Lighting Use and Conservation in Commercial Buildings

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Lighting represents a substantial fraction of commercial electricity consumption. This paper provides a statistical profile of commercial lighting, to examine the potential for lighting energy conservation in commercial buildings. The principal conclusion from this analysis is that energy use for lighting could be reduced by as much as a factor of four using currently available technology.

The analysis is based primarily on the Energy Information Administration's (EIA) 1986 Commercial Buildings Energy Consumption Survey (CBECS). The more recent 1989 survey had less detail on lighting, for budget reasons. While changes have occurred in the commercial building stock since 1986, the relationships identified by this analysis are expected to remain generally valid. In addition, the analytic approach developed here can be applied to the data that will be collected in the 1992 CBECS.

Introduction

Lighting represents a substantial fraction of commercial electricity consumption. A wide range of initiatives in the Department of Energy's (DOE) National Energy Strategy have focused on commercial lighting as a potential source of energy conservation. This paper provides a statistical profile of commercial lighting, to examine the potential for lighting energy conservation in commercial buildings. The principal conclusion from this analysis is that energy use for lighting could be reduced by as much as a factor of four using currently available technology.

This paper is excerpted from a more detailed analytic report (Energy Information Administration 1992). The analysis is based primarily on the Energy Information Administration's (EIA) 1986 Commercial Buildings Energy Consumption Survey (CBECS). The more recent 1989 survey had less detail on lighting, for budget reasons. While changes have occurred in the commercial building stock since 1986, the relationships identified by this analysis are expected to remain generally valid. In addition, the analytic approach developed here can be applied to the data that will be collected in the 1992 CBECS.

Lighting Energy Conservation Potential

Substantial energy savings are possible using more efficient commercial lighting equipment and practice. Estimates of the potential savings depend heavily on assumptions regarding the types of lamps and fixtures to be replaced, the effectiveness of various lighting conservation measures, and how strong a lighting level is to be maintained. The savings estimates under various assumptions span a wide range, from under 30 percent to nearly 80 percent of current use (Figure 1).

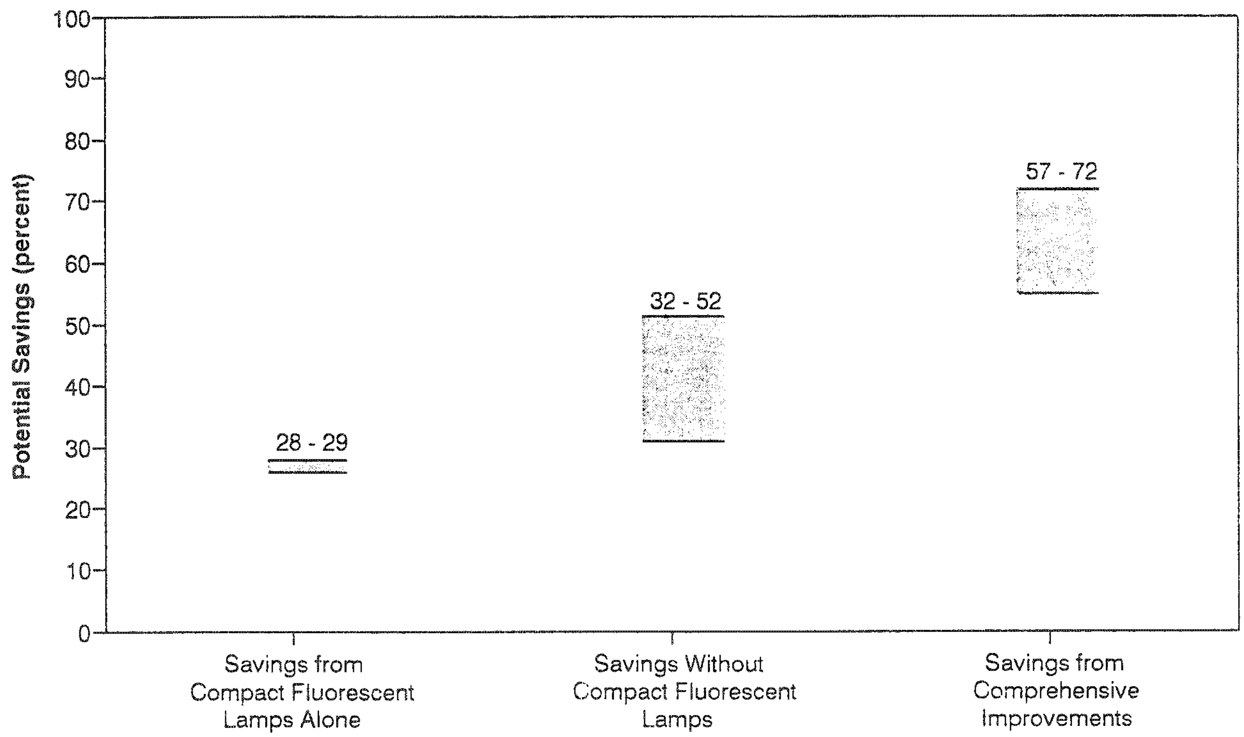
Savings from Compact Fluorescent Lamps. Converting all incandescent bulbs (the typical screw-in type) to compact fluorescent lamps with reflectors is estimated to save close to 30 percent of current (1986) energy use for commercial lighting.

