TUTA/IOE/PCU

Journal of the Institute of Engineering, 2017, ***13(1):*** *102-107*

Printed in Nepal

Impact of Rise in Atmosphere Temperature on an Official Building's Energy Consumption in Kathmandu

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Received: *April 10, 2017* ***Revised:*** *Dec 10, 2017* ***Accepted:*** *Dec 15, 2017*

Abstract: The objective of this research is to study the impact of rise in atmospheric temperature, in buildings energy consumption in the future. An existing Typical Meteorological Year (TMY) weather file of time span 1973-1996 composed of weather data by Solar and Wind Energy Resource Assessment (SWERA) project is assumed as the baseline climate in this study. Monthly average temperature of future years in business as usual scenario predicted by Meteonorm is downscaled to hourly temperature data using downscaling method, morphing. This showed that annual average air temperature of the atmosphere will increase by 1.64¬0C, 2.12¬0C, 2.52¬0C and 2.28¬0C from baseline year in the years 2010, 2020, 2030, and 2040 respectively. Building energy simulation tool eQUEST is used to analyze the energy consumption pattern of a selected building located in Kathmandu. Study has shown that total energy consumption of the building for heating, cooling, lighting and miscellanies equipment will increase by 4.9%, 6.2%, 7.3% and 8.3% for the years 2010, 2020, 2030 and 2040 respectively from baseline year whereas cooling load will increase by 19%, 23%, 27% and 31%. The study also has shown that insulating a building will decrease the energy consumption. There will be decrease in the cooling energy consumption by 2.29%, 2.98%, 4.06% and 4.78% in the years 2010, 2020, 2030 and 2040 respectively after addition of insulation material mineral wool/fiber.

Keywords: Building, energy, cooling load, TMY, eQUEST

1. Introduction

Climate change is an emerging problem of global scale having deep impacts at local scale. Effects of global warming encompass all vital systems supporting world populations, namely, water resources, human health, agriculture, forests and biodiversity. Predictions published by the Intergovernmental Panel on Climate Change (IPCC) indicate an increase in global average surface temperature in different scenario from 1.1 – 2.98^0C to 2.4 – 6.48^0C from a 1990s baseline at the end of the 21st century [8]. Global surface temperature for the end of the 21st century is likely to exceed 1.5°C relative to 1850 to 1900 for all Representative Concentration Pathways (RCPs) scenarios except RCP2.6 [8].

According to Organization for Economic Co-operation and Development (OECD), there is significant warming trend in Nepal [1]. Nepal is among the most vulnerable countries to climate change since the annual mean temperature growth (0.06^{0}C) is at least six times higher than the global average [13]. Trend analysis of maximum temperature data from 49 stations in Nepal for the period 1971-1974 showed that the average temperature increased by 1.8^{0}C and the average temperature increase was 0.06-0.12^{0}C per year in the Mountain and Himalayan regions [14]. Observed data indicates consistent warming and rise in maximum temperature at an annual rate of 0.04 – 0.06ºC [11]. Mean annual temperature across Nepal is projected to increase by 0.5 – 2.0 º C with the multimodal mean of 1.4 º C by 2030s and 1.7- 4.1 º C with a multi-model mean of 2.8 º C by 2060s [12].

The concern on climate change leads to growing demand for minimization of energy use. As building is one of the largest energy consuming sectors, it is essential to study the impact of climate change on building energy performance.

In the more developed regions of the world about 75% of the population live in urban areas. In most modern cities, air-conditioned building is the largest electricity consumption sector. This implies that the effects of climate change need to be addressed specifically in the urban built environment. It is therefore essential to start incorporating the potential impacts of climate change into building design strategies and urban planning regimes now, since consideration at an early stage will help to prevent or at least diminish the occurrence of negative impacts such as flooding or excessive overheating [9]. In the recent years, there is increment of the commercial buildings in Nepal accompanied by the thermal comfort demand. The lack of electricity and other commercial sources of energy in our country necessitated the use of energy efficient buildings.

