AN INVESTIGATION ON RELATIONSHIP BETWEEN ENERGY CONSUMPTION OF HIGH RISE INSTITUTIONAL BUILDINGS AND THE CLIMATE OF DHAKA CITY

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ABSTRACT

Growth in population, mounting demand for building services and comfort levels, along with the rise in time spent inside buildings, assure the upward trend in energy consumption of large scale public buildings in Dhaka city. For this reason, energy efficiency in buildings is a prime objective today for energy policy at regional, national and international levels. This paper devotes to discuss the holistic utility bills analysis method for investigating and analyzing whole building energy consumption of public buildings with special emphasis on private sector institutions in a tropical region like Dhaka city. Correlations between operational records of energy consumption of three institutional buildings and the meteorological data including monthly mean outdoor dry-bulb temperature (To), and relative humidity (RH) of Dhaka city have been derived. The findings of the study reveals that the overall building energy consumption is highly dependent on climate, building design characteristics including internal layout, orientation, fenestration and site configurations, and ownership. The analysis of such kind of model is especially useful for building managers and owners to track energy use during pre-retrofit and post-retrofit periods and to reduce building operational costs in the tropical region.

Keywords: Energy consumption, Institutional buildings, Utility bills, Heat gain, Meteorological data.

1. INTRODUCTION

Dhaka, the capital of Bangladesh and one of the world's fast growing mega cities accommodates more than 13.1 million people within its 1,353 square kilometer area (BBS, 2003; UNEP, 2005). According to the most recent UN estimate, its population will reach 16.8 million by 2015 (United Nations, 2006). The population is growing by an estimated 4.2% per year, one of the highest rates amongst Asian cities (Mcgee and Terry, 2006). With very limited resources and very high urbanization rate, Dhaka is going to face greatest challenge ever to reach standards of sustainability and minimum emission level. Growth in population, increasing pressure for building services, and enhanced comfort levels, together with the rise in time spent inside buildings, assure that the upward trend in energy demand will continue in the future. Thus built environment is an important factor for the increment of per capita CO_2 emission despite being responsible for only 0.15% of global CO_2 emissions (EIA, 2006; 2008). For this reason, energy efficiency in buildings is today a prime objective for energy policy at regional, national, and international levels (Lombard et al. 2008, pp 394-398).

Due to rapid urbanization, huge population growth and economic advancement, urban developments have ignited a widespread construction boom introducing high-rise to the city landscape which is in turn impacting the city's energy consumption [Figure-1]. In view of the limitation of land space coupled with ever growing demand for higher studies and number of students, institutional buildings specially private universities have been put up to the multi-storied building blocks, which is increasing the energy load.

The climate of Dhaka is characterized by high temperatures, high humidity, heavy rainfall and marked seasonal variations (Mourshed 2011). According to Koppen–Geiger climate classification Dhaka's climates is classified as Aw or tropical wet and dry (Kottek et al. 2006). The energy demand from a building is influenced by a large number of variables ranging from weather parameters (e.g., temperature solar radiation, wind, moisture content of air, etc.) to the characteristics of the building (e.g., envelope, form, shape, materials, construction, etc.), its occupants (e.g., occupancy, activities, etc.) and its systems (e.g., type, performance,

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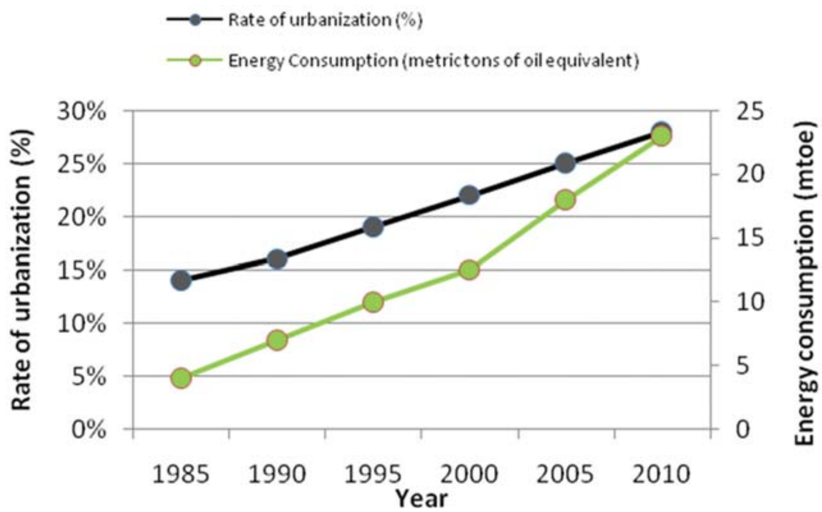

