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Benchmarking of Buildings for Energy Consumption in Pakistan

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***Abstract*— Pakistan suffers a continuous energy crisis and needs all out efforts to overcome this problem. The use of locally available renewable energy and energy conservation offers a viable solution to the energy crisis. As Pakistan consumes 50% of its primary energy in the building sector, and therefore, offers a huge potential for energy saving. This study estimates the energy consumption in buildings as a function of heating and cooling degree days for all climate zones of the country. Both components (weather independent and dependent) of the energy used in buildings are calculated using EnergyPlus software. Energy consumption is estimated both for conventional buildings and buildings built approximating Building Energy Code of Pakistan (BECP). The results show a huge reduction in energy consumption in BECP buildings. The paper also demonstrates how to calculate energy consumption in houses in all zones of Pakistan.**

***Index Terms*—Building Energy Consumption, Cooling Degree Days, EnergyPlus Software, Heating Degree Days.**

I. INTRODUCTION

Buildings consume about 50% of the total primary energy in Pakistan [1]. This consumption is rising at the rate of 5% annually [2]. An analysis of the life cycle costs of buildings shows that 80 to 90% of the energy goes for operating the building [3]. The heating and cooling energy consumption make a significant component of the building operating bills. These facts clearly show the potential for energy conservation in the building sector. Energy consumed by buildings has two components, one weather independent and other weather dependent. The energy saving potential is much higher in the weather dependent component of building energy consumption. The weather dependent component can be determined by plotting the monthly energy consumption of the building against Heating Degree Days (HDD) and Cooling Degree Days (CDD) of the city in which the building is located [4]. This technique uses linear regression to decompose metered monthly energy use into two parts, a non-weather sensitive component or intercept (α); and a weather sensitive component consisting of βHDD/CDD for that location (1-3)

$$Energy = \alpha + \beta HDD/CDD \quad (1)$$

$$Heating\ Energy = \alpha + \beta HDD \quad (2)$$

$$Cooling\ Energy = \alpha + \beta CDD \quad (3)$$

Where is α intercept (MJ/(m^2-year)), β is heating/cooling slope (MJ/(m^2-year-DD))

HDD and CDD are a function of the base temperature. The base temperature corresponds to the best regression of energy use on degree days.

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This technique has been used in the analysis of conservation measures designed to save heating/cooling energy in residential structure [5]. The present study uses this concept to estimate the energy saving potential in different climatic zone of Pakistan. To achieve this goal, we have estimated the heating and cooling degree days for 15 cities of Pakistan with 6 different base temperatures for 12 months of the year. We calculated heating and cooling energy consumption for the same building envelope built with conventional specifications using EnergyPlus software [6]. We plotted the heating energy consumption of the envelope against the HDD and the cooling energy consumption against the CDD for all cities. It is to be noted HDD and CDD used in the regression above was those calculated with 19°C as base temperature. Finally we repeated the above process to calculate the energy consumption for the same building built using BECP specifications [7].

II. METHOD OF CALCULATING HEATING AND COOLING DEGREE DAYS

Fifteen cities located in different climatic zones of Pakistan were taken (Fig. 1). From the monthly average dry bulb temperature of the all cities [8] were used to calculate HDD and CDD with six base temperatures, ranging from 15°C to 20°C for all months of the year. The detailed calculation for the process is shown for Islamabad only (Table1).