In literatures, it is found that under the IPCC's most likely carbon emission scenario (A2), cooling electricity usage will increase by about 25% under the condition that the cooling technology stays at the same level in the future over the next 100 years in certain areas of California [15]. Another study found that there will be substantial increase in A/C energy consumption under the impact of future climate change, ranging from 2.6% to 14.3% and from 3.7% to 24% for office building and residential flat, respectively [5].

The main aim of the study is to assess the impact of climate change on energy consumption pattern of a selected building in the years 2010, 2020, 2030 and 2040. Year 2010 has also been taken as a future year in reference to the baseline year to show the trend of results. In addition to this, the effect of insulation of the building in the energy consumption has been discussed. The energy simulation has been performed using eQUEST.

2. Methodology

A building located in Sanepa, Kathmandu is selected. The building model is according to related design standards and survey data. AutoCAD drawings of the building are used to extract the building footprint design. Occupancy profile, lighting profile and other miscellaneous profiles are on the basis of standard profiles for official building. Building envelope materials properties are based on the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1-2006 guide. An existing TMY weather file of time span 1973-1996 composed using weather data by SWERA project was assumed as the baseline climate in this study. The file consists of the hourly data of various weather parameters. Meteonorm is used to predict the future monthly average temperatures. It is a meteorological database containing comprehensive climatological data for solar engineering applications and building applications. A 'business as usual' scenario, which assumes mid-range economic growth but no measures to reduce greenhouse-gas emissions is selected in prediction process.

In order to apply the future monthly mean temperatures to the building energy demand predictions a downscaling method, Morphing, is utilized to generate the future TMYs on the basis of an existing TMY. The Morphing method was constructed by Belcher and has been widely used by researchers from USA, UK, Australia, and HK [3]. By means of shifting and stretching, the predicted changes of the future monthly mean temperatures are downscaled and combined with the hourly temperatures of the existing TMY.

Energy simulation tool e-QUEST is used which predicts hourly energy use and energy-cost by carrying out hourly energy simulation of the building design for one year based on input weather data. e-QUEST can calculate hour by-hour building energy consumption over an entire year using hourly weather data for the location under consideration. Here, simulation is carried out for the baseline year and future years for the same building setup.

3. Results and Discussions

3.1. Comparison of Hourly Temperatures of Baseline Year and Future Years

Annual average temperature of Kathmandu is 17.67^{0}C for the selected Typical Meteorological Year. Monthly average data downscaled to hourly data showed that this annual average temperature will increase from 17.67^{0}C to 19.39^{0}C, 19.79^{0}C, 20.19^{0}C and 20.49^{0}C for the year 2010, 2020, 2030 and 2040 respectively. It also concluded that 50% of total number of hours of a year will have temperature more than 22^{0}C in the year 2040 which is only 19^{0}C at the baseline years. Only 25% of total number of hours of baseline year is having more than 22^{0}C dry bulb temperature but for the future year 2040 we will be facing this temperature for 50% of total number of hours of a year. All these indicate that there will be rise in the atmosphere temperature in the coming years.