Figure-1: Energy Consumption versus Rate of Urbanization. (Source: BP Statistical Review, 2010)

control schedules etc.) (Mourshed 2011). Whereas, the facades or envelopes of the recent construction of tall office buildings in urban areas of Dhaka city have been designed without any respect to the interdependency between outdoor and indoor climate (Ahmed 2003). Thus, fenestration and building envelope design has been found to be the most significant factor affecting energy use in high-rise buildings in the tropics (Muhammad et al. 2005). Eventually, this ill planning is leading towards immense energy consumption.

Dhaka city has experienced a constant gap between power generation and the growth of inhabitants, thus the supply of basic services never met with requirements [able-1] (Moinuddin 2010). Though Dhaka city consumes 41.22% of the total generated electricity, but only 20–25% of total population of the city is enjoying the benefits of electricity directly (Khundakar 2010). And the per capita availability is only 120 kW h per annum (GoB 1991). Energy is therefore recognized as a critical input parameter for national economic development of Bangladesh. Tall buildings, in general, consume more energy than low-rise buildings. Therefore, their 'carbon footprints' are bigger. The high-rise buildings have approximately 60% more energy embodied per unit gross floor area (GFA) in their materials than the low-rise buildings (Ali and Armstrong 2008). Thus remarkable increase of energy consumption is a repercussion of rapid urbanization and economic development which in turn affects the building sectors' and people's life style. Energy efficiency is defined as decreasing the use of energy per energy service without substantially affecting the level of these services (UNISE 2000). In this regard, appropriate energy consumption in terms of electricity usage for building operation should be methodically analyzed to establish a correlation between climate, building design characteristics including internal layout, orientation, fenestration and site configurations, and ownership. Aiming for a reliable electricity demand analysis, this research concentrates on holistic utility bills analysis method for the high rise institutional buildings of Dhaka city. Lessons from this research regarding changes in electricity use with time, different location and varied situations can yield future power policy and will help building managers and owners to track energy use during pre-retrofit and post-retrofit periods for making building energy efficient.

Service Category	Service Provider	Demand	Supply	Shortage
Power Supply (in Dhaka City Corporation only)	DESCO	450 Mega Watt	290 Mega Watt	150 Mega Watt
	DPDC	950 Mega Watt	500 Mega Watt	450 Mega Watt

Table-1: Scenario of Power supply provided by city authority compared to existing demand in Dhaka city according to the number of inhabitants (Moinuddin 2010)

