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Water and Energy Retrofitting – A Case Study of Community Building

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Abstract

Efficiency and effectiveness are the decisive parameters for most of the appliances. It is the same when it comes to planning, designing, constructing, and maintaining a building. Less consumption of electricity and water are key parameters which are being focused by regulatory agencies, water authorities and a variety of stakeholders due to their increasing cost, scarcity, and losses. Green community buildings serve this purpose of making buildings efficient, effective, and environmentally friendly. This case study took NED University Mosque as case study for community buildings. This study investigates; first the latest energy efficient equipment available in the local market to save the energy consumption, followed by economic analysis and its lifecycle cost for different Light-emitting diodes (LEDs) products, based on these parameters the most efficient energy equipment was selected. Water consumption was also considered and for that, different types of button faucets and aerator were analyzed and among them the best one was selected. The application of these alternatives in NED University Mosque proved to be more effective and efficient which is reflected in this study.

Keywords

Efficient, Green Building, Community, Energy and Water

1. Introduction

Energy efficiency is considered as a key factor for green building movement due to its significant economic and environmental benefits (Dwaikat & Ali, 2018). The environment is getting affected negatively by building construction industry. Around the globe 20-40 % energy consumed by commercial and residential building (Zhao et al., 2019). As the population of the world increases and according to (Dwaikat & Ali, 2018), the population can go up to 7 billion to 9 billion by 2050 ultimately will increase the demand for water and energy. Worldwide energy consumption can be reduce by green building practices (Darko & Chan, 2016). As compared to conventional building, green building uses less resources yet providing better indoor quality (Darko et al., 2017). The impact of building on environment can be reduced by green building (Zhang et al., 2019). Both the developed and developing countries started Promoting green building (Kontokosta, 2011; Sharma & Swain, 2011; Dwaikat & Ali, 2018). Worldwide awareness about importance of sustainability in the construction industry is growing, and several other challenges such as climate change, population growth, and fast urbanization have boosted the demand for green buildings for long-term development (Goud & Rajaram, 2016). Green building, which has evolved over three decades, is a managerial and technological method for the building and construction industries to achieve resource and energy sustainability (Wang et al., 2018). There is a lot of emphasis on the need for 'green' structures all over the world, including Pakistan, that are efficient, have minimal negative impact during construction and during their existence, and have a positive impact on the climate and surrounding environment (Farooq & Yaqoob, 2019). Pakistan is among those countries which has highest demand of energy at domestic level, therefore there is an urgent of green building here (Baig, 2018). There has always been a concern of shortage of water and electricity in Pakistan, so there is a need of implementation of efficient retrofits which can enhance performance and, at the same time reduce consumption so as to save valuable resources which is a purpose served by green buildings. Following are the objectives of this study, i.e., first, to decrease the consumption of energy and water, second, to perform life cycle analysis of LED lights.

For energy and water retrofitting, NED University mosque is chosen for case study. Water and electricity consumption is aimed to be decreased. For water consumption, ablution area of mosque was selected. Water consumption can be reduced by using different alternatives i.e. button faucets and aerators. For electricity consumption, the same area was considered. The selected area was also used as a model for lumens calculation and life cycle cost analysis for a period of one year for LEDs.

2. Methodology

As shown in the below Figure 1, this study started from gathering and reviewing literature and observing and considering them for our study area i.e., NED Mosque and our targets which is to decrease consumption of energy and water. The considered options (faucets, aerators, and LEDs) are compared with respect to their availability, cost and different parameters defined below in further description. Existing conditions and appliances were studied, and their data was recorded. Options from the market were applied in the Mosque and data was recorded and compared with the options that were applied previously. Difference in consumption reflects savings in consumption. In case of LEDs, lifecycle analysis was also done which included Return on Investment and Pay Back period.

