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Lighting Use Characteristics and Potential of LED Replacement of Single Householdin University Town

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Abstract

This study analyzes and quantifies the pattern of single-person households' using lighting fixtures in college neighborhoods. In addition, potential of LED light replacement is estimated based on numerical calculation for applicable decision-making process is presented. This study collected data on occupancy schedule of single-person households in college neighborhoods at 10 minute resolution, their lighting system specification, and utilization schedule in a bid to estimate lighting energy consumption trends in consideration of the characteristics of single-person household. It was found that all subjects studied used only fluorescent lights and incandescent lamps as light sources. If the advantages of replacement LED lights are to be predicted in consideration of such lighting use pattern of single-person households in college neighborhoods, Lighting source replacement only in studio room used as bedroom is expected to result in energy efficiency gain by reducing energy consumption by 45.2kw/year and CO2 emission by 21.3kgCo2/year per single-person household unit available for rent in college neighborhood.

Keywords: Lighting Fixture Usages, Single-Household, University Town, LED Substitution Effect

1 Introduction

Supply of single-person residences is rising rapidly in Korea because of college admission ratio remains high and students choose to live in university town apart from their families [7], but not many studies have attempted to suggest energy-efficient solutions for single-person households.LED light is touted as a futuristic eco-friendly lighting solution more energy-efficient that fluorescent light and incandescent lamp. LED lights are replacing lighting fixtures in many applications these days. The preceding studies indicate that penetration of LED light in rental housing is sluggish around university town.[5] As lighting is one of large energy consumers in buildings[1], improvement of lighting efficiency delivers relatively significant potential for reduction of energy consumption in buildings. This study intends to identify the characteristics of single households near university town and estimate quantitative potential from LED light replacement in a bid to encourage single-person housings in university town to replace lighting fixtures with LED lights.

2 Material

This study surveyed 83 occupants representing households near the university town and chose 31 samples that are single households within less than 1km from colleges in terms of the physical distance through purposive selection. Excluding four samples whose TUS data was lost from the 31 samples subject to detailed analysis, lighting energy consumption tendency of 27 single-person households in university town was analyzed.

Table 1 shows the type and capacity of lighting system installed in applicable households. All 83 subjects surveyed prior to purposive selection were found to use FL and IL as light sources. Table 2[6] shows the time of using main light in studio room that is the primary living space of those surveyed and used for bedroom by them along with the cycle of turning the light on/off. Light consumption time was 410 minutes on workdays and 276 minutes on weekends, which revealed difference of about 1.5 fold, but no significant difference was found in the cycle of turning the light on/off. Table 3 shows the characteristics of lighting system derived from generic residential lighting fixtures widely distributed in market to estimate the potential of LED light replacement. 22W LED light designed to replace 32W fluorescent light described in Table3 is associated with the design life of 50,000 hours which is five times longer than conventional fluorescent light for home use. In addition, the former is found to be 30% more energy-efficient than the latter.

Table 1. Specification of lighting system in single-household near university towns

Installation place	Type of unit light	W of unit light	W Total	SD
Studio room	FL[1]	24,36	65.85	27.94
Kitchen	FL,IL[2]	6, 12, 18, 20, 24, 30	34.79	15.12
Bath &etc	FL,IL	12,18,20,24,55	18.69	7.40

Table 2. Specification of lighting system in single-household near university towns

	Workday	Weekend
Average of lighting time	410min	276min
Average of Numbering of On/Off	2.44	2.05

Table 3. Specification of lighting system in single-household near university towns

	Compact fluorescent lamp			Bulb Type Fluorescent Lamp			LED Fluorescent Lamp	
Watt(W)	24	32	36	11	20	23	19.8	22
Efficiency (lm/W)	75	83.44	74.17	53.64	60	65.22	118.69	109.09
Lumen(lm)	1,800	2,670	2,670	590	1,200	1,500	2,350	2,400
Life(h)	10,000	10,000	10,000	10,000	10,000	10,000	50,000	50,000

3Lighting Energy Use Characteristics

Table 4[5] shows daily energy consumption per lighting usage. Lighting usage time is found to be the longest in bedroom representing a primary living space of single-person households. More lighting energy was consumed on workdays than on weekends. It was found that the average gross floor area of single-person households surveyed in college households was 30.72 ㎡(Std. Dev. 12.77) and lighting energy consumption unit was 440w/㎡•month. Accordingly, monthly lighting energy consumption per household is estimated to be 13~14kw.