2. PROBLEM STATEMENT

Bangladesh, having one of the least per capita in power generation (176 kWh in 2008) in the world has already appeared as a country of power crisis, and therefore, frequent load shedding takes place in Dhaka city (The Daily Star 2010). Dhaka has a daily shortfall of 2,000 megawatts of power, which is half of the entire country's average daily production (Energy Daily, 2010). Due to this increasing demand, the country is facing shortage of electricity, gas and water, which in turn is making the city unsustainable day by day. At present this demand supply gap and load shedding have increased [Figure-2]. Massive power outages, particularly during peak summer, have become a regular feature in the capital city for a number of years, where on an average, a typical Dhaka household experiences power failure for about three hours per day (Akter 2008). The general daily power deficit in Dhaka ranges between 450 and 500 MW per day, which reaches up to 1,800 MW during summer (DESA 2006). During the summer period, due to high indoor temperatures, dependency on electricity among city dwellers has increased, thus widespread power interruptions caused disruptions in daily activities. High rise buildings are among the worst perpetrators in urban areas when it comes to energy consumption and carbon emission, with outdated heating, cooling and lighting systems (The News Today 2011). In addition to that, the widespread use of electric motors in air-conditioning, chillers, pumps, air compressors, and lifts in building systems and motor energy use represents well over half of all electric energy used by industrial, commercial, and institutional facilities (Saidur 2009). Therefore, it is evident that Bangladesh will require more electricity in future as a consequence of many factors affecting the future demand, like population growth, on-going social changes, and the restructuring of the Bangladesh economy together with the expected technological development in building sector (EIA 2010).

3. RESEARCH METHODOLOGY

The study is an attempt to investigate the association involving the energy consumption of high rise institutional building mainly private-sector universities and climatic data of Dhaka city, with the following objectives:

- To develop a relationship between the monthly electrical energy consumption of three high-rise private sector universities with correspondent weather data of Dhaka city.

- To investigate the inherent relationship between the energy consumption of selected buildings with their respective physical features like, internal layout, orientation, fenestration and site configurations.

In this research three institutional buildings were selected among all the high rise private sector universities in Dhaka metropolitan area. One of them was designed primarily for institutional purposes but the other two were for commercial use. This research explored a simple approach to estimate how energy is consumed in a building using information from monthly electricity bills from January, 2009 to December, 2009 from the zonal office of Dhaka Electric Supply Company Ltd (DESCO) and Dhaka Power Distribution Company Ltd (DPDC). As electricity is the only energy used in these private universities, so the electricity

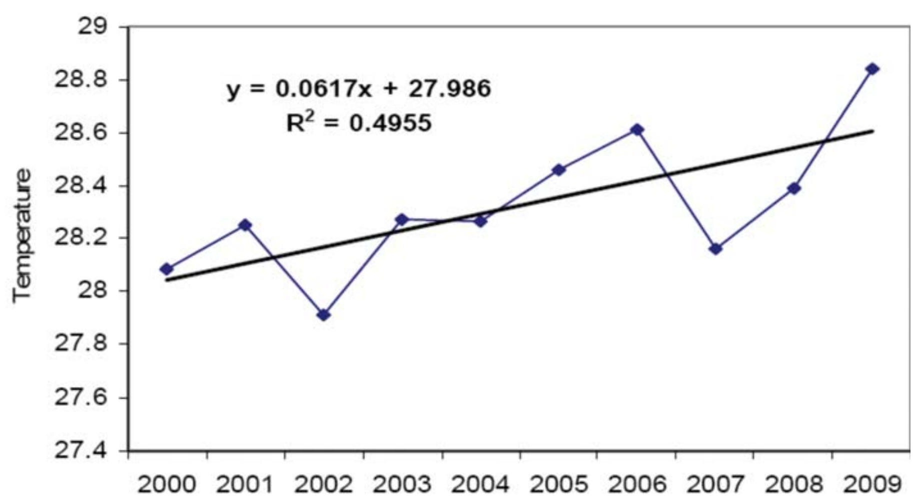

Figure-2: Power demand-supply gaps and load shedding (BPDB 2006)

Institutional Building	Address	Storied	Building Area (m^2) Approx.	Air conditioned Area (m^2) Approx.	Naturally Ventilated Area (%)
1. Ahsanullah University of Science & Technology(AUST)	Plot: 141-142, Tejgaon I/A, Dhaka.	**10**	**39370**	**26102**	**33.7 %**
2. Khalique Tower (Prime Asia University campus-01)	Road 17, Banani C/A, Dhaka	**16**	**4820**	**3800**	**21.2%**
3. Star Tower Ltd (Prime Asia University campus-02)	12 Kamal Ataturk Avenue North South, Dhaka.	**17**	**7590**	**6510**	**14.2%**

Table-2: Introduction to three case-studied institutional buildings
(Source: Field survey by authors)

usage is the only energy measurement factor. The corresponding weather data of that period, such as outdoor dry bulb temperature (To), relative humidity (RH), are collected from the zonal Met Office in Dhaka. Moreover, the data of average wind speed, and precipitation (PP) also have been collected to find a relationship with average relative humidity.