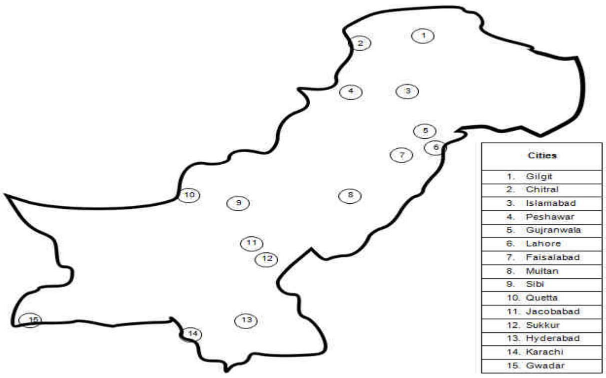

Fig. 1. Fifteen cities of Pakistan

TABLE I. ISLAMABAD DEGREE DAYS

Month	Average Temperature [°C]	Base Temperature											
		15 [°C]		16 [°C]		17 [°C]		18 [°C]		19 [°C]		20 [°C]	
		HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD
January	10.1	151.9	0	182.9	0	213.9	0	244.9	0	275.9	0	306.9	0
February	12.1	81.2	0	109.2	0	137.2	0	165.2	0	193.2	0	221.2	0
March	16.9	0	58.9	0	27.9	3.1	0	34.1	0	65.1	0	96.1	0
April	22.6	0	228	0	198	0	168	0	138	0	108	0	78
May	27.5	0	387.5	0	356.5	0	325.5	0	294.5	0	263.5	0	232.5
June	31.2	0	486	0	456	0	426	0	396	0	366	0	336
July	29.7	0	455.7	0	424.7	0	393.7	0	362.7	0	331.7	0	300.7
August	28.5	0	418.5	0	387.5	0	356.5	0	325.5	0	294.5	0	263.5
September	27	0	360	0	330	0	300	0	270	0	240	0	210
October	22.4	0	229.4	0	198.4	0	167.4	0	136.4	0	105.4	0	74.4
November	16.5	0	45	0	15	15	0	45	0	75	0	105	0
December	11.6	105.4	0	136.4	0	167.4	0	198.4	0	229.4	0	260.4	0
Sub Total		338.5	2669	428.5	2394	536.6	2137.1	687.6	1923.1	838.6	1709.1	989.6	1495.1
Total		3007.5		2822.5		2673.7		2610.7		2547.7		2484.7	

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The base temperature of 19°C gave the best fit for a limited data from urban residential buildings. Using base temperature of 19°C HDD and CDD for each city were calculated for each month and added to get annual total HDD and CDD for each entry (Table 2).

TABLE II. DEGREE DAYS

City	Base Temperature 19 [°C]		Combine HDD and CDD
	HDD	CDD	
Gilgit	2053	794	2847
Chitral	1980	858	2838
Islamabad	839	1709	2548
Peshawar	706	2061	2767
Gujranwala	509	2311	2820
Lahore	442	2397	2839
Faisalabad	502	2401	2903
Multan	448	2734	3182
Sibi	316	3345	3661
Quetta	2017	828	2845
Jacobabad	232	3186	3418
Sukkur	140	2904	3044
Hyderabad	372	2627	2999
Karachi	341	2245	2586
Gwadar	34	2263	2297

The annual HDD were calculated using the relation (4)

$$HDD = \sum_{a=1}^{12} (T_b - T_a)^+ \quad (4)$$

Where T_b is the average ambient temperature of the month (°C), The "+" superscript indicates that only positive values of the bracketed quantity is taken to account and negative value are taken as zero.

The annual CDD were calculated using the relation (5)

$$CDD = \sum_{a=1}^{12} (T_a - T_b)^+ \quad (5)$$

III. Results of HDD and CDD

Heating degree days divide the Pakistan territory in zones. Whole of Sindh, some parts of Baluchistan and Punjab falls in the zone where annual HDD vary from 0 – 400. Central Pakistan where the annual HDD fall between 401 – 700 in a separate zone. The area KPK and Punjab adjacent northern areas have HDD between 701 – 1500 fall into another zone. Northern areas and some part of Baluchistan fall into another zone with HDD between 1500 – 2100 (Fig. 2).

