LIGHTPAD™ 2.0
A PORTABLE AUDIT AND DESIGN (PAD) TOOL FOR EVALUATING RETROFIT LIGHTING OPTIONS

Karl F. Johnson
Electric Power Research Institute, Palo Alto, CA USA
G. Kimball Hart
Hart, McMurphy & Parks, Middleburg, VA USA
Tom McDougall
The Weidt Group, Minnetonka, MN USA

ABSTRACT

The EPRI LightPAD program is a simple but powerful lighting audit and analysis tool for assessing installed lighting systems and proposing cost-effective, energy-efficient retrofit alternatives. LightPAD enables on-site data entry to the analysis program, improving both speed and accuracy by removing the step of making hand-written field notes. The data can be checked and validated on-site, and retrofit alternatives compared on-site. Lighting calculations are based on the lumen methodl. Project files containing the total building kW profiles may be exported to EPRI's COMTECHtm program to perform more complex financial. analysis and to integrate the lighting system into a total building systems audit.

INTRODUCTION

The Electric Power Research Institute (EPRI), together with Consolidated Edison (Con Ed), the Bonneville Power Administration (BPA), and the Empire State Electric Energy Research Corporation (ESEERCO) developed the LightPAD program in response to the need for a speedier and more accurate method of auditing lighting systems in commercial buildings. Audits are generally either done by hand or with computer assistance in a two-step data entry process. Both methods are slow and can also have calculation errors—neither encourages checking calculations on-site. Furthermore, errors in data entry can lead to paying incorrect rebates, and overestimating customer paybacks, energy savings, and the overall impacts of efficiency programs. A review of lighting audit software — including EPA's DSS, FLEX, and Xenlight — prior to LightPAD's development, showed that none of the available programs satisfied all the program requirements sought by the electric utility industry.

LightPAD enables on-site data entry to the analysis program, which means that measured lighting values in a room can be compared to calculated values to validate the specified fixture and room characteristics while in the field, and retrofit alternatives can be designed and compared on-site on the first visit if desired. For ease of use at the work site, LightPAD Version 2.0 has been designed to operate in "Windows" on a lightweight, pen-based "tablet" computer, or on a notebook or portable computer. The design for Version 2.0 focused on making the program very user-friendly to auditors in the field, more intuitive to first-time users, and more process oriented than Version 1.0.

PROGRAM OVERVIEW

The EPRI LightPAD program is specifically designed as a simple and flexible auditing tool—not an auditing procedure. LightPAD accommodates a wide range of auditing styles and utility lighting programs. The program may be used as a simple screening tool to quickly estimate a building's lighting energy use, or as a detailed analysis tool for determining both lighting energy use and current lighting levels. Different components, lighting use schedules, energy rates, and other variables may be input to more accurately recommend retrofit alternatives that both reduce energy consumption and maintain proper light levels. All data can be input directly in the EPRI LightPAD program on-site. Auditors describe the current space and lighting system layout and can evaluate alternative lighting systems by comparing calculated lighting levels, power requirements, cost of installation, and cost of system operation. LightPAD will produce reports on each of these factors.

Lighting calculations are based on the lumen method (see "Illuminance Calculations" below); the program does not do isolux mapping or point-by-point illuminance calculations. Project files containing the total building kW profiles may be exported to EPRI's COMTECH™ program, a screening tool for commercial building technologies, to perform more complex financial analysis and to integrate the lighting system into a total building systems audit.

The EPRI LightPAD program is divided into two distinct components: the Auditing program, and the

Database Editor program. The Auditing program accesses database files that are modified by the Database Editor. The information contained in the databases can only be edited through the Database Editor, not through the auditing screens. This safeguard maintains the integrity of data previously input into a project and ensures auditing consistency from project to project. The database files allow users to easily input data describing fixtures and controls, cost and rebate information, lighting use schedules, utility rate schedules, and space type characteristics. The databases include information on approximately 100 generic fixture and control types.

AUDITING PROGRAM

In LightPAD™ Version 2.0, the auditing side of the program has three key screens—*Audit, Retrofit,* and *Analysis*—from which users access all of the program's auditing, retrofitting, and analysis functions. A fourth screen, *Notes*, is available to record project notes at any time during an audit. The access buttons for these four screens are arrayed like file folder tabs down the right hand edge of the computer screen (see Figure 1). A touch of the pen on the appropriate button opens the screen.