Physical features of these three high rise institutional buildings have been collected through rigorous field survey and photographic survey [Table-2]. Data has been obtained from observations, documentation and interviews.

For data analysis, statistical analysis has been done using Microsoft Excel 2007 so as to find the relationship which increased the validity and reliability of the findings.

4. ANALYSIS AND DISCUSSION

The total energy consumption of a building is that required to support all energy consuming end-uses, inclusive of the losses due to appliance and system efficiencies. To evaluate the performance of energy consumption in a building, there are two major methods: simulation method and statistical analysis method. As the topic of interest of this research is on high-rise institutional buildings, mainly the private sector Universities, so the statistical method of analysis has been used for analyzing energy consumptions.

4.1 Introduction to Investigated Buildings

4.2 Analyzing Microclimatic Condition

The sky view factor (SVF) is often used to describe urban geometry (Upmanis 1999; Svenson 2004, pp 201-211). By definition, SVF is the ratio of the radiation received (or emitted) by a planar surface to the radiation emitted (or received) by the entire hemispheric environment (Watson and Johnson 1987, pp 193-197). It is a dimensionless measure between zero and one, representing totally obstructed and free spaces, respectively (Oke 1988).

The SVF variations have impact on microclimates and the importance of SVF in relation to other central parameters such as thermal admittance is also important. Surrounding buildings in Dhaka are at very close proximity to plots. Hence, buildings constructed get shade form existing landmasses in almost all cases. Buildings, however, do not get shade from surrounding trees due to the absence of green spaces. The above mentioned criteria does not directly generate reductions in energy use. Instead, they provide air movement for ventilation and help to keep buildings cool through the shade provided by surrounding buildings. Microclimatic features of three case study buildings are shown in [Figure-3].

Figure-3: Microclimatic Features of Three case studied buildings (Source: Field survey. Google earth)

