State Options in Lighting:

*Efficiency Standards for
Existing Public Buildings*

July 1979

Washington, D.C. 20036

Contract No. EM-78-C-01-5255

MASTER

Prepared for:

U.S. Department of Energy
Assistant Secretary for
Conservation and Solar Applications
State Energy Conservation Programs

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Available from:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price: Printed copy: \$5.25
Microfiche: \$3.00

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ABSTRACT

This report discusses requirements and options for state lighting efficiency standards for existing public buildings under the Energy Policy and Conservation Act (EPCA). EPCA, as implemented under present regulations, is found to allow great flexibility to the states in what they adopt, so long as they do adopt some standard.

A wide variety of substantive standards is described and it is recommended that states adopt a standard based on a maximum lighting power budget with cost-effectiveness criteria.

Several options for adoption and enforcement of standards are discussed. It is recommended that states adopt a requirement that owners of all public buildings submit reports of lighting energy audits and estimates of energy savings from modifications to comply with substantive standards. It is further recommended that while filing of reports should be mandatory, substantive compliance, at least initially, need not be; if it turns out that voluntary compliance is not great enough to achieve a state's desired energy savings, compliance could then be made mandatory.

It is recommended that exemptions from the standards be limited to small buildings and that variances under a mandatory standard be available only when an applicant can show insufficient capital to make required modifications, even though they would soon pay for themselves in reduced operating costs.

It is suggested that a lighting standard of the kind recommended could substantially reduce wasted energy in lighting, be simple enough to be easily understood and applied, be technically and economically reasonable, and allow for needed exemptions without loopholes.

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STATE LIGHTING EFFICIENCY STANDARDS FOR EXISTING PUBLIC BUILDINGS¹

Introduction

Recognizing the end of our long era of abundant, cheap energy, Congress enacted the Energy Policy and Conservation Act (EPCA) in late 1975.² Part of EPCA provides for federal technical and financial assistance to states to help them develop and implement energy conservation plans that meet certain requirements.³ Required features include mandatory lighting efficiency standards for nonfederal public buildings.⁴ Optional features related to lighting standards include restrictions governing the hours and conditions of operation of nonfederal public buildings,⁵ restrictions on the use of decorative or nonessential lighting,⁶ programs of public education to promote energy conservation,⁷ and any other appropriate program to conserve energy or to improve efficiency in energy use.⁸

The original goal for state plans in the regulations under EPCA⁹ called for each state to reduce the use of energy within the state by at least 5 percent below the level that would be projected for 1980 if the state's planned conservation measures were not taken.¹⁰ Lighting efficiency standards were naturally included in this goal since lighting consumes a substantial part—roughly 20 percent—of all electricity used in the United States, or 4.8 percent of the total national energy budget.¹¹ Of the roughly 3 percent of national energy used to light public buildings (including nearly all commercial use and the public portions of residential uses) about 20 to 50 percent could be saved, depending on how rigorously conservation is pursued.¹² This is a substantial fraction—10 to 30 percent of the original 5 percent goal of the EPCA state plan program. At this late date,¹³ the full potential of a newly enacted lighting standard may not be realized by the end of 1980, but a large contribution to that goal is still possible.

While EPCA mandates lighting standards for public buildings in state plans, the standards need not be mandatory. According to the regulations

under EPCA, "mandatory" lighting efficiency standards for public buildings must be implemented statewide¹⁴ and apply to all public buildings above a certain size determined by the state.¹⁵ The standards for new buildings¹⁶ must be no less stringent than section 9 of ASHRAE Standard 90-75,¹⁷ but the standards for existing public buildings need only "contain the elements deemed appropriate by the state."¹⁸ For existing public buildings, then, states are given full rein either to innovate and severely cut back lighting energy use or to do very little. Under EPCA state plans, most states have enacted a lighting standard for new buildings based on ASHRAE 90-75;¹⁹ few have actually adopted standards for existing public buildings.

This report examines the wide variety of approaches to lighting standards for existing public buildings that have been proposed and in some cases adopted. In addition to substantive requirements, it discusses options for defining classes of public buildings to be regulated and for choosing methods to enact and enforce the standards. The report also recommends a particular combination of substantive standard, cost-effectiveness criteria, and an enforcement program that should overcome opposition to enactment and enforcement.

Defining Public Buildings Subject to Standards

Federal Requirements

EPCA defines public building as "any building which is open to the public during normal business hours,"²⁰ and a building as "any structure which includes provision for a heating or cooling system, or both, or for a hot water system."²¹ In other words, EPCA's definition does not cover public buildings that have neither heating, cooling, nor hot water systems, regardless of how extravagant their use of energy for lighting may be. This definition, although clearly not limited to the usual meaning of a government building, is much too vague to be useful: What does "open to the public" mean, and what are "normal business hours"? Are private clubs covered? Are buildings open only at night or on weekends exempted?

