1. Introduction

Bilkent University dormitories cater to more than 4000 students in order to provide them with accommodation during their studies [1]. This proposal will focus on the use of electricity in said dormitories, specifically, the Dormitory 78. The dormitory features 89 rooms reserved for female students and 147 rooms for the male students. Ultimately, the building has the ability to host a grand total of 586 students [1]. Alongside so many students living in one building, come certain issues that need to be addressed such as the water and energy consumption of the students, as well as the infrastructure to dispose of the waste produced by such a vast crowd. One such topic to be examined relating to Dormitory 78 is the consumption of electricity by its inhabitants.

In an interview made with İsmail Türesin Özpineci on 29 June 2017, who is the electrical engineer responsible for the management and application of the electrical system of Bilkent University, it was found that the Dormitory 78 uses, on average, 1582 kWh of eletricity per day. Considering the number of students living inside the dormitory, it is concluded that an inhabitant of Dormitory 78 spends, on average, 2.69 kWh of electrical energy per day. Moreover, it is found that in Stanford University, a student who is living inside its dormitories spends typically 1.04 kWh of electrical energy per day [2]. Looking at these two numbers, one can observe that a resident of Bilkent University Dormitory 78 consumes more than twice the electrical energy compared to a student living in one of Stanford University's dormitories. This project investigates the possible causes of the aforemenetioned excessive usage of electricity, and presents possible solutions to the problem.

2. Problem Definiton

The problem at hand is the excessive consumption of electricity inside Bilkent Dormitory 78. As an attempt to further explore the problem and its components, three root causes have been identified.

2.1. Human error and lack of control mechanisms

One big issue that could be causing the waste of electricity inside Dormitory 78 is that students are forgetting to turn off the lights in the common-use spaces inside the building as well as the lights in their own rooms. There is a kitchen, and bathrooms on each of the floors and sections inside the dormitory, all of which are shared by the students [1]. In addition, there are the hallways which must always be kept lit. In a survey conducted to the residents of Dormitory 78 with the aim of finding out student habits related to the lights inside their dormitory; it was found that 74% of students often forget to turn off the lights in the common use areas. Moreover, 67% of students stated that they have found the lights left on unnecessarily in these common use areas more than 5 times a month. Resulting from a combination of human error and the lack of control mechanisms to regulate the lighting, electrical energy is wasted throughout the dormitory building.

2.2. Out-of-date and worn-out lightbulbs

The lights used inside the dorm are fluorescent lights which are relatively old in terms of technology and, as a result, they are not up to the standards when it comes to energy savings. Moreover, some of the lights inside the dormitory are worn-out as a result of heavy use and they are now consuming more unnecessary power. These worn-out lights consume the same amount of electricity but produce much less illumination as a result of most of the energy turning into heat. The equipment inside the dormitory is not maintained properly and it is technologically inferior; as a result, electricity waste arises.

2.3. Unplanned installment of lighting fixtures

The illumination of the dormitory building was not designed with efficiency in mind, resulting in redundant quantities of lighting to be distributed along the commonly used areas on the floors, as well as the needlessly large fluorescent lights to be placed inside smaller areas that do not require such devices. The figure below shows the floor plan of Dormitory 78, with the placement of the lights mapped out according to observation. As can be observed, the lights are distributed unnecessarily close to each other, especially in the commonly used areas such as the kitchen, where 3 fluorescent light strips are placed approximately every 1.5 meters.

Furthermore, in the survey conducted 42% of the students stated that they do not need all of the lights turned on to see properly in the common-use areas. However, 64% of the students said they turn on all the lights in the room when they enter as a habit. Considering the possibility that these lights can be left on as the students leave the room, the unnecessary electricity consumption markedly increases.

