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Energy Efficient Modelling of USPCAS-E UET Peshawar Building using eQUEST Software

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***Abstract*—** Energy consumption by the domestic sector in Pakistan is 46% which is one of the highest use by any country. The Government of Pakistan has planned to save 3 Million Tons of Oil Equivalent (33,000 MW) by 2025 through energy efficiency and conservation practices. Conserving this chunk of energy without effecting quality of life and measurements to improve buildings energy efficiency is a problem to be resolved. Several studies have been conducted to evaluate the performance of implementing various sustainability measures in existing buildings via various simulation tools. The purpose of this study is to analyze a fully functional building and find the possible cost effective measurements that can be taken to conserve available energy potential using eQUEST software. The building under study is United States Pakistan Center for Advance Studies in Energy (USPCAS-E), University of Engineering and Technology (UET), Peshawar. An energy efficient model of the building is calibrated in the study in comparison with the actual billing data. The simulation results are very close to actual energy consumption of the building. The overall results indicates that the building is state of the art building with almost all necessary measures already considered but some policy propositions are needed. HVAC and lightning are the significant energy users (SEUs) here and there is a substantial potential for improvement which is presented. Some changes are made in the building occupancy scheduling and some regulations are presented for the occupants behavior change towards energy use.it.

***Keywords*—** HVAC; heating, ventilation, and air conditioning, SEUs; Significant Energy Users, MW; Mega Watt.

I. INTRODUCTION

For the socioeconomic development of any country, energy is considered to be the lifeline and most important instrument and it has become the biggest problem for the entire world because of the increasing demand and dependency on it. So, every country needs a sustainable and affordable energy supply due to increasing population, urbanization and industrialization [1]. Acute energy shortage is the supreme challenge of Pakistan facing severe energy crises since decades and currently facing an electricity shortage of almost 18 hours in rural areas while 10 to 12 hours in urban areas [2]. In addition to adopting alternatives and renewable sources of energy, a country must pay attention on effective use of energy, controlling wastage and saving of energy. Pakistan has a huge potential of saving energy in different sectors. Pakistan can save up to 1,100 megawatts of energy if its industries and households – the two main energy consuming sectors with a 74% share – try to change their behavior about energy conservation, International Project Coordinator Espier Martin Straehle [3].

Pakistan is one of the countries with the highest energy consumption for domestic use. Annual energy consumption by the domestic sector is 45.9% of the total, whereas the industrial sector, consumes about 27.5%. About half of the total energy consumed is used in buildings and/or heating, ventilation and air-conditioning (HVAC) and lighting appliances. [4]. Buildings consume about 50% of the total primary energy in Pakistan [5]. This consumption is rising at the rate of 5% annually [6] half of the total energy consumption and greenhouse gases emissions in the developed countries and fifth of the world's total energy consumption is contributed by the built environment [7]. In 2012, World Energy Outlook published by International Energy Agency (IEA) estimated that by 2035, 41% of the Total global energy saving potential will be from the building sector [8]. An analysis of the life cycle costs of buildings shows that 80 to 90% of the energy goes for operating the building [9]. The governing body for efficiency and conservation of energy in Pakistan is National Energy Efficiency & Conservation Authority (NEECA) with the aim to achieve the challenging task of energy efficiency and conservation in all sectors of economy [10].

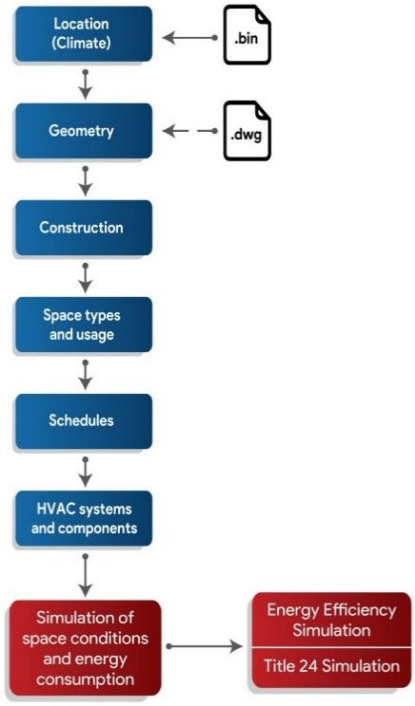

Fig. 1. General work flow in the design development wizard of eQUEST.