The regulations retain the EPCA definition of building as is,²² but they elaborate on the term "public buildings":

"Public building" means any building which is open to the public during normal business hours, except exempted buildings, including—

(a) Any building which provides facilities or shelter for public assembly, or which is used for educational, office or institutional purposes;

(b) Any inn, hotel, motel, sports arena, supermarket, transportation terminal, retail store, restaurant, or other commercial establishment which provides services or retail merchandise;

(c) Any portion of an industrial plant building used primarily as office space; or

(d) Any building owned by a State or political subdivision thereof, including libraries, museums, schools, hospitals, auditoriums, sport arenas, and university buildings./23/

This enumeration covers most intended public buildings, yet the ambiguity of "open to the public during normal business hours" remains. It appears that even a building specifically listed would not be regulated unless it is open to the public during normal business hours.

"Exempted buildings" include:

(a) Any building whose peak design rate of energy usage for all purposes is less than one watt (3.4 Btus per hour) per square foot of floor area for all purposes;

(b) Any building with neither a heating nor cooling system;

(c) Any mobile home; or

(d) Any building owned or leased in whole or in part by the United States./24/

Thus, a building is not a covered "public building" if it uses less than a watt per square foot (a rate that is still excessive, say, for a parking garage)²⁵ or if it has neither a heating nor cooling system but does have a hot water system.²⁶

Federal buildings are not generally subject to state and local regulations.²⁷ A separate section of EPCA did establish, however, a requirement for lighting efficiency standards for buildings owned or leased by the federal government.²⁸

State Options

The federal requirements for "public buildings" to be covered in lighting standards under a state energy conservation plan are minimum requirements; states may, and should feel free to, use more inclusive definitions or definitions that fit better with their other laws, if they prefer

to do so. States with a statewide building code may apply lighting standards to existing buildings in listed use or occupancy groups as defined in the code. New Jersey's standards apply to a list of virtually all building uses regardless of size; one- and two-family residential and the dwelling parts of multi-family residential buildings are excluded.²⁹ On the other hand, Massachusetts, which also has a statewide building code, chose to regulate all buildings existing as of July 1, 1978 with a gross floor area over 10,000 square feet, except for one- and two-family buildings, the dwelling part of multi-family buildings, and the manufacturing part of industrial plants.³⁰ This latter approach seems simpler, and certainly clearer than the lengthy federal regulations.

The simplest regulatory approach would apply rules to all existing buildings, then list only particular classes of buildings that are to be exempted. The exemption of buildings without heating and cooling³¹ is unnecessary for a lighting standard, although quite sensible for an insulation standard.³² Unless standards for new buildings apply to building modification, the exemption of buildings built after a certain date (as in Massachusetts) seems unwise. A building that met the lighting standards for new buildings might lawfully be modified later to use more energy than would be permitted under either the new or existing building standards for lighting. Also inappropriate to a lighting standard is the exemption of buildings that use less than one watt per square foot,³³ since even that amount is more than needed for some uses.

The exemption of small buildings under a specified size as permitted under the federal regulations³⁴ seems fair, but an exemption of only small buildings using less than a specified total connected lighting power might be wiser.³⁵ The range in exempted "small building" size under adopted and proposed state standards is enormous. New Jersey does not exempt any small buildings, as indicated above. Florida exempts buildings under 1,500 square feet.³⁶ Minnesota exempts buildings under 5,000 square feet.³⁷ A West Virginia bill, on the other hand, would exempt existing buildings under 250,000 square feet and new buildings under 25,000 square feet³⁸—hardly a good faith effort to comply with EPCA. DOE may wish to modify its regulations to avoid such wholesale exemptions.

The exemption of federal buildings need not go so far as to exempt whole buildings where the federal government owns or rents only a part.³⁹ It should suffice to exempt the federally owned or leased portions only.

Renovation Standards

Alterations and repairs to buildings pose yet another problem of definition that states should consider carefully: when should standards for existing or new structures apply? Since it is easier and cheaper to build an efficient lighting system in the first place than to redo an existing one, standards for new construction can be more stringent than those for existing buildings. A lighting standard for new buildings will almost certainly be in a building code; a lighting standard for existing buildings may be in a building code, but need not be, as explained below.⁴⁰ A typical building code might provide the following distinction:

- o If alterations or repairs during a twelve-month period cost more than 50 percent of the value of the structure, the whole structure must be made to conform to the code requirements for new buildings.
- o If the work costs less than 25 percent of the structure's value, the building may be restored to its condition before deterioration or damage with the same kinds of materials used originally (in essence, the old standards apply).
- o If the work costs between 25 and 50 percent, the building official may decide what parts of the structure must conform to the new and old standards./41/

A host of variations is found in this kind of provision and a state may wish to retain discretion to require or waive conformity to new standards for alterations and renovations.

The Georgia lighting standards for new buildings apply to "renovated buildings," which are defined as:

- (a) a building undergoing alteration of the exterior envelope, heating, ventilation and air conditioning systems, water heating systems or lighting systems, for which the aggregate cost exceeds ten percent of the assessed value of the building immediately prior to such alteration; or
- (b) a building undergoing alteration in the physical configuration or interior space for which the aggregate cost of alteration exceeds one-fourth of the assessed value of the building immediately prior to such alteration./42/

Considering that property is usually assessed at less than its actual market value, this could be a stringent criterion if standards for new buildings are much tougher than those for existing buildings. In many jurisdictions, however, the measure of value is often the replacement cost of the building,⁴³ and as this is usually greater than the market value, such a standard would be less strict. Another criterion, probably the least stringent, would apply the new standards only to renovation that increases the replacement value of the existing structure (as determined by the county assessor) by 50 percent or more.⁴⁴