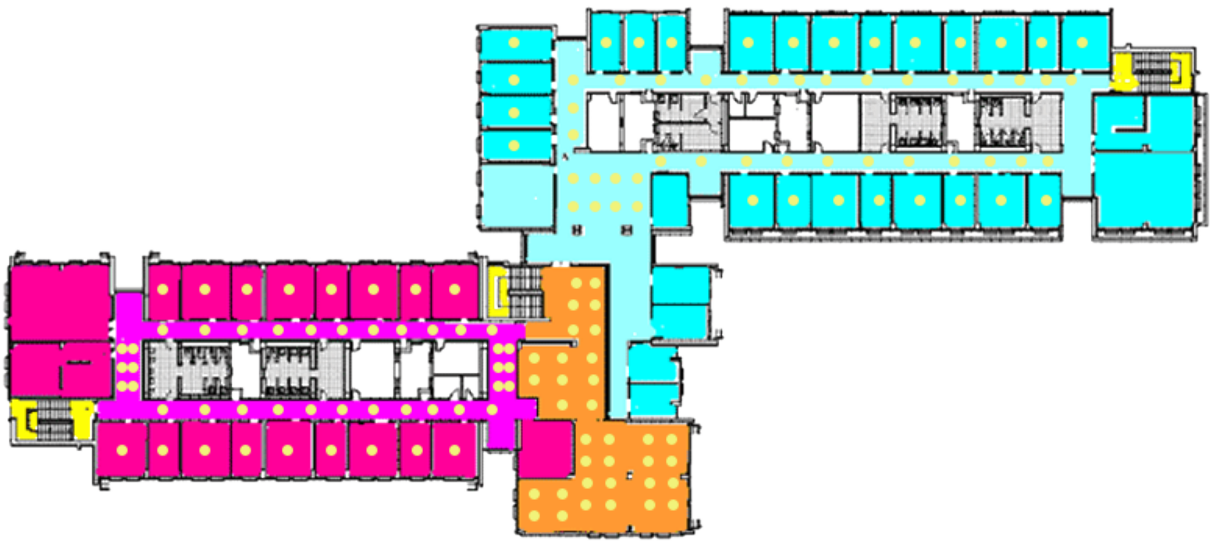

Figure 1, Lighting distribution inside Dormitory 78 (Source image taken from Bilkent Dormitory Website with the light sources mapped as part of observation) [1]

3. Proposed Solutions

3.1. Use of sensors to cut down on unnecessary up-time

Proximity sensors could be installed on the areas used commonly by all students and the student rooms, so that the lights will only be turned on if there is someone present to use the facilities. This solution is expected to eliminate the problem of human error, that is, students forgetting to turn off the lights inside the building, by installing a computer controlled mechanism into the lighting fixtures.

3.2. Incorporating energy efficient lightbulbs

Energy expenditure can be reduced by installing energy saving lightbulbs that use new technology instead of the traditional lights currently used inside the building. The most efficient form of lightbulb available currently are LED lights. On average, one LED lightbulb saves 2.5$ annually if it is used instead of the traditional incandescent lightbulbs [3]. Furthermore, LED lights consume up to 50% less energy compared to fluorescent lights [4]. By removing the outdated and worn-out fluorescent lightbulbs and installing the technologically superior and more efficient LED lights, considerable energy savings could be achieved.

3.3. Optimizing the distribution of lightbulbs

The placement of the lights can be designed in such a way to optimize the quantity and the power of the lights installed in each of the rooms. The optimization process hopes to maximize the effectiveness of each lightbulb, so that the living areas inside the dormitory could be illuminated using as few lighting fixtures as possible. First off, the color of the walls inside the building are mostly light-yellow or white, which are appropriate colors for reflection. The light sources can be constructed near the walls in order to benefit the most from the reflection, as the reflection will also provide some amount of illumination. Moreover, LED lights provide different a different amount of illumination compared to fluorescent lights. As a result, the placement of LED lights should be different than fluorescent lights to provide adequate lighting to desired areas. Lastly, in accordance with the survey results it can be inferred that currently there is an excessive amount of lighting fixtures installed in the common use areas and the corridors. These can be further reduced and optimized by taking into account how much lighting an area needs to receive to be considered illuminated, and the placement of the lightbulbs should be arranged accordingly.

4. Criteria for Assessing Solutions

The solutions were examined according to the following criteria:

Cost - effectiveness: There should be a reasonably satisfactory value (savings) returned from the implemented solutions in relation to the monetary cost of realizing such systems. For instance, if one considers the solution of installing sensors; then the electricity savings resulting from installing the sensors should be satisfying in relation to the cost of installing the system.

Acceptability: The proposed solutions should be easy for the students to adapt to, and they should not interfere with the students' day-to-day life. For example, some students might have a problem with LED lights because it may cause them eye-strain, which would make this solution less acceptable. In addition, the building management and the Bilkent Dormitory Management should accept and support the changes that will be brought about by the implementation of the solutions.

Feasibility: The solutions should be technically rational and suitable for the building's status. For example, a redesign of the building's lighting layout may or may not be possible depending on the construction of the building and the installation of sensors may not be possible depending on the technical specification of the lighting system. Lastly, the technology that is aimed to be implemented should be reasonably achievable with the technical staff and qualifications that the project has.

5. Research Methodology

Multiple interviews and surveys were conducted, and calculations were done to assess the proposed solutions with respect to the criteria. A table detailing each procedure employed to assess the solutions can be found below.