With the increasing interest in energy efficient building design, whole building energy simulation programs are increasingly employed in the design process to help architects and engineers determine which design alternatives save energy and are cost effective [11]. Energy simulation tools are increasingly used for analysis of energy performance of buildings and the thermal comfort of their occupants. Today, there are many building performance simulation programs with different user interfaces and different simulation engines that are capable of these analyses. The eQUEST software is most easy and quickest Energy Simulation Tool and allows users with limited simulation experience to develop 3-dimensional simulation models of a particular building design. These simulations incorporate building location, orientation, wall/roof construction, window properties, as well as HVAC systems, day-lighting and various control strategies, along with the ability to evaluate design options for any single or combination of energy conservation measures. According to the eQUEST website, ”eQUEST was designed to allow you to perform detailed analysis of today’s state-of-the-art building design technologies using today’s most sophisticated building energy use simulation techniques but without requiring extensive experience in the ”art” of building performance modeling [12].

II. Energy Modeling

A. *Description of the USPCAS-E, UET Peshawar Building:*

The building under study is located in Hayat-Abad Phase 5 Peshawar, an old city in the province of Khyber-Pakhtunkhwa (KP) Pakistan. It’s a three story West facing building with a plot area of 52,000 square-feet and the area covered by the building is about 19,112 ft.-sq. The city is located in an extremely hot weather zone.

Fig. 2. USPCAS-E, UET Peshawar Building.

B. *USPCAS-E Building Envelop (Materials and Construction)*

This is a state of the art building with simple brick and concrete walls of about 12 inches width and each roof is an 8 inches concrete slab. The floor to floor height is 10 feet with a floor to ceiling gap of 2.5 feet. The three stories of the building are three different shells in eQUEST placed immediately above each other. Auditorium and external reception are separate shells with auditorium immediately in west side of the building and reception at south west. Each shell/floor has internal finishing of ceramic stone tiles. The ceilings interior finish is Lay-in Acoustic tiles with no Batt Insulation. All The vertical walls are mass type.

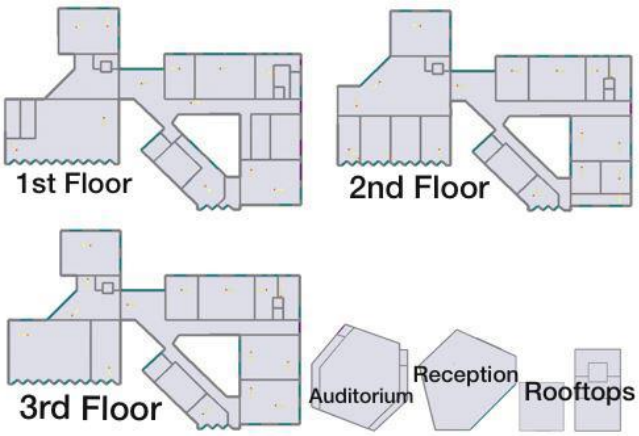

Fig. 3. 2D Model of all the shells of USPCAS-E Building from eQUEST

There are two types of doors and two types of windows defined for each floor and all the doors and windows on all sides are customizes accordingly as shown in the 3D view of the Building. There are no exterior window sheds or blinds to any floor/shell of the building as shown in the 3D view of the building in Figure 5. Any zone in any shell in the building that has some windows are considered as day-light zones and the rest as non-day light zones as shown in Figure 6. The ground floor of the building has a very strong base and is in direct

contact with the earth with a 12 inches concrete with no external cavity insulation and interior finishing of ceramic stone tiles. The exterior finish of the exterior walls of the Building are Asphalt Pavement weathered with brown medium light color. The exterior walls has no board and furred insulation.

C. *Energy intake of USPCAS-E Building*

The building depends on Peshawar Electric Supply Company (PESCO) for its Electricity needs. There is no gas connection to the building. Gas is used only in the Kitchen for cooking purpose which is totally a private party concern who is handling the Kitchen and Cafeteria on contractual basis. So gas consumption in the building is not considered in the overall energy conservation considerations and is thus not considered for simulation as well. There are two Generators for back up purpose during emergency or load shedding hours. But they are not considered for the Simulation purpose because they are fulfilling the same need as connection from the PESCO.

