

Determining the impact of CDDs on Energy consumption of an office building in Hyderabad using Energy Plus Software

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Abstract — Climate change and cooling degree days are the cursors of higher heating and cooling energy demand and may affect thermal comfort significantly. The high energy consumption to make environment comfort results in environmental degradation along with depletion of conventional energy resources and can burden the whole economy. Thus, a sensible usage of energy along with better management of environmental issues affiliated with energy consumption, results in cost reduction. The main purpose of this research is the calculation of cooling degree days (CDD) and its impact on electrical power consumption in Hyderabad Pakistan. To achieve this, a fixed base temperature of 24°C (75.2°F) is used to estimate the cooling degree days (CDD) for the months from March to September. To find out the impact of CDD on energy demand, a single room building having an air conditioning system has been simulated using Energy Plus software. A 3D model of building having an area of 20m² and other parameters like design day and material specifications have been provided for simulation. The results show that to overcome 1°C of air conditioning load 5675 kJ (1.576 kWh) of energy is required. The energy factor is then used to determine the power required for an air conditioning system to overcome CDD or to maintain thermal comfort. It is found that 232.6 kWh/m² energy is required during the month of March while 539 kWh/m² during the month of May based on CDD to maintain required level of thermal comfort.

Index Terms— CDDs, Energy consumption in building, energy consumption prediction using Energy Plus, Energy Plus.

I. INTRODUCTION

Energy used in buildings accounts for 20% of the world's total energy consumption. The Energy Outlook 2018 (IEO 2018) benchmark scenario showed that energy consumption in buildings worldwide will increase by an average of 1.3% per year between 2018 and 2050.[1]

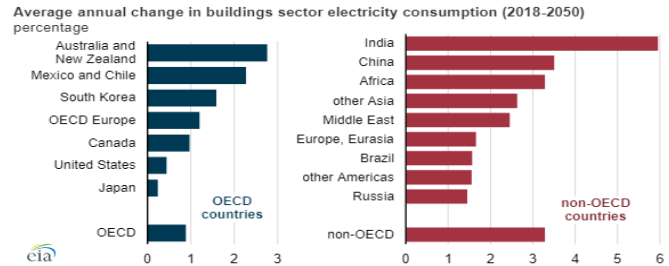


Fig 1. Average-annual change in building sector electricity consumption in OECD and non-OECD countries.[1]

The EIA expects total building electricity consumption in non-OECD countries to exceed electricity consumption in OECD countries in the early 2020s. By 2050, buildings in non-OECD countries combined will consume twice as much electricity as in OECD countries. Building electricity consumption per capita in OECD countries will increase by 0.6% per year between 2018 and 2050. The relatively slow growth is influenced by the development of building regulations and improvements in the efficiency of appliances and equipment. Although the rate of growth is lower than in non-OECD countries, per capita building energy consumption in OECD countries will continue to be higher than in non-OECD countries due to higher demand for energy-intensive services such as space cooling. Where in Pakistan the electricity consumption is low due to the high price of electricity.[2], [3] [1]

A. Introduction to CDDs

CDDs are basically the way to measure the energy consumption more the CDDs more the electricity consumption so ASHRAE has proposed the way to calculate CDDs. It is the simply the degrees to be cooled to make the space thermally comfortable.[4]–[6]

B. Importance of CDDs

CDDs or simply degree days play important role to predict the demand of electricity in particular season and at particular location it changes location by location and depends on average temperature.[7]–[9] .

II. OBJECTIVES

This research work is carried to determine the energy factor from the simulation using the energy plus software of the

office building in Hyderabad and using the value of power factor in KWH. By this we will achieve monthly power consumption for months and impact of CDDs on Energy consumption of building in Hyderabad.

