

Feasibility Analysis for Introducing ESCO Program of LED Luminaire Replacements in Schools

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Abstract

Public institutions should replace their luminaires with LED lighting by 2020 to save energy. Because the LED lighting installation rate in schools has not yet reached the legal goal, the ESCO program feasibility was investigated. The amount of electricity used, electric rates, times of use in classrooms and fluorescent lighting maintenance costs etc., as well as the elements of lighting maintenance were analyzed. In the case of schools, the lamp usage time was so short that the ESCO projects with only energy savings were impossible. In order to execute the ESCO projects, the maintenance cost savings by replacing an existing luminaire should be considered and the introduction of the relatively cheaper tube type LED lamp than the flat type LED luminaire was required.

Key Words : LED Lightings, ESCO Program, Lighting Maintenance, Energy Saving

1. INTRODUCTION

According to the “Regulations on public sector energy use rationalization”, public institutions’ luminaires should be replaced with LED lighting by 2020[1]. However, the LED luminaire installation rate was low because of financial shortages.

In 1997 an illumination improvement project for schools within the jurisdiction of the Seoul

Metropolitan Office of Education(SMOE) was started to meet the new standard illuminance 300lx with fluorescent luminaires. These luminaires had been used for more than the useful life of 15 years as determined by the SMOE itself, and it was time to replace the obsolete lighting installed initially.

The aim of this paper was to research the possibility of introducing ESCO(Energy Service Companies) projects, because nowadays the budget for construction and maintenance expenses of school facilities was declining day by day.

Luminaire replacement projects brought two effects. One was a decrease in energy usage and the other was the effect of reducing maintenance costs of the existing luminaire due to the long life of LED lamps compared to fluorescent. The amount of electricity used, electricity rates, hours of using

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Received : 2015. 9. 23.

Accepted : 2015. 12. 6.

classroom etc., the elements of lighting maintenance were investigated and the ESCO program feasibility of luminaire replacement in school was analyzed.

2. The luminaire usage

2.1 Luminaire replacement

One classroom was equipped with 9 fluorescent lamps of 32W×2 lamps on the ceiling and 2 fluorescent lamps of 32W×1 lamp for the blackboard. The fluorescent luminaires were typically replaced with flat type LEDs.

Table 1. LED luminaire installation ratio

Public schools	Total (EA)	LED (EA)	Ratio (%)
957	1,305,458	93,377	7.2

There were 957 public schools and the number of LED luminaire was 93,377 of the 1,305,458 as of January 1, 2015.

2.2 The luminaire usage

The legal minimum school days are 190 a year[2]. The survey was conducted on 55 schools and inspected that the classroom was used for 10.51 hours a day with average electricity rates of 127₩/kWh.

Table 2. School days and electricity usage

Wattage (W)	School days (d)	hours (h/d)	rates (₩/kWh)
2 of F/L 32W = 64W	≥ 190	10.51	127

The wattage 64W that was a value including the power consumption of electronic ballasts.

The measured average illuminance of classroom is 369lx, the illuminance simulated with a fluorescent lamp of 32W×2 lamps, 4,266lm is 368lx[3]. Hence this study was based on the replaced LED luminaire of ≥4,300lm.

3. Analysis of ESCO project feasibility

3.1 ESCO investment program

ESCO is the Energy Service Company as determined by the ‘Energy Use Rationalization Act’. The concept of the ESCO investment projects is that ESCOs obtain financing for the installation of energy saving facilities, executes the project, guarantees energy savings and energy users redeem the investment cost with their energy cost savings[4]. However, schools had the problem of a short usage time in obtaining the proper redemption period as the time of use of the luminaire was so short that the effect of energy cost savings was small. Thus it seemed that the ESCO projects were impossible to implement in schools.

The SMOE held a policy forum on “Introduction of LED luminaires for classrooms” October 29, 2013. One city councilor, 17 companies of ESCOs and LED luminaire manufacturers including civil servants of education office, 46 in all, attended the forum. ESCOs and manufacturers insisted that the project would take at least 15 years or more than 25 years in order to repay the investment with energy cost savings according to their research. They also suggested that SMOE had to redeem some part of the investment expenses with energy cost savings for 10 years and had to make up the difference by funding the shortfall on its own. So, the Seoul Metropolitan Office of Education planned to start the LED luminaire replacement projects after securing

more than 50% of the required investment budget.