1 FL : Flouorescent light
2 IL : Incandescent lamp

Table4. Daily lighting energy consumption of investigated household

Installation place	Time used for lighting (Unit:minute)		Energy Consumption (Unit:W)	
	Workday	Weekend	Workday	Weekend
Bed room	410	276	450	302
Kitchen	73.6	41.3	42.6	24
Bath	18.1	26.3	5.6	8.2

Fig 1 shows the lighting use pattern when single-person household rooms are occupied. Although lighting may not be used intermittently, subject to external conditions such as availability of natural lighting source even when a room is occupied by the resident, lighting is used when a room is occupied. In particular, given that 60% or more occupants use lighting in 14:00~17:00, it is believed that room occupancy affect lighting usage more than the intensity of external illumination.

Fig 2 shows the hourly energy usage pattern from lighting energy consumption. The pattern indicates that more lighting energy is consumed on workdays than on weekends. Hourly energy usage pattern on workdays was different from that on weekends, subject to the characteristics inherent to occupants such as eating out the pattern, changes in rising hour, and home-coming hour, etc. In addition, unlike ordinary households, lighting energy demand was observed in early morning on workdays, which is deemed to reflect the inherent characteristics of residents in university town (studying, irregular daily living routines) prevailing in seasonal semesters as the survey was conducted in December to January.

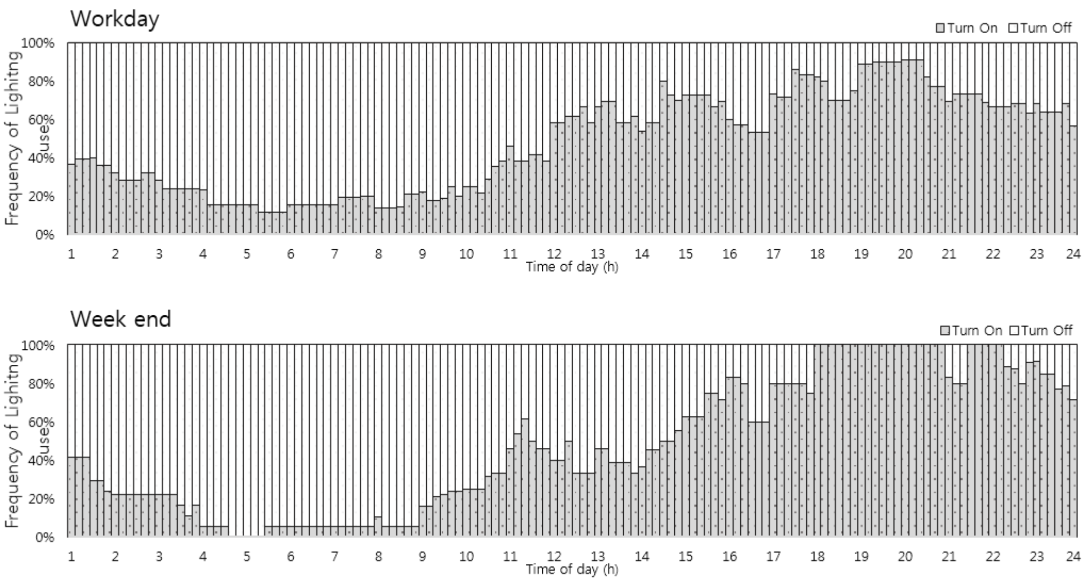

Fig 1.The hourly lighting use patterns of the single-household during the occupied periods