D. *HVAC Zoning*

This is basically a School/college, University type building in eQUEST with total five defined shells and each shell have a different zoning and use pattern. The building basically includes Conference room, staff offices, management offices, class rooms, labs, auditorium, library, lavatory, staff and ladies waiting areas, Kitchen and Cafeteria etc. There are total 45 small zones in the building and is conditioned by three different systems. A central HVAC system condoning the three floors/shells of the building. Separate Split ACs in some zones of the three floors and a separate cooling system for the auditorium.

E. *HVAC System*

The HVAC system installed at the USPCAS-E building is made in Thailand by DAIKIN Industries. This company is considered among world top class air conditioning companies. The installed system has a rated power supply of 380-400 V at 50 Hz frequency. It operates at pressure range of 33-40 bar. The refrigerant used in this system is R410A having a mass of 6.3 kg.

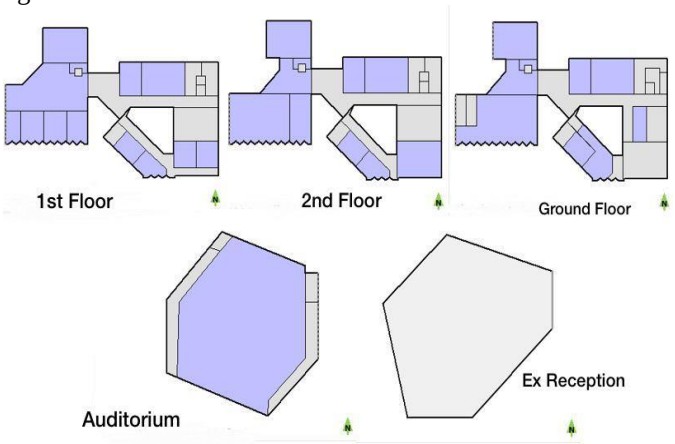

Fig. 4. Zoning pattern off all five shells with blue colored Conditioned zones and white colored unconditioned zones

This refrigerant is a replacement of the older R-22 refrigerant and is classified as the best option for air conditioning applications [10]. This refrigerant is comparatively more environment friendly and causes lesser damage to ozone layer compared to R-22. Compared to R-22, R410A is also better at absorption and generation of heat thus making it energy efficient compared to the rest of refrigerants available in the market.

F. *Building schedules and operations*

The schedules and operating hours for the models are very comprehensive. The building has different schedules for Monday to Friday and different schedule for weekends and holidays. From Monday till Friday the building is open from 9:00 am to 5 pm. On weekends and Holidays the building is almost close. Not all the zones are open from 9:00 am to 5:00 pm some are open just for one or two hours. Over all the building schedules are varying from type to type for different zones. There are total five class rooms in the building and hardly one class of 2-3 hours is conducted per day, same is the case of Laboratories, stores etc and are not open all the working day. There is a break time of about one hour daily from Monday till Friday between 12:30 pm to 1:30 pm. The schedule for auditorium and conference room isn't defined. Both are hardly used on average an hour a day. There is no proper schedule of the Cafeteria, people come and go as they need.

III. RESULTS

The Building is energized from Peshawar Electric Supply Company (PESCO).

