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Green Energy Audit Approach for Public Building Integrated with the LEED Protocols

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Abstract

The reduction of energy consumption in buildings is a priority issue nowadays since it has been shown that this sector consumes most of the produced energy worldwide. Energy can be conserved through good energy management, awareness and using an efficient green building that includes equipment and building envelopes. Green Energy Audit deals with the energy and environment. LEED methodologies strengthen the role of the conventional energy audit since it can lead to sustainable energy building. This paper analyses the energy consumption of an existing public building "place for social activities and Religious rituals" founded in 1983 in Columbia Missouri. The building constructions as, as well as the electric and gas usage, re-recorded and studied. A walk through the building was conducted to investigate the actual case of the equipment usage and things that affect the thermal load. The effects of the variation of weather on energy consumption were also studied. Recommendations for enerenergy-savings are suggested with the estimated cost and the pay payback odds. It has been found that most of the energy consumption was due to cooling and heating during summer and winter and the outside weather has a great influence on energy consumption.

Disciplinary: Green and Sustainable Energy.

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1 Introduction

The increasing rate of energy demands, worldwide, has a negative impact on the environment, such as global warming and ozone depletion. Both residential and commercial sectors are responsible for 30% of greenhouse gas emissions and 40% of the total energy consumed by the end end-user in the USA [1]. The commercial sector includes offices, malls, stores, schools, hospitals, hotels, warehouses, restaurants, and places of worship and public assembly.

Improvement of the lifestyles surely raises the energy needs to a level that fossil fuel resources will be exhausted and consequently, have a serious impact on the environment. For that, the current energy behaviors are clearly unsustainable and the efficient use of energy will play an important role in reducing energy usage & the hazard impact to the atmosphere. Sustainability development requires an energy policy followed by real actions to have energy-efficient **b**uildings. Petroleum, natural gas, coal, renewable energy, and nuclear electric power are primary energy sources for the United State of America. Electricity is a secondary energy source that is generated from primary energy sources. The electric power sector generates most of the electricity in the United States [2]

Many authors [5-11] conducted an energy audit for buildings like schools, universities, historical buildings, or companies. The aim is to reduce the running cost for the utility bills which leads to energy conservation and increasing also equipment life. Sait [4]studied the energy consumption of an educational building in Rabigh, Saudi Arabia where the area is hot and humid. It was founded 90% of the energy consumption was due to air-conditioning during summer. The rest of the electric consumption was due to lights, elevators, computers, and machines in the workshops and labs. From his studies, he concluded that the thermostat of cooling should be adjusted to 23^{o}C. This will save about 37% of the total energy consumption. Sensors should be applied for light to control on and off for it during operating and non-operating hours saving energy. Windows must be shaded internally by a curtain or externally by having a shutter or suitable extended arms. Magrini *et.al.* [5] studied the energy consumption of a modern and historical building at the University of Pavia in Italy. They used Normalized Energy Indicator for Heating which was developed by the Italian National Agency for New Technologies as an indicator to evaluate the building. In the end, the building is classified into Good, Sufficient, or poor according to the value of the Normalized Energy Indicator.[5]

Dimitrios *et al*, [6] audited Craiglockhart Primary School, a historic building in the UK. They also suggested renewable energy integration within the building. The building was classified as “poor” in terms of energy consumption. Payback back periods for the suggested glazing improvement and insulations were eight years. The hyper system will add an income to the school, but the payback period was about 40 years due to the high initial cost.

Marinosci *et al.* [7] audited the historical building of the School of Engineering and Architecture of Bologna in Italy using Building Energy Signature (BES), which is defined as the thermal power required by the building as a function of the outdoor air temperature (OAT). Implementing multi-scenario in energy-saving like modification of the indoor temperatures in the heating season, replacement of the old actual boilers with condensation gas heaters, and substitution of the actual fenestration systems can lead to an energy saving of 32%.

Qawasmeh et al. [8] and Hassounah [9] conducted an energy audit for residential and school buildings respectively. They calculated the cooling and heating load. They both agree to implement double glazing for saving energy. Hassounah et al. [9] stated by installing double glazing and insuinsulating external walls, had a payback period of 1 year. In addition, they commented that by installing electrical sensors, dimmer the payback periods can be less than three months.