Installing sensors	Cost-effectiveness	Calculations of the installment cost and the savings sensors would provide
	Acceptability	Survey for students, building management interview
	Feasibility	Interview with Chief Electrical Engineer Türesin Özpineci
Increase efficiency of bulbs	Cost-effectiveness	Calculations and comparisons between fluorescent and LED bulbs
	Acceptability	Interview with Dormitories Manager Zeki Samatyalı
	Feasibility	Examining previous similar work, interview with Türesin Özpineci
Layout optimization	Cost-effectiveness	Interview with Chief Electrical Engineer Türesin Özpineci
	Acceptability	Survey for students, building management interview
	Feasibility	Interview with Türesin Özpineci and Financial Manager Ali Mehmet Kılınç

Table 1, Research Methodology

For cost-effectiveness, calculations provided sufficient quantitative data, enabling an educated decision to be made. In addition, interviews with the Construction Department of Bilkent University provided solid information about the labor cost required to implement some of the solutions, which aided in making a valid assessment of the proposed solutions.

For acceptability, interviews and surveys provided both qualitative and quantitative data in order to judge whether the possible solution is suitable for the people who are going to use it. Moreover, in order to make the most ideal assessment of the solutions, two points of view were needed: the students accepting the solution and the administration approving of the solution.

For feasibility, experts were consulted to see if the solutions are reasonable enough in a technical sense which gave suitable information to judge the solutions' workability.

6. Results & Analysis

6.1. Analysis of the use of sensors

6.1.1. Cost-effectiveness of sensors

According to the building plan, there exists approximately 612 lightbulbs inside the building to install the sensors [1]. Internet research has shown that the cost of an average movement sensor is 17₺ [5]. Scaling up the findings, the total cost of acquiring the sensors is calculated as 10,404₺. During a follow-up interview conducted with İbrahim Türesin Özpineci on July 23rd 2017, the labor cost of installing these sensors was approximately 1000₺, bringing the final cost to 11,404₺.

By implementing the sensors, a 40% cut on the uptime of the lighting fixtures inside the dormitory building is expected based on the collected data and calculations. Taking into account that 1kWh of electricity is worth approximately 0.41₺, the reduction in the running time of the lighting inside the dormitory building is expected to bring about 2594.48₺ per month [8]. Comparing the resulting number to the initial cost suggests a break-even point of 4 to 5 months. Considering a relatively short time to break even, installing sensors mostly satisfies the cost-effectiveness criterion.

6.1.2. Acceptability of sensors

A survey was conducted to assess the acceptability of installing sensors from the students' point of view. From the results of the survey, it was concluded that 67% of the residents of Dormitory 78 accepted the implementation of sensors into the lighting fixtures. Furthermore, an interview was conducted with the dormitory administration, which stated that the solution would be acceptable if there were alterations being made to the building's lighting fixtures already; however, it would not be acceptable as a single and isolated solution. To conclude, installation of the sensors was accepted by the students and conditionally accepted by the building administration.

6.1.3. Feasibility of sensors

An interview with the Chief Electrical Engineer Türesin Özpineci in Bilkent Construction Department was conducted to assess the feasibility of installing sensors into the ligthing fixtures inside the dormitory building. Mr. Özpineci stated that the solution was feasible because it required small to moderate modifications to the electrical grid of the building. Furthermore, Mr. Özpineci has affirmed that the university has enough personnel with sufficient technical expertise to realize the system. Therefore, installing sensors into the lighting fixtures satisfies the feasibility criterion.

6.2. Analysis of installing LED lightbulbs

6.2.1. Cost-effectiveness of LED lightbulbs

Internet research has showed the cost of an LED lightbulb to be 15₺ [6]. The total cost of replacing all 612 lightbulbs inside the dormitory would be 9180₺. LED lights consume up to 50% less energy compared to their fluorescent counterparts, which are currently installed inside Dormitory 78 [4]. After some calculations taking into account the previously discussed information, the total savings that would come from installing LED lightbulbs is estimated as 9729₺ per month. Lastly, the break-even point for realizing this particular solution is close to a month, which indicates this solution to be considerably cost-effective.

6.2.2. Acceptability of LED lightbulbs

An interview was conducted with the Dormitories Manager Zeki Samatyalı in order to assess the acceptability of installing LED lightbulbs inside the dormitory building. The dormitory management has approved of the solution as they have said that the process is simple and does not obstruct the lives of the students nor the building staff. In addition, they have found the solution to be the most appropriate out of all the three solutions that were discussed with them. All in all, the dormitory management is on board with the solution, hence, the solution satisfies the acceptability criterion.

6.2.3. Feasibility of LED lightbulbs

A case study was conducted featuring Stanford University in order to assess the feasibility of the solution with respect to the implementation of similar systems in other institutions. The research conducted has showed that Stanford University managed to reduce campus-wide electrical energy usage by 25%, through installing LED lights in place of the fluorescent ones [7]. Furthermore, in an interview, Türesin Özpineci has stated that the solution is fairly simple and does not require technical expertise. As a result, it was concluded that this solution was technically viable, thus making it technically feasible.