III. METHODOLOGY

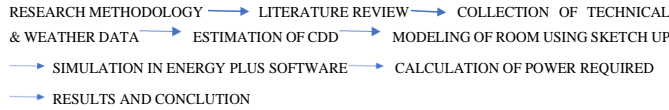


Fig: 2 Flow Chart

- Weather data has been collected from meteorological department website, NOAA[10] and some other from non-governmental organization and cooling degree days thus obtained taking the base temperature of 24°C. In this research work, we collected the hourly as well as daily average air temperature data from different sites at the latitude of +25.383°N, longitude of +68.417°E and at the elevation of +41ft which includes Dry bulb temperature (degree Celsius), pressure (bar), relative humidity (%), wind speed (m/s) to estimate the cooling degree days and energy consumption relating to cooling degree days. [11]
- The room designed here is located in the area of Hyderabad and has a latitude of 25.38 degrees and a longitude of 68.42 degrees. Room area 20m², ceiling height 3m. It is a naturally ventilated room with surfaces made of various materials such as brick, marble, concrete, wood, glass, etc. The door in the window opening is on the south wall and is made of wood. There is also a window. The window is located on the west wall and has a floor area of 2 m². A room is built in a single zone with the Energy Plus zone option.
- CDD are calculated using $CDD = T(AVG) - T(BASE)$ whereas $T_{avg} = (T_{max} + T_{min}) / 2$ and $T_{base} = 24^{\circ}C$. [7]
- The daily average air temperature data for Hyderabad is used to determine cooling degree-days to achieve thermal comfort. To find out impact of cooling degree days on energy consumption, we collected the temperature data to estimate the cooling degree hours of months mentioned above. For this purpose, we subtracted temperature data from base temperature and multiply with 24. The temperature after subtraction from base temperature was the required cooling degree hours that is to be decreased to achieve the thermal comfort. $DH = DD * 24$. [12]
- Sketch up CAD software was used to Design room. [13], [14]
- Energy plus is fully integrated software package by US energy department to use in HVAC applications. [15]
- Simulations are done on EP Software.
- Note : degree hour can be estimated by multiplying degree days with 24. [16]

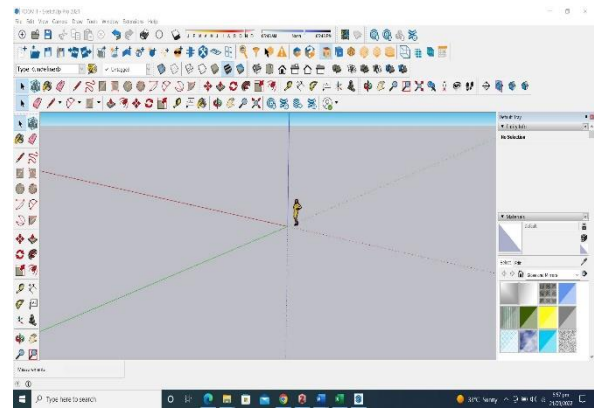


Fig. 3 Workspace of SketchUp

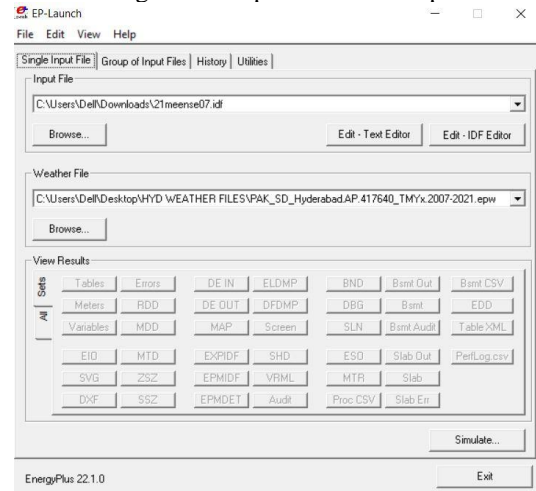


Fig: 4 Energy Plus 22.0 Version workspace.



Fig: 5 Energy plus run status

TABLE: I Room Description

S. No.	Field	Size	Unit
1.	Longitude	68.36	Degree
2.	Latitude	25.38	Degree
3.	Ceiling Height	3	m
4.	Length	5	m
5.	Width	4	m
6.	Floor & Roof Area	20	m ²
7.	City	Hyderabad	-
8.	Weather file	Hyderabad	-

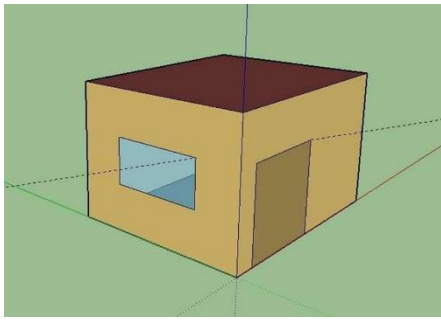


Fig: 6 Single Room

TABLE II: Site Location

S. No.	Field	Units	Object
1.	Name	-	Hyderabad, Pakistan
2.	Longitude	Degree	68.36
3.	Latitude	Degree	25.38
4.	Time zone	Hour	5
5.	Elevation	m	30

TABLE III: Single Zone detail.