Dongellini et al. [10] conducted an energy audit e in the facilities of an Italian Automotive company located in Emilia Romagna, close to Bologna. A series of possible energy-saving actions have been individuated; using the numerical MC4 Suite model. For each action, the primary energy saving per year has been estimated. The analysis has shown that it is possible to individuate a series of energy-saving measures, like thermal insulation of walls and roof-tops, the replacement of old boilers, and the use of heat recovery units in the HVAC systems that can produce a saving of about 100000 € per year with a pay-back time less than 6 years.

The worshipping places like Mosques or Churches are widely spread in the USA. There are 384,000 Churches in Uthe SA (2012)[11] and 3186 Mosques (2015) that serve 3.3 million [12] people around the country [13]. Both Churches and Mosques are considered non-profit organizations and depend on donations from visitors to run them. Islamic Center of Central Missouri (ICCM), founded in 1983 is one of 44 Islamic centers or Mosques distributed around the Missouri State. Like any other public building, the ICCM needs all kinds of services like gas, electricity, and water to serve the visitors. The average cost for the utilities was about $18000/year for the past 3 years. In this paper, a green energy audit is made for the ICCM. This includes gathering the data for the building such as construction materials, sizes of utility bills. Then, sustainability can be achieved by applying a retrofit measure in conjunction with reference to the Leadership in Energy and Environmental Design (LEED) Protocol. With this approach the energy consumption can be reduced, the operating costs will be less, and the building will be more efficient to the environment.

1.1 Green Energy Auditing and LEED

The Green Energy Audit has the same requirements as the basic energy audit, in which the energy consumption profile must be investigated. In addition, actual measurements need to be collected, so that comparisons to the ideal case can be done. After that suggested improvements based on the analysis of the collected data are performed with cost/benefit analyzing and reporting on the completed work. A case by case approach must be implemented, in which to consider Return of Investment, (ROI). All cases of an audit must be paid for by the returns values it will generate. The energy audit approaches can be classified into three levels: walkthrough, standard, and simulation. A walk-through audit gives an idea about the location of the building, it's surroundings, types of walls, windows, ventilation, A/C syste,m and bill details. It will open up more questions about all options that might be put in front of the client. Ithe is a first step towards subsequent energy audits at a higher operational level. The Standard Audt, has a more challenging energy audit than the walk-through audit. It provides details about cost and effectiveness. More resources and skills are needed to fulfill this technical approach. Simulation Audit provides a virtual model of the building. Then, the effectiveness of the proposed strategies can be verified.

Table 1: Expected results from different audit categories

Walk-through	Standard	Simulation
Review of bill details Ages of systems or management; review of codes; list of required data	Current building structure point to deficiencies in systems or management; defining the codes Cost evaluation	Deeply investigate the current situation and adopt many options solution with its effectiveness to the building, compare the current wian th ideal situation

The Green Energy strategy focuses on sustainability. The auditing team should propose sustainable choices that lead to a degree of improvement in the sustainability of the building as a whole. Such choices must take into consideration, several aspects such as environmental issues, indoor air quality, and comfort,t and water/sewage management. The Green Energy goals are focusing on creating many advantages with respect to sustainability and do not necessarily generate an advantage in terms of energy.

LEED is used for green building rating in many countries in the world including the USA. It can be applied to all buildings. Healthy, highly efficient, and cost-saving green buildings can be created by LEED. The building can be certified by LEED (Figure 1) which is a globally recognized symbol of sustainability achievement. The certification can be one of the four categories according to the collected points as shown in Fig. Instructions on how to get the certificate is available on the LEED website. The evaluations include integrative process, location, and transportation, sustainability, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, Innovation, Regional and regional priorities.

Figure 1: Classification of LEED certificate.

2 Weather Analyzing in Columbia Missouri

2.1 About Columbia Missouri

Columbia Missouri is in the Midwest Region of the USA. The total population of Columbia is about 120,606 in 2016, [14]. Columbia is located in a region that is below the average weather in the USA during winter and on the average weather during the summer, Figure 2. Although humidity is considered to be high during summer, it stays within the average value of the country during winter and summer, Figure 2. Overall, Columbia- Missouri has harsh weather for almost most of the year, and the air-conditioning for heating or cooling is a must.