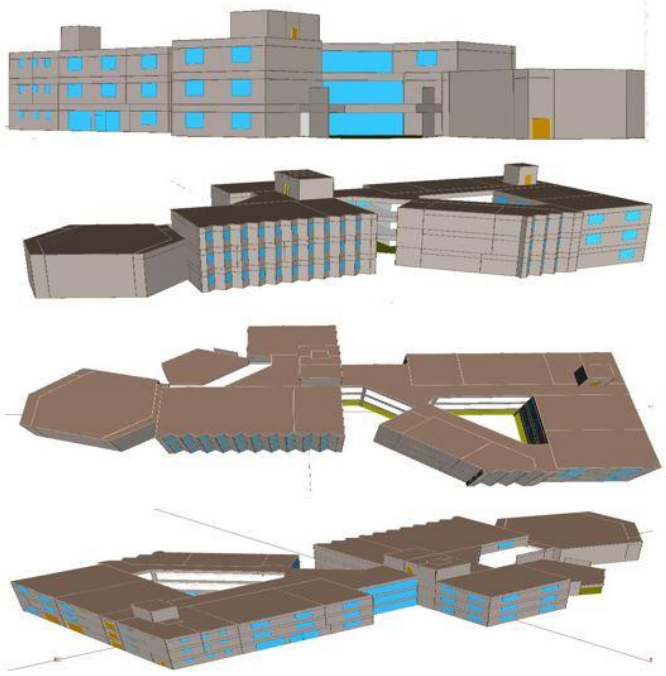

Fig. 5. 3D Model of USPCAS-E Building from eQUEST

The Building parameters that are included in the simulation process are, The building envelop, The HVAC systems, The lightning system of the Building and the miscellaneous

equipment which also include the office equipment , personal equipment of the occupants and laboratory Machinery etc. The study for Gas use in the building is not considered here because the building do not have any gas connection. Gas is used only in the Kitchen portion which is totally concerned with the contractor running cafeteria. The office equipment, miscellaneous equipment, Laboratory machinery are all up to date having latest energy efficient technologies. We have mainly focused on building energy consumption parameters.

A. Electric Consumption of the Building (kWh):

The monthly Electric Consumption of the USPCAS-E Building is shown in the Graph in figure 6.1 for the whole 2019 year. It can be clearly seen from the Graph that the most of Kilo Watt hours are consumed by the HVAC system of the building. The Second Highest Consumption is by miscellaneous equipment i.e. 25% which includes office and laboratory machinery as well. The third remarkable consumption is by area lightning's shown by the yellow color in the graph in Figure 6.1. The energy consumption because of other factors can be clearly seen in the graph.

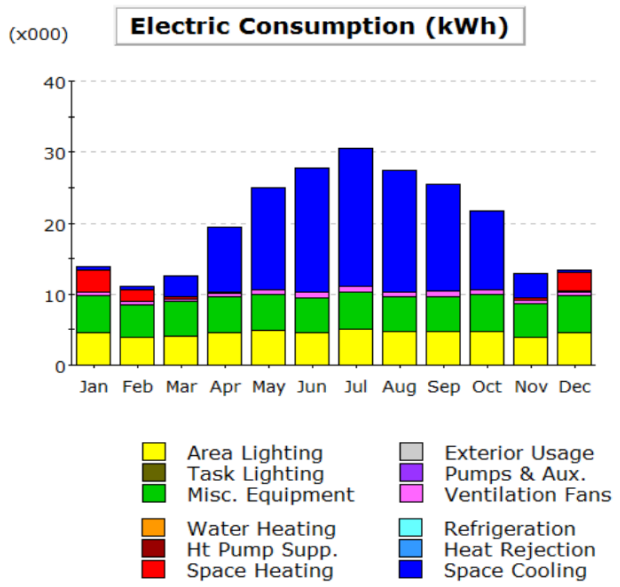

Fig. 6. Electric Consumption (kWh) of the USPCAS-E Building from eQUEST Simulation Results

The Electrical Energy Consumption of the building starts on increasing from the month of April and reaches its peak in July. This is mainly because of the hot weather of the region and thus more use of HVAC system. In July, the Total energy consumed by HVAC system according to eQUEST Simulation and ASHRAE standards for cooling is 19,420 KWh which is more than 60% of the overall consumption. After the month of July, the monthly Kilo Watt hour's consumption starts to decrease as the weather of the region tends to become less warm during winter and thus the use of HVAC also decreases. The consumption for the month of December and January are even more than that for November because the temperature of the region falls down to less than 10 degree Celsius. So more energy is consumed for the space heating purpose.

