Development of Simple Prediction Tool for Lighting and Electrical Outlet Power Consumption in the Non-Residential Buildings

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ABSTRACT

The main objective of this research is the presentation of a method for finding lighting and power outlet energy consumption volume, which is both easy to calculate, and possesses a certain degree of accuracy, from the Japanese background of few lighting & outlet energy data and useful caclulation tools. Firstly, the existing and newly measured data of office buildings and commercial buildings were collected, and the consumption structures were analyzed. Then, considering the results of analysis described above, the calculation algorithm based on the concept of CEC/L (Coefficient of Energy Consumption for Lighting) in the energy-saving laws of Japan with lumen method for main area was proposed for the lighting consumption. As to the electrical outlet consumption, 3-leveled electrical densities were considered. Finally, to carry out above calculation process with ease, the tool using general-purpose spreadsheet software was developed.

1. INTRODUCTION

This research was carried out to predict the consumption volumes of electricity for lighting and power outlets in non-residential buildings. It aims at reducing the burden that buildings place upon the environment.

Despite the fact that lighting and power outlets occupy a large percentage of a building’s overall energy consumption volume, there has never been a detailed understanding of this consumption. One of the reasons for this is the extreme difficulty in partitioning and measuring the energy consumption volumes of lighting and power outlets.

There are some researches (e.g. Shirai, 2004), which report the general energy consumption ratio between lighting and power outlets in the buildings. But since the energy consumption volume of lighting is greatly influenced by lighting systems and designed illuminance level, and that of power outlets is greatly influenced by the installation density (forinstance, office equipment), it is considered that it would not be appropriate to apply a single share ratio between lighting and power outlets unilaterally.

Among the tools for predicting energy consumption volume, which have already been developed and made public (e.g. ECCJ, 2008), for predicting the yearly energy consumed by air conditioning there is a method that carries out a detailed simulation after calculating thermal loads. This is done using local climate data, but for lighting and power outlet energy consumption, the use of quite simple methods is common. Thus, while there has been a formulation of detailed simulation-based forecasting logic for predicting energy consumption volume for air conditioning, the fact that energy consumption volume prediction for lighting and power outlets has not advanced, is one of the problems in formulating energy consumption volume prediction systems/tools.

Thus, the main objective of this research is the presentation of a method for finding lighting and power outlet energy consumption volume, which is both easy to calculate, and possesses a certain degree of accuracy.

2. METHODS

Office buildings and commercial facilities were considered for our research. We first acquired actual energy consumption performance data measured by completely separating lighting and power outlets, and then analysed the consumption structure. Next, we researched a combined method of easy lighting design for major lighting sections based on the lumen method, results of the analysis and calculating structure of Coefficient of Energy Consumption for Lighting (CEC/L (Institute for Building Energy Conservation, 2004)) in Energy Use Law of Japan. We set the power outlet to a 3-leveld load density (W/m²), and researched methods using this setting. Furthermore, in order to be able to carry out lighting and power outlet consumption predictions easily, we tried developing an eergy consumption volume calculation tool, which uses general-purpose spreadsheet software. Lastly, to verify our accuracy, we carried out a case study on a mid-scale building, for which there existed actual performance data measured separately for lighting and power outlets.

3. COLLECTION OF ACTUAL PERFORMANCE VALUES, AND ANALYSIS OF THE CONSUMPTION STRUCTURE

3.1 Collection of Actual Performance Values

For acquiring actual performance data, new data as well as pre-existing publicly-released data were collected. For office buildings and for data that included as-yet-publicly-unreleased data, we obtained detailed information by considering five buildings out of ten, which in recent years had been the recipients of an Energy Efficient Architecture Award from the Institute for Building Environment and Energy Conservation (IBEC) of Japan. For these buildings the lighting and power outlet electricity consumption data existed. The data for three of those five buildings could be separated by lighting and power outlets. Un-separated data consisted of the data for the remaining two buildings and data for 150 tenant office buildings of Company N. For pre-existing publicly released data, we collected data from the Energy Conservation Center, Japan (ECCJ). We were unable to obtain any new actual performance data for commercial facilities. Since the information regarding the consumption volume share occupied by effects lighting, such as spotlights, and those on sales floors is indispensable in the formulation of a prediction method, we implemented field surveys on base lighting and effects lighting (spot lighting), both in person and using photographs, for department stores, supermarkets and mass retailers, which included a total of ten buildings.