Different Rules for Different Defined Classes of Public Buildings

A state may wish to consider different rules for different types of buildings. Buildings could be distinguished on the basis of ownership, use, or size. The following distinctions might be made:

- o public buildings owned or used by states
- o public buildings owned or used by subdivisions of states
- o privately owned public buildings
- o nonresidential nonpublic buildings
- o residential nonpublic buildings

A state might set standards for its own buildings, including improvements and frequent maintenance, that would not be considered cost effective for private individuals and businesses.⁴⁵ A state could also schedule the use and cleaning of its buildings to make the most of daylight. A state might have similar, possibly not quite so stringent, requirements for state subdivisions and earmark state funds to help localities implement such programs.⁴⁶

Standards for nonpublic buildings are not called for in the EPCA lighting standards program but they could fall under programs of public education and other appropriate programs to conserve energy authorized in the act.⁴⁷ These should be voluntary rather than mandatory standards.

Options for Substantive Lighting Standards

In the course of research for this report, a surprising variety of approaches to substantive standards for regulating lighting energy use in existing buildings was encountered. Some of the approaches seek to control the design of lighting systems; others seek more to control conduct, and to affect hardware only indirectly. The discussion of substantive standards is divided into the following categories:

- o maximum lighting levels
- o maximum lighting power budgets
- o maximum lighting energy budgets
- o minimum percentage cutback in lighting levels, power, or energy
- o fixed utility budget
- o mandating or prohibiting certain hardware or maintenance procedures

The length and detail of the discussion varies widely with the category. The category discussed most thoroughly is the maximum lighting power budget, which is widely viewed as the most promising for general application.

Lighting energy used in existing public buildings can be reduced in many ways. (See the appendix for a short discussion of technical options.) Most standards, enacted or proposed, force changes in lighting hardware and use by control of either lighting levels, power, or energy. The distinctions among these fundamentally different concepts are clarified below:

- o Standards based on lighting levels regulate how much illumination may be used. Lighting level standards are commonly stated in terms of footcandles (or lux in SI units)./48/
- o Standards based on lighting power regulate the rate at which energy may be used for illumination. Lighting power standards are commonly stated in terms of watts per square foot.
- o Standards based on lighting energy regulate the amount of energy that may be used for illumination during a given period, generally one year. Lighting energy standards are commonly stated in terms of kilowatt-hours per square foot per year (or an equivalent number of Btus per square foot per year)./49/

Maximum Lighting Levels

In a maximum lighting level standard, a schedule of acceptable lighting levels for various tasks is provided. The most widely accepted source for recommended lighting levels for various tasks is found in the Illuminating Engineering Society's IES Lighting Handbook.⁵⁰ The IES levels, however, are only minimum recommended levels. In studies for the U.S. General Services Administration (GSA)⁵¹ and the former Federal Energy Administration (FEA, assimilated by DOE),⁵² Ross & Baruzzini described the research basis for such standards and recommended specific levels for common tasks in government work.⁵³ These figures were adopted by the GSA⁵⁴ and FEA⁵⁵ as recommended guidelines. The GSA apparently intended that their guidelines be used for U.S. government buildings only, whereas FEA recommended theirs for public, commercial, and industrial buildings.

It should be noted that the GSA/FEA recommended maximum lighting levels are generally much lower than the IES levels, and are far less discriminating among various tasks. For this reason, members of the lighting design profession seem largely contemptuous of this "simplistic" standard.⁵⁶

The enforcement of lighting level standards is by measurement with a portable light meter. Several measurements are taken at each task area and the average is not to exceed the maximum set by the standard for the task in question. Enforcement is difficult for several reasons. First, the measured light level is inaccurate—it will vary markedly with light meter placement within a work space; variation by a factor of two is not uncommon. Second, daylight from nearby windows must be taken into account. This is difficult, suggesting that inspectors might have to work at night. Two inspections could easily obtain different average measurements. Would a finding of a violation be enforceable?⁵⁷

The main problem with this kind of standard is that it is not a lighting efficiency standard at all! So long as the maximum lighting level is not exceeded, the efficiency of the sources, fixtures, or setting does not matter. A distant incandescent lamp in a fixture that bounced light off a dark ceiling onto a task would be as acceptable as a nearby fluorescent lamp in a fixture that focused the light directly on the task. The former could easily use more than ten times as much energy as the latter.

Maximum Lighting Power Budgets

This approach is most widely seen as promising. As a result, there are many proposals worth scrutiny:

- o IES's four standards for new and existing buildings
- o California's standards for new and existing buildings
- o Massachusetts' standard for existing buildings
- o New Jersey's standard for existing buildings
- o Minnesota's standard for existing buildings
- o North Carolina's standard for new buildings

These standards range in complexity from IES's elaborate EMS-1 procedure to the simple one-number standard of North Carolina. Not all of these standards were written with existing buildings in mind, but any could be used for them.

IES's EMS-1⁵⁸ (ASHRAE 90-75). This standard offers a procedure developed by and for the use of lighting professionals. It was written for, and incorporated in, the widely adopted ASHRAE Standard 90-75, Energy Conservation in New Building Design as section 9. While it is nominally a standard for new building design, it has been adopted verbatim as a standard for existing buildings,⁵⁹ and it serves as the basis (or target standard) for several standards that are expressly for existing buildings.