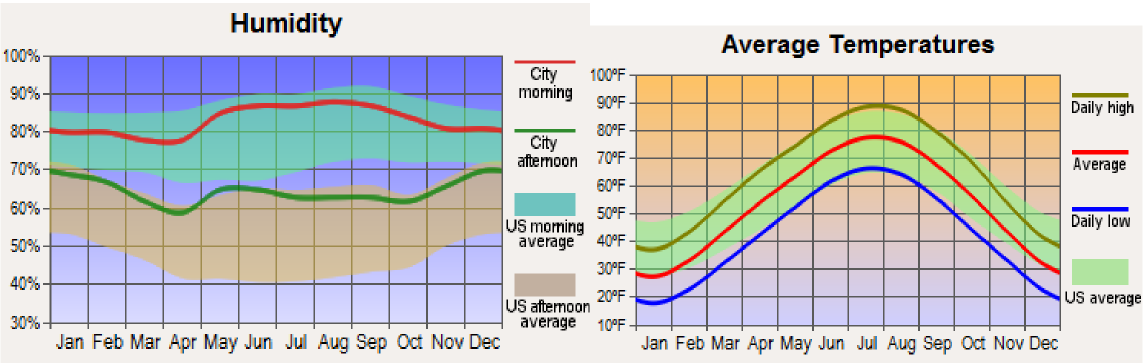


Figure 2: Average temperature and humidity of Columbia- Missouri through the year [14]

Cumulative cooling degree days are shown in Figure 2. The monthly degree day data is represented by each line. Each month's degree total is added to the months before, which makes this type of data useful in budgeting and forecasting. It can be shown from Fig.4 that the temperature during the cooling season of 2016-2017 is much worse than another year in the past 5 years. This can help in explaining the amount of bills and relate this with weather situations. On the other hand, the cumulative heating degree days/month for the heating season, shown in Figure 3, shows fewer severs which leads to less energy consumption for heating.

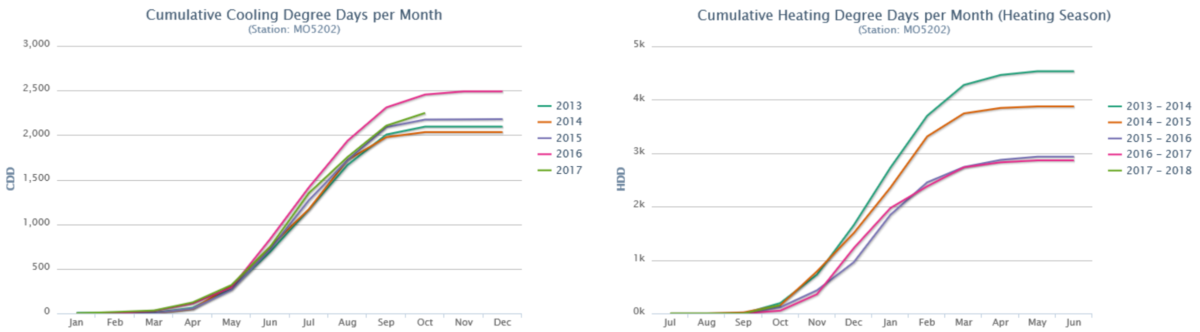


Figure 3: Cumulative cooling degree days for Columbia Missouri for the duration 2013-2017

Figure 4 shows the wind speed of Columbia during the year. The winter season shows a higher wind speed than summer. The wind season starts in Oct. and goes up-to mid of April. The maximum wind speed can reach 16.3 mph in mid of March, while the lowest wind speed was in summer with 3.8 mph between July and Aug.

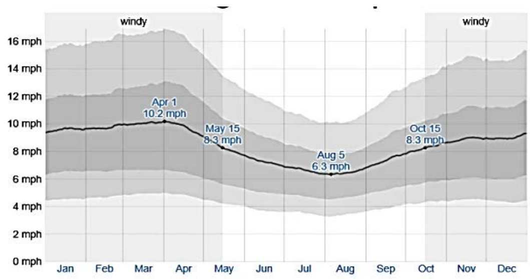


Figure 4: The average of mean hourly wind speeds (dark gray line), with 25th-75th and 10th-90th percentile bands [15].