Savings Without Compact Fluorescent Lamps. Even greater savings can be achieved without using any compact fluorescents, but converting all lamps and fixtures to the most efficient version of the same type (fluorescent, high-intensity discharge, or incandescent), together with lighting control devices.

Savings from Comprehensive Improvements. Universal replacement of lamps and fixtures by more efficient equivalents, together with lighting controls, could save as much as 72 percent of current commercial lighting energy use. The replacements for this case include the best of the previous two cases. If, in addition, lighting levels are reduced by 25 percent, the total savings could reach nearly 80 percent.

The savings analysis spans a range of plausible assumptions. Nonetheless, other modifications to equipment and practice could be considered, and other assumptions for the effectiveness of these might be more appropriate. This report presents a framework that allows alternate savings estimates under alternate assumptions.

These savings estimates are based on the use of current commercially available technologies and assume that all



Note: Each shaded band indicates the range of savings estimates obtained, under varying assumptions for the effectiveness of the conservation features considered for each case. The potential savings are shown for each case as a percent of the base case lighting energy estimate (321 billion kilowatthours). Additional savings are possible if lighting levels are reduced.

Sources: Energy Information Administration, Office of Energy Markets and End Use, *Energy Consumption Series: Lighting in Commercial Buildings*, DOE/EIA-0555(92)/1.

