



LightCAD™ and LightPAD™

Two New Programs for Improving the Design and Application of Lighting in Buildings

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Abstract

The Electric Power Research Institute (EPRI) has recently released two new programs, LightCAD and LightPAD, to enhance the design and application of lighting in commercial buildings. LightCAD is a companion program to AutoCAD and is used by lighting designers and drafts persons to design more energy-efficient lighting systems in new buildings. LightCAD 2.0 is an advanced lighting layout tool in the CAD environment aimed at improving basic lighting in standard commercial environments-it is not a highly sophisticated analysis tool for detailed or specialized lighting analysis. LightCAD 2.0 features include a library of "generic" fixtures for reference; the ability to import fixture data in IES format, ceiling grid placement and fixture layout capability, tabulation of fixtures, controls, connected Watts, and total building kW and kWh; a library of utility lighting rebate programs and the ability to add new ones using EPRI's LREP Program; and the ability to prepare an export file for the ASHRAE/IES Lighting Code-Checking Routine. LightCAD 2.0 also contains a new sub-routine, BEEM, for analysis of daylighting options. LightPAD is a simple but powerful lighting audit and analysis tool for assessing installed lighting systems and proposing cost-effective and 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. It also makes possible on-site analysis so that estimated lighting values in a room can be checked in the field and adjusted if necessary. In addition, it allows the auditor to analyze retrofit options and present estimates to the building owner/operator on the first visit. Such improvements in auditor productivity and accuracy can have major impacts on utility incentive programs.

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Introduction

The Electric Power Research Institute (EPRI), as part of its program to encourage the use of energy-efficient lighting in commercial buildings, developed two computer software packages, LightCAD and LightPAD. The EPRI LightCAD program, initially released in 1991, introduced a totally new approach to lighting design and analysis. Never before had a lighting analysis program, a computer-aided design (CAD) program, and a graphic input to a lighting code-check program been combined into a single piece of software. With the release of Version 2.0 in 1992, EPRI further enhanced LightCAD, most notably adding daylighting analysis, comparative economic and energy analysis, and built-in, easily accessible technical references.

EPRI developed the LightPAD program in response to the need for a speedier and more accurate method of auditing lighting systems in commercial buildings. Due to significant growth in lighting conservation

programs over the last several years the demand for lighting audits often far exceeds the capacity of utility companies to respond in a timely manner. 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 or inflated rebates and overestimating energy savings and overall impacts of the conservation program.

LightCAD™ Program Overview

First and foremost, the EPRI LightCAD program is a convenient tool for designing energy-efficient lighting systems. The program can be used to speed the basic drafting functions necessary to design and layout a lighting system. By making the process of layout and drafting easier, and by putting new information about efficient lighting systems at designers' fingertips, EPRI hopes that design professionals will gain enough time to investigate and specify more efficient lighting systems.

The EPRI LightCAD program is designed to work in conjunction with AutoCAD® for the layout of lighting systems in new commercial buildings. LightCAD can also be used on any retrofit or rehab project that is large enough to require a new set of drawings. LightCAD is simple enough to be used by any draftsman with a basic understanding of lighting layout. Experienced AutoCAD users will find LightCAD very easy to use.

Market analysis by EPRI found CAD programs to be the fastest growing PC application in architectural and engineering offices—clearly the wave of the future. At the same time, research by the Illuminating Engineering Society (IES) showed that less than one-fourth of the lighting analysis programs currently available had any CAD interface. The goal of the EPRI LightCAD program is to provide both—a lighting analysis program and a CAD interface—to run within the PC environment.

For Versions 1.0 and 2.0 of LightCAD, EPRI chose to do an adequate level of lighting analysis (Room Cavity Ratio), but not the most sophisticated level of analysis (point-to-point illumination). Room cavity ratio (RCR) analysis is a higher level of analysis than is performed on the vast majority of lighting layouts done today. However, LightCAD should not be the only tool used where very sophisticated analysis is required.

LightCAD is not intended to replace large and complex lighting analysis programs. Its goals are to do reliable lighting analysis and fast CAD layout. LightCAD is the only program available to date to

accomplish both goals while operating within AutoCAD Version 11 or greater.