3.2 Consumption Structure Analysis

For office buildings, we compiled and analysed the data obtained throughout the process described above.

Figure 1 shows the relationship between gross floor area of office buildings, and yearly electricity consumption volume for both lighting and power outlets combined. We see from this that there is a high correlation between the gross floor area, and overall yearly electricity consumption volume for both lighting and power outlets combined.

Fig. 2 shows the relationship between the electricity consumption volume for lighting, and the electricity consumption volume for power outlets. We see from this that, in offices, the electricity consumption volumes for lighting and for power outlets are at almost the same level. Compared with previous result (Shirai, 2004), it can be thought that some reasons for the bigger share that has come to be occupied by power outlets are the nature of structures which were granted an Energy Efficient Architecture Award, which made the energy-efficient lighting techniques widespread, and also of the CEC/L notification results. The light source efficiency is advancing and consumption efficiency for lighting has been rising in newly-constructed buildings. The influence of difference in office equipment density is also conjectured, but we were unable to obtain clear evidence of this.

For commercial facilities, we separately estimated the consumed power density (W/m²) for base lighting and effects lighting from photographs obtained during our field surveys. We derived the power outlet electricity values (W/m²) based upon the total electricity (W/m²) of both lighting and power outlets in department stores, which appeared in past literature (Institute for Building Energy Conservation, 2004), and the estimated lighting values mentioned above.

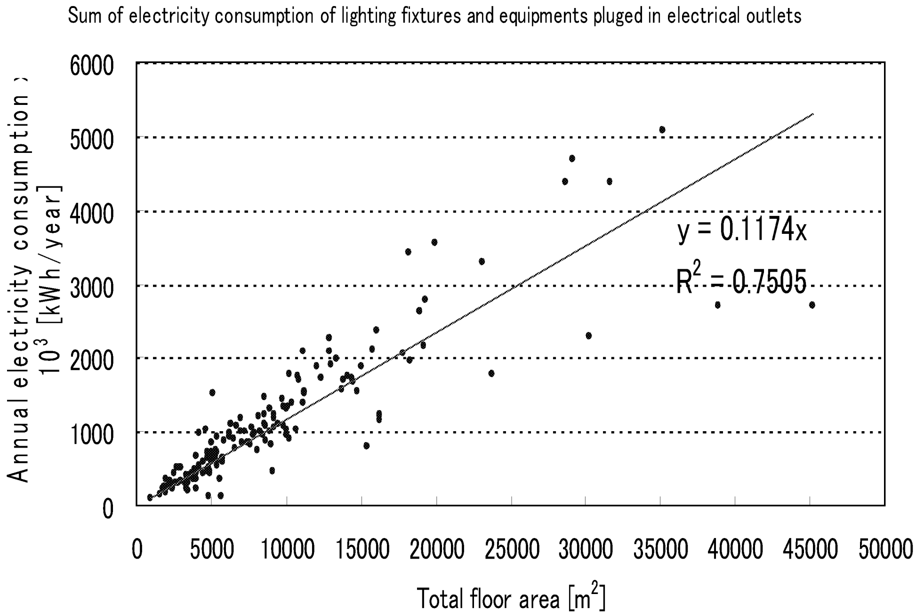


Figure1: Relationship between total floor area and annual electiricity consumption (lighting and outlets combined)