Figure 1. Ranges of Potential Savings, Maintaining Current Lighting Levels

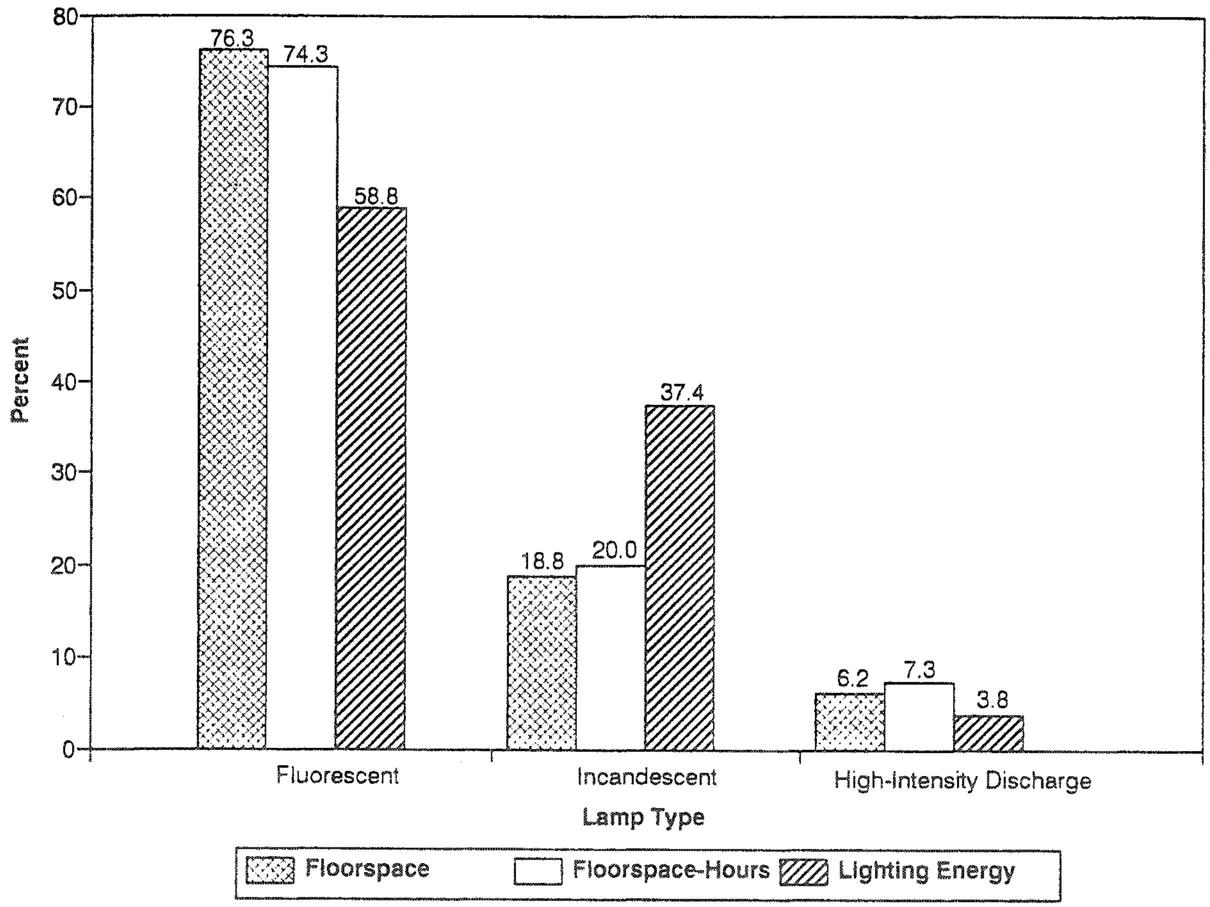
lights of a given type are replaced immediately. Actual replacements would, of course, occur over time as the new lighting equipment penetrates the marketplace and associated costs are reduced as the technology improves. Indeed, in all likelihood some of the potential savings have already been achieved, through increased penetration of energy-efficient equipment since the time of the survey the analysis is based on. Thus, the savings estimates are provided only to describe the potential for savings and are not a prediction of the level of savings that will be realized in the marketplace.

Commercial Lighting Energy Profile

The potential for commercial lighting energy conservation is derived from a statistical profile developed in this report of commercial lighting energy. This profile reveals important relationships among lighting energy use and building characteristics including activity, building size, operating hours, and lighting equipment.

Lighting Energy. Energy used for lighting in commercial buildings is on the order of 1 quadrillion Btu, 40 to 50 percent of commercial electricity use for 1986. On a per floorspace basis, energy use for lighting is estimated to be around 6 kWh per square foot.

Lighting Equipment. Incandescent bulbs serve only 19 percent of the lighted commercial floorspace, but account for 37 percent of commercial lighting energy consumption (Figure 2). Substantial energy could be saved by converting space lighted by incandescent bulbs to more efficient lighting equipment.



Note: For each lamp type, the percents are the estimated amounts served by the lamp type, as percentages of the total commercial lighted floorspace (49.59 billion square feet), lighted floorspace-hours (3.5 trillion square foot-hours), and lighting energy (321.4 billion kilowatthours). Components sum to slightly more than 100 percent because some floorspace is lighted by more than one lamp type.

Source: Energy Information Administration, Office of Energy Markets and End Use, *Energy Consumption Series: Lighting in Commercial Buildings*, DOE/EIA-0555(92)/1.