Using the IES method, a lighting system designer computes a maximum power budget for lighting and then strives to develop the actual design within the budget. The procedure for computing the budget is the most elaborate of any standard discussed in this report. While designers must go through the prescribed procedure, they need not make their actual designs within the budget.⁶⁰ In other words, this standard maximizes procedural complexity and cost without compelling any substantive result whatsoever!⁶¹ The standard sets forth what the designer "should" do and "should consider" but does not say what "shall" be done. ASHRAE 90-75 in section 8 on wiring does state that "switching shall be provided for each lighting circuit, or for portions of each circuit, so that partial lighting required for custodial or for effective complementary use with natural lighting may be operated selectively."⁶²

The EMS-1 procedure for finding a maximum lighting power budget requires the following steps:

- o Identify each room, corridor, foyer, etc., and measure it.
- o Identify each task area⁶³ and measure it.
- o Compute "room cavity ratios" from a formula or tables.⁶⁴
- o Select appropriate task lighting levels, general lighting levels, and noncritical lighting levels for each area.
- o Assume lamp efficacies appropriate to the needs for color rendition in each area.
- o Assume certain ceiling, wall, and floor cavity reflectances and a specified light loss factor.
- o Select appropriate luminaires for each area and look up their "coefficient of utilization" in tables (certain minima must be met).
- o Plug all these factors into formulas given and compute the wattage allowances for each area; the sum of them will give the interior lighting power budget.

This is the general procedure for interiors; there are exceptions for special cases and an additional procedure for exterior lighting, which is figured differently. The total lighting energy budget for the building is the sum of the interior and exterior budgets.

This procedure is too complex to be understood and applied by most lay people; it is intended for lighting design professionals only. To appreciate fully the complexity of this procedure, the reader should scan the 9 pages of EMS-1 or the 12 pages of section 9 of ASHRAE 90-75 and the massive IES Lighting Handbook, which is adopted by reference in the standard, especially the 96-page chapter 9, "Lighting Calculations."

As a voluntary standard, this IES standard is unlikely to produce significant energy savings in existing buildings.⁶⁵ The IES/ASHRAE standard has been translated into a somewhat simpler form for adoption as a mandatory building code, the Code for Conservation in New Building Construction.⁶⁶ Although greater energy savings could be expected from this mandatory form, the difficulty in applying the complex IES procedure remains.

IES's EMS-1R. EMS-1 has been refined slightly⁶⁷ and the ASHRAE standard is in the process of revision. The principal revision to the lighting standard limits task areas as a fraction of total room areas to 50 percent in figuring the budget.⁶⁸ This extra step adds a little to the complexity. The

overall process is the same, and budgets are slightly lower.⁶⁹ EMS-IR does not appear to have been adopted anywhere as a lighting standard for existing buildings.

IES's EMS-4⁷⁰ (ASHRAE 100.P series). This standard, or procedure, has two main parts. The first part (Appendices A and B)⁷¹ has guidelines and forms to prepare lighting power budgets for existing buildings. While they differ only slightly from those in EMS-IR, and the budget is consistent with EMS-IR, the forms and guidelines are said to be tailored specifically for use in existing buildings.⁷² The second part of EMS-4 sets out a lighting energy management program (Appendix C).⁷³ This program and its handy checklist of 52 items to consider for lighting efficiency improvements and maintenance would be a worthy addition to a state's voluntary standards or to a state's educational materials in a program to encourage energy conservation.⁷⁴ Rather than describe this lengthy program here, the reader is invited to consult the original.⁷⁵

As of this writing, EMS-4 has been adopted only in New Jersey.⁷⁶ The New Jersey Department of Energy regards EMS-4—correctly in our estimation—as "a rather complicated procedure, [so that] it is best to have a qualified lighting engineer assist you."⁷⁷ For this reason, New Jersey has also adopted a short-cut method that can be used for common applications in rooms of regular shape.⁷⁸

EMS-4 (in draft form, as well as EMS-1) served as the basis for the lighting portions of an ASHRAE 100.P series. As ASHRAE 90-75 was written for new building design, ASHRAE has been working on drafts for a series of standards for energy conservation in existing buildings. The series consists of six proposed standards:

- o 100.1P for low-rise residential buildings
- o 100.2P for high-rise residential buildings
- o 100.3P for commercial buildings
- o 100.4P for industrial buildings
- o 100.5P for institutional buildings
- o 100.6P for public assembly buildings

These standards are substantially similar to EMS-4 (and EMS-1) in their lighting provisions. Their overall target level of lighting energy consumption

for existing buildings is the same as 90-75's. Each of these standards has two fundamental differences from ASHRAE 90-75 that bear special consideration.

First, each of these standards has provisions describing principles for better lighting use in existing buildings. The discussions vary in length and are adapted to the diverse kinds of buildings covered by the proposed standards.⁷⁹ Three of the standards also adopt EMS-4's lighting management program.⁸⁰ Such a program would not be needed in a mandatory standard, but could be helpful in educational materials or in a voluntary standard.