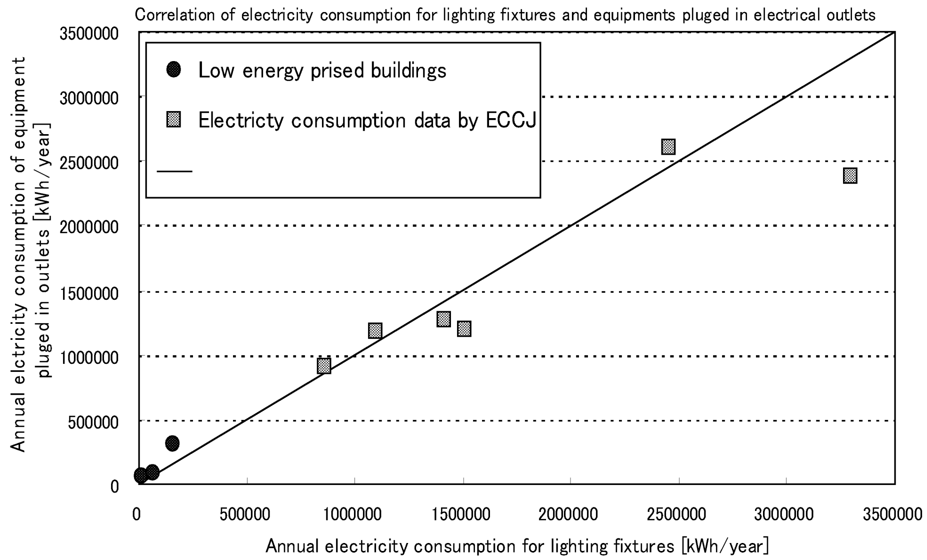


Figure2: Relationship between annual electricity consumption of lighting and annual electricity consumption of outlets

4. OUTLINE OF THE LIGHTING AND POWER OUTLET ENERGY CONSUMPTION VOLUME PREDICTION METHOD

For the prediction method for lighting, we devised a method of cumulative equation calculation based on the CEC/L consumption structure (lighting fixture electricity x yearly illumination hours x energy efficient lighting control correction coefficient). First the manufacturer's calculation methods for the number of lighting fixtures were procured. Based on this, for predicting lighting consumption for office buildings, for major areas (office rooms), we considered the algorithm, which was calculated by taking into consideration arbitrary yearly illumination hours and the correction coefficients of energy conservation lighting control, with the attendance ratio for the task lighting, based on the number of general lighting fixtures and ambient lighting fixtures deduced according to the lumen method. This was in accordance with space dimensions and the lighting fixtures with four kinds of designed illuminance level. For common-use areas, we set three levels of electricity (W/m^2) depending upon illumination level, and multiplied them by the average yearly illumination ratio. We multiplied them by a fixed energy efficiency correction coefficient in the case that some type of control was in use. For predicting power outlet consumption in office buildings in major areas (office rooms) only, it was so arranged that the office equipment installation density could be selected in three levels, and then multiplied by the power outlet usage ratio, which corresponded to each of those levels.

For predicting lighting consumption in commercial facilities, the same as with office buildings, we considered the algorithm, which was calculated by taking into consideration the arbitrary yearly illumination hours and energy efficient lighting control correction coefficients, based on the number of base lighting fixtures according to the lumen method and the grade of the effects lighting deduced. Base lighting was in accordance with the choice from among the four different kinds of lighting fixtures. For common-use areas, we set three levels of electricity (W/m^2) depending upon illumination level, and multiplied them by the average yearly illumination ratio. We multiplied them by a fixed energy efficiency correction coefficient in the event that some form of control was in use. For predicting power outlet consumption at commercial facilities, this was also the same as for office buildings, the major areas (sales floors) were arranged such that the power outlet load density (W/m^2)could be selected in three levels multiplied by the power outlet usage ratio, which corresponded to each of those levels. However, in the case of commercial facilities, we did not assume the usage of office equipment.