Audit. The *Audit* screen (shown in Figure 1) is divided into two parts. The top portion is for project setup and status information and shows the square footage audited and the percentage of the total project this represents, both of which are tracked automatically by the program. Highlighted buttons access dialog boxes for entering optional information relative to the customer and utility, and for entering a summary of the project building's current energy usage. The user also selects the appropriate utility rate, picking from a list of utility rate schedules previously entered in a database. The bottom portion of the screen shows a list of the currently audited spaces together with summary information on each space. The user picks *Insert* to add a new space, *Edit* to modify information on an existing space, or *Delete* to remove an existing space. When inserting a space the user defines the geometry of the space and attaches the existing fixtures and controls in the Space Editor dialogue box (see Figure 2). The process is simple and intuitive. Touching the pen to clearly labeled buttons takes the user to appropriate dialog boxes. Most space characteristics are entered automatically from selected default settings, which can be edited as necessary. A multi-function numeric key pad is displayed, when applicable, to speed the entry process. Fixtures and controls are picked from dialogue boxes containing database listings. To further speed the process of entering spaces that are similar or the same as spaces previously defined, LightPAD allows for the automatic copying of all the characteristics of an existing space to a new one.

A major drawback of most existing audit procedures is the difficulty of validating the accuracy of the audit data. With LightPAD, users can easily validate inputs by displaying the calculated light level and energy results for a space. The program calculates light levels and compares the result to a recommended footcandle value and to a measured footcandle value that can be entered by the user. Energy results are similarly compared to ASHRAE/IES code values. If the results appear unreasonable, the inputs are easily checked and changed if necessary. With on-site validation, the likelihood for errors decreases substantially.

Retrofit. The EPRI LightPAD program automatically creates three copies of the base (existing) lighting scheme that are designated as Alternates 1, 2 and 3. Users may then make changes to one or all of the alternates and compare the results. Retrofit alternative lighting schemes can be defined building-wide or on a space-by-space basis. Defining building-wide alternates can involve changes by component, by operation, or by using a combination of both approaches.

Selecting *Component* on the *Retrofit* screen brings up a component comparison dialog box (see Figure 3). The top half of the dialog box is divided into four sections showing the components in the base and a duplicate listing of those components in each of the three alternates. The bottom half of the dialog box is similarly divided into four results boxes. To see the effect of retrofitting a component, the user simply picks a component for replacement in one of the alternates. The fixture (or control) database appears and an appropriate replacement is selected. The new fixture appears in the alternate box replacing the existing fixture (in that alternate only) on a one-for-one basis throughout the building. Calculating results will show a comparison between the base and alternate lighting schemes. Results show total peak lighting demand (kW), lighting energy (kWh/yr.), annual energy cost ($/yr.), and total annual operating cost including maintenance ($/yr.); and for the alternates only, total component cost ($), the sum of any applicable rebates ($), total first cost ($), and the average simple payback (yrs). The results, for any alternate containing one or more component changes, also show the percentage savings (where applicable) between the alternate and the base. Users may also select how the rebate is to be calculated—by component, by energy reduction (both $/kW and $/kWh); or, for a custom rebate, by specifying a fixed dollar amount.

Selecting *Operation* on the *Retrofit* screen brings up an operation comparison dialog box similar to the component comparison dialog box described above. Here users may see the effect of applying a different utility rate, changing from spot relamping to a fixed relamping period, or adjusting the lighting use or peak diversity factors.

The *Retrofit* screen also shows a listing of the audited spaces in the project. To see the effect of retrofitting components or changing certain space characteristics such as reflectance values on a space-by-space basis, users simply select the desired space, input the changes in any alternate, and calculate results. In this case, light level and energy use results calculated for the alternate are shown in comparison to the base calculated results rather than to measured or ASHRAE/IES recommended values. Retrofitting on a space-by-space basis also allows users to see the effect of changing the lighting design in a space rather than simply retrofitting fixtures on a one-for-one basis.

Analysis. LightPAD™'s analysis program allows users to view and compare results from several different perspectives. The *Analysis* screen divides the results displays into two groups: comparison displays that show the base audit and all three alternatives together, or summary displays that show the base audit or any single alternate individually.