Field	Units	Object
Name		Zone
Direction of Relative North	Degree	0
X Origin	m	0
Y Origin	m	0
Z Origin	m	0
Type		1
Ceiling Height	m	3
Volume	m3	60

IV. RESULTS AND DISCUSSION

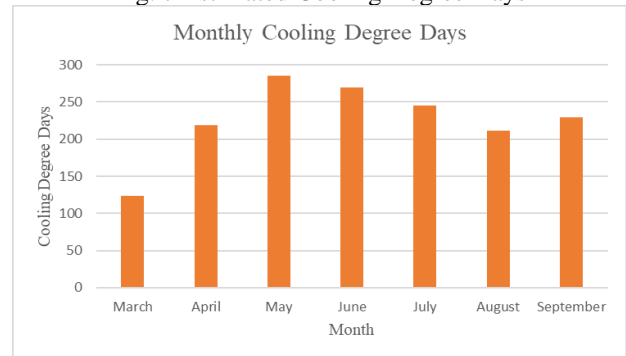
Estimation of CDDs

Using meteorological data, the cooling degree days of months: March, April, May, June, July, and September are estimated. To achieve this goal a fixed base temperature of 24°C (75.2°F) is used to estimate the cooling degree days (CDD). Estimation of cooling degree days for each month in tabular form is shown below. A trend is also presented showing cumulative degree days of above-mentioned months. Table: 4 shows that cooling degree days are highest during the month of June whereas lowest during the month of March. Fig: 7 shows the variations in cooling degree days. This analysis also shows the need of energy required by an air-conditioning system to overcome CDD or to maintain thermal comfort.

TABLE IV: Estimated Cooling degree days

Day/Month	Cooling Degree Days for Year 2021 Hyderabad						
	March	April	May	June	July	August	September
1	-1	7	8	9	9	7	9
2	1	8	8	9	8	7	9
3	2	8	8	9	8	7	7
4	3	6	8	9	9	7	5
5	5	7	9	9	8	7	7
6	4	7	8	9	9	7	7
7	3	6	9	9	8	7	8
8	3	6	10	9	8	7	8
9	3	7	9	9	8	6	5
10	2	8	9	9	9	7	7
11	2	9	9	9	10	6	7
12	1	9	9	9	5	5	9
13	2	7	9	9	9	6	10
14	4	5	9	9	9	6	10
15	4	7	10	9	8	7	9
16	5	7	11	10	7	7	9
17	5	5	12	9	9	7	9
18	3	7	8	8	8	7	9
19	4	7	10	9	7	7	7
20	5	6	9	9	7	7	8
21	5	6	9	9	9	7	8
22	3	8	9	9	9	8	7
23	3	9	8	9	9	7	8
24	5	8	9	8	8	7	3
25	5	9	10	9	8	7	6
26	7	9	12	9	7	7	8
27	8	9	10	9	6	6	8
28	8	7	9	10	5	6	8
29	3	7	9	9	7	6	9
30	8	8	9	8	7	7	5
31	7	-	9	-	7	9	-
Σ Sum	123	219	285	269	245	211	229

Fig. 7 Estimated Cooling Degree Days



Simulation Parameters and results

Simulation has been done in the building operating in air-conditioned space to determine the energy factor to overcome 1°C. Different input and output parameters for an air conditioning building are used to determine the energy factor. The input parameters include input data file (IDF) with a day designed with specific temperature, humidity, and other factors. Whereas output parameters include Cooling: District Cooling [kJ] and Cooling: Energy Transfer [kJ]. The energy factor after simulation found out to be 5675.472 kJ (1.576 kWh). This energy factor is then utilized to determine the power required by an air conditioning system to overcome CDD or to maintain thermal comfort. Moreover, we have plotted the power graphs of months: March, April, May, June, July, August, and September.

Energy consumption results based on CDD

The cooling degree hours of months: March, April, May, June, July, August, and September are estimated. The energy factor then used to determine the power required by an air

conditioning system to overcome thermal comfort in afore mentioned months. In doing so, total power required by the system has been calculated for each hour of above-mentioned months and the power graph are also plotted showing the variation in energy consumption.