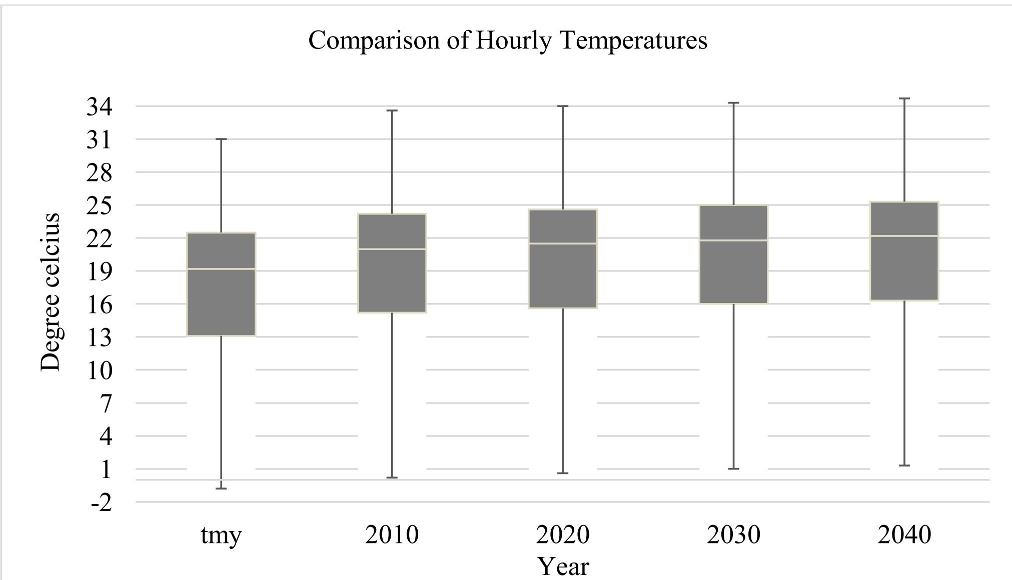
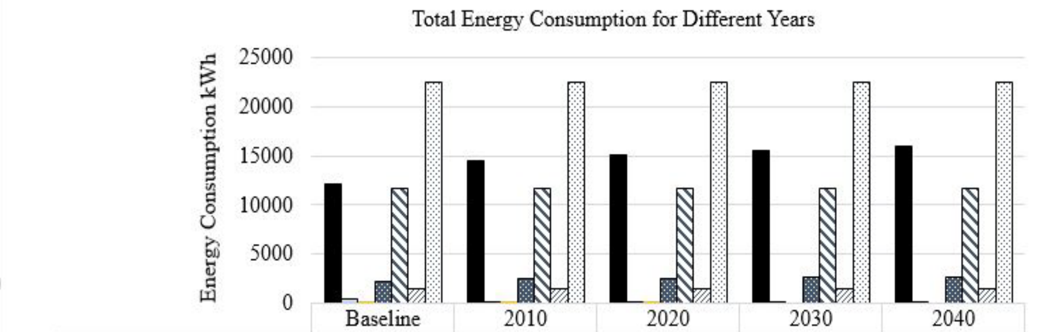


Fig. 1: Comparison of Hourly Temperatures

3.2. Comparison of Energy Consumption for Different Years

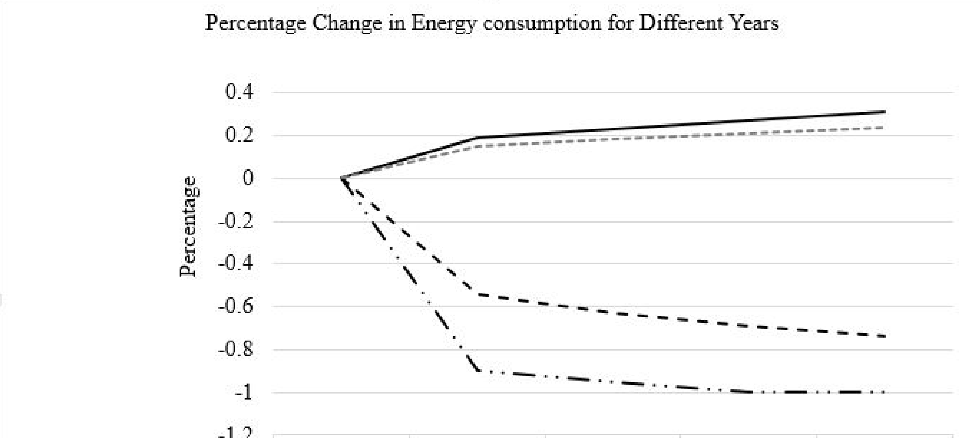
Fig. 2 is the total energy consumption for different years in different parameters. Total electric consumption of the building in the baseline is 50,271 kWh which will increase up to 52707 kWh, 53377 kWh, 53927 kWh and 54,432 kWh for the year 2010, 2020, 2030 and 2040 respectively.