3 Methodology

To audit the building, it is needed to have many measurement tools like temperature, airflow ,and air quality. Construction drawing details and utility bills for coa uple of years must be available. The temperature of various rooms and halls should be recorded sometimes to ensure the comfortability of people during on off-hoursours.

3.1 Building Specification

The ICCM is in the middle of the town Northwest of the MU Campus at 38.6° N and 92.2° W, Figure 5. It consists mainly of 4 parts, a parking lot with a capacity of 200 parking, a 2-story house, an Islamic school, and the Islamic Muslims Community Activity Building.

The building under consideration is the Muslims Community Activity Building which has two stories and consists of prayer halls for men and women, an activity rooa m, secretary officea , meeting room kitch,en and restrooms. All dimensional details are shown in Table1below.

3.2 Building Occupancy

The estimated occupancy for the building is about 500. The average daily visitor is about 150. The operation hours are from 6 am up8 pm 8 pm, normally. It extends during the Holly months of Ramadan to become from 5 am up to 2 am.

Table 2: Building specification and occupancy

No.	Item Description	Unit	No.	Item Description	Unit
1	Age of building.	35 yrs	10	Secretary office	15 m^2
2	Total interior volume	2158m^3	11	Meeting room	7 m^2
3	Exterior walls area	502m^2	12	Kitchen	12 m^2
4	Total Glass area, widows	31.92 m^2	13	Restrooms	40 m^2
5	Total Glass area, Doors	16.78 m^2	14	Weekly usage hours	60-70 hrs
6	Occupancy (based on 5ft^2/person) for the prayer halls	0-888	15	Aspect ratio.	15:22:6.2
7	Roof/Floor /area	327m^2	16	Gross floor area.	654 m
8	Prayer halls	204.4 m^2	17	Air-conditioned area.	640 m^2
9	Activity Hall	150 m^2	19	Equipment/appliances pacification/capacity.	33398 kW

The building's main entrance faces east and has all sides with plenty of space in front of them, so basically, no other building close to them affects the sun radiation on the building nor the wind movement.

Figure 5: Location and the main entrance of ICCM.

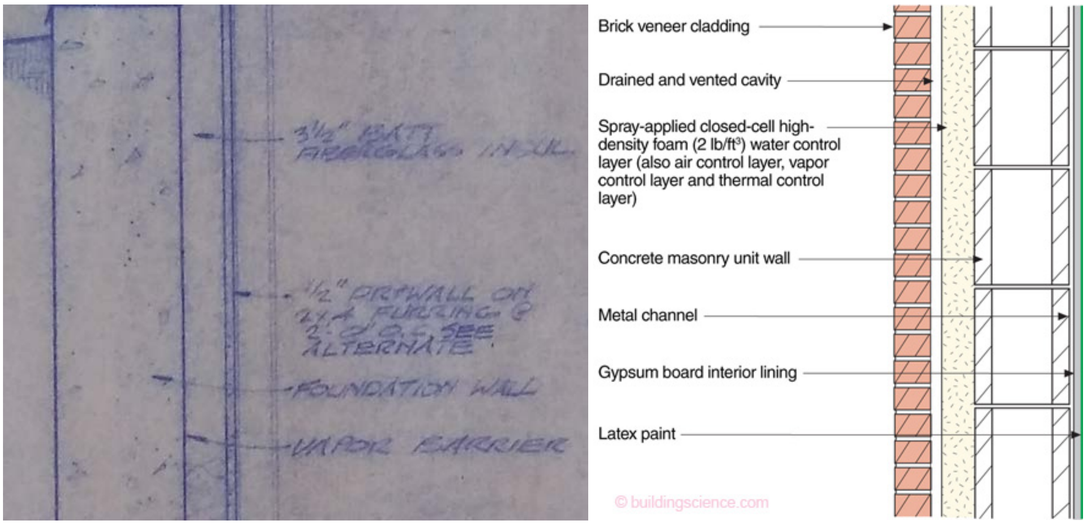
The building is a concert constructed with multilayers materials as shown in figure 5, for the side wall and roof. Part of the ground floor is a concrete side, to compile with the street height of the street. The exterior wall consists of 10 cm clay brick, 5cm plywood sheeting, 5x15cm stud, 15cm fiberglass insulation, anddrywalll. The roof consists of drywall, 22.5cm fiberglass insulation, wood roof truss, bbuild-u toproof and 2 cm plywood CDX.