LightCAD calculates lighting levels based on the photometric characteristics of lighting fixtures, and on the characteristics of the room, including room geometry, surface reflectances, and the number and height of fixtures in the room. The Room Cavity Ratio method calculates average illumination in a room, that is, average footcandle levels at the workplane height. The formulas used in performing LightCAD calculations are drawn from the *IES Lighting Handbook*, Chapter 9 (Reference Volume, 1984, Waverly Press, Baltimore, MD).

One of LightCAD's most important functions is creating a fixture database for use on lighting projects. Once a fixture is entered in the database, it can very quickly and easily be called up and used on subsequent projects. LightCAD is designed to read and accept any files of fixture data that are written in approved IES format. This makes fixture data entry significantly easier.

In the past, communications between a lighting analysis package and a CAD package have typically been through a DXF file. The processes of creating files, opening programs, closing programs, and transporting DXF files between programs have all severely limited communications with CAD packages. With the release of AutoCAD Version 11, it became possible for a program, like the EPRI LightCAD program, to reside *within* the host program, eliminating the need for DXF file transfers and even the process of "shelling out" of the host program.

This innovation allows the drawing portion and the database portion of LightCAD to be dynamically linked. Whenever a change is made on a LightCAD drawing, it automatically appears in the LightCAD database (for example on a fixture schedule or room schedule). Whenever a change is made in the database, that change (with certain minor exceptions) appears on the LightCAD drawing. This important innovation significantly increases both the speed and accuracy of drafting, and makes possible much more rapid comparisons of alternatives for improving lighting systems.

LightCAD Inputs

The EPRI LightCAD program requires the following inputs:

- AutoCAD drawing of a building
- Fixture data
- Space definition and lighting calculation variables
- Control information
- Daylighting zone definition (optional)

LightCAD™ is designed to do room cavity ratio lighting calculations as well as to feed information to the ASHRAE/IES code-checking program. Serving both objectives requires a fair amount of initial input data. To save the effort of entering all of these data every time the program is used, LightCAD provides a set of default values organized by a list of 11 building types that appear in the ASHRAE/IES lighting code. However, in order to run LightCAD, the user must provide both photometric data and energy use data for each fixture used on a project. LightCAD uses some data directly, while other data are required for daylighting analysis, informational purposes, or to run the code-check program. LightCAD is designed to make this data entry process as easy as possible.

There are three options for entering fixture data:

- **Import a manufacturer's IES file.** This is the easiest way to enter data about a fixture. (The term fixture is used here to refer to the lamp/ballast/luminaire combinations.) Many manufacturers are now providing fixture data on computer disk. LightCAD accepts disks that follow the standard format established by the Illuminating Engineering Society. In most cases, some supplemental data must be added. IES files are especially helpful in entering photometric data.
- **Use the LightCAD Master Fixture Library.** The EPRI LightCAD program comes with a library of "generic" fixtures already installed. This library contains photometric and energy data for approximately 100 fixtures representing a broad array of lighting and performance characteristics. This provides an easy way to experiment with a class of fixtures to see if they merit further investigation. The data in this master file do not represent the products of a particular manufacturer. It is recommended that actual manufacturer data be entered before preparing final project analysis, recommendations, and specifications.
- **Enter Fixture Data by Hand.** This is the most time-consuming approach to entering fixture data, particularly if the fixture has a large table of photometric data. The LightCAD program provides a form to assist in entering data if this approach is required.

Although the process of entering fixture data may, at first, appear time consuming, it need be done only once for each fixture. Most lighting layouts use only a limited number of fixtures per project so, over time, the flow of projects through an office will build a master fixture file.

Lighting Rebate Entry Program (LREP)

The EPRI LightCAD fixture database tracks "rebates" for both fixtures and components. The growth of utility-sponsored lighting incentive programs over the last few years has significantly changed the economics of designing a lighting layout in many areas of the country. LightCAD assists in using these incentives wherever possible to improve the energy efficiency of lighting layouts within the cost limitations of both design and construction budgets. With the release by EPRI of LREP, EPRI member utilities have the option to transfer their rebate information to disk so that it can be entered directly into LightCAD. In Version 2.0 of LightCAD, this information is included for approximately 20 utility companies.

In many cases, electric utility lighting incentive programs include incentives for lighting designs that reduce energy use below a certain threshold or code standard. LightCAD can be used to develop a comparison of a final design versus a benchmark to assist in calculating rebates.