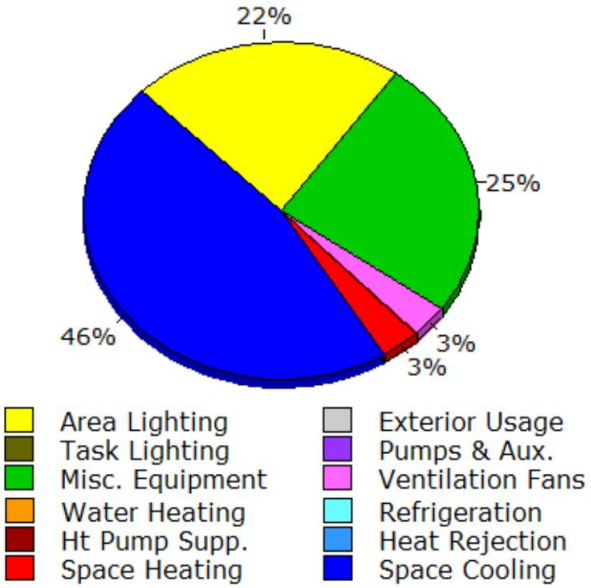

Fig. 7. Pei Graph of percentage of Electric Consumption from Simulation Results

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun
Space Cool	0.39	0.64	2.84	9.25	14.33	17.48
Heat Reject.	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-
Space Heat	3.05	1.57	0.30	0.02	-	-
HP Supp.	0.03	-	-	-	-	-
Hot Water	-	-	-	-	-	-
Vent. Fans	0.49	0.43	0.44	0.57	0.73	0.76
Pumps & Aux.	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-
Misc. Equip.	5.29	4.62	4.90	5.07	5.09	4.87
Task Lights	-	-	-	-	-	-
Area Lights	4.55	3.92	4.03	4.56	4.87	4.62
Total	13.80	11.18	12.52	19.46	25.02	27.73

	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	19.42	17.13	15.16	11.02	3.45	0.43	111.56
Heat Reject.	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-
Space Heat	-	-	-	-	0.30	2.57	7.81
HP Supp.	-	-	-	-	-	0.10	0.13
Hot Water	-	-	-	-	-	-	-
Vent. Fans	0.84	0.77	0.75	0.64	0.43	0.49	7.35
Pumps & Aux	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-
Misc. Equip.	5.29	4.90	4.87	5.29	4.68	5.29	60.14
Task Lights	-	-	-	-	-	-	-
Area Lights	5.01	4.68	4.75	4.72	3.99	4.55	54.24
Total	30.56	27.48	25.53	21.67	12.85	13.43	241.23

Fig. 8. Detail of the Electric Consumption in kWh of the USPCAS-E Building from eQUEST Simulation Result

The percentage of annual Energy Consumption by each parameter in the building is shown in Fig. 7. More than 45% of the total annual energy is consumed by HVAC system for space cooling, this is because of the extremely hot weather in summer. The second highest chunk of energy as already mentioned is consumed by miscellaneous equipment i.e. 25% and lightning of the building is the third parameter to consume more energy, it consumes about 22% of the total annual energy.

The Monthly energy consumption of each systems in the building is given in detail in the table in Fig. 8. Taken from eQUEST baseline result for year 2019. This result is produced by the eQUEST software according to LEED and AHSRAE building standards. There is some difference in the energy consumption each month between the actual data and simulation result but the total annual energy consumption is almost equal to the annual energy consumption of the building. The total actual energy consumed by the building in year 2019 is 241,600 Kilo Watt hours while the total consumed energy from simulation result for the same year is 241,230 Kilo Watt hours showing a very small annual gap between simulation and actual result. This is mainly because of using a very old weather file for simulation purpose the comparison of the actual monthly KWh consumption and the simulation result is given in table 1.

TABLE I. COMPARISON OF ACTUAL ENERGY CONSUMPTION AND SIMULATION RESULT

Month	Actual Energy Consumption KWh	Simulation Result KWh	Month	Actual Energy Consumption KWh	Simulation Result KWh
January	15,360	13,800	**July**	24,320	30,560
February	19,360	11,180	**August**	34,720	27,480
March	16,000	12,520	**September**	29,920	25,530
April	12,160	19,460	**October**	25,280	21,670
May	11,360	25,020	**November**	15,360	12,850
June	18,400	27,730	**December**	19,360	13,430