The roof, walls and ground are insulated with different sizes of fiberglass insulation. The overall heat transfer coefficient, U-value for the building is as follows, 0.45, 0.57 and 0.48 W/m^2.K respectively. Table 3 shows the thermal conductivity of construction layers

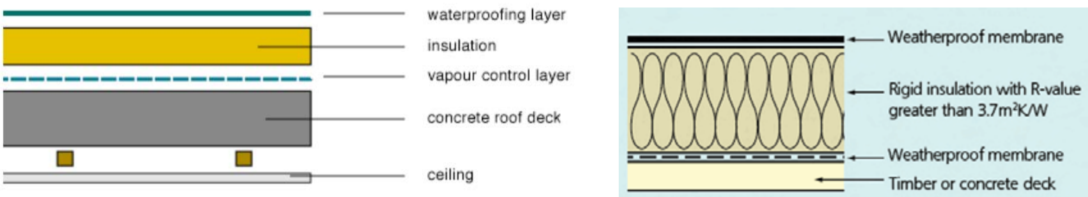
The building has 58 double windows (U=4.49 W/m^2.K) with a total area of 31,92 m^2 and 3 single glass (U=7.24 W/m^2.K) outdoor doors wita h total area of 16.78 m^2. So the total percentage of glass to wall area is 9.7%.

Table 3: Thermal conductivity of construction layers.

No.	Materials of the wall/roof/ floor	K (W/m.K)
1	Clay brick	0.4-0.7
2	plywood sheeting 2in	0.12
3	Fiber glass 6 in	0.035-0.045
4	Dry wall 5/8in	0.17
5	Vinyl asbestos	0.15-0.25
6	Concrete Slab 4 in	0.87
7	Vapor Barrier	0.038-0.042
8	Rock Bare 4in	2-6



(a)



(b)

Figure 6: Building layers details for the wall (a) and roof (b).

Using the data collected, then the annual energy consumption of equipment can be calculated as

$$P_c^a = H^u x C x PF \quad (1),$$

where H^u is the yearly usage hour for equipment, C is the equipment capacity and PF is the power factor. Then the energy intensity (*EI*) can be found by

$$EI = \frac{\sum_i^n \; P\,(kWh)}{Total\,floor\,area(m^2)} \quad (2).$$

Energy can be saved by regulation *EI*. Energy savings as a result of such regulation can be estimated as

$$ES_y = (EI_{ave} - EI_{ideal})A_s \quad (3).$$

Energy-saving for equipment, AC or improving the insulation materials can be found by having the percentage of the expected saving, *%ES* and then

$$ES_y = EC \; x \; \%ES \quad (4),$$

where *EC* is annual energy consumption. Then the bill saving associated with the energy savings can be estimated as

$$BS = ES_y x EP_u \quad (5),$$

where EP_u is the average electricity price in US$/kWh.