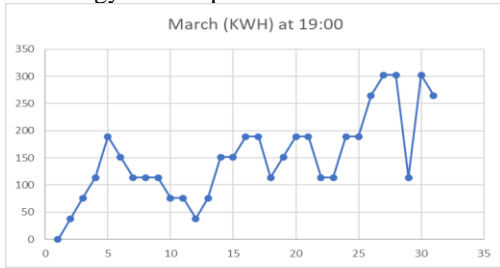


Fig. 8 Energy Consumption for March

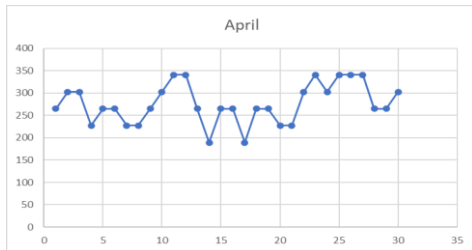


Fig. 9 Energy Consumption for April

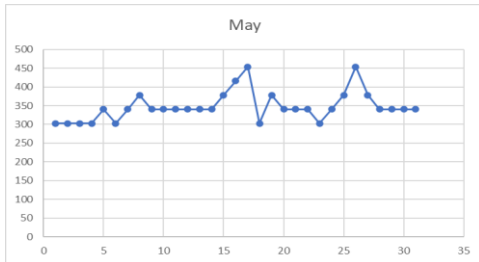


Fig. 10 Energy Consumption for May

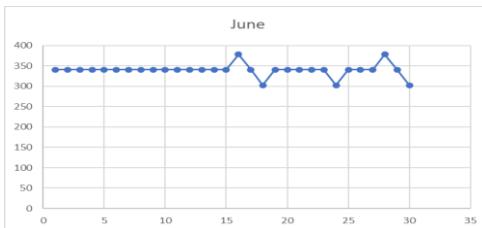


Fig. 11 Energy Consumption for June

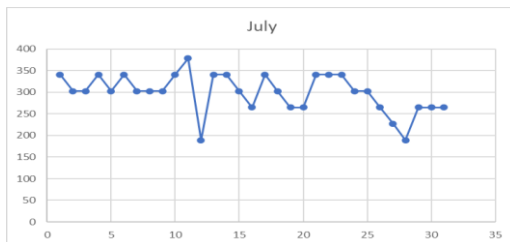


Fig. 12 Energy Consumption for July

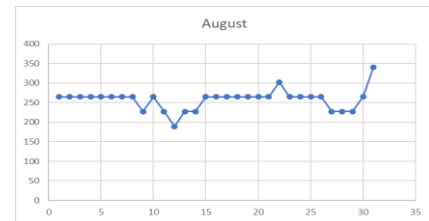


Fig. 13 Energy Consumption for August

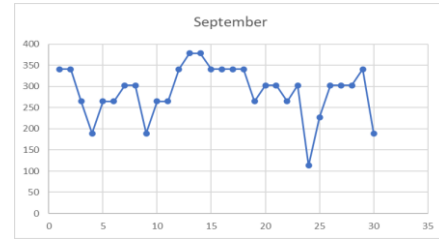


Fig. 14 Energy Consumption for September

Overall Comparison of different months

This is monthly overall power required to maintain thermal comfort the highest was observed in month of May and lowest in month of march.

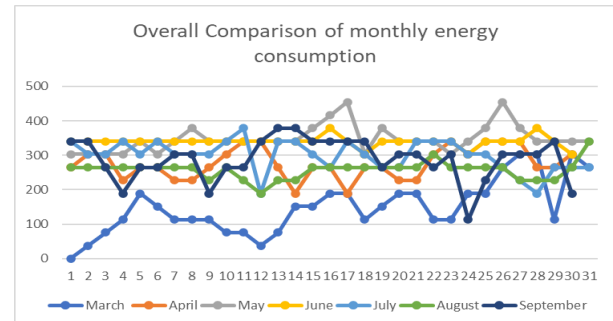


Fig. 15 Overall Comparison of monthly energy consumption.

V. CONCLUSIONS

Estimated the cooling degree days for the months of March, April, May, June, July, August & September. The highest cooling degree days were observed during the month of May i.e., 285 which is being considered as hottest month. On contrary the lowest cooling degree days were observed during the month of march i.e., 123 which is generally consider the month having modest temperature in location like Hyderabad. This estimation concluded that large amount of energy is required during the month of May and less amount of energy is required during the month of march to maintain thermal comfort. Ultimately proper energy management can be easily done using cooling degree days.

It is estimated through cooling degree hours for every individual day for the months of March, April, May, June, July, August, and September. Energy plus software is used for the simulation purpose to determine the energy factor required by an air conditioner to overcome 1°C which was found to be 1.576 kWh. Then we multiplied this factor with the cooling degree hours of each month mentioned above and got monthly energy consumption of each month. The highest energy consumption was observed during the month May i.e., 10780 kWh and the lowest energy consumption was observed during the month of March i.e., 4652 kWh. This implies that the

power requirement is highest for the month of May and lowest for the month of March. This study makes us able to utilize appropriate power for different months and can also reduce power wastage which ultimately results in reduced electricity cost.

It can be concluded that by analyzing the estimation of cooling degree days better and proper energy management can be easily done. Furthermore, by considering the cooling degree hours monthly as well as annual power requirement to maintain thermal comfort can be easily determined, and it will also make us able to utilize the appropriate power which will result in reduction of energy wastage.

It is thus concluded that DDs have direct impact on energy consumption of building.

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