Figure 2. Lighting Service Measures by Lamp Type

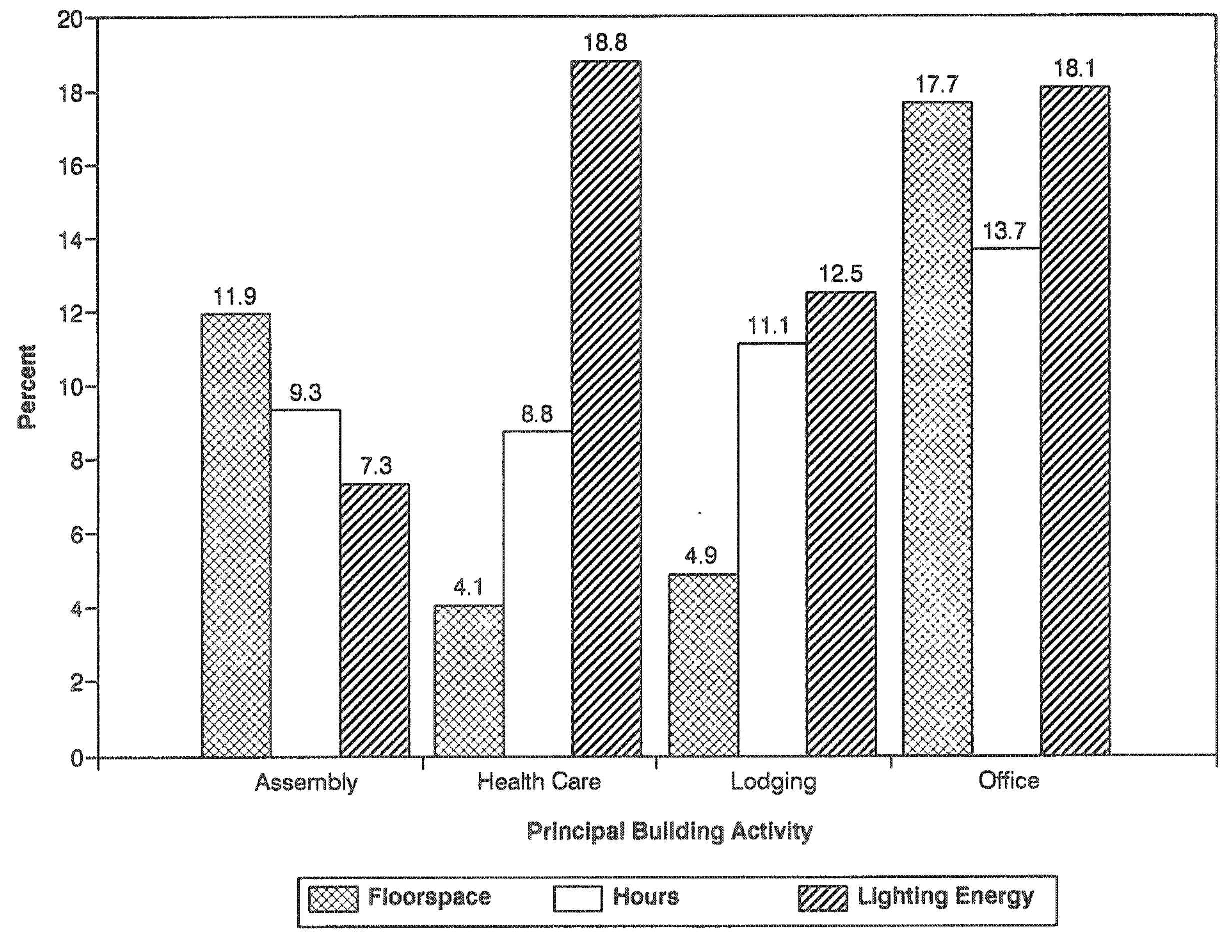
Efficient Equipment. Buildings with greater lighting needs tend to have more efficient equipment. Higher lighting levels and longer hours represent greater lighting needs.

Building Activity. Health care and lodging buildings account for relatively high proportions of commercial lighting energy use compared to their floorspace (Figure 3). Both these buildings types tend to have long hours of use (Figure 4). Health care buildings also have high lighting levels (Figure 5). Lodging buildings tend to have a high proportion of space served by incandescent bulbs, which are relatively inefficient.

Building Size. Larger buildings tend to have higher lighting energy use per square foot (Figure 6). The higher energy use is related to longer operating hours and activities associated with higher lighting levels. The effects of longer and stronger lighting use are somewhat mitigated by the use of more efficient equipment in larger buildings.