The payback period for different energy-saving actions can be calculated as

$$Pay\;back\;period = \frac{incremental\,cost}{annual\,saving} \quad (6).$$

4 Results and Discussion

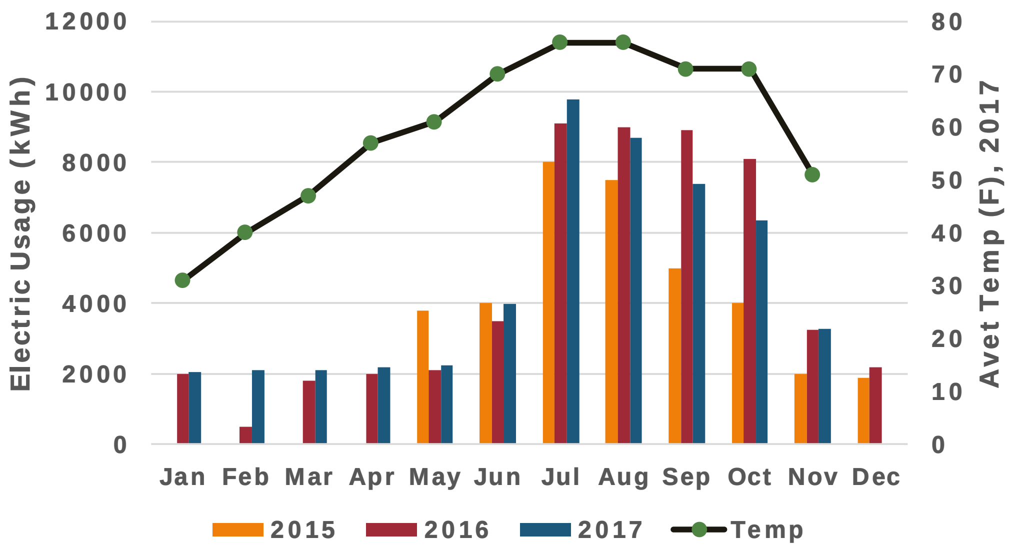


Figure 7: Electric Usage for ICCM vrs Temp change

The monthly electric consumption for the ICCM is shown in Figure 7 for the years 2015-2017. It is clear that the electric consumptions increase as the outside average temperature increases and vice versa. This is a clear indication that most electric power is consumed by air-conditioning in the summertime.

On the other hand, the gas consumption increases as the average outside temperature decreases as shown in Figure 8.

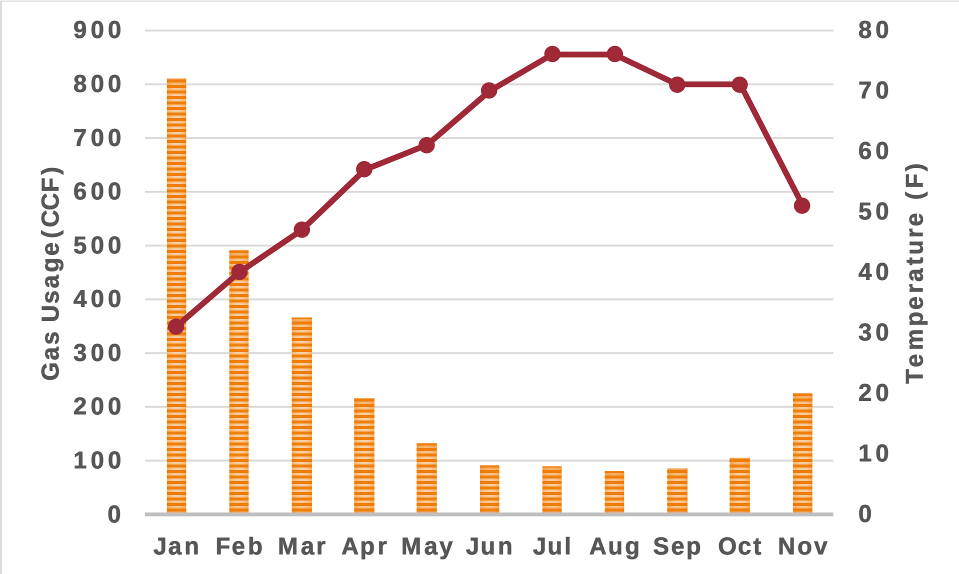


Figure 8: Gas Consumption versus Ave. Temp variation during 2017.

This is also an indication that most of the power in low-temperature seasons goes for heating. Most of the effort of the energy conservations should go for the cooling or heating during summer and winter. The walk-through auditing showed the following:

- Parts of the ground floor, like the library and activity room have not had enough heating during winter and most. The people feel uncomfortable.
- The second floor was in general comfortable enough for practicing and office use.
- Outside lights were working all during the night and some of the interior lights.
- Leaks of water were noticed in the restroom.
- The air conditioning filters are not periodically maintained.
- The air conditioning equipment is more than 10 years old, which does not satisfy the new code of energy efficiency.
- There are no lights sensors in any place in the ICCM.

The total annual energy consumption in kWh has been estimated for air-conditioning equipment and lightings, and other equipment using Eq.(1) and presented in Table 4. Along with the total energy consumption, % break down of this equipment is shown. The air-conditioning system consumes the most portion of the total energy consumption (43% for cooling and 24% for heating), followed by lighting (20%), while other equipment consumes less than 10% of the total electric consumption of the building, which is the case in most countries [16]. The total power consumption for the ICCM building was 74.7 kWh/m^2/year. Comparing this value with the average consumption of other buildings in Uthe SA, it seems the ICCM is more energy-efficient than other buildings [16]. However, there is still room for improvements to reduce further energy consumption by introducing an energy savings policy or options.