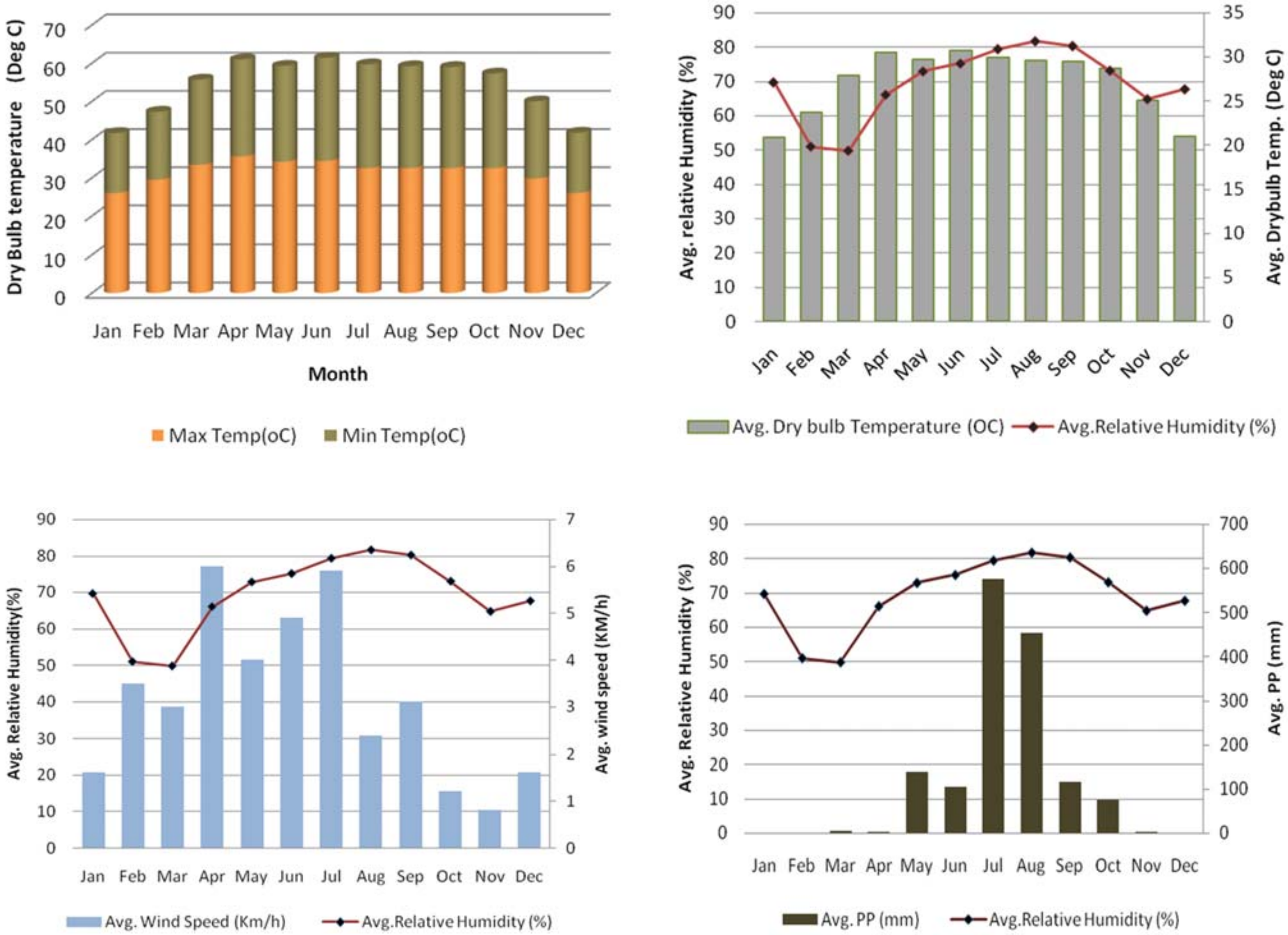

Figure-4: Correlation among Mean Air Temperature and other Monthly Climatic Data of 2009 (Source: Bangladesh Meteorological Department, 2009)

4.3 Electricity Consumption Scenario

By analyzing various meteorological data of year 2009, a relationship among dry bulb temperature and relative humidity has been established [Figure-4]. Along with these, an investigation has been carried out to find out a relationship with average relative humidity (%) and both average precipitation (mm), and average wind speed (km/h). From the figure it has revealed that average ranges of dry bulb temperature are found to be higher from March to October in this year. Again a strong correlation has been established between dry bulb temperature and average relative humidity. The relationship between average relative humidity and average wind speed in the same year showed a moderate correlation. But from August to September, there is a negative relationship between average relative humidity and average precipitation (mm).

4.3.1 Utility Bill Analysis with Meteorological Data

Through analyzing the energy consumption data with the meteorological data, it revealed that the electrical energy consumption is high during March to August than the rest of the year for the three selected buildings [Figure-5]. Again the same scenario is visible for the total billed amount (in BDT) for electricity consumption.

For both cases, the energy (electricity) consumption per unit area (m^2) of Khalique Tower (Prime Asia University campus-01) is always higher as it has glazed curtain walls at southern and northern sides.