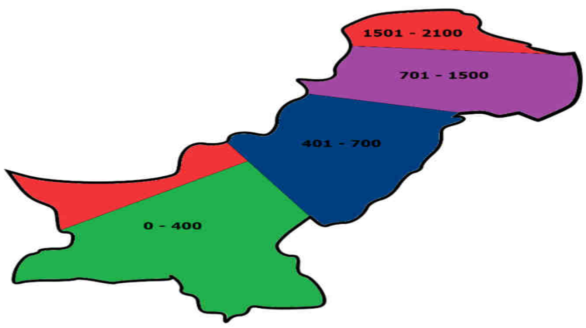

Fig. 2. Heating Degree Days

Cooling degree days divide Pakistan into three zones. The Northern areas and Quetta neighborhood has CDD between 700 –1200 is the first zone. The second zone consists of parts of KPK and Punjab and coastal area of Baluchistan and Sindh with CDD between 1201 – 2500. The third zone consisting of parts from Baluchistan, Sindh and Punjab with CDD between 2501 – 3400 (Fig. 3).

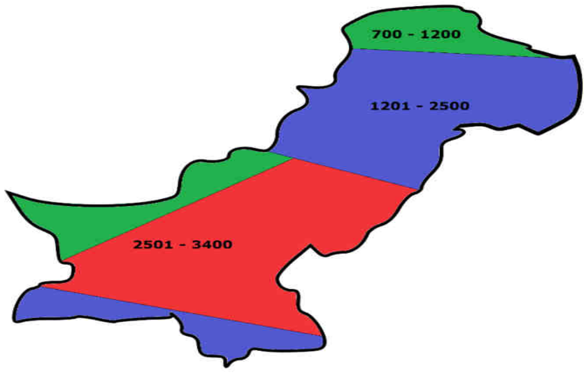

Fig. 3. Cooling Degree Days

IV. Relation of CDD/HDD with Energy Consumption in Buildings

A. *Methodology*

The climatic data of one city from each zone was used as input to EnergyPlus software to calculate the energy consumption in MJ/(m^2-year) for same building envelope for the whole year. The EnergyPlus is an energy analysis and thermal load simulation program. It calculates heating and cooling load necessary to maintain indoor thermal comfort in the specified building. The specific building envelope in our study (Fig. 4) is a rectangular structure with 15 m length, 10 m width and ceiling height 3 m with the long sides facing north and south. The windows are 25% of the total exposed area of the walls and are located in the north and south walls. The component specifications are simulated building are given in (Table 3).

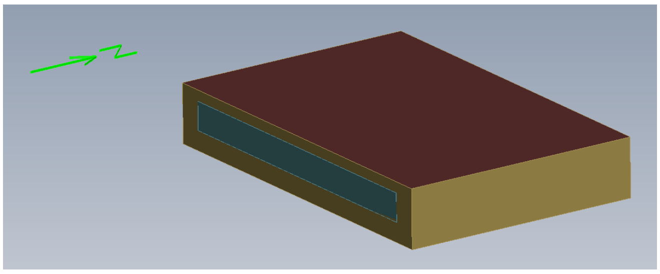

Fig. 4. Building Envelope

TABLE III. SPECIFICATIONS OF CONVENTIONAL BUILDING

Components	Specifications	U (W/(m^2-K))
Walls	229 mm brick wall with 25 mm plaster on both sides	2.14
Windows	5 mm glass, single glazed	5.79
Roof	102 mm concrete slab	4.43
Floor	102 mm concrete slab	6.30
Over all U value		4.59

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The simulators have the following assumptions:

- Indoor temperature set points are between 18°C and 26°C.
- The total internal gain due to people (3.33 W/m^2), lighting (4 W/m^2) and home appliances (2.67 W/m^2), totaling 10 W/m^2

B. Simulation Results

1) Results from Conventional Buildings

The weather data for one city from each zone were input to EnergyPlus for simulation runs. The output from the each run gives heating and cooling energy required to keep the building within the specified temperature range. The heating and cooling energy were plotted against the heating and cooling degree days (Fig. 5). On the x-axis the right side of zero are HDD while on the left side of zero are the CDD. Y-axis represents the energy required by the building in comfortable conditions in MJ/(m^2-year) of floor area. The positive readings are heating and negative readings are for the cooling. The scale of the graph covers HDD and CDD that can possibly occur in Pakistan. A first degree polynomial was fitted using this data and thus the following equation (6) was obtained.

$$\textit{Energy consumption, } E = 0.1423x - 17.6847 \qquad (6)$$

Where E is in MJ/(m^2-year), x is HDD or CDD.