	Baseline	2010	2020	2030	2040
Space Cooling	12182	14502	15023	15535	15999
Space Heating	359	166	131	110	93
Heat Pump Supplies	20	2	1	0	0
Ventilation Fans	2150	2477	2551	2612	2669
Miscellaneous Equipment	11697	11697	11724	11724	11724
Task Lights	1398	1398	1403	1403	1403
Area Lights	22465	22465	22544	22544	22544

Fig. 2: Total Energy Consumption in Different Years

There will be increase in the space cooling energy from 12182 kWh to 14502 kWh, 15023 kWh, 15535 kWh and 15999 kWh in the years 2010, 2020, 2030 and 2040 respectively. Other parameters of energy consumption are presented accordingly.



	Baseline	2010	2020	2030	2040
Space Cooling	0	19%	23%	27%	31%
Space Heating	0	-54%	-63%	-69%	-74%
Heat Pump Supplies	0	-90%	-95%	-100%	-100%
Ventilation Fans	0	15%	18%	21%	24%

Fig. 3: Percentage Change in Energy consumption for Different Years

Fig. 3 shows the percentage change in the energy consumption in different years. There will be increase in the space cooling energy by 19%, 23%, 27% and 31% for the year 2010, 2020, 2030 and 2040 respectively. Also there will be decrease in the space heat consumption by 54%, 63%, 69% and 74% for the year 2010, 2020, 2030 and 2040 respectively. Although the percentage value of decrease in heating load is higher than increase in cooling load, amount of increase in cooling load is very larger than decrease in heating load. Since the building running operation and other schedules are kept same, other parameter of energy consumption will remain nearly as it is. There will be 8.3% increment in the total building's energy consumption in year 2040 from the baseline year.

3.3. Results Analysis after Insulating the Building

After the result analysis for the different years, insulating material is added in all the exterior walls. The material is added inside the vertical wall surfaces. Insulating material added is Mineral Wool/Fiber of thickness 3.5 inches with total thermal insulation value R-11 (h·ft2·°F/Btu). Building energy simulation performed after the addition of thermal insulation showed that there will be decrease in the energy consumption of the building.

Table 1 shows that insulating a building will decrease the energy consumption. There will be decrease in the cooling energy consumption by 2.29%, 2.98%, 4.06% and 4.78% in the years 2010, 2020, 2030 and 2040 respectively. Furthermore there will be decrease in the building heating load by 0.5%, 0.92%, 1.27% and 1.51% in the years 2010, 2020, 2030 and 2040 respectively.

Table 1: Energy Consumption after Insulating the Building

Year		Space Cooling (kWh)	Space Heating (kWh)
2010	Without Insulation	14502	166
	With Insulation	14169	45
2020	Without Insulation	15023	131
	With Insulation	14575	37
2030	Without Insulation	15535	110
	With Insulation	14903	29
2040	Without Insulation	15999	93
	With Insulation	15234	25

4. Conclusion

The impact of climate change mainly due to rise in atmospheric temperature, in buildings energy consumption in the future has been studied. It has been found that there will be increase in the total building's energy consumption by about 4.9%, 6.2%, 7.3% and 8.3% for the years 2010, 2020, 2030 and 2040 respectively. Space cooling energy will increase from 12182 kWh to 14502 kWh, 15023 kWh, 15535 kWh and 15999 kWh by 19%, 23%, 27% and 31% for the year 2010, 2020, 2030 and 2040 respectively. Also there will be decrease in the space heat consumption from 359 kWh to 166 kWh, 131 kWh, 110 kWh and 93 kWh by 54%, 63%, 69% and 74% for the year 2010, 2020, 2030 and 2040 respectively. Although the percentage value of decrease in heating load is higher than increase in cooling load, amount of increase in cooling load is very larger than decrease in heating load. The study concludes that annual cooling loads will increase at a much greater rate than heating loads will decrease. Since the building running operation and other schedules are kept same, other parameter of energy consumption has remained nearly as it is. Further it is concluded that addition of insulation material in the vertical exterior walls will reduce the energy demand.

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