Second, each of these standards has economic criteria that must be met before a measure (such as delamping, relamping, or installing more switches) would be required. Each has its own formula and wording, meriting examination here.

ASHRAE 100.1P (low-rise residential) provides that compliance is demonstrated

when all of the energy conserving modifications available for application to the project, meeting the following criteria, have been accomplished:

(a) An estimate of each energy conserving modification as made in a manner acceptable to the authority having jurisdiction and using accepted ASHRAE/IES procedures, results in an annual energy savings of 20% or more of the cost of the modification.

(b) The costs considered in computing energy, labor, equipment, and materials shall be those currently in effect appropriate to the project./81/

In this standard for low-rise residential buildings, each modification must be cost effective, with a simple 5-year payback period; this is a marginal cost method. Costs are actual costs to the party regulated, rather than average costs to a class of regulated persons or average statewide costs figured from standard formulas. This is important, for environmental standards are often based on average costs. The cost definition appears to apply only to the modification itself. It does not include costs of a feasibility study or energy audit, nor is there consideration of the economic life of the building.

ASHRAE 100.2P (high-rise residential) provides that compliance is demonstrated

when all of the modification means available for application to the project, meeting the following criteria, has [sic] been accomplished.

(1) An estimate of each modification, as made by a licensed design professional, using accepted ASHRAE and IES procedures, results in an annual energy cost savings of 10% or more of the installation cost of the retrofit.

(2) Buildings [that] have a demonstrated life of less than 10 years will be in compliance with this Standard if the estimated annual energy cost savings equals or exceeds two (2) divided by the life in years times the modification cost.

(3) Cost [sic] considered in computing energy, labor, equipment, and material shall be those currently in effect appropriate to the project./82/

In this standard for high-rise residential buildings, computation must be made by a licensed design professional. This may be helpful, but mandating it is not recommended. The standard would have the estimate be made according to "accepted" ASHRAE and IES procedures, which are not listed specifically by publication titles and dates. Laws that leave such details to an open-ended set of procedures incorporated by reference should be avoided; otherwise, it is not clear what rules apply. Such laws may be unconstitutional either for vagueness or for attempting to delegate legislative power to a private body. It would be better for a state to strike the "ASHRAE and IES procedures" language and refer to regulations of a state agency or set out the procedures in the standard itself.⁸³ A 10-year payback period applies and remaining economic life is taken into account. Inexplicably, if a building has a 10-year life, a 10-year payback period applies, but if it has a 9-year life, a 4 1/2-year payback period applies. This is an anomaly found in some, but not all, of the other 100.P series standards, as will be seen below. The reference to "installation costs" makes it clear that study and audit costs are excluded.

ASHRAE 100.3P (commercial buildings) provides:

All possible retrofit means available which can be estimated by accepted ASHRAE and/or IES methods to pay back in 10 (ten) years of [sic] less, using current energy, labor and material costs appropriate to the building shall be accomplished. Buildings having demonstrated remaining economic life less than 10 (ten) years shall meet the Standard if the estimated payback is equal to or less than the demonstrated life divided by two./84/

This simpler version for commercial buildings is essentially equivalent to that of 100.2P, except that it does not require a licensed design professional to estimate savings.

ASHRAE 100.4P (industrial buildings) calls for an annual energy audit.⁸⁵ The cost-effectiveness criterion states:

On facilities having a demonstrated life of 8 years or more, an estimate of each modification cost shall be made, using accepted ASHRAE-IES procedures. If the estimate results in an annual energy cost savings of 25% or more of the modification, it shall be considered for implementation in accordance with Paragraph 4.3.3.

Buildings having demonstrated lives of less than 8 years will be in compliance with the Standard if the estimated annual energy savings equals or exceeds two (2) divided by the life in years times the modification costs.

Modification costs include energy, labor (including personnel, consulting and analysis fees), equipment and materials and shall be those in effect at the time of the study and/or appropriate to the study./86/

Note that the payback period of 4 years fits with the 8-year economic life so that there is no discontinuity for shorter economic lives, and that consulting and analysis costs—presumably including audit and estimating costs—are included.

Sections not quoted here provide that each year a list of energy usage reduction opportunities is to be drawn up; measures that do not meet the cost-effectiveness criterion need not be implemented, but the initial list of those that do must be completed within 48 months of adoption of the standard.⁸⁷ The minimum energy reduction for each year is 1/8 of the cost-effective modifications on the list.⁸⁸ These provisions are part of an overall standard including such features as insulation requirements. Thus, no lighting efficiency improvements need be made in any particular year if energy usage is reduced enough in other ways. This, together with the complexity and unclear wording of these provisions, does not commend their adoption. The main features of the cost-effectiveness section, however, are excellent (not including the "accepted ASHRAE-IES procedures" language).

ASHRAE 100.5P (institutional buildings) also requires energy audits to identify opportunities for conservation,⁸⁹ but it omits the complexities of

100.4P. The payback period is 5 years with a 10-year demonstrated economic life.⁹⁰ The only major new feature is:

All modifications resulting in combined annual energy cost savings of 20% or more of the combined cost of the modifications shall be performed. This shall be determined by appropriate analysis of the costs and expected energy savings of the combinations of modifications./91/

Thus, even if a modification itself is not cost effective, it must be made if, when averaged with other more cost-effective measures, it does not drive the payback period beyond 5 years. This is a much more severe criterion than requiring each modification to be cost effective. It is not unreasonably harsh, however, since a 5-year overall payback should be acceptable; many other environmental laws, as in air and water pollution abatement, never pay back their costs to the regulated party.