Data and Research Needs

This study was performed using the 1986 CBECS data, because the more recent 1989 CBECS had less detail on lighting equipment and conservation features. Extending the methods used here to other survey years would



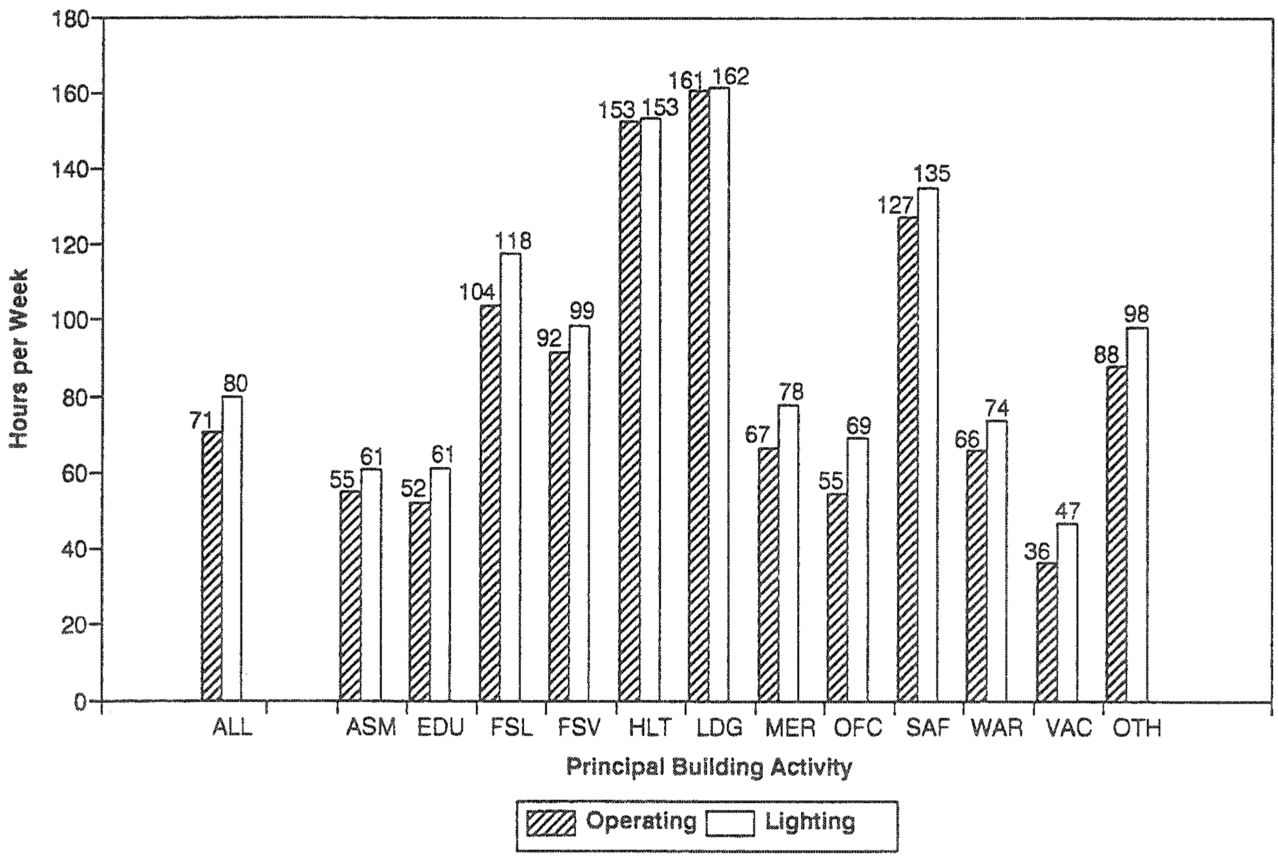
Note: For each principal building activity, the percents are the estimated amounts for the activity as percentages of the total commercial lighted floorspace (49.59 billion square feet), lighted floorspace-hours (3.5 trillion square foot-hours), and lighting energy (321.4 billion kilowatthours).
Source: Energy Information Administration, Office of Energy Markets and End Use, *Energy Consumption Series: Lighting in Commercial Buildings*, DOE/EIA-0555(92)/1.

Figure 3. Lighting Service Measured by Selected Building Activity

therefore require further assumptions and approximations. However, more detailed lighting questions will be restored for the 1992 cycle. The analysis can be repeated directly for the more up-to-date data when they become available. In addition, the 1992 CBECS sample will be a revisit to the 1986 sample, allowing longitudinal comparisons over the past six years.