6.3. Analysis of the optimization of lighting fixture layout

6.3.1. Cost-effectiveness of the lighting fixture optimization

In order to optimize the lighting fixture layout as described in the solutions section of the report, approximately 400 lightbulbs need to removed and 122 lightbulbs need to be installed. This process is extensive and requires many alterations to both the building's ceiling construction as well as its electrical system. As a result, the labor cost of such a complex procedure is estimated to be 15,000₺ based on the interview done with Mr. Özpineci. After the process of replacing the lighting fixtures, about 280 lights will have been removed form the building, which would result in the total savings of 7783₺ per month. The break-even point for this solution is 2 months, a considerably short time which indicates that the solution satisfies the cost-effectiveness criterion.

6.3.2. Acceptability of the lighting fixture optimization

An interview with the dormitory management was conducted to assess the acceptability of the solution. The results from the interview suggest that the dormitory administration does not approve of the solution because it is too obstructing for both the students living in the dormitory and the dormitory staff. In addition, a survey was conducted with the student residents of Dormitory 78 and 82% of the participants have stated that they would not prefer this solution to be implemented. To conclude, this solution has failed the acceptability criterion.

6.3.3. Feasibility of the lighting fixture optimization

Interviews with Electrical Engineer Türesin Özpineci and Bilkent University Financial Director Ali Mehmet Kılınç were conducted to assess the feasibility of the proposed solution. The results from the interview indicates that the initial cost of realizing such a system is too high and the university cannot justify to spend such large amounts of money. Moreover, the proposed solution dictates a sizeable overhaul to the building's electrical system layout as well as the building's construction. Ultimately, the lighting fixture optimization has failed the feasibility criterion.

7. Conclusion & Recommendations

To sum up, according to the findings, the best solution out of the three proposed solutions was replacing the current fluorescent lightbulbs with LED lightbulbs. This solution satisfied all criteria and therefore it is deemed as the most appropriate solution. Installation of sensors was the second most appropriate solution as it was not as cost-effective as the LED lightbulbs, nor was it as feasible. Lastly, the layout optimization solution is deemed the least preferable solution as it was rejected by both the building administration and the students.

The suggested plan of action for implementing these solutions is combining the sensors and the LED lightbulbs solutions, with priority given to the installation of LED lightbulbs. As the sensor solution was considered acceptable only if it would be implemented alongside other solutions, it seems appropriate for it to accompany the LED lightbulbs and be integrated into the building while the lightbulbs are being changed. With both of these solutions implemented and integrated into the building's infrastructure, the electricity consumption of Dormitory 78 could be expected to decrease significantly.

References

[1] Bilkent University, ‘Hizmet ve Olanaklar’, 2013. [Online].
Available: http://www.yurt.bilkent.edu.tr/78a.html [Accessed: 26-Jun-2017]

[2] Stanford University, ‘Fact Sheet: Student Housing’, 2016. [Online].
Available: https://sustainable.stanford.edu/sites/default/files/FactSheet_StudentHousing.pdf [Accessed: 23-Jul-2017]

[3] Earthled.com, ‘LED Light Bulbs Vs. CFL Light Bulbs: Which is Best for Me?’, 2015. [Online].
Available: https://www.earthled.com/blogs/light-2-0-the-earthled-blog-led-lighting-news-tips-reviews/35906628-led-light-bulbs-vs-cfl-light-bulbs-which-is-best-for-me [Accessed: 30-Jun-2017]

[4] Lowes.com, ‘Lightbulb Buying Guide’, 2016. [Online].
https://www.lowes.com/projects/decorate-and-entertain/Lightbulb-Buying-Guide/project [Accessed: 25-Jul-2017]

[5] Elektrikmarket.com, ‘Tavan Hareket Sensörleri’, 2017. [Online].
https://www.elektrikmarket.com.tr/Sensor-180-Derece-Beyaz-Horoz-088-001-0003,PR-50780.html [Accessed: 24-Jul-2017]

[6] Vatan Computer, ‘Goldmaster LED AMPUL E27’, 2017. [Online].
http://www.vatanbilgisayar.com/la-127-bl2-led-ampul-e27-duylu-10w-75w-akkor-220v-3000k-sicak-beyaz.html [Accessed: 24-Jul-2017]

[7] Stanford University, ‘Advancements in Energy Efficiency’, 2016. [Online].
Available: https://sustainability-year-in-review.stanford.edu/2016/features/advancements-in-energy-efficiency/ [Accessed: 23-Jul-2017]

[8] Gazelektrik.com, ‘Mesken Elektrik kWh Fiyatları’, 2016. [Online].
http://gazelektrik.com/faydali-bilgiler/1-kwh-elektrik-kac-tl [Accessed: 24-Jul-2017]