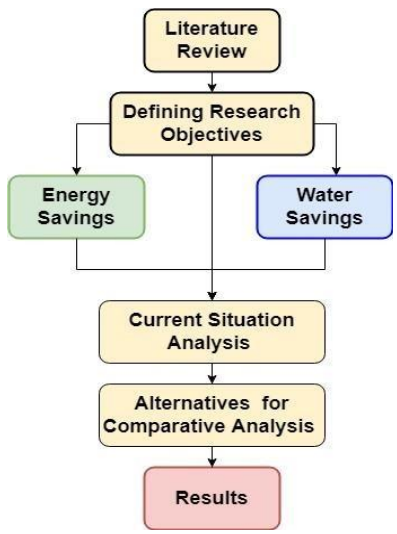


Fig 54. Methodology of Study.

3. Data Collection

3.1. Collection of Existing Data for Energy Consumption

To see the total load of the mosque, One-line diagram was used to record number of appliances and their respective consumption in terms of watts. The consumed energy (watts/hour) in existing condition was calculated. The below Figure 2 gives graphical representation of existing appliances' energy consumption based on the different areas of building.

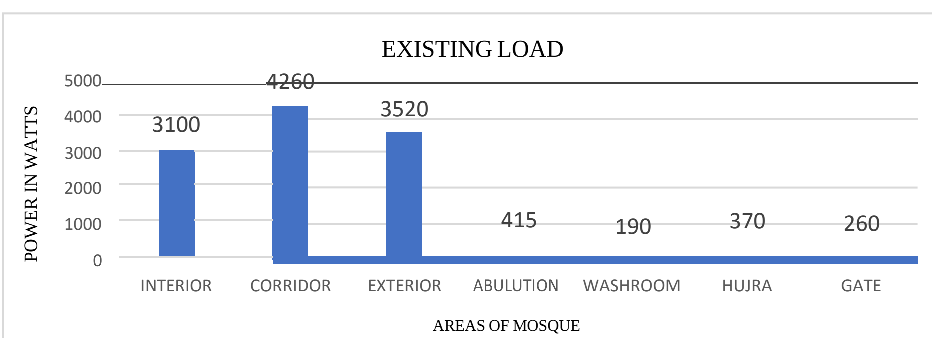


Fig 55. Existing Load of Appliances.

The optimal replacements were considered like LEDs, and they were replaced by the existing ones at a smaller scale. Scale modeling was used to calculate the overall consumption of replacements. The details of existing data are given in Table 1.

3.2. Collection of Existing Data for Water Consumption

Firstly, volume of overhead water tank (OHWT) was calculated, which was found to be 1062.1 cu-ft. The water consumption was computed before and after each prayer. Volume of water was calculated before and after each prayer for two weeks, we can find out the total usage of water per prayer or per day or per week from Figure 3.

Table 12. Loading of Appliances Inside Building

Location	# of Fans (80 Watts)	# of Tube light (40 Watts)	# of Bracket Fan (60 Watts)	# of Bulbs (25 Watts)	# of Exhaust (30 Watts)	# Of System (1000 Watts)	Total Load (Watts)
Interior	15	12	7	0	0	1000	3100
Corridor	23	38	15	0	0	0	4260
Exterior	28	32	0	0	0	0	3520
Ablution	0	6	0	7	0	0	415
Washroom	0	4	0	0	1	0	190
Hujra	1	1	2	4	1	0	370
Gate	0	4	0	4	0	0	260
Total (Load)	5360	3880	1440	375	60	1000	12115