There are two available comparison selections: *Space* or *Group* (*Space Comparison* is shown in Figure 4). These two results displays are used primarily to compare light levels and to see the amount of demand kW that could be saved in any of the three retrofit alternatives. The two displays are essentially the same; however, for the group comparison the space results are combined into assigned groups allowing the user to check the potential savings for a particular group of spaces, e.g., all "private offices."

There are five possible summary display selections: *Component, Group, Bldg. Energy, Material List,* or *Space*. Users first pick the lighting scheme they want to see (Base, Alt 1, Alt 2, or Alt 3) and then select the desired summary display button. The component summary shows total connected kW and energy cost by fixture type. The space and group summaries show light levels (both the calculated and recommended FC values), power density comparisons, total connected kW, and total energy use. The energy summary compares actual metered data for the building's entire electrical system to the LightPAD estimates for demand kW, energy use, and energy cost for the existing or proposed lighting schemes. The material summary shows the labor and materials costs of implementing a retrofit alternative.

Notes. *Project Notes* is a blank screen where the user can conveniently enter notes concerning the audit. Users can simply write freehand using the pen, or they may access the keyboard from the pen-system "tool box."

DATABASE EDITOR PROGRAM

The Database Editor is a separate program within LightPAD. It is in the Database Editor that users can add to or edit the various schedules or libraries that are accessed by the Auditing program. Editing information in these libraries should be done with caution. Any information contained in a project will be changed in that project if the information is subsequently changed in the Database Editor. In order to safeguard project results and to encourage consistent audits by keeping the information available to different auditors the same, it may be prudent to restrict access to the Database Editor. When installing LightPAD, users can choose whether to install the Database Editor along with the auditing side of the program. Users may wish to load only the Auditing program onto computers used by auditors, and keep the Database Editor on a separate system in the office. If users want to have multiple database directories—for customized building types or archiving purposes, for example—they may copy the database files into different directories.

The database side of the EPRI LightPAD program contains a total of nine database libraries: Fixtures, Housings, Lamps, Ballasts, Controls, Daily Lighting Use Schedules, Annual Lighting Use Schedules, Electric Utility Rate Schedules, and Default Space Types. The databases supplied with the program contain a library with average performance data for approximately 100 "generic" fixtures, and typical examples of the various schedules. No cost data are included. Users can customize the libraries to include any other schedules and fixtures that they need, and the cost and rebate information commonly used in their service territory.

The editing screen for the fixture library (see Figure 5) includes two important features: *Photometrics* and *Retrofits*. The fixture library supplied with LightPAD includes IES formatted photometric files[2]. Selecting *Photometrics* allows users to view the light distribution table for an existing fixture, or when adding a new fixture to the database, allows for the automatic loading of a new IES photometric file (many manufacturers provide fixture data on disk as well as in hard copy formats). *Retrofits* allows users to select which other fixtures in the database are the most likely retrofit alternatives for any other fixture in the database. These retrofit fixtures will then appear in a retrofit database listing in the Auditing program when the fixture to which they are attached

is selected for replacement. This feature is designed to speed the retrofit process, saving users the need to scroll through the entire fixture database; the complete database however, is also available for selection if required.

REPORTS

LightPAD™ performs a variety of lighting calculations and will prepare a report based on the inputs described above. Report files can be imported into virtually any word-processing program for reformatting (if desired) and printing. LightPAD Version 2.0 will also allow project data to be graphically displayed in spreadsheet software. Reports include:

Building Lighting Performance Summary: Present and proposed kilowatts (kW), kilowatt hours (kWh), and proposed kW and kWh savings; footcandles calculated by the lumen method utilizing fixture photometric data; material cost, labor cost, and net first cost after rebate; operating cost; and average simple payback

Component Retrofit Report: Present and proposed listings of components by name and quantity

Retrofit Material Summary: Listing the type, count, and cost of all retrofit components used in the proposed retrofit alternative

Space Description Report: Present and proposed lighting system description for each space; and a summary of results including average light level (FC), power density (W/sf), connected Watts, and annual energy usage (kWh/yr.)

ILLUMINANCE CALCULATIONS

LightPAD calculates average maintained illuminance (FC) using the lumen method. Only the illuminance contributions from fixtures identified as *GenI=Y* (general illumination fixtures) are used. Fixtures identified as *GenI=N* are not considered in illuminance calculations.