The EPRI LightCAD program can display rebate information in two ways: by displaying a list of components for which customers receive a rebate, either for new construction or retrofit applications; or by displaying a detailed description of incentive programs, perhaps explaining rebates tied to reductions in demand rather than the installation of specific equipment. LREP allows utilities to easily create component lists using simple menus, text templates, and pop-up screens. Descriptive text can be readily imported from virtually any PC-based word processor or text editor.

LightCAD Outputs

LightCAD's principal function is to assist in preparing better lighting system drawings, and doing so more quickly, within regular AutoCAD® drawings. The drawing functions available in LightCAD include selecting rooms from an AutoCAD drawing, defining and placing ceiling grids, placing fixtures, placing controls, and connecting controls to fixtures. The result of a typical drawing session is a reflected ceiling plan within a set of AutoCAD drawings. All additions made to an AutoCAD drawing using LightCAD become an integral part of the AutoCAD drawings. The LightCAD portion of these drawings can be prepared for plotting and plotted according to the normal procedures used for other AutoCAD drawings.

In addition to the features mentioned above, the EPRI LightCAD program also has several unique functions including: calculating the area of each room, tracking default values for each room, calculating the necessary number of fixtures to meet footcandle specifications

within a space, calculating watts per square foot for each room, and summing connected fixture watts per control. The program performs all of these calculations *automatically*. Various schedules are prepared from the database in support of these functions and provide summary information on a design. Hard copies of schedules can be printed. Three of the six schedules, Room Schedule, Fixture Schedule, and Control Schedule, contain the following information:

Room Schedule:

- Calculated square footage
- Design power and lighting levels
- Calculated power and lighting levels
- Summary of fixtures and controls placed in the room
- Fixture coefficient of utilization
- Number of tasks in room
- Default values for room height, wall and ceiling reflectances, and maintenance values

Fixture and Control Schedules:

- Number of fixtures by type
- Number of controls by type
- Watts per fixture
- Cost per fixture or control
- Total cost by fixture or control
- Rebate per fixture or control
- Total rebate by drawing (e.g. floor or building)
- Total net cost by drawing (e.g. floor or building)

Analysis

In the analysis portion of LightCAD™, users may create alternate lighting schemes, using both new fixtures and/or controls, and compare the alternates in terms of lighting, energy, and economics. Users may also apply daylighting analysis to various lighting schemes, or choose to apply different daylighting approaches to a series of identical alternates. LightCAD allows a user to print a report comparing economic and energy data for various lighting designs using LightCAD analysis alone, or with the integration of BEEM™ daylighting analysis.

The economic analysis program calculates and displays differences between the alternate lighting schemes created in LightCAD, including lighting system first costs, energy costs, energy use, and demand. When applicable, daylighting analysis results are displayed as delta values: the net change in cost for the selected daylighting configuration relative to a base case containing no daylighting controls and inexpensive fenestration. Daylighting results include fenestration costs, HVAC plant costs, lighting energy costs, HVAC energy costs, miscellaneous costs (e.g., the cost for automated shade withdrawal), energy use, and demand. Users may also input adjustments in first costs, maintenance costs, or energy costs not

otherwise included in the analysis; for example, to reflect changes in maintenance costs when considering longer-life bulbs. Finally, the economic analysis program sums the total first costs and operating costs, and calculates the average simple paybacks for the alternate lighting systems relative to the current drawing.

Building Energy Estimation Module (BEEM)

LightCAD is integrated with the BEEM program to allow users to evaluate the effects of daylighting on their various lighting schemes. BEEM is used to calculate workplace daylighting, energy use, peak demand, costs, and other impacts of a given window and lighting control configuration, and to compare different configurations. BEEM may be used by itself or with LightCAD. With LightCAD, BEEM provides daylighting-related energy and cost impacts for integrated economic analysis within an overall lighting context.

BEEM daylighting predictions are based on a simplified form of the *IES Recommended Practice of Daylighting*. Thermal calculations are based on ASHRAE methodologies. Typical-day analysis is used for energy values, and demand calculations are based on an assumed 3:00 p.m. (solar time) building peak. Results were validated with actual building daylight measurements and with simulations of daylighting and thermal effects using the DOE-2 computer program.

