied circular shape office building of 100 ft high and 50 ft radius with total floor area 78,529 ft<sup>2</sup> and net exterior wall area 31,416 ft<sup>2</sup> has been considered in this investigation. The

analyzed model is suitable for 292 peoples. Exterior window to wall ratio has been chosen about 40%. The circular shape of office building model has been chosen in order to avoid shape and orientation effect because different geometric shapes have different capacity to receive solar energy depending on its orientation. For instance, rectangular shape elongated East-West direction received highest amount solar insulation with compare to other orientation(Ling, Ahmad, & Ossen, 2007).Autodesk has provided the virtual code of weather stations for the climatic zones, outdoor maximum and minimum temperature. The key information for the seven climatic zones of Bangladesh was presented in Table 1.

Table 1: Key information for the climatic zones of Bangladesh

Climatic Zones	Regions	Major city	Coordinates	Code of weather station	Outdoor Temperature (°F)		
					Max	Min	Average
A	South Eastern	Chittagong	22°22'N91°48'E	756952	96	51	73.5
B	North-Eastern	Sylhet	24°54'N91°52'E	756334	101	49	75
C	Northern part of the northern region	Panchagarh	26.25°N 88.50°E	456719	100	45	72.5
D	North- western region	Rajshahi	24°51'N89°22'E	456026	102	44	73
E	Western zone	Bogra	24°22'N88°36'E	458057	101	47	74
F	South-western zone	Jessore	23.17°N 89.20°E	457028	101	43	72
G	South-central zone	Dhaka	23°42'N90°22'E	460412	101	46	73.5

## 4.2 Energy Simulation

Computerized building information modeling (BIM) tools such as Autodesk Revit<sup>®</sup>2015 has been used as a tool to create the mass model. Building categories have been chosen as the office building. The same model has been used for energy simulation at seven climatic zones where major influencing factors were weather data such as temperature, solar radiation, wind condition and humidity. The percentage of glazing was kept 0.4 for all the models. The office buildings operating schedule was 24/7 and HVAC system was central VAV, HW heat, chiller 5.96. Typical energy analyzed model and sun path diagram and the whole building energy simulation process is shown in figure 2,3 and 4 respectively.