ASHRAE 100.6P (public assembly) differs slightly in wording from 100.4P, but it has the same cost-effectiveness criterion, without quite such complex requirements for completing lists of energy reduction opportunities.⁹²

IES's draft UPD method. The Energy Management Committee of the IES has been working on a new, simplified IES method for calculating lighting power budgets.⁹³ The method, called the Unit Power Density (or UPD) approach, allows the user to skip steps in EMS-1R for finding lighting levels, assuming particular surface reflectances, identifying appropriate luminaires, finding the luminaires' coefficients of utilization, and considering the appropriate source efficacies to assume for the color rendition requirements. Instead, the user looks up the task in a table and is given a key number, which defines a line in the UPD table. Then, given the room cavity ratio (figured as in the EMS-1 procedure), the table provides the lighting power allowance per square foot (unit power density) for rooms that are 50 percent or more task area. These figures must be corrected using another table for rooms with less than 50 percent task area. The total power budget is the sum of all the areas times the corrected UPD number for that area. The method is set out in just over one page and there is no need to consult the voluminous IES Lighting Handbook. Although there are pages of tables for the hundreds of different tasks⁹⁴ and another page for

the UPD table, the method is clearly simpler, faster, and less likely to produce errors than EMS-1 for the lay person. Since the same assumptions are used as in EMS-1, virtually the same budget results.

The IES draft also includes a Lighting Power Budget (LPB) approach that is a slightly simplified version of EMS-1R. Since the UPD approach is said to be derived from the LPB approach, the purpose of the more complex LPB approach is not clear from the draft.⁹⁵

This method for finding power density, or watts per square foot directly, instead of light levels and a procedure to figure power density indirectly, is more suitable to a lighting standard because it avoids needless complexity. Some other approaches based on a watts-per-square-foot method adopted by states are discussed below. All are simpler than IES's draft UPD approach.

California standards. California has a mandatory lighting efficiency standard for new nonresidential buildings⁹⁶ and a voluntary standard for existing buildings.⁹⁷ Each has unique features worth examining.

In the standard for new buildings, the allowed power density for each task area is entered directly in a list of tasks adopted from the IES task list, with two columns of density figures: one for room cavity ratios of 0 to 5 and another for those over 5.⁹⁸ For tasks requiring intense light (close inspection, detailed drafting, and the like), figures in footcandles rather than power densities are given, and no wattage limit applies.⁹⁹ The lighting for these tasks must be by "local or localized general lighting."¹⁰⁰ This vague requirement is clearly a weakness as it would be difficult to administer,¹⁰¹ but it is better than a total exemption of "task lighting" as found in the Massachusetts standard (described below). This California standard also requires that lighting using more than 1 watt per square foot be capable of being dimmed by at least one-half in areas over 100 square feet, and it limits the maximum current that can be controlled by a single switch.¹⁰² The standard as a whole, and the provisions for dimming and switching capability in particular, would not seem applicable to existing buildings, unless cost-effectiveness criteria such as those in the ASHRAE 100.P series were added.

The California standard for existing buildings essentially offers guidelines to businesses for saving money by improving lighting efficiency.

As a voluntary standard, it has much useful information that could be used by states for education. It also has an excellent suggestion on the problem of lighting difficult visual tasks. Section 3 tells how to estimate the lighting power needed for an efficient design. In offices, for example, it suggests a target of 1 1/2 watts per square foot (with ceilings at 9 feet or less) plus 100 watts for each occupant performing special tasks such as bookkeeping and drafting. The standard indicates that actual results of redesign have ranged from 1 to 2 watts per square foot.¹⁰³ What is novel here is the maximum power limit imposed on a per occupant basis for special tasks: There is no such limit in the California mandatory standard for new buildings or in any of the other standards discussed in this report. This would be a useful refinement to a watts-per-square-foot standard, especially if a switch for special task lighting were required to be available to the individual user.¹⁰⁴ The power limit per occupant (or work station) could be set higher or lower than the 100 watts here, depending on the particular task.

Massachusetts standard. This standard is embodied in the state building code¹⁰⁵ and applies to all existing buildings over 10,000 square feet,¹⁰⁶ except as specifically exempted.¹⁰⁷ Unlike the IES-based approaches discussed earlier, with their hundreds of task categories, it is based on 37 categories of use with 6 specified maximum power densities:¹⁰⁸

Lighting Limit (Connected Load)
for Listed Occupancies: Existing Building

MAX. WATTS/ SQ. FT.	TYPE OF USE
	Interior
3.00	Category A: Classrooms, office areas, automotive mechanical areas, museums, conference rooms, clerical areas, laboratories, merchandising areas, kitchens, examining rooms, book stacks, athletic facilities
1.00	Category B: Auditoriums, waiting areas, spectator areas, restrooms, dining areas, transportation terminals, working corridors in prisons and hospitals, book storage areas, active inventory storage, hospital bedrooms, hotel and motel bedrooms, enclosed shopping mall concourse areas, stairways
0.50	Category C: Corridors, lobbies, inactive storage areas