Again though the total yearly energy consumption of Ahsanullah University of Science & Technology (AUST) is higher than other two but the amount of energy consumption per square meter is the lowest due to having

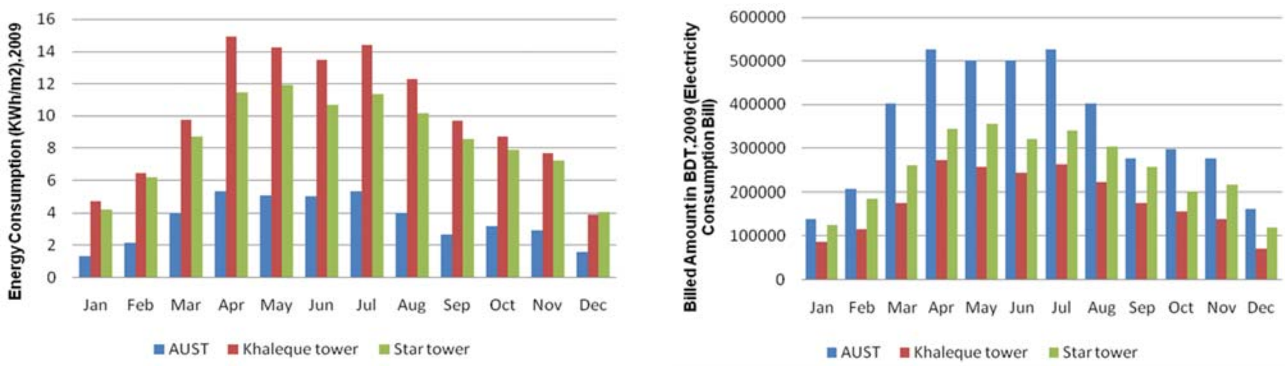

Figure-5: Energy Consumption Data per Month, for the Year 2009

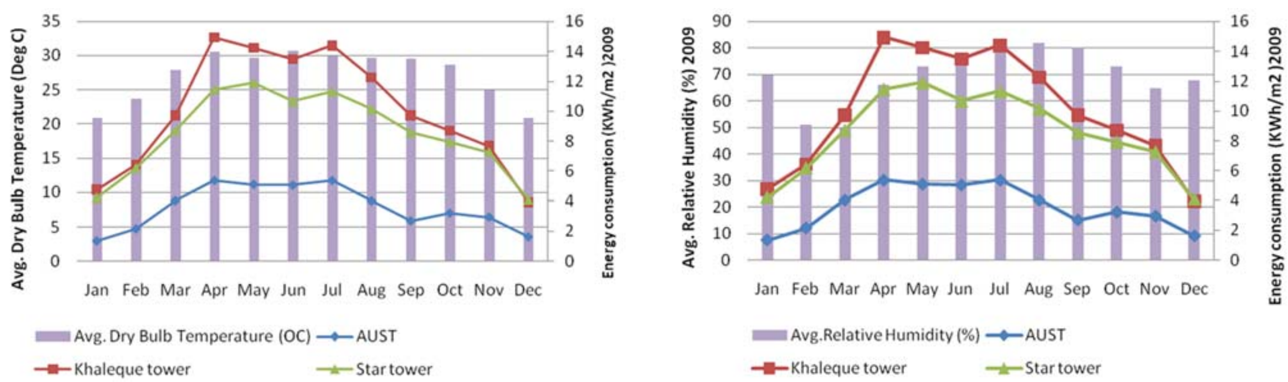

Figure-6: Relationship between Meteorological Data and Energy Consumption Data, Year 2009.

highest percentage of naturally ventilated area in comparison to other two institutional buildings [Figure-6].

From the [Figure-6], a positive relationship is revealed through this analysis. There is an impact of climate on energy consumption of high rise institutional buildings of Dhaka city, as similar increase or decrease in energy consumption correlating the fluctuation of curves of average dry bulb temperature (To), and relative humidity (RH).

4.3.2 Statistical Analysis

The calculated results from utility bills showed a good correlation with climatic data of the year 2009 [Figure-7 & 8]. It is evident from the analysis that the energy consumption of all three case study buildings showed a stronger positive correlation with dry bulb temperature than the average relative humidity.