B. Energy Consumed by HVAC System (kWh)

It is clear from the graph in Fig 8 that HVAC System in the building is consuming the greatest chunk. The energy consumption for space cooling starts to increase from the month of April and reaches its peak in July where the total energy consumed by HVAC for cooling is equal to 19,420 KWh, it falls down to 17,130 KWh in Aug and keeps on decreasing with the weather till November where it's just 3,450 KWh. After that the weather of the region is very cold and 2,570 KWh of Energy is consumed in the building for space heating in December and 3,050 KWh in January. In the same way the energy consumed by ventilation fans increases from the month of March till July where it reaches its peak of 840 KWh and then it starts to decreases month after month till November. From November to onward till March, the change in Energy consumption by ventilation fans is not that much noticeable. The Annual Energy Consumption by Air side HVAC is 126,850 KWh out of 241,230 KWh which is more than 50% of the total Annual Energy Consumption of The Building. The HAVC system installed in the building is made by DAIKIN industries the most up to date and energy efficient available till now. Still there is some chance of conserving a valuable amount of energy from this side by changing thermostat set points and some building occupancy schedules.

C. Energy Consumed by Lightning System in the Building

The Kilo Watt Hours (KWh) Consumed by Lightning System in the Building are slightly changing every month. The Total annual energy consumption is 54,240 KWh out of 241,230 KWh. It is about 22.4% of the total Annual Energy Consumption. There is a significant conservation potential in this parameter of the building energy consumption which can be conserved with a small change in behavior by issuing a policy for lightning use.

D. Energy Consumed by Miscellaneous Equipment

Miscellaneous equipment include all Office equipment, and Laboratory Machinery as well. All the equipment used in the building are of the most advance and energy efficient technology. The total annual energy consumed by miscellaneous equipment is 60,140 KWh which is about 25%. All these equipment taken together are a Significant Energy User (SEUs). There is a substantial potential to be conserved here as well by some policy implications on occupancy scheduling and machinery use. There use schedule must be defined according to the occupancy schedule of the concerned zones.

E. Gas Consumption of the Building

As already mentioned in the start of this chapter, there is no gas connection to the building. Gas is used only in the kitchen for cooking purpose which is brought in in gas cylinders. This gas use is not considered in the study as it is concern of a private party who runs cafeteria and kitchen on contract basis. This gas is not used for any other purpose in the building.

F. Areas of Conserving Energy through Cost Effective Measures

The HVAC system, the lightning system of the building and the miscellaneous equipment are the three main components of energy consumption. The building is used as an educational facility majorly focused on advance studies in Energy. It was made exactly for this purpose so everything installed here is of the most up-to-date and energy efficient Technology. It is noticed during the whole year that the excessive billing is mainly because of the behavior of the occupants towards energy use. People are observed using air conditioning system at very low temperature during extreme summer even causing headache to some of the occupants. Excessive lightning in most of the areas of the building was found even where there was no need. Students instead of sitting in library for studying used class rooms alone, the lightning and the air-condition use for a single person although it was already available in library. Lab attendants used to spend their day inside the labs alone with all lights, HVAC system and additional equipment turned on although there was no experiment conducted throughout the week and there was plenty of space available for him in the staff offices as well. On a count, just five or six persons used auditorium for their presentation and even a normal lecture for 10-15 students was conducted so many times inside auditorium for which class rooms were already available. So there are many things that need to be monitored and changed through the use of behavior change tool which can either be a good policy or some necessary restrictions.

G. Overall Energy Efficiency Measurement

The energy conservation potential in various sectors of energy consumption is shown in the Table 6.3. HVAC system is consuming the greatest chunk out of overall energy consumption in the building and it has the greatest potential that is conservable. The second highest consumer of energy is lightning system in the building and similarly it has the second highest potential of conserving energy.