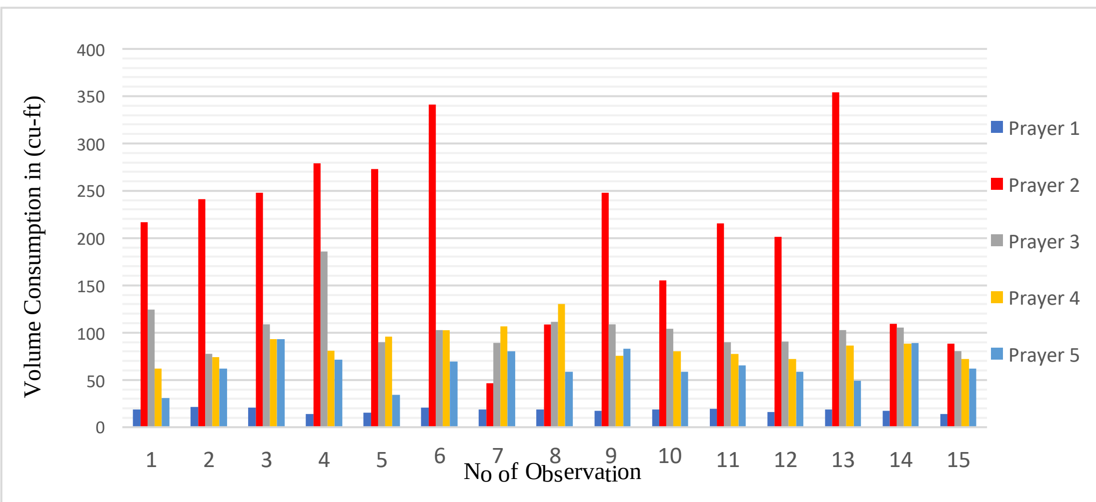


Fig 56. Volume Consumed per Day in (cft)

There are 15 observations means 15 days' observations and every day of 5 Prayers. Most of water was consumed in the noon (Zohar) prayer. After this calculation, now it is the time for the using different substitutes and makes comparison of them with existing conditions. After collecting the existing data, the study focused on a particular area where different strategies can be applied to attain the objectives.

3.3. Area Consideration

The ablution area of Mosque was selected because it had the maximum use of tube lights with respect to time. These use of tube lights and bulbs when gets replaced by LEDs gave a good model for the whole Mosque for further replacement and for lessening of electricity consumption throughout the Mosque. Same area is selected for water as most of the water in the mosque is used in ablution area.

3.4. Criteria of Energy and Water Consumption

Parameters for energy consumption like watts consumed by lights and bulbs, and lumens produced by these lights and bulbs were used to calculate energy consumption. For lessening consumption of water, flow rates and overall volumes consumed are computed before and after applying faucets and fixtures like aerators were considered as parameters to calculate the difference in consumption. They were aimed to be curtailed for making the system efficient.

3.5. Energy Consideration

Market surveys were also done in this regard to check availability, cost and operating quality and warranty of the efficient equipment within its lifetime. Best alternative for replacement of lights and bulbs was considered. Lumens produced by LED lights and their influence area with reflectance factors in accordance with lumens, their consumption, different brands offering warranted and unwarranted products like Phillips, were tested and the best choice considering the above-mentioned parameters was made. It is the process of using measurement to determine the actual savings created within an individual facility by an energy management program. The main purpose of this is to determine actual energy savings (E(saving)) due to the implementation of retrofit measures. Energy savings can be determined by equation below:

$$\boldsymbol{E(saving) = E(pre - retrofit) - E(post - retrofit)} \qquad \textbf{eq (1)}$$

Where, E_{saving} is the energy saving; $E_{pre\text{-}retro}$ is the energy use measured (or estimated) for a defined period in the pre-retrofit period; $E_{post\text{-}retro}$ is the energy use measured (or estimated) for a defined period in the post-retrofit period. Through survey, best replacements were considered with respect to availability, durability, expenses, watts, and lumens (brightness unit). These replacements or products includes, Phillips, Arkin, Dia-Shida, Alpha LED, LED-T8 respectively.