0.25

Category D: Indoor parking

Exterior

5.00 (per linear foot)

Category E: Building perimeter, wall-wash, facade, canopy

0.10

Category F: Outdoor parking

The allowance for open office space of 2,000 square feet or more is reduced to 2.5 watts per square foot, in effect adding a seventh power density category.¹⁰⁹

Unlike the standards discussed earlier,¹¹⁰ the figures apply to whole rooms rather than to specific task areas within rooms; moreover, power densities are independent of room dimensions.¹¹¹ The standard is so simple that it is printed on 2 pages (plus 4 pages of forms and instructions on how to fill in the forms). Massachusetts has supplemented it with excellent educational materials.¹¹²

The principal weakness in the Massachusetts standard is the exemption of all "task lighting" from the budget calculations.¹¹³ Task lighting is defined as "illumination applied to an individual location, with local control of switching. Examples include desk lamps, examining lamps, and machine lights."¹¹⁴ From an energy conservation standpoint, this wholesale exemption is worse than a complex alternative. Massachusetts should carefully monitor buildings to make sure that the intent of the law is not violated by, for example, the exchange of efficient fluorescent ceiling lighting for inefficient incandescent desk and other task lamps. Another peculiarity of this standard is the separation of the interior and exterior budgets.¹¹⁵ The reason for this is unclear.

The Ohio Board of Building Standards adopted a standard apparently based on the Massachusetts standard, although it differs in several respects.¹¹⁶ It does not treat larger open office spaces differently, so there are six rather than seven lighting power categories. Audit requirements¹¹⁷ and forms¹¹⁸ are different. The definition of public buildings¹¹⁹ and added exemptions,¹²⁰ apparently taken from the EPCA regulations (with some refinement), are less satisfactory than the Massachusetts definition. The Ohio standard is mandatory only for state buildings and recommended for others.¹²¹

Wisconsin also adopted a similar, briefer standard¹²² that applies to new buildings, to additions to existing buildings, and to existing buildings if there is any change of occupancy or use that would require an increase in energy consumption.¹²³ The power density categories and allowances¹²⁴ differ somewhat from the Massachusetts standard:

LIGHTING POWER VALUES

<u>Area/Use</u>	<u>Maximum Connected Lighting Load</u>
Offices	3.0 watts/sq. ft.
Factories, mercantile buildings, classrooms, day care centers and other chapter 54 and 56 occupancies not listed elsewhere in this table	2.5 watts/sq. ft.
Conference rooms, toilet rooms, theaters and other places of assembly (i.e., entertainment, recreation, worship, or dining areas)	2.0 watts/sq. ft.
Corridors, bulk manufacturing buildings, places of abode or detention, lobby areas, and other chapter 57 and 61 occupancies	1.0 watt/sq. ft.
Dead storage areas	0.5 watts/sq. ft.
Indoor parking structures and other hazardous occupancies	0.25 watts/sq. ft.
Outdoor parking areas	0.05 watts/sq. ft.
Building perimeter, facade	5.0 watts/lin. ft.

As in Massachusetts, local task lighting with switches under the user's immediate control are exempted.¹²⁵ Wisconsin accepts compliance with section 9 of ASHRAE 90-75 as an alternative to this much simpler scheme.¹²⁶

New Jersey standard. In addition to EMS-4, New Jersey has its own "Rapid Estimating Method" (REM) for various listed "retail tasks."¹²⁷ These tasks include not only retail stores, but common service businesses such as barber shops, dry cleaners, auto parking and service garages, laundromats, restaurants, and watch repair shops, as well as offices, malls, art galleries, and warehouses.¹²⁸ For each business there are power density allocations for rooms with 25, 33, and 50 percent of total room area used for tasks.

REM applies only in buildings with rooms that are not unusually large or small (in the range from 50 to 90,000 square feet)¹²⁹ with ceilings between 8 and 20 feet high¹³⁰ and with regular (rectangular) shaped areas. The method does not apply to areas requiring specialized lighting, such as art work and printing, medical and dental work, and theatres.¹³¹

The REM procedure computes the allowance for each area from the product of the allowed power density, the floor area, and a "room factor."¹³² The sum of these allowances is the total budget for the building. The total wattage used in the building must not exceed this sum.¹³³

Minnesota standard. Minnesota adopted section 9 of ASHRAE 90-75 as its standard for existing buildings,¹³⁴ as well as a simplified alternative method.¹³⁵ A unique feature of the standard is its cost-effectiveness criteria. While the criteria are not internally consistent and satisfactory, Minnesota is the first state to take this important step.