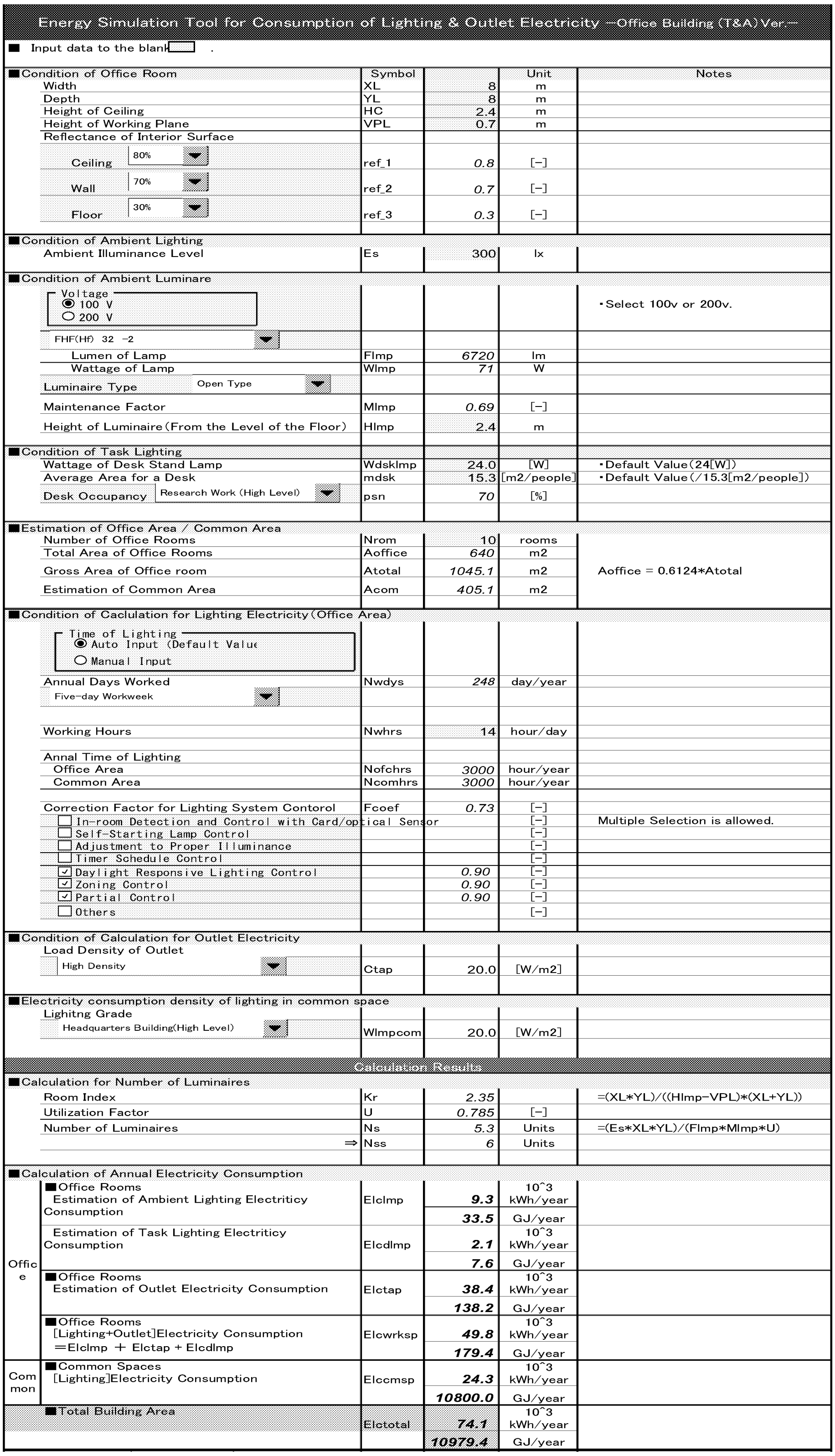
Furthermore, regarding the major sites' energy efficient lighting control correction coefficients used as mentioned above, we carried out a comparison of the correction coefficients (Institute for Building Energy Conservation, 2004) set by the CEC/L, and the values pertaining to energy conservation efficiency ratios obtained in a review of the literature for the past five years from the Architectural Institute of Japan, the Institute of Electrical Installation Engineers of Japan, the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan and the Illumination Engineering Institute of Japan. Since there was a great deal of erratic variation between the results of our study of realistic values and the actual energy conservation efficiency that we investigated, for office buildings we decided to use the correction coefficients from current CEC/L lighting energy efficiency techniques, while for commercial facilities, we decided to use the after-business-hours timed dimming controls.

These are thought to be a closer reflection of the actual situation, to which the correction coefficients were added.

5. THE CREATION OF TOOLS MAKING SIMPLE CACULATIONS POSSIBLE AND A CASE STUDY

5.1 The Creation of Tools Making Simple Calculations Possible

Based upon the above algorithms, we attempted to create a lighting/power outlet consumption volume prediction tool interface. With this tool, using general-purpose spreadsheet software, it is possible to continue using a framework similar to the CEC/L structure, and to carry out easy calculations using cumulative equations. The image of the prediction tool is shown in Fig. 3.