To justify the above comparative analysis with some definite numeric outcome, some statistical analyses like correlation, F-test, T-test and Linest [Table-3] is done among the detail monthly record of meteorological data and electrical energy

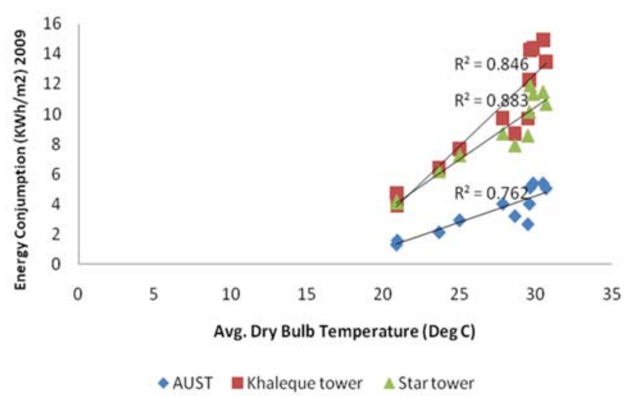

Figure-7: Regression Analysis between Average Dry Bulb Temperature and Energy Consumption Data, Year 2009.

consumption data of the studied area for the year 2009 with the help of 'Microsoft Excel' software. Here, 'F-test' function is used to determine whether these two types of data have different variances. 'T-test' is done to determine probability associated with these data, whereas 'Linest' is done to calculate some linear values that best fits these data. The value of R properly justifies this above mentioned

Met. Data type	Highest Correlation with Energy consumption 'R'	'F test' with Energy consumption	'T Test' with Energy consumption	Digression with Energy consumption (LINEST)
Average Dry bulb Temp Deg C	0.94	0.22	0	2.2
Average RH (%)	0.39	0	0	4.3

Table-3: Statistical Analysis of meteorological data and energy consumption and the results, Year 2009
(Source: Met Data and DESCO, DPDC and MS Excel, 2007)

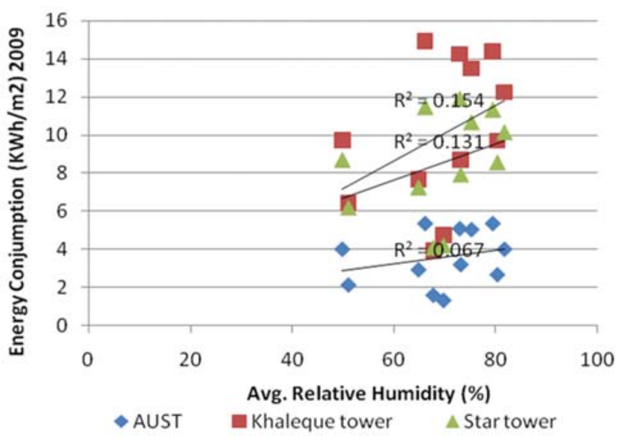

Figure-8: Regression Analysis between Average Relative Humidity and Energy Consumption Data, Year 2009.

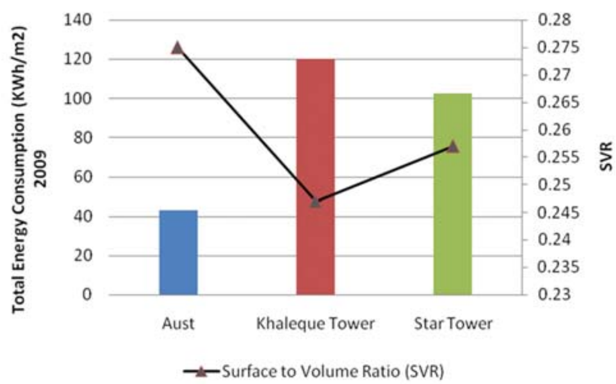

Figure-9: Comparative analysis between energy consumption data and surface to volume ration of three buildings.
(Source: DESCO, DPDC and Field survey).

statement. The highest correlation (R=0.92) showed between the energy consumption of 'Khaleque Tower' and average dry-bulb temperature. Along with that, both 'AUST' building and 'Star Tower' showed the highest values of 'R', which is 0.87 and 0.94 consecutively. Whereas, the value of 'R' between average relative humidity and energy consumption for each of these three buildings are lower than their respective average dry bulb temperature. The value of 'R' between average relative humidity and energy consumption of 'AUST', 'Khaleque Tower' and 'Star Tower' is respectively 0.26, 0.39, and 0.36.