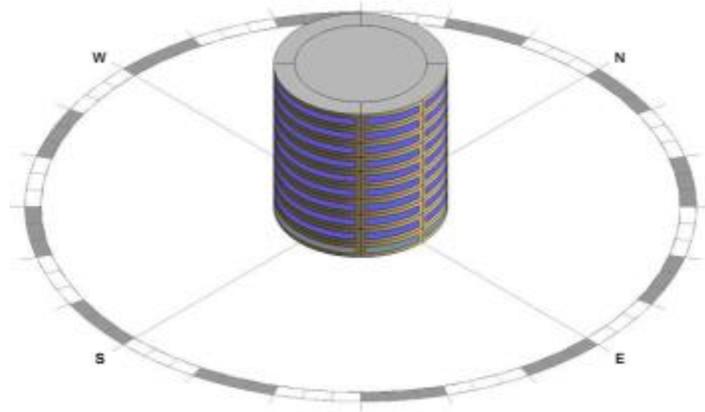


Figure 2: Energy analytical model for the analyzed building

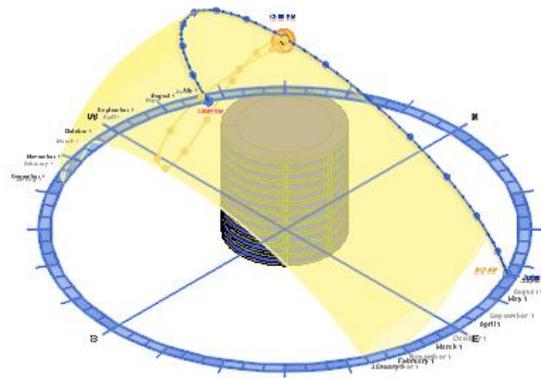


Figure3: Sun path diagram at Dhaka city for summer session

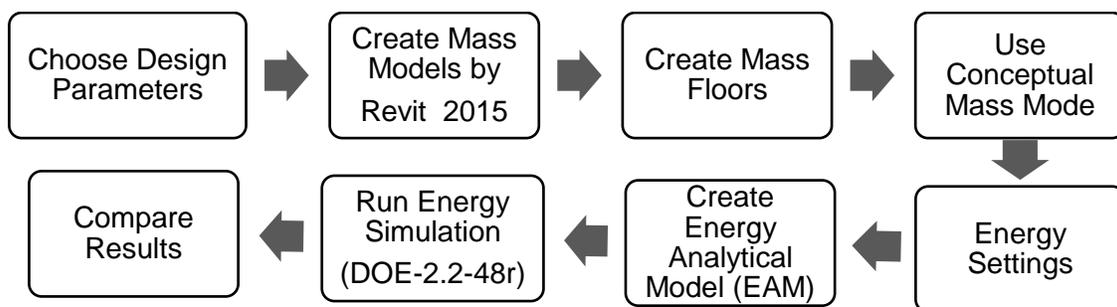


Figure 4: Conceptual energy simulation flow diagrams by BIM

## 5. RESULTS AND DISCUSSION

### 5.1. Life Cycle Energy Consumption

The simulation results in figure 5 showed that life cycle energy consumption varies from climatic zone to climatic zone of Bangladesh. Whole life energy consumption at Chittagong, Sylhet, Panchagarh, Rajshahi, Bogra & Jessore is almost identical but Dhaka city consumed around 20% higher than rest of the zone of Bangladesh. It was found from the simulated results that natural gas used in Dhaka city around 13% of total energy. Likewise, the rest of the city individually used around 6-7 % of total energy.

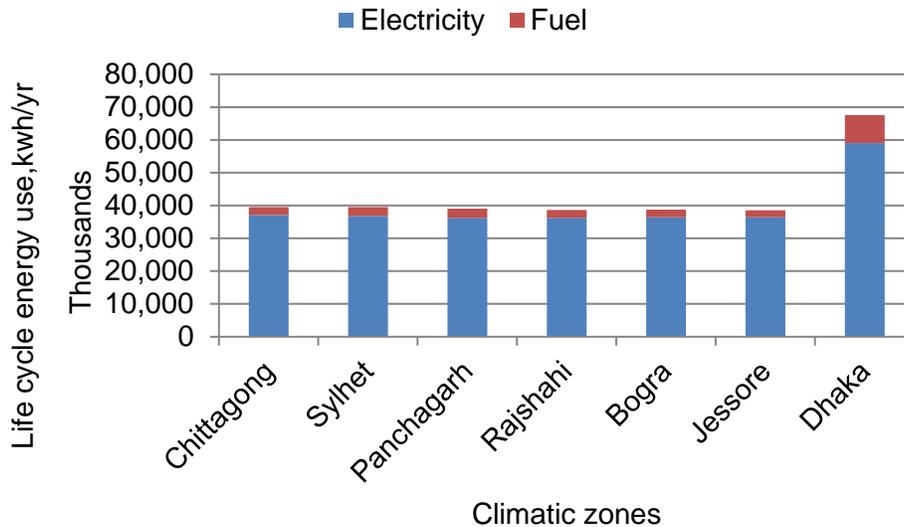


Figure 5: Life cycle energy consumption at various climatic zones

### 5.2. Monthly Electricity Consumption

Monthly electricity consumption for the analyzed building model at various climatic zones of Bangladesh is illustrated in figure 6. From the simulated results it has been found that except Dhaka city the energy consumption pattern for the rest of the city almost identical but Dhaka city consumed almost 33% higher than others zones. The energy requirement for all cities is low from November to February because of low temperature during the winter season. The principle influencing factors that were responsible for the variation of energy consumption were weather condition which is temperature, relative humidity, wind condition and solar radiation.