Using Equations (2)–(6), energy savings and associated bill savings for different energy-saving measures have been quantified and presented in Table 4. It has been found that 20251 kWh energy and US$2312 bills can be saved.

The old ACs run at fa fixed speed turns on and off according to a signal from thermostats, which indicates the demand for cooling within the conditioned area. The cooling demand usually varies highly in the conditioned area, in which the ON/OFF control cannot keep the area within a close temperature tolerance. The inverter air conditioners use variable speeds compressors that are adjusted automatically according to the cooling demand of the room.

Moreover, this feature also ensures that the compressor motor is not exposed to the frequent stress of ON/OFF, which puts considerable stress on the winding of the motor as well as creates disturbances on the power feeder line, which reduces the life of the compressors.

INVERTER AC, ofers a very smooth mode of operation and also delivers outstanding performance in terms of energy conservation and overall efficiency.[17]

About 30% of fuel energy is wasted by old furnaces vented directly to the atmosphere. Reducing the waste can be achieved by installing an “inducer” fan to pull the exhaust gases through the heat exchanger and induce a draft in the chimney. The escaping heat is also can be reduced by “Condensing” furnaces, in which exhaust gases are cooled below 60°C.[18]

Table 4: Building consumption for the previous years

Item	Power	No.	Total Power (kW)	Daily Operation Time (hrs)	Daily Total Con. Power kWH	Yearly kWH	% of total
Air-conditioning cooling	54.498	1	54.498	5	277	27700	43.08682
Air-conditioning heating	31.058	1	31.058	5	155	15500	24.10995
Lights	75	48	3600	10	36.000	12960	20.15903
Computer	200	2	400	8	3.200	1152	1.791914
Printer	50	2	10	8	0.080	28.8	0.044798
Scanner	50	1	50	1	0.050	18	0.027999
Refrigerator	200	2	400	24	9.600	3456	5.375742
Oven and Stove	2500	1	2500	1	2.500	900	1.399933
Microwave	1500	1	1500	0.5	0.75	270	0.41998
						5824	9.04
Exhaust fans(ventilation)	200	2	400	16	6.4	2304	3.583828
Total Power	33398					48878	
Energy Intensity						74.7 kWh/m^2	

Since the air-conditioning in severe climate weather consumes most of the energy in the building, little percentage saving in the A/C system might equal the majority of savings in other appliances. For a sustainable A/C system that will lead to Green Energy features, the A/C systems must have a programmable thermostat, smart filters, and high efficient running equipment. The building's construction materials, on the other hand, must achieve the Green Energy goals. Insulated and environmentally friendly materials should be used in walls and roofs. Windows are the main source of heat for the internal zone of the building. They are must be shaded during summer and exposed to solar radiation during winter.

Table 5: Potential energy saving and payback periods by replacing the existing equipment with more efficient equipment

Equipment	Consumption kWh	% Energy saving due to efficient equipment	Yearly Energy saving (kWh)	Bill Saving ($)	Cost ($) of replacing equipment	Payback periods
AC (Cooling)	27700	48% [Ref]	6382	765.84	8500 [19]	11
AC (Furnace)	15500	10%	1550	186	4253[20]	22.5
Lights	12960	80 %[Ref]	10368	1244	432+900 [21]	1.06
Equipment	8129	12%	975.5	117	3000	25
Total	64289		20251	2312		

Infiltration is the main source of losing energy, so dual door systems and air barriers should be installed in the building and the windows should be tight enough. Humidity which is mostly generated from bathrooms has a bad effect on the internal parts of the building and creates a good environment for growing Bactria and Molds. Ventilation fans must be activated during on and off working hours to achieve dryness in the building. A recycled system must be adopted for sustainability which will add extra points to LEED. By such advanced methodology, the building will be achieved the Green Goals and can be classified in one of the LEED categories.