To use (6) for heating energy calculation, number of HDD should be plugged with positive sign. For cooling energy calculations, the number of CDD should be plugged with negative sign. The total annual energy consumption of the building would be the sum of heating energy and absolute value of the cooling energy.

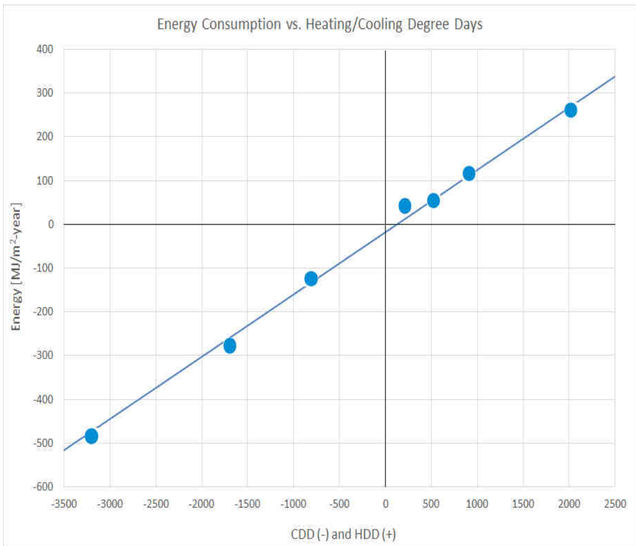

Fig. 5. Energy Consumed with Conventional Specification

2) Results for a Building Built according to BECP

The BECP proposes that building roof should have a value for thermal conduction of 0.58W/m^2-K [9]. With similar values for thermal conductance of Walls, Windows and Floor. The specification of the BECP are shown in (Table 4). The results for the BECP building in different HDD and CDD zones are shown in (Fig. 6) and follow the following equation (7).

$$\textit{Energy consumption, } E = 0.0363x - 14.8233 \qquad (7)$$

Where E is in MJ/(m^2-year), x is HDD or CDD with similar restriction as in (6).

TABLE IV. SPECIFICATIONS OF BECP

Components	Specifications	U (W/(m^2-K))
Walls	229 mm brick wall with 25 mm plaster on both sides	2.14
Windows	5 mm glass, single glazed	5.79
Roof	102 mm concrete slab	0.58
Floor	102 mm concrete slab	6.30
Over all U value		3.31

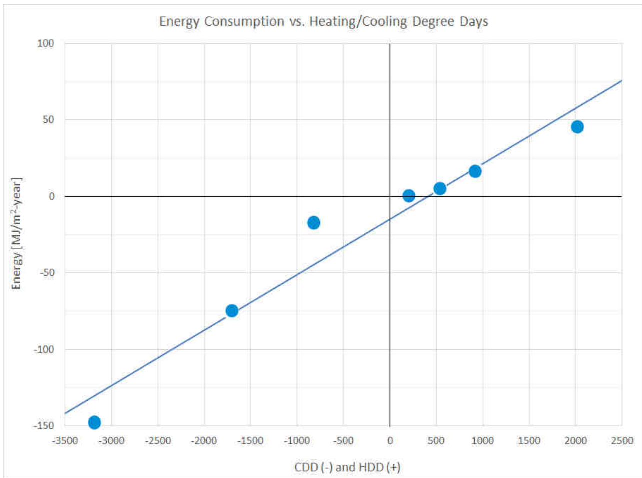

Fig. 6. Energy Consumed with BECP

The simulation results for conventional and BECP building show a huge reduction in energy consumption of the building (Fig. 7). It is to be noted that cooling energy required by the building at zero degree days represent mainly the internal heat loads.