Average maintained illuminance (FC) in a space is determined by[3, 4]:

Photometric distribution of fixture
Lumen output of fixture
Ballast, thermal, and application factor of fixture
Room cavity ratio of the space for a given fixture configuration
Number of fixtures in the space
Lighting maintenance factors
- LLD (Lamp Lumen Depreciation)
- LDD (Luminaire Dirt Depreciation)
- RSDD (Room Surface Dirt Depreciation)

Existing manufacturer's photometric files, in IES format, are attached to each generic fixture type in the LightPAD fixture library. These files provide a candle-power distribution table based on specific test conditions. Identified with each photometric file are:

Fixture tilt
Number of lamps
Lamp lumens
Ballast factor
Thermal factor

When a fixture is outfitted with different lamps and ballasts than in the base file, a correction factor is applied to the calculated illuminance (FC). The base photometric table cannot be edited; it will always appear in its original form.

For a given space, fixture type, and fixture height the general illuminance calculation is:

$FC_{base\ fixture}$ = *Function (Base fixture photometrics, RCR)*
And:

$FC_{actual} = FC_{base\ fixture} \times (BF \times TF \times Avg.\ LLD \times LDD \times RSDD) \times (Lamp\ Lumens\ actual / Lamp\ Lumens\ base) \times number\ of\ fixtures$

Where:

FC = Footcandles
RCR = Room Cavity Ratio
BF = Ballast Factor
TF = Thermal Factor
Avg. LLD = Average Maintained Lamp Lumen Depreciation (see calculation below)
LDD = Luminaire Dirt Depreciation
RSDD = Room Surface Dirt Depreciation

Average LLD (Lamp Lumen Depreciation) Factor Calculation

The LLD factor considers the reduction of light output as a lamp ages. The LLD value entered in the Lamp Database is the percentage of light output at the end of the rated lamp life. The LLD factor calculation in LightPAD will apply the average maintained percentage of initial light output to the illuminance calculation based on the lamp maintenance practice identified in the *Operation Comparison* screen. This screen provides two types of lamp maintenance practices that are applied building-wide:

- Spot Relamping (default selection)
- Group Relamping (where period is entered in months)

Two cases exist for calculating LLD based on the lamp maintenance type selected:

Case 1: Spot Relamping

Avg. LLD = [100 + LLD value] / 2

Case 2: Group Relamping (period = GRP months)

IF: Annual operating hours/yr. x (GRP months / 12 mnths/yr.) is greater than or equal to Lamp Life hrs
THEN: Calculate Avg. LLD as Case 1

IF: Annual operating hours/yr. x (GRP months / 12 mnths/yr.) is less than Lamp Life hrs
THEN: Calculate as follows:

Avg. LLD = [100 + ((LLD value - 100)/lamp life hrs) x ((annual operating hrs/yr.) x (GRP mnths/12)) + 100] / 2*

* Avg. LLD assumes a linear lamp depreciation trend over time from initial to final light output. Some lamp types depreciate faster in the beginning, while others depreciate faster near the end of their lives. LightPAD™ approximates a specific lamp's actual depreciation curve by calculating an average lamp lumen depreciation value over the entire life of the lamp. Formulas are based on integer percentage values for LLD.

COMTECH™

COMTECH, a PC-based program also developed by EPRI, is an interactive screening tool for evaluating the cost impacts of a variety of technologies in commercial buildings. It is a powerful tool that allows analysis of a number of options quickly and easily. COMTECH offers a complete framework for determining the operating and capital costs for differing technologies, including alternative lighting systems, in buildings of all types and sizes.

LightPAD users may select *Export to COMTECH* from the *File* menu to automatically write out four files (the base and three alternates) for their current project. Each file contains the total building kW hourly profiles for the base and the three alternate lighting systems developed in LightPAD. These files may then be imported into COMTECH to perform more complex financial analysis and to integrate the lighting system into a total building system audit. COMTECH provides estimates of energy use impacts, utility bill impacts, and equipment cost impacts for each lighting scheme. Also, interactions between lighting energy and heating and cooling loads are incorporated.

TECHNICAL REFERENCES

The EPRI LightPAD program contains an extensive on-line technical reference database. Version 2.0 includes eight major lighting topics. Future versions of the program will update and expand this database.