4.1 Effect of Weather on Energy Consumption

The data available in the Commercial Building Energy Consumption Survey (CBECS) can help to obtain a basic weather assessment for a building. From the CBECS survey data, it can be shown that about half of energy expenses in offices is due to weather for a building, [22]. Degree day data can indicate the effect of weather on building energy use. Then the energy management, energy efficiency, and utility bill be tracked. Heating or cooling degree days represent a need for heating or cooling to maintain a comfortable temperature in a building.

4.2 Determining a Balance Point

In order to determine the degree days is to find a consistent balance point temperature in which a building requires neither heating nor cooling. The balance point value depends on construction materials, insulation and date of construction. The daily degree day totals can then be calculated by obtaining the mean daily temperature for the building location and comparing that value to the building balance point.

WeatherDataDepot.com gives guidance to find any desired balance point. The default setting is 16°C. Using the CBECS survey tool, a correlation between weather and energy use for many building types can be determined. "Once the weather impact for building energy consumption is known, that knowledge can aid in budgeting, forecasting, and trend analysis" [21].

Table 5 below [23], compares heating and cooling degree days in a base year (2013) with partial data from the current comparison year (2017). Degree days provide a metric for weather severity.

Table 5: Degree Day Comparison for Columbia Missouri

	Base yr (2013)			Comparis on Yr 2017			Comparis on %ges"		
Month	HDD	CDD	TDD	HDD	CDD	TDD	HDD	CDD	TDD
Jan.	807	6	813	752	0	752	-6%		-7%
Feb.	715	0	715	406	16	422	-43%		-40%
March	659	0	659	356	16	372	-45%		-43%
April	251	58	309	93	91	184	-62%	56%	-40%
May	81	213	294	38	195	233	-53%	-8%	-20%
June	0	412	412	0	429	429	--	4%	4%
July	0	477	477	0	603	603	--	26%	26%
August	0	499	499	0	404	404	--	-19%	-19%
Sept.	0	341	341	0	352	352	--	3%	3%
Oct.	194	89	283	153	143	296	-21%	60%	4%
Nov.	533	0	533	--	--	--	--	--	
Dec.	925	0	925	--	--	--	--	--	--
Through Oct.	2707	2095	4802	1798	2249	4047	-34%	7%	-16%
Annual Total	4165	2095	6260	--	--	--	--	--	--

As it can be seen from the table data, the weather for the first five months of 2017 was less severe than the base year. In Jan.2013, for example, there were 807 heating degree days (HDD). By contrast, in Jan.2017, 752 heating degree days were recorded for that location. The comparison percentage columns show that this difference represents a 6% increase in weather severity. The following equation can be used to get Normalized Energy Indicator for air conditioning IEN [0]:

$$IEN = 1000\ (AFC.BSF.TF)/(HV.HDD) \qquad (\mathrm{Wh/m^3HDD\ y}) \qquad (8),$$

where

AFC is: average Annual Fuel Consumption [kWh/y],

BSF is Building Shape Factor depends on the value of S/V,

TF is Time Factor depending on the building system operation time and on working hrs,

HV is air-conditioning Volume (gross volume),(m^3) and

HDD is Heating Degree-Days

From equation (8) we can evaluate the building. The IEN for the ICCM is 0.06 which ranges in the category of good building in terms of consumption for air-conditioning.[5]

When we look at months through Oct. average (Jan-Oct.), we see a 34% decrease in weather severity, expressed as heating degree days, from the base year. Combining this information with the CBECS weather data [24], make it is possible to calculate a reasonable value for budget impact. The Weather Load equals 43% of energy expenditure and has an increase of 34% with the comparison year. So, the percentage decrease in energy expense is 14.62%, which indicates that weather has a huge effect on energy consumption.

5 Conclusion

Public building in severe weather area was audited for energy consumption. It has been found that 43% of the total consumed energy during the year goes to cooling while 24% goes for heating and 20% for lighting. Updating the current cooling units with invertor can save up to 48% with the payback periods of 11 years while updating the lighting with lead efficient lamps can save energy up to 80% with the payback period of 1.06 years. The structure of the building can be modified by double glass windows and movable blinds to reject or absorb heat during summer and winter, respectively.

The CBECS data suggests office building will consume 110kBtu/Sqft/year (348 kWh/m^2/year), of which 47kBtu/Sqft will be attributable to weather. This represents 43% of the total energy use for the facility.[22]

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

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