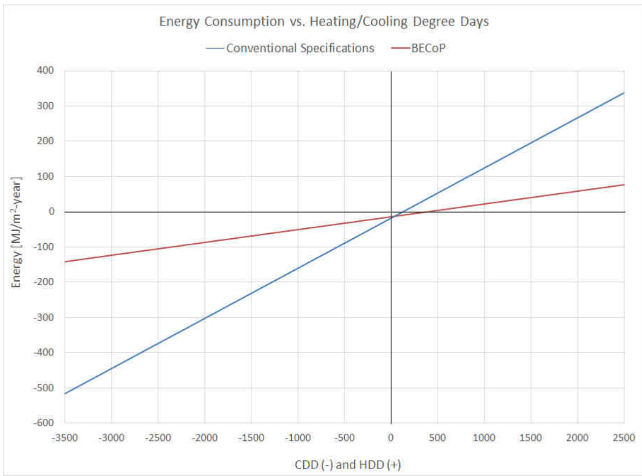

Fig. 7. Comparison of Conventional Specification with BECP

V. PRACTICAL USE OF THE RESULTS

The (Fig. 7) may be used to determine the annual energy consumption of a building envelope in any part of the country. As an example, we calculate the total energy of a building in Islamabad. The heating and cooling degree days for Islamabad are 839 and 1709 respectively. For the conventional building of 200 m^2 covered area using (6). We

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get heating energy of 102 MJ/(m^2-year) * 200 m^2 equals to 20,400 MJ/year and cooling energy 261 MJ/(m^2-year) * 200 m^2 equals 52,200 MJ/year. Therefore the total energy for 200 m^2 conventional house in Islamabad is 72,600 MJ/year.

The house in Islamabad with BECP specification will use heating energy using (7), 16 MJ/(m^2-year) * 200 m^2 equals to 3,200 MJ/year and cooling energy 77 MJ/(m^2-year) * 200 m^2 equals 15,400 MJ/year. The total energy for heating and cooling for BECP house in Islamabad is 18,600 MJ/year.

A house built with BECP specifications saves 54000 MJ/year. The monetary value of this energy is 54000 MJ/year * Rs0.5/MJ equal Rs27000/year. The investment made for roof improvement in BECP building costs Rs350/m^2 [10] is Rs70000/year. Therefore, the payback period of the investment is 2.6 years.

VI. CONCLUSIONS AND RECOMMENDATIONS

- The heating and cooling degree days are important indicators of weather dependent component building energy consumption in all climates. The HDD and CDD based on monthly average dry bulb temperatures are easy to calculate and therefore used in this study.
- The climate zones derived on the basis of HDD and CDD are similar to BECP base ambient dry bulb temperature range.
- The quantification of energy consumption in buildings in different climate zones of Pakistan is explored, perhaps for the first time in Pakistan. The results of this study may be used to set up a benchmark for energy consumption of buildings in Pakistan.
- There is a significance reduction in energy consumption of building using BECP specification with improved roofs.
- A law should be passed to construct all new buildings according to the BECP to overcome energy crises in the country.
- The results of the study may be used to estimate total energy required for heating and cooling of the building anywhere in Pakistan.

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Imran Iqbal, Bachelor of Computer and Information Technology, Master of Information Technology, Master of Science in Mathematical Modeling and Scientific Computing, Imran Iqbal and Irshad Ahmed, Energy Saving Potential in Buildings for Karachi Climate Using Daylight, Conference Proceedings of International Conference on Energy Systems and Policies 2014, November 24-26, 2014, Air University, Islamabad, Research: Cost Effective Net Zero Energy Home in Karachi Climate.

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