Several extensions to this analysis could be made. One would be to reconcile the energy estimates with total building electricity consumption. Another would be to incorporate assumptions about the degradation of equipment efficiency over time. The CBECS data also contain complete weekly operating schedules; together with the estimates obtained here for in-use lighting power densities, these schedules could serve as the basis for estimation of lighting load shapes.

Additionally, the results developed here can be combined with economic equipment assessments to provide estimates of the costs associated with the conservation strategies. As part of the Lighting Initiative sponsored by the Office of Conservation and Renewable Energy, economic analysis of different lighting options has been conducted by Lawrence Berkeley Laboratory (Atkinson et al. 1992). Results from this report may be linked to that work.



Note: The building activities are abbreviated as follows: ASM = Assembly; EDU = Education; FSL = Food Sales; FSV = Food Service; HLT = Health Care; LDG = Lodging; MER = Mercantile; OFC = Office; SAF = Public Order and Safety; WAR = Warehouse; VAC = Vacant; OTH = Other.

Source: Energy Information Administration, Office of Energy Markets and End Use, *Energy Consumption Series: Lighting in Commercial Buildings*, DOE/EIA-0555(92)/1.

Figure 4. Building Operating Hours and Lighting Hours by Principal Building Activity

Endnotes

1. Current affiliation XENERGY, Inc.

2. The opinions and conclusions expressed herein are solely those of the authors and should not be construed as representing the opinions or policy of any agency of the United States Government.

References

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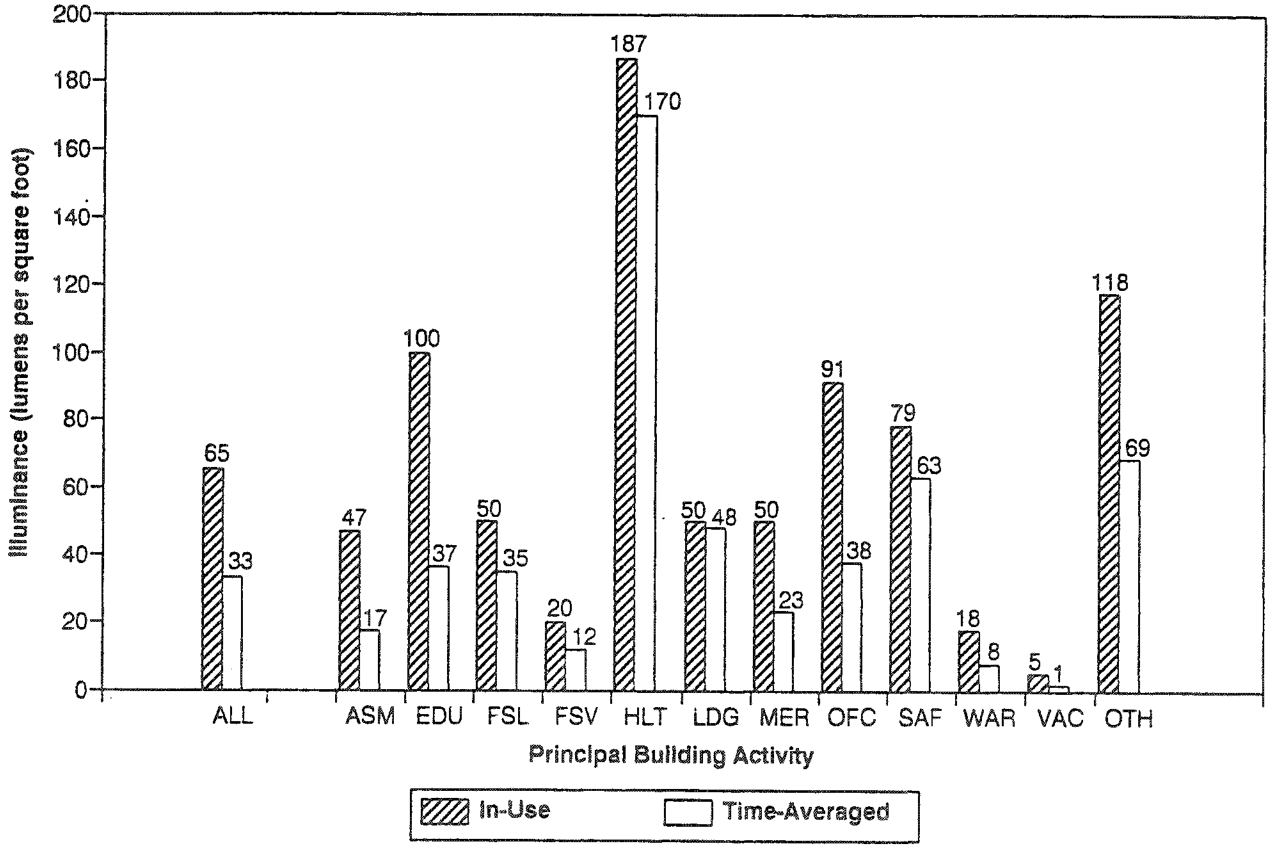