4.4 Comparative Analysis of Energy Consumption and SA:V Ratio

The greater the surface area, the more is the heat gain/ loss through it. So, small surface to volume ratio implies minimum heat gain or minimum heat loss. To minimize the losses and gains through the fabric of a building, a compact shape is desirable. In tropical region, S/V ratio should be as low as possible as this would minimize heat gain. This might not necessarily minimize the S/V ratio. Further, the materials of construction should be such that they do not store heat. Surface to volume ratio shows an almost reverse or negative correlation with the total energy consumption [Figure 9]. Though the energy consumption per unit area is smaller for Ahsanullah University of Science and Technology (AUST), but it has the highest S:V ratio. This shows that there are other parameters or variables like orientation of the building, fenestration, user behavior etc. to guide the total energy consumption of a building.

4.5 Comparative Analysis of Energy Consumption and Percentage of Naturally Ventilated Area

It is evident from [Figure-10], that if the percentage of naturally ventilated area increases, the energy consumption decreases. According to the scope of study and its observations, analysis and results, it is clear that there is very little effort and apparent initiatives to design and build

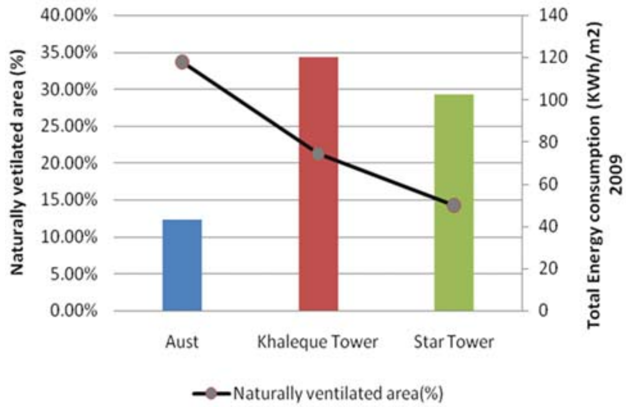

Figure-10: Comparative analysis between energy consumption data and percentage of naturally ventilated area of three buildings. (Source: DESCO, DPDC and field survey)

institutional buildings with a prior plan for substantially lower energy consumption. Thus diagnosis and analysis for building energy consumption as the first step of building energy saving project, is the most important to improve the management of building energy.

5. CONCLUSION

The growing trend of building energy consumption in Dhaka city will continue during the coming years due to expansion of built-up areas and associated rising trend of energy needs. Energy in the form of electricity is used in buildings to operate equipment for the safety, efficiency and comfort of its occupants and users. This indicates an alarming situation for future of Dhaka. Thus an effective initiative should be taken to supervise the building energy consumption scientifically.

Careful architectural design can contribute to a reduction in a building's energy consumption and thus improve its performance. Passive design measures incorporating local climatic parameters and surrounding site conditions can play an important role in improving indoor thermal conditions, which will eventually reduce the overall energy consumption of respective building. Therefore, energy efficiency supervision system composed of five basic systems, which are, energy consumption statistics, energy audit, energy-efficiency public notice, energy consumption ration and price rising for over ration for large-scale public (Jin et al. 2007, pp 19-22) is essential. The analysis of such kind of model is especially useful for building managers, owners to track energy use during pre-retrofit and post-retrofit periods and to reduce building operational costs in the tropical region. Thus to achieve a safe, comfortable, healthy and productive environment, a seamless integration and collaboration among various professionals is required.

Acknowledgment: Special acknowledgement to Prof. Dr Khandaker Shabbir Ahmed for his guidance and Department of Architecture, Bangladesh University of Engineering and Technology (BUET).

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