4. Analysis of Products

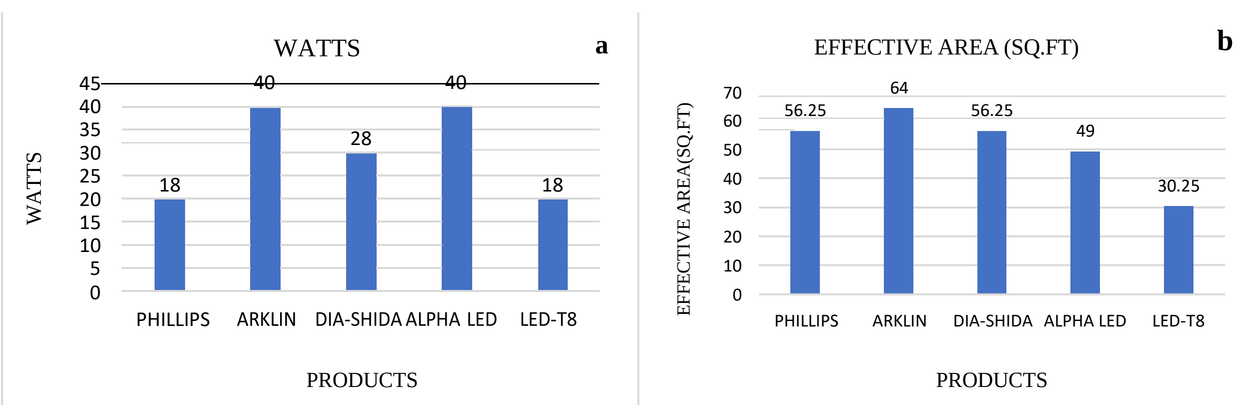
First step involves analysis and comparison of all selected energy saving products based on their watts, lifetime, brightness with respect to their effective area, as well as their price. This analysis will provide primary examination of each product. All alternatives are compared with each other for the better picture of products.

4.1. Watt Perspective Comparison

Comparison of all best efficiency products is initiated based on their watts' utilization. Product having minimum watt utilization will automatically save cost of electricity if other factors are constant and find out watt consumption of each product as shown in Figure 4(a). Figure 4(a) explains that the maximum consumption of watts is 40 which is consumed by Arkin and the minimum consumption is 18 watts consumed by Philips, if other factors including conditions of the product remain unchanged. Watts consumed by Philips LED were minimum in all.

4.2. Comparison on Basis of Effective Area

Effective area means an area where light intensity is high. If the effective area of product is high, it will provide least requirement of lights in that place. It is necessary find out effective area of each product separately and then compared all products as shown in Figure 4(b).