3.2 Criteria

Energy savings of $\geq 5\%$ and 10 years of repayment terms make the ESCO projects possible, according to the “Regulations on public institution promoting energy utilization rationalization”[5]. The Korea Energy Agency secures funds with an interest rate of 2.75%[6]. Public institutions must use the efficiency of LED lightings 95lm/W when installing $30\text{W}\sim 60\text{W}$.

Table 3. ESCO program condition on public institutions

Savings	Max term	Loan ratio	Luminaires specification
$\geq 5\%$	10 years	2.75%	$\geq 95\text{lm/W}$ $30\text{W}\sim 60\text{W}$

3.3 Luminaire maintenance costs

The minimum cost of an LED 40W luminaire was $\text{₩}91,000$, having the size of $1200\text{mm}\times 300\text{mm}$, flat type. With a size of $1200\text{mm}\times 75\text{mm}$, 20W LED price was $\text{₩}78,000$. Efficacy was 110lm/W . If including the installation costs of $40\text{W}\times 9\text{EA}$ for classrooms and $20\text{W}\times 2\text{EA}$ for blackboards, $\text{₩}1,394,270$ per classroom was required. The total construction costs of $\text{₩}1,394,270$ consisted of material costs, labor costs, legal expenses and other costs. The survey was conducted on 29 schools of the 55 schools mentioned above. By researching the maintenance of the existing fluorescent lightings in 2011~2013, 14.32% of lamps and 1.74% of ballasts were replaced in a school per year. There are, respectively, 20 fluorescent lamps and ballasts per classroom and 2.86 lamps and 0.35 ballasts were replaced per year.

Table 4. Fluorescent luminaire maintenance

Qty (EA)	Lamp		Ballast	
	Change (EA)	Ratio (%)	Change (EA)	Ratio (%)
59,852	8,570	14.32	1,041	1.74

The material and labor costs were calculated to be about $\text{₩}4,689$ per classroom a month. The fluorescent luminaire maintenance cost is shown in Table 5.

Table 5. Fluorescent luminaire maintenance costs(1 classroom per year)

F/L	Change (EA/yr)	Expense (₩/yr)	Costs (₩/mo)
Lamp	2.86	24,962	2,080
Ballast	0.35	31,311	2,609
Total	-	56,273	4,689

3.4 The ESCO project expense analysis

3.4.1 The ESCO projects with the flat type LED luminaire

If fluorescent lightings were replaced by 9 of 40W and 2 of 20W LED per room, electricity consumption savings would be 39.94kWh/mo and electricity bills would be cut $\text{₩}5,072$ monthly. At an interest rate of 2.75%, $\text{₩}5,072$ a month, it takes about 36 years and 2 months to repay the replacement cost of $\text{₩}1,394,270$, making the ESCO program unfeasible.

The success of the ESCO projects required $\text{₩}13,303$ per month based on the interest rate 2.75% and repayment terms of 120 months. The reduced electricity load was 0.3kW per room and the average rate of electricity was 127₩/kWh , the implementation of the projects with the energy savings was required at about 437 hours a month, about 5,238 hours a year of using lightings, which

translated to be 2.6 times the luminaire usage time of the current 1,997 hours a year, which was practically impossible.

The ESCO projects provided energy savings and reduced maintenance costs of the existing fluorescent luminaires. The maintenance costs of fluorescent lamps and ballasts were ₩56,273 per year, which came to ₩4,689 per month. Therefore, the total cost savings were about ₩9,761 a month if changing to LED luminaires. Considering the existing luminaire maintenance costs, the ESCO projects took approximately 14 years and 5 months. This was longer than 10 years but if considering the maintenance costs as well as the energy savings, the ESCO project could be possible.

3.4.2 ESCO projects with tube type LED luminaire

The price of LED luminaire should be at ≤ ₩64,000 to complete the ESCO projects with ₩9,761 per month by way of the repayment period of 120 months and an interest rate 2.75%, with a cost of ₩1,020,420 per classroom.

LED luminaires that could be purchased at ≤ ₩64,000(₩32,000×2) were an external converter tube LED, a converter built-in tube LED lamp or a built-in tube direct-type LED lamp. Their minimum power consumption was 17W.