Notes: • In-use illuminances are average assigned values based on IES recommended categories. • Time-averaged illuminance is in-use illuminance adjusted by the estimated proportion of time the lighting is in use. • The building activities are abbreviated as follows: ASM = Assembly; EDU = Education; FSL = Food Sales; FSV = Food Service; HLT = Health Care; LDG = Lodging; MER = Mercantile; OFC = Office; SAF = Public Order and Safety; WAR = Warehouse; VAC = Vacant; OTH = Other.

Source: Energy Information Administration, Office of Energy Markets and End Use, *Energy Consumption Series: Lighting in Commercial Buildings*, DOE/EIA-0555(92)/1.

Figure 5. Illuminance by Principal Building Activity

Energy Information Administration. 1988. *Nonresidential Buildings Energy Consumption Survey: Characteristics of Commercial Buildings 1986*. DOE/EIA-0246(86), U.S. Department of Energy, Washington, DC.

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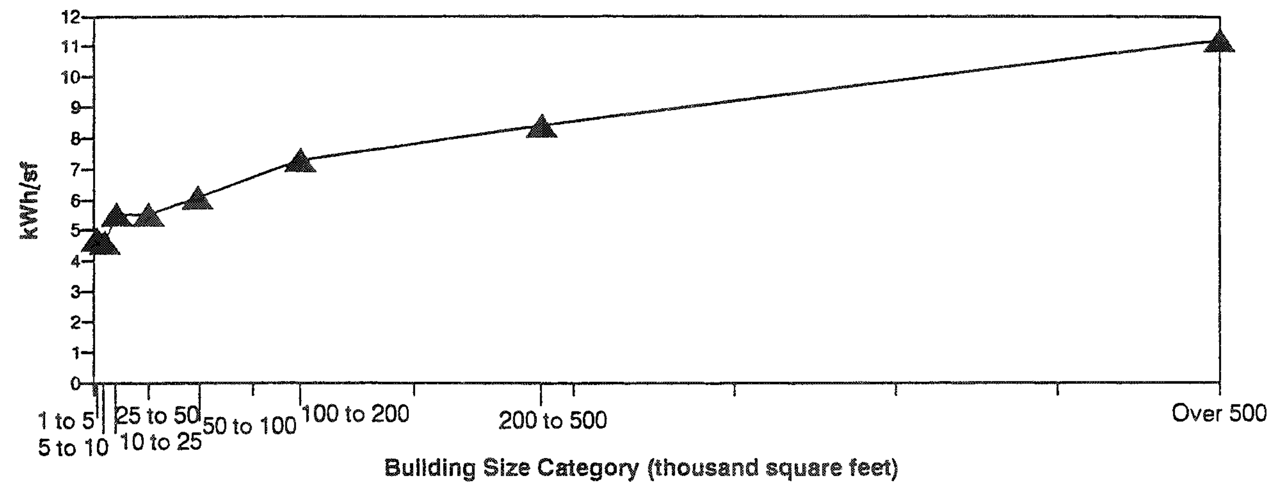

Note: • Average quantities for each size category are plotted at a horizontal position corresponding to the average size for buildings in that category.

Source: Energy Information Administration, Office of Energy Markets and End Use, Energy Consumption Series: Lighting in Commercial Buildings, DOE/EIA-0555(92)/1.

Figure 6. Lighting Energy per Square Foot by Building Size Category