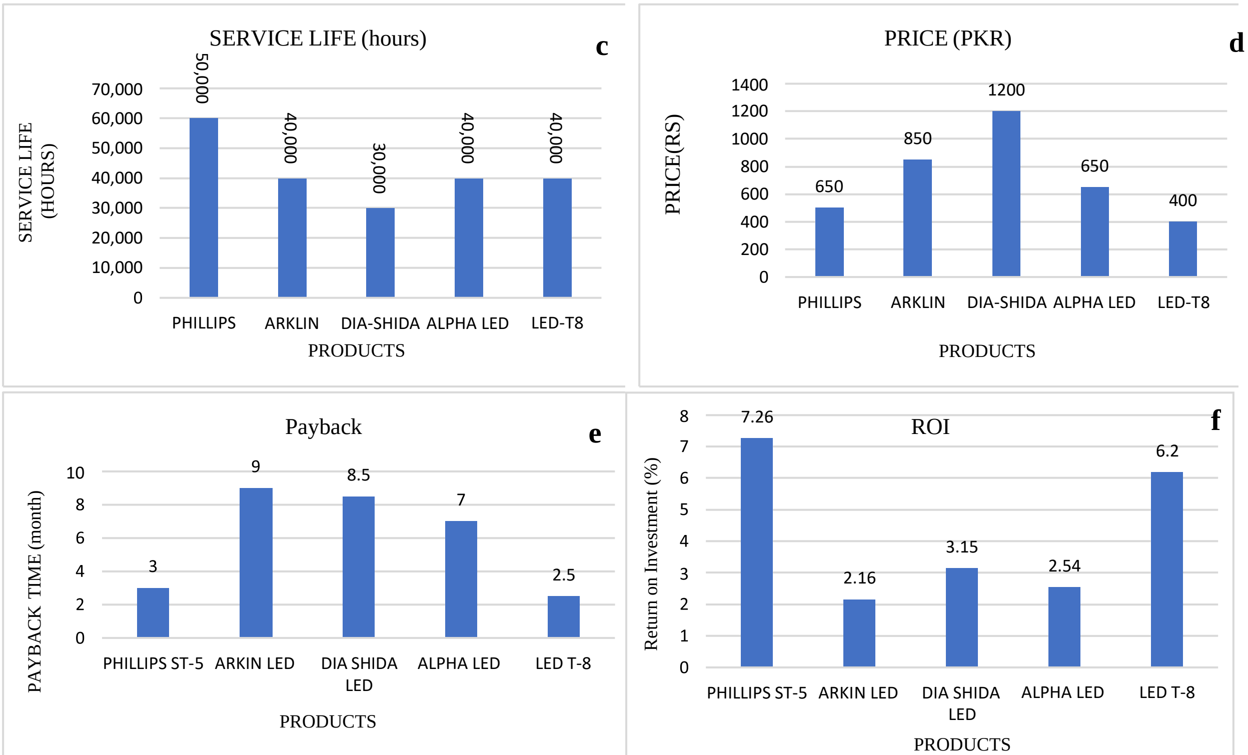


Fig. 57. (a) Watts Comparison of Products, (b) Coverage area of products, (c) Service life comparison of products, (d) Price of each product in PKR, (e) Payback period for each product, and (f) Return on investment for each product

4.3. Service Life Comparison

Comparison based on service life of all the efficient products was calculated for energy savings. Long service life of the product saves the repairing cost for long period of time. It is necessary to find out service life of each product and then compared as shown in Figure 4 (c). Figure shows that the service life of the Philips LED is much more as compared to all other energy devices. So, Philips LED provides least repairing cost because of their durability.

4.4. Price Comparison between the LEDS

During market survey the priority is to consider low pricing because it was necessary to find out effective product but with low market rate. Therefore, the comparison of price of each product as shown in Figure 4 (d). Existing Condition of ablution area was overly devised, lumens were 3300 lumens per each tube light. Light level recommendation in handbook were rendered with 2600 lumens which is tantamount to the Phillips T-5 series tube light and sufficient for brightness in ablution area. By considering all norms, tenets, regulations, and technical aspect, the team was able to devise light design for ablution area and by considering economical aspects, the team come up with the solution that Phillips is the best substitute for the existing condition in the mosque. Phillips LED is performing well in the current scenario, but it isn't finalized until the comparison of Life Cycle Cost analysis is done among the comparative products.

5. Life Cycle Cost Analysis (LCCA)

Life cycle cost analysis (LCCA) is a tool to determine the most cost-effective option among different competing alternatives to purchase, own, operate, maintain and, finally, dispose an object or process, when each is equally appropriate to be implemented on technical grounds. It was done between comparative products with considering their initial cost, maintenance, and service life for 20 years because Philips LED has life span of 20 years. The cost of other parameters including Ballast, starter and Frame was also included. The payback period and return on Investments (ROI) was calculated for a period of one year. The payback period was done in such a way that if the existing tube lights were replaced by the available LED products, then how much time would it take to recover the investment. The least payback period is in Phillips LED. From the Figure 4 (f), it can also be seen that ROI is highest in Phillips LED, so it can be said that Phillips LED is the best among other available products.

6. Water Considerations

Market survey was done for finding out the alternatives for existing faucets (bib cocks). The alternatives were button faucets and aerators. Simple devices that mix water and air can reduce both water flow rates and splashing while increasing areas of coverage and wetting efficiency. For example, faucet aerators can save water use by up to 50% during hand-washing. After doing the market survey two products were selected according to the availability in market, suitability and cost. 1st is Button and the other is Aerator.