LightCAD users define zones comprised of rooms that are similar or the same in orientation, footcandle level, occupancy, and so forth. BEEM is then used to analyze the effects of, for example, various glazings, shading systems, and daylighting controls, to identify the optimum daylighting scheme. Selected results are passed back to LightCAD for review. When the best lighting alternative, whether it includes daylighting, or not, has been identified, the current lighting scheme can be automatically replaced with the alternate.

Replacement

Replacement is a special feature of the EPRI LightCAD program. The replace functions can be used on either a room-by-room basis or as a global change to a whole drawing. Replacement by room clearly shows the impact of replacement on three critical variables: footcandles, watts per square foot, and connected watts. When used in conjunction with the summary schedule for fixtures, you can also see the impact of a fixture replacement in terms of total cost, rebates, and net cost. Replacement by room might typically be used by designers to assess the use of different fixtures in one room, before applying that

lighting scheme to other rooms of the same type in their drawing.

Replacement by drawing allows for the complete change-out of a lighting scheme, including both fixtures and controls, with an alternative scheme. This would typically be done after assessing the overall economic and energy implications of various lighting schemes, which may also have included considerations of daylighting.

Code Checking

The EPRI LightCAD™ program is designed to work in concert with the new ASHRAE/IES *Lighting Prescriptive and System Performance Compliance Calculation Program* (LTGSTD 2.1). LightCAD has been written so that lighting designs can be checked quickly and easily against the ASHRAE/IES Standard 90.1. The LightCAD program automatically prepares a file of information from LightCAD drawings for input to LTGSTD 2.1. This feature not only speeds the process of doing a take-off from LightCAD drawings, it also increases the accuracy of the process. In the language of program builders, LightCAD can be used as a "graphic front end" to the LTGSTD program.

Technical References

LightCAD contains an extensive technical reference database covering eight major lighting-design topics. Future versions of the program will update and expand this database. The technical references can be accessed from all the database screens and all the major drawing screen menus. Depending on the screen a user is in, selecting Technical References will access the topics relating most specifically to that screen.

LightPAD™ Program Overview

The EPRI LightPAD program, for assessing installed lighting systems and proposing cost-effective and energy-efficient retrofit alternatives, is specifically designed as a simple and flexible auditing tool—not an auditing procedure. LightPAD accommodates a wide range of auditing styles and utility conservation 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. Hourly lighting use levels, differing energy rates, and other variables may be input to more accurately recommend retrofit alternatives that both reduce energy consumption and improve lighting quality. All data can be input directly in the EPRI LightPAD program on-site, the data is checked and

validated on-site, and retrofit alternatives compared on-site.

Auditors can describe the current space and lighting system layout, and evaluate alternative lighting systems on the basis of calculated comparative lighting levels, power requirements, cost of installation, and cost of system operation. LightPAD will produce reports on each of these factors.

The program operates on inexpensive notebook or portable computers. Auditors can carry a lightweight computer to the work site, plug it in (or use battery-power for shorter periods), input information about the space, check results using a number of data displays at the building, space, and component level, evaluate alternative lighting designs, and save reports that can be printed via the utility's word processing software back at the office.

Lighting calculations are based on the room cavity ratio method; the program does not do isolux mapping or point-by-point illuminance calculations. Project files 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 the databases, allowing users to easily input data describing components, lighting use schedules, utility rate schedules, and space type characteristics. However, the information contained in the databases themselves can only be edited through the Database Editor, not through the auditing screens. This safeguard is intended to maintain the integrity of data previously input into a project, and to maintain auditing consistency from project to project.

Auditing

Auditing screens are grouped into four "levels":

- *Project Level.* The project levels screens are primarily used for general project information, project status, and notes. When users first enter the program they will always see the Project Customer Information screen. The Project Utility Information screen will show summary results for the base and each of the three alternates on separate screens.
- *Space Level.* At this level, the different spaces within a building are defined. The geometry of each space is recorded and the existing fixtures and controls are attached to each space. Alternatives may be defined and compared on a

space-by space basis. Separate screens are used to review the information for the base and each of the three alternates.