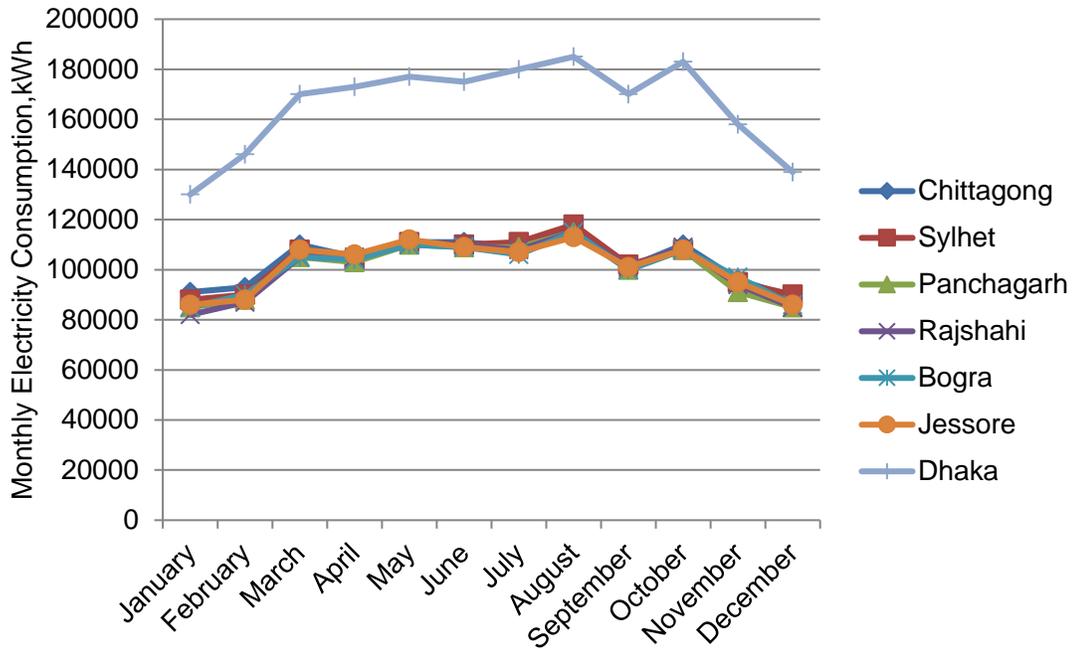


Figure 6: Monthly energy consumption at various climatic zones

### 5.3. Life Cycle Energy Cost

The estimated energy usage and cost over the life of the building assuming a 30-year lifespan. In order to estimate life-cycle cost, the unit rate of electricity is \$0.09/kWh and natural gas is \$0.78/ Therm has been considered. The rate has been chosen by Autodesk based on statewide, territory-wide or nationwide average utility rates. From the simulated result, it was noticed that the life cycle energy cost varies from climatic zone to zone that has been represented in figure 7. The life cycle cost for the selected building model is higher at Dhaka city and lower at Rajshahi city. Except for Dhaka city, the variation of life cycle cost for rest of the city is very little. Life cycle cost for the analyzed office building in Dhaka city is around 64 % higher than the average cost of the other climatic city.

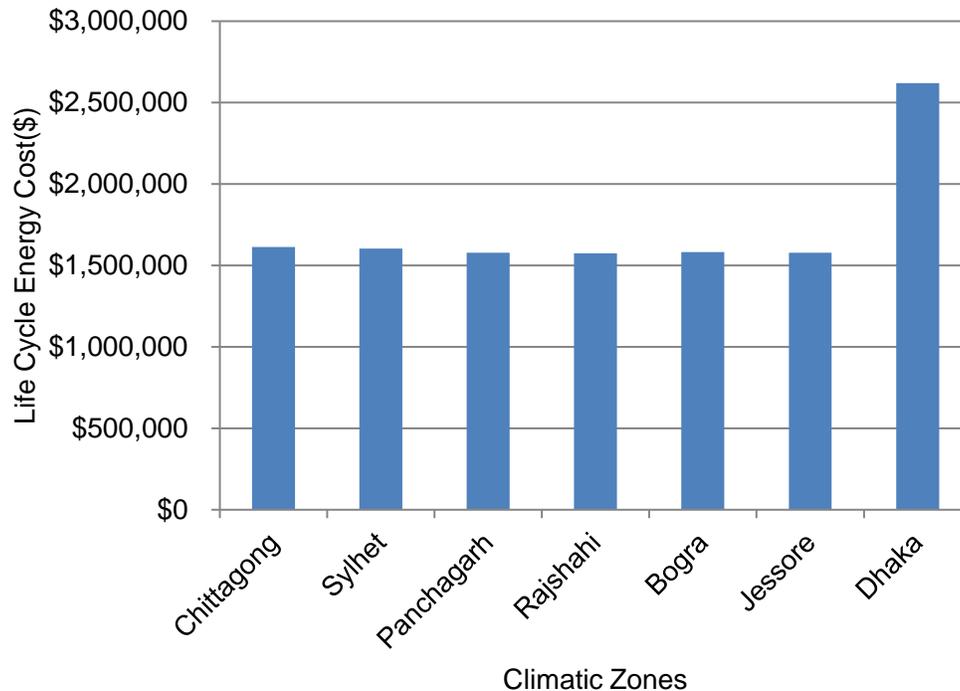


Figure 7: Life cycle energy cost at various climatic zones

## 6. CONCLUSION

Bangladesh is divided into seven climatic zones and the energy simulation of the analyzed building model conducted for each climatic zone. From this research, it has been concluded that climatic zone of Bangladesh plays a significant role in building energy performance. Building located in the South-central region of Bangladesh where Dhaka is the main city consumed around 20 % more life cycle energy than other zones of Bangladesh. Energy consumption for all climatic zones except South-central region is almost identical. The energy performance of the analyzed building model at Dhaka city is greatly affected by temperature, relative humidity, solar radiation & wind condition. However, it is very much important to classify the climatic zone precisely otherwise energy simulation results will not consistent with real climatic characteristics.

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