Energy Simulation Tool for Consumption of Lighting & Outlet Electricity —Office Building (T&A) Ver.—				
■ Input data to the blank .				
■Condition of Office Room	Symbol		Unit	Notes
Width	XL	8	m	
Depth	YL	8	m	
Height of Ceiling	HC	2.4	m	
Height of Working Plane	VPL	0.7	m	
Reflectance of Interior Surface				
Ceiling 80%	ref_1	0.8	[-]	
Wall 70%	ref_2	0.7	[-]	
Floor 30%	ref_3	0.3	[-]	
■Condition of Ambient Lighting				
Ambient Illuminance Level	Es	300	lx	
■Condition of Ambient Luminare				
Voltage ◉ 100 V ○ 200 V				・Select 100v or 200v.
FHF(Hf) 32 -2				
Lumen of Lamp	Flmp	6720	lm	
Wattage of Lamp	Wlmp	71	W	
Luminaire Type Open Type				
Maintenance Factor	Mlmp	0.69	[-]	
Height of Luminaire (From the Level of the Floor)	Hlmp	2.4	m	
■Condition of Task Lighting				
Wattage of Desk Stand Lamp	Wdsklmp	24.0	[W]	・Default Value (24[W])
Average Area for a Desk	mdsk	15.3	[m2/people]	・Default Value (/15.3[m2/people])
Desk Occupancy Research Work (High Level)	psn	70	[%]	
■Estimation of Office Area / Common Area				
Number of Office Rooms	Nrom	10	rooms	
Total Area of Office Rooms	Aoffice	640	m2	
Gross Area of Office room	Atotal	1045.1	m2	Aoffice = 0.6124*Atotal
Estimation of Common Area	Acom	405.1	m2	
■Condition of Caclulation for Lighting Electricity (Office Area)				
Time of Lighting ◉ Auto Input (Default Valu ○ Manual Input				
Annual Days Worked	Nwdys	248	day/year	
Five-day Workweek				
Working Hours	Nwhrs	14	hour/day	
Annal Time of Lighting				
Office Area	Nofchrs	3000	hour/year	
Common Area	Ncomhrs	3000	hour/year	
Correction Factor for Lighting System Contorol	Fcoef	0.73	[-]	
☐ In-room Detection and Control with Card/optical Sensor			[-]	Multiple Selection is allowed.
☐ Self-Starting Lamp Control			[-]	
☐ Adjustment to Proper Illuminance			[-]	
☐ Timer Schedule Control			[-]	
☑ Daylight Responsive Lighting Control		0.90	[-]	
☑ Zoning Control		0.90	[-]	
☑ Partial Control		0.90	[-]	
☐ Others			[-]	
■Condition of Calculation for Outlet Electricity				
Load Density of Outlet				
High Density	Ctap	20.0	[W/m2]	
■Electricity consumption density of lighting in common space				
Lighitng Grade				
Headquarters Building(High Level)	Wlmpcom	20.0	[W/m2]	
Calculation Results				
■Calculation for Number of Luminaires				
Room Index	Kr	2.35		=(XL*YL)/((Hlmp-VPL)*(XL+YL))
Utilization Factor	U	0.785	[-]	
Number of Luminaires	Ns	5.3	Units	=(Es*XL*YL)/(Flmp*Mlmp*U)
⇒	Nss	6	Units	
■Calculation of Annual Electricity Consumption				
Office ■Office Rooms Estimation of Ambient Lighting Electritiy Consumption	Elclmp	9.3	10^3 kWh/year	
		33.5	GJ/year	
Office Estimation of Task Lighting Electritiy Consumption	Elcdlmp	2.1	10^3 kWh/year	
		7.6	GJ/year	
Office ■Office Rooms Estimation of Outlet Electricity Consumption	Elctap	38.4	10^3 kWh/year	
		138.2	GJ/year	
Office ■Office Rooms [Lighting+Outlet]Electricity Consumption =Elclmp + Elctap + Elcdlmp	Elcwrksp	49.8	10^3 kWh/year	
		179.4	GJ/year	
Common ■Common Spaces [Lighting]Electricity Consumption	Elccmsp	24.3	10^3 kWh/year	
		10800.0	GJ/year	
■Total Building Area	Elctotal	74.1	10^3 kWh/year	
		10979.4	GJ/year	

Figure3: The interface of prediction tool for lighting and outlet power consumption

5.2 A Case Study

To verify our tool's accuracy, we carried out a case study on a mid-scale building, for which there existed actual performance data measured separately for lighting and power outlets. As a result of the case study, the predicted value was well correspondent to actual performancel.

6. CONCLUSIONS

In this research, with office buildings and commercial facilities as our foci, and taking as our objective the formulation of a lighting/power outlet electricity consumption volume prediction method, which makes simple calculation possible and also possesses a certain degree of accuracy, we have proposed computation methods and have created easy tools. The attempt to carry out multiple case studies, and the convergence of a variety of parameters into an appropriate form, can be listed as issues to be confronted henceforth.

ACKNOWLEDGEMENT

This study was made under the authority of a comprehensive project named "Development of technology to evaluate and improve CO_2 / waste minimizing performance of buildings -toward a sustainable society."

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