The standards required that in the case of lamp power at ≤22W, efficiency was at ≥130lm/W, so the total luminous flux of 17W LED lamp was at ≥ 2,200lm. Power consumption was cut down on by 30W, energy savings were about 46.9% and a school could save electricity rates of ₩6,340 monthly. Under the same condition as flat type, the project took 16 years and 9 months with ₩6,340 a month, and in order to be completed within 10 years, energy savings was required about 3,066 hours a year of using lightings, or at 1.5 times the luminaire usage

time of current about 1,997 hours a year, which was practically impossible. However, involving the maintenance cost ₩4,689, the saving effect came to ₩11,029 and took 8 years and 8 months to complete the project.

The total installation expense of a Converter built-in tube LED lamp was cheaper than others. However, constant use of the existing ballast had to be considered as well as compatibility.

4. The ESCO project Effects

4.1 Analysis of investment effects

At a high school with 70 classrooms, if 20 luminaires of 17W were replaced, it would cost ₩1,020,420 per classroom and, in total, ₩71,429,400. By the way of a fixed interest rate of 2.75% and monthly ₩11,029 involving energy and existing luminaire maintenance cost savings, the projects could be implemented.

Table 6. The ESCO project expenses

rooms	1	70
Expense (₩)	1,020,420	71,429,400
Repayment (₩/mo)	11,029	772,030
Duration (mo)	104	104
Interest (₩)	126,596	8,861,720
Amount (₩)	1,147,016	80,291,120

It was analyzed that the project duration was 8 years 8 months and total repayments were ₩80,109,120 including interest ₩8,679,720.

Through the project, power consumption of 64W was changed to 34W and the electricity rates of ₩162,308 were reduced to ₩86,226 per year. The saving effects were 46.9%.

Table 7. Energy Saving effects
(1 classroom, 17W 20EA, 127₩/kWh)

Items	Before	After	Savings
Wattage (W)	32	17	15
Using time (h)	1,997	1,997	-
Amount (kWh/yr)	1,278	679	599
Bills (₩/yr)	162,308	86,226	76,082

According to the previous study, the lighting load density per classroom (7.5m×9m) is 9.99W/m²[3]. Every school had a different quantity of luminaires. In the case of 9 fluorescent lamps of 32W×2 lamps per classroom and 2 fluorescent lamps of 32W×1 lamp for blackboards, the replaced 20 LED luminaires of 17W made the illumination load density 5.04W/m².

Table 8. State of lighting power

Load (EA)	Consumption (W)	Density (W/m ²)	Type
32W×20	640	9.48	F/L
17W×20	340	5.04	LED

4.2 LED lamps simulation

The flat type (40W) and tube type (17W) LED simulation were executed with ReluxPro 2014.

The LED, in this simulation, was a flat type 40W and tube type 17W, the efficacy of the 40W LED was 110lm/W, the efficacy of the 17W was 130lm/W. They were made by the Company H. The reflectivity of classroom finishing materials was used from prior measured data [3] and the maintenance factor was applied at 70%.

The result of the simulation using a flat type LED and external converter tube LED lamps showed an illuminance distribution of the classroom to be suitable for illuminance standards. The results are shown in Table 9.



Fig. 1. Simulation result of LED 17W×20EA

Table 9. Expected illuminance in the case of LED lamp application

Type	Desk surface illuminance		Blackboard illuminance	
	Eav (lx)	Uniformity	Eav (lx)	Uniformity
Flat	395	0.69	480	0.55
Tube	399	0.66	470	0.59

5. CONCLUSION

At public high schools controlled by the Seoul Metropolitan Office of Education, fluorescent luminaires had been in use for longer than the useful life determined by the SMOE itself. According to the “Regulations on public sector energy use rationalization”, public institution luminaires should be replaced with LED. But lighting equipment improvement projects were delayed because of a shortage of education funding related to school facilities, and therefore the ESCO program was analyzed.

The ESCO projects for application to high schools had issues of a relatively expensive price for LEDs and an absolute short time to obtain the proper payback period.

In order to complete the ESCO program, it was first necessary that the maintenance cost savings as well as energy saving effect were included, and second, that the price of the LED luminaire to be installed in place of the fluorescent one should be at ≤₩64,000. Currently, the external converter type

LED lamp makes the ESCO program feasible. Also, a converter built-in tube LED was useful to the project, if considering that the existing ballast was used continuously and is compatible with the fluorescent ballast. Old sockets had to be converted to new to prevent the lamp from falling.

Further research into the possibility of the ESCO program for elementary and junior high schools equipped with similar luminaires is needed.

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Biography



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