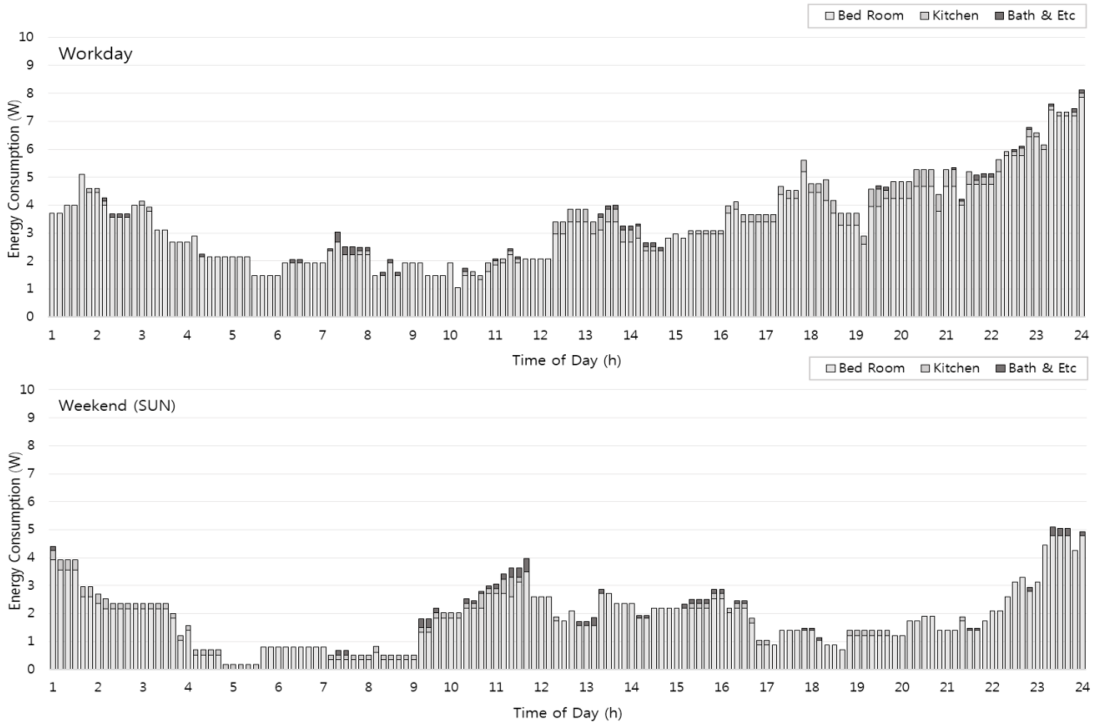

Fig 2.Energy consumption of investigated single-household

4 Substitution effect of LED Lighting

In this study energy saving effects of LED light replacement per household was estimated. For estimation, lighting fixture characteristics of rental houses in university town were analyzed. Average fluorescent lamp capacity was assumed to be 64W. For comparative analysis, two 22W LED lights providing the similar intensity of illumination to the assumed fluorescent lighting capacity were assumed to be installed. With this setting, effects of LED light replacement in rental housings in university town were estimated in consideration of the light usage pattern of occupants. For CO_2 emission saving attributable reduction of energy consumption, the evaluation process recommended by the IPCC was used. It was found in the analysis that replacement with LED lights could save energy by 45.2kw on annual average per household and reduce CO_2 emission by 21.3kgCO_2.

$$L_l = (L_{u.t.} + \gamma L_{on/off})\chi \qquad (1)$$

L_l $= initial\ service\ life\ of\ lighting\ fixture(h)$

$L_{u.t.}$ $= daytime\ lighting\ usage\ time(h)$

$L_{on/off}$ $= daytime\ light\ turning - On/Off\ \ cycle(Numer\ of\ \ On/Off)$

$\gamma = reduction\ of\ service\ life\ day$

In addition, Equation (1) is presented for the estimation of the light replacement cycle [6]. For initial service life or design life of lighting fixture, values presented in Table 3 are used. Daytime lighting usage time and light turn on/off cycle are used as suggested in Table, but workdays and weekends were assumed to be five days and two days respectively, irrespective of holidays. Possible reduction of lighting fixture life attributable to turning on/off of light was assumed to be one hour of fluorescent light according to values suggested in a preceding study [3]. As no reduction of service life attributable to turning on/off was reported for LED light, the comparable value was set to be 0. It was found in the analysis that replacement frequencies of applicable lighting fixtures were 155 weeks for fluorescent light and 1,153 weeks for LED light, which indicates that fluorescent light is replaced by about 7.4 times per one cycle of LED lighting fixture.

5 Conclusion

This study attempted to quantify possible benefits of replacing residential lighting fixtures with LED lights in rental housings around university town. To estimate lighting usage pattern varying subject to the characteristics of occupants and corresponding lighting requirement and energy consumption, lighting usage pattern derived from a survey of 31 rental housings in college neighborhood was used. It was found in the survey that the potential of LED light replacement would be significant as only fluorescent lights and incandescent lamps were used in such housings. However, as lighting usage is less intense in kitchen or bathroom of single households near university town, it is not cost-effective to use high-efficiency lighting fixtures such as LED light in such space. But, it was found that lighting usage time was 410 minutes longer in a bedroom than in kitchen or bathroom. Thus, it is believed that replacing bedroom lighting with high-efficiency lighting system could result in energy saving and environmental load reduction.

It is estimated that replacing the lighting fixture of the bedroom that is the primary space of living routines with LED light could save energy consumption by 45.2kw/year. And the CO_2 emission by 21.3kgCO_2/year per one rental housing near University town. In addition, it is found that given the possible reduction of service life of lighting fixture due to turning on/off, fluorescent light is to be replaced about seven times per one LED light.

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