SUMMARY

This paper has provided an overview of a new lighting software program developed by the Electric Power Research Institute together with Consolidated Edison, the Bonneville Power Administration, and the Empire State Electric Energy Research Corporation. The EPRI LightPAD program is designed to speed the process of making accurate audits of building lighting systems and greatly facilitate the work of lighting auditors. LightPAD makes possible the on-site analysis of both existing lighting systems and retrofit lighting alternatives. With lighting accounting for approximately one-third of the electric energy consumed in the commercial sector, this program can have a major impact on reducing consumer energy costs and improving utility customer services and load shapes.

REFERENCES

1 "IESNA Lighting Handbook, References & Application," 8th Edition, IESNA, 1993

2 "IES Recommended Standard File Format for Electronic Transfer of Photometric Data," Publication No. IES LM-63-1986

3 " Advanced Lighting Guidelines: 1993 (Revision 1)," EPRI, 1993

4 "IESNA Lighting Handbook, References & Application," 8th Edition, IESNA, 1993

FIGURES

Figure 1: AUDIT SCREEN

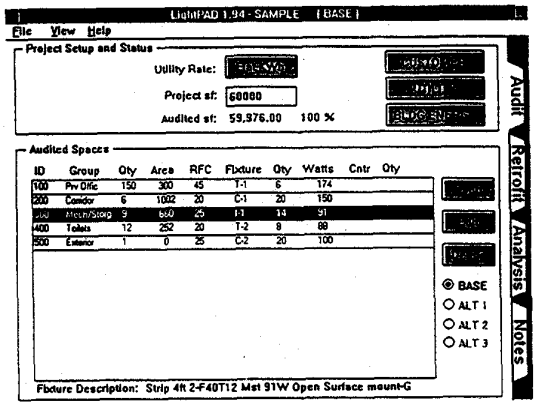

Figure 2: SPACE EDITOR

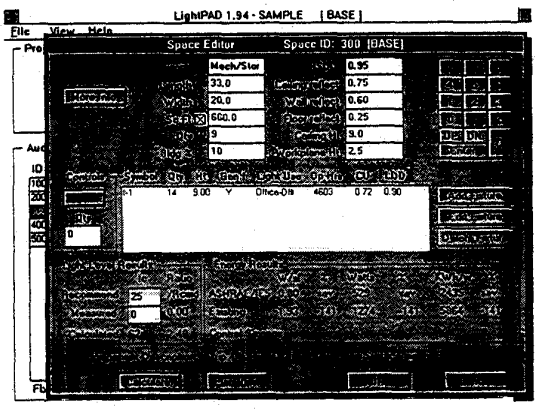

Figure 3: COMPONENT COMPARISON

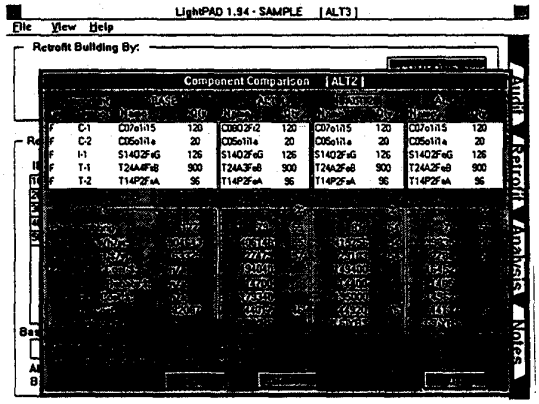

Figure 4: SPACE COMPARISON

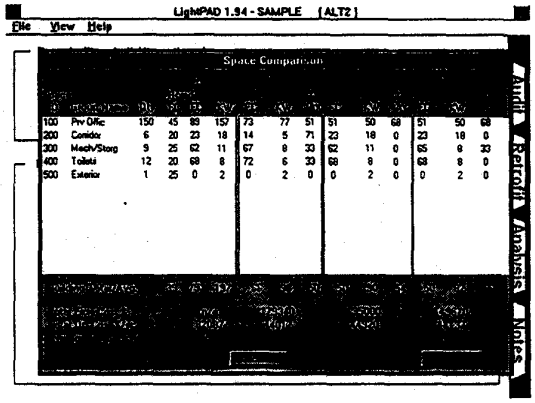

Figure 5: FIXTURE EDITING SCREEN