TABLE II. ENERGY CONSERVATION POTENTIAL IN VARIOUS SECTORS OF ENERGY USE

Sr. No.	**Area of Energy Conservation**	**Energy Conservation Potential (%)**
1	Package HVAC Energy Efficiency Measurement	13.53
2	Whole Building Lightning Power Energy Efficiency Measurement	10.56
3	Whole Building Miscellaneous Equipment Energy Efficiency Measurement	10.41
4	Overall Energy Efficiency Measurement	35+

Whole Building Miscellaneous Equipment which also include laboratory machinery and personal equipment of the occupants has nearly the same energy potential to be conserved as the lightning system. So the total available energy conservation potential is more than 35%. In addition to this 35% energy conservation potential in the different sectors of energy consumption, a remarkable potential can be conserved through various policy implications in the building occupancy and scheduling side. During the process of study throughout the year it was noticed that excessive space was occupied for no reason which resulted in the excessive use of HVAC and lightning causing over billing. Students were noticed studying alone in a class room, lectures were conduct for 10-15 students in the auditorium, people were seen using conference room for a meeting of 3-4 persons, elevator was excessively used to climbed just the two floors by healthy young people, computers in the Library and simulation lab were left running most of the time without any use people left there HVAC running in Labs, classes, offices even at break time, extra lightning use during the day time in various building space and this all is no doubt unfair for a building used for advance studies in Energy. Because of the above mentioned reasons, a section of policy propositions is included below to control the excessive use of energy in the building.

CONCLUSIONS AND POLICY RECOMMENDATIONS

In Pakistan numerous studies have been carried to assess the exact potential of energy conservation and efficiency improvement in buildings, transport, agriculture and industrial sectors, showing a huge gap which is a big Question for National Energy Efficiency and Conservation Authority (NEECA). This study has taken the plan that NEECA is going to adopt and will cover all the necessary areas for saving energy in a building according to a proposed standard. This research work will help the Government of Pakistan to carry their policy

of effective use and conservation of energy in buildings sector through NEECA.

It is noted during the study throughout a year that excessive use of HVAC and Lightning system in the building was because of ignorant behavior towards energy saving, unidentified occupancy and scheduling. The University has paid excessive bills not because of the equipment and systems installed in the building, they are all up to date with latest energy efficient technologies. The building is state of the art building with almost all necessary measures already considered so this could be only controlled with some policy propositions in the building and proper training of the occupants. Overall Energy Efficiency Measurement show that the energy conservation potential in various sectors of energy consumption in the building is more than 35% and a remarkable potential can be conserved through various policy implications in the building occupancy and scheduling side.

A. Policy for Building Occupancy:

A good behavior towards energy use and conservation can save a lot of energy. This can be achieved through proper trainings, seminars and sign boards at various points. The building is used for advance studies in energy and the behavior of the occupants must change accordingly. Following are some policy points that must be considered for a positive change in behavior towards energy saving:

- A seminar must be arranged for the current occupants of the building on impact of behavior change on energy use and energy conservation
- A similar event must be arranged for every fresh enrolled batch
- Any new recruited person in the staff or faculty must go through a meeting with expert of behavior change in this regard
- Cardboards and signboards must be used in support of energy conservation where necessary
- Elevators to be used only by disabled, luggage careers and old age people

B. Policy for Behavior Change:

A lot of energy throughout the year is wasted because of uneven and useless occupancy, thus extra use of HVAC and lightning system. This was a serious issue that needed attention. Therefore following important rules must be imposed strictly and immediately to tackle the loss and save energy:

- Class rooms shall remain close during the time of no class
- No class shall be conducted in auditorium
- Lab engineers and lab attendant shall remain in labs only during lab class or during use of the lab for private party and they must be given a space in other offices. labs shall remain close in rest of the time
- Students for their self-study and personal use must use library space
- Conference room and video conference room shall be used for the dedicated purpose only and not for individual use
- No class room, conference room or any other room is to be used for self-study or individual occupancy

C. Policy for Building Scheduling:

This is also a serious point of concern to conserve energy. Most of the students have hardly three classes a week. Some of them have just to work on their research topics. The schedule of the classes must be so well defined that the building is as less occupied as possible to prevent the excessive use of HVAC and lightning system. So the following points must be taken serious while making a schedule for the building;

- Students from different streams studying the same subject shall share the same time slot and building space
- Students working on their thesis shall occupy a slot in a simulation lab or library and there must be a defined schedule for them
- The schedule of the labs shall be defined for each class and shall be strictly followed
- For commercial use of each lab there must be a dedicated day mentioned on the website
- Auditorium shall be used according to defined schedule with respect to activities of the whole week
- The duty timings of the building must be strictly followed

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