- *Summary Level.* The Component Schedule screen is used both to prepare a schedule of existing fixtures and controls to be input at the space level, and to view summary information. The other summary level screens are mainly used to validate inputs. Summary information is viewed for the existing lighting system and for each of the three alternates on separate screens.
- *Comparison Level.* At this level, alternative lighting systems can be defined and compared to the existing lighting system. LightPAD™ analyzes alternatives to the present lighting system on a system-wide basis. Four of these screens, Component Comparison, Space Comparison, Group Comparison, and Operation Comparison, show inputs and results for the base and three alternates on the same screen. Material Comparison shows results only for each of the alternates on a separate screen.

The EPRI LightPAD program is a flexible auditing tool, easily adapted to a wide range of auditing approaches and DSM programs. Users may access any of the auditing screens at any time—there is no hierarchy. The path taken and the screens used will depend on the auditing style and the level of analysis required for each project. For the most part, users may input or change data at any stage of the audit. An auditor does not have to enter data in all the screens to obtain results. As few as four screens could be used to calculate the current lighting energy use for a building, validate the inputs, define and compare retrofit alternatives, and view the resulting potential lighting energy use savings. LightPAD recognizes the need to obtain accurate results whether a building is surveyed at the most basic level, to very quickly estimate potential energy savings; at the most painstaking level, inventorying the building on a room-by-room basis; or somewhere in between, using the inventory data from typical spaces to extrapolate both energy use and lighting levels for the whole building.

One of the major drawbacks to most existing audit procedures is the inability for users to easily validate the accuracy of the audit data. With LightPAD, users can input data and compare results to metered data, measured and recommended light levels, and ASHRAE/IES power density data on-site. If the results appear unreasonable, the inputs are easily checked and changed if necessary. With on-site validation, the likelihood for errors decreases substantially.

Databases

The database side of the EPRI LightPAD program is divided into five main categories, containing a total of nine database libraries:

Fixtures:

- Fixtures
 - Photometrics
 - Retrofits
- Housings
- Lamps
- Ballasts

Controls:

- Controls

Lighting Use:

- Daily Lighting Use Schedules
- Annual Lighting Use Schedules

Electric Utility Rates:

- Rate Schedules

Space Groups:

- Default Space Types

The auditing side of the program accesses the database libraries, usually in the form of a scrolling pick list. However, the information contained in these libraries can only be edited in the Database Editor program.

The databases supplied with the program contain typical examples of the various schedules and a library containing average performance data for approximately 100 "generic" fixtures. No cost data are included. Users should 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 Database Editor is a separate program from the LightPAD Auditing program. 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 that is subsequently edited in the Database Editor will be changed in that project. 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 you have the option to install the Database Editor along with the auditing side of the program or not. Users may perhaps 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.

Inputs to LightPAD

Auditors can input information on:

- **Space Definition:** Room dimensions, room area, surface reflectances, room maintenance factors, ceiling plane, lighting plane, workplane, occupancy schedules, and relamping practices. The user may also validate and adjust LightPAD calculations by measuring actual characteristics and light levels of the room and modifying parameters.
- **Lighting Equipment:** Generic fixture information includes data on luminaire type, lamps, and ballasts. Generic control information includes control type. The user may also specify actual fixtures for analysis within LightPAD™ based on manufacturer information. IES format files can be entered automatically. The user must input information on cost for all fixtures and controls.
- **Utility Program Information:** LightPAD has the ability to calculate simple kilowatts and kilowatt hours based on estimated occupancy. LightPAD also allows utilities to include customized rate and rebate information for their service areas.

Reports from LightPAD

LightPAD does a variety of lighting calculations and will prepare a report based on the inputs described above. Report includes:

- **Space illuminance analysis:** Footcandles calculated by the room cavity ratio method utilizing fixture photometric data.
- **Power use analysis:** Kilowatts, kilowatt hours, and lighting power budget in watts per square foot.
- **Financial analysis:** Capital cost, operating cost, net costs after rebate, average simple payback.
- **Material Comparison:** Listing the type, count, and cost of all retrofit components used in the proposed retrofit alternative.

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 technical reference database. Version 1.0 includes eight major light-related topics. Future versions of the program will update and expand this database.

Summary

This paper has provided an overview of two new lighting software programs developed by the Electric Power Research Institute. The EPRI LightCAD™ program is built on the simple philosophy that if you can make the job of drafting easier for the lighting layout person, you can give them a little bit of extra time, within very constrained design budgets, to investigate more energy-efficient design alternatives. 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, these programs can have a major impact on reducing consumer energy costs and improving utility load shapes.