6.1. Button Faucet Option

Button faucet is the special type of faucets which can reduces the usage of water very surprisingly. It has a button on its one end whenever a person wants to use water from this faucet he has to push or touch the button and the person whom using water has to push continuously whenever he stops to touch the button the flow of water will be stopped and meanwhile water is saving because in normal faucet this thing is not attainable. The below Figure 5 shows the market available button faucet.

Fig 5. Available Button Faucet

6.2. Aerator Options

Aerator is another substitution for the saving of water. An aerator is often found at the tip of modern indoor water faucets. It can be simply screwed onto the faucet head, creating a no-splashing stream and often delivering a mixture of water and air. During the market survey there were various kinds of aerators available with different openings and different sizes. The below Figure 6 shows, three different types of aerators which were available in market.

Fig 6. Three Types of Aerators

6.3. Comparison between Faucets and Aerators

The main purpose of this is to determine water savings due to the implementation of retrofit measures. Water savings (W(saving)) can be determined by equation below: There were two types of comparison made for mitigating the water consumption, first by flow rate, and second by taking amount of consumed water.

Figure 7 (a) shows the difference in flow rates. There were seven observations of taking flow rates and in each observation, it shows that the flow rate without aerator (normal /existing) faucet is having a high flow rate as compared to a faucet having aerator. By these results a 10-30 % of water can be saved after the introduction of faucets. Whereas the Figure 7 (b) shows the consumption of volume per WUDU by each faucet that is a normal faucet, button faucet and aerated faucet. There is total 7 observations for each faucet with the same person performing WUDU on each of them. After seeing these results, it states that there is a major difference approximately up to 60-70% difference between a normal faucet and button faucet and a 20-30% difference between a normal faucet and aerator faucet. These results show that 60-70% water can be saved after the implementation of button faucets and 20-30% water can be saved after the implementation of aerator on existing faucets.

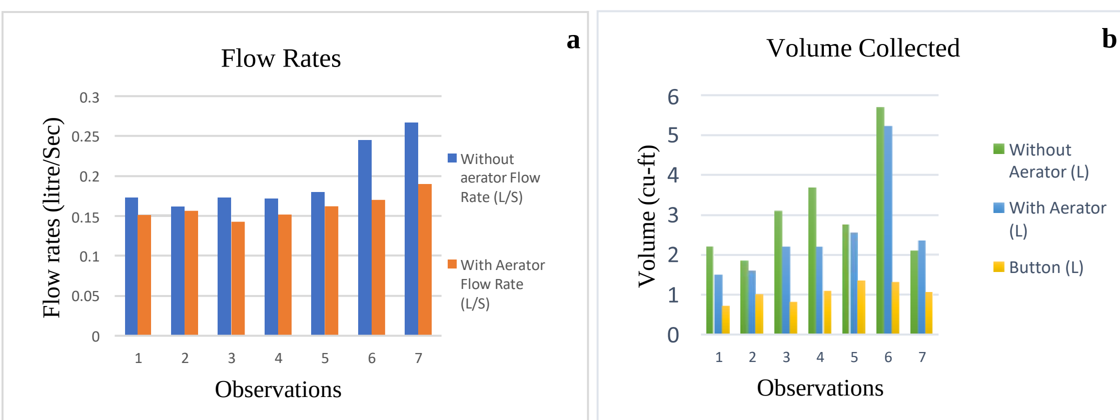


Fig 7 (a). Flowrates Graphical Representation (b) Graphical Representation of Volume Consumption

7. Conclusions

The followings are the conclusion of this case study:

For water consumption, the average volume consumed is 96.3cft per Prayer which is= 96.3 *5= 481.5cft/day. By flow rate water saving comes out to be 0.036 (liter per second). With use of aerator, saving comes out to be 0.537 (Liters).

With use of buttoned faucets, saving comes out to be (2 Liters). Button Faucet is the best alternatives as from the results i.e., 2 liter saving per person per wudu.

For electricity consumption, Phillips T-5 series would be an efficient option as a substitute by considering its lightning intensity, payback period, role in mitigating consumption, savings, and return on investment aspect

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