The simplified budget procedure is similar to yet simpler than that of Massachusetts, but it only applies to listed categories of occupancy.¹³⁶ Interior and exterior budgets are separate.¹³⁷ The exterior budget is 2 percent of the interior budget,¹³⁸ as under ASHRAE 90-75. The power densities allowed¹³⁹ are listed below:

MAXIMUM INTERIOR LIGHTING POWER BUDGETS
(CONNECTED LOAD) BY TYPE OF OCCUPANCY

TYPE OF OCCUPANCY	MAXIMUM WATTS PER GROSS SQUARE FOOT
Retail stores and banks	2.60
Mall concourses	0.75
Hospitals and clinics, schools, office buildings, museums and art galleries, libraries, court houses	2.20
Restaurants, cafeterias, police stations, correctional facilities, field houses, gymnasiums	1.60
Nursing homes, hotels, motels, churches, funeral homes, passenger terminals, auditoriums, public assemblies	1.00
Maintenance garages, parking garages	0.50

Here there are 6 power levels with 28 listed kinds of area use. A key difference from other standards is that the above figures apply to the gross square footage of the major type of occupancy for the building.¹⁴⁰ The only apparent exceptions are shopping mall concourses, since they are never separate buildings; garages within buildings may or may not be an exception as well, as they are sometimes separate buildings. This should be clarified unless Minnesota intends that basement, storage, and garage gross footage be included in the area allowed the full power density of the major occupancy. Simplification need not—should not—go as far as in Minnesota's standard.

Whether computed by the simplified method or by ASHRAE 90-75 procedures, only those lighting system modifications and operation and maintenance changes that are "economically feasible" under the Minnesota Energy Agency's formulas are required.¹⁴¹ There are two formulas from which to choose.

Under the simpler formula, the payback period is figured by dividing the modification cost by the excess in the annual savings of electricity over any increase in annual maintenance and operating costs due to the modifications.¹⁴² The modification cost is estimated according to procedures in two standard construction cost manuals.¹⁴³ It appears that a bona fide bid by a local independent contractor to do the work is not allowed; this is unfortunate, since a contractor might charge more or less than the cookbooks say. While the wish to discourage arbitrarily figured costs (to escape making lighting changes) is understandable, the Minnesota rule goes too far. Annual electricity savings are estimated on the basis of marginal costs of electricity, including any decrease in peak demand charges.¹⁴⁴ Although it is not clear, a decrease in maintenance or operating costs must presumably be added to savings, just as increases are subtracted.

A modification is considered economically feasible and thus required if the payback period is less than the remaining useful life of the building,¹⁴⁵ which is estimated by a specified procedure.¹⁴⁶ This is unrealistic for two reasons. First, a payback period may be longer than the economic life of the modification (such as new fixtures and especially lamps), yet shorter than the remaining life of the whole building.¹⁴⁷ Second, any investment that

does not pay for itself in a few years is not considered a good investment. The ASHRAE 100.P series' periods of 4 to 10 years or half the remaining life of the building, whichever is shorter, is as long a period as is likely to receive cooperation from regulated parties. While it is true that environmental regulations need not pay back at all to be legal, they should provide a reasonable return to be politically palatable and enforceable without great cost to the state.

An alternative formula allows the user to consider the effect of inflation on annual maintenance and electricity costs as well as the user's discount rate. The formula, procedures, and their explanation are too elaborate to be described here.¹⁴⁸ A few questionable assumptions must be noted, however. An inflation rate for electricity of 8.5 percent is assumed.¹⁴⁹ It is further assumed that the discount rate ("the annual return on the best investment which can be made by the building owner"),¹⁵⁰ or the rate paid on money borrowed to make modifications,¹⁵¹ will be less than 8.5 percent.¹⁵² A discount rate on the order of 6 to 10 percent is said to be reasonable,¹⁵³ yet it is doubtful that all Minnesota businesses can borrow at such low rates to make lighting modifications.

While Minnesota's scheme for figuring economic feasibility needs to be simplified and its assumptions on payback periods made more realistic, it is a useful contribution to the development of fair and usable lighting standards.

North Carolina standard. This standard is for new residential buildings only. It is mentioned here as an example of simplicity in the extreme. The entire lighting standard is printed below:

(a) Energy used for lighting is included in the total building energy load allotted in Table V. However, the maximum allowable load for lighting shall not exceed 3.0 watts per gross square foot.

(b) For building spaces larger than 200 SF, circuiting and individual switching or dimming shall be provided so that:

(1) Lighting energy can be reduced by at least one-half.

(2) Lighting can be turned off.

(c) Exterior decorative lighting shall not exceed 2 percent of the total interior lighting load./154/

Such a single number standard can be used for a single occupancy, as here, but it could not be fairly applied to the wide range of tasks in various public buildings. The North Carolina Conservation Plan nonetheless indicates that the state will apply this same standard to new business, school, institutional, assembly, industrial, and storage buildings as well.¹⁵⁵

Maximum Lighting Energy Budgets

If a lighting power budget figure (watts per square foot) is multiplied by the number of hours in a year (8765.76 hours on the average), a lighting energy budget figure (watt hours per square foot per year)¹⁵⁶ is found. Since lights in public buildings rarely need to be operated at full power 24 hours a day all year long, however, such a figure is inflated. A practical budget figure would have to be lower than this.

We have seen no separate lighting energy budget proposal for existing public buildings. There are various overall building energy performance standards (BEPS) under development by states for new state buildings;¹⁵⁷ and the U.S. DOE is working on BEPS for all new building construction.¹⁵⁸ These are energy allocations for all uses in Btus or Kwh per square foot per year. When completed, they may provide a reasonable basis for separate lighting energy standards, but they might be difficult to apply to existing buildings.

The main difficulty in energy-based standards for lighting lies in enforcement, because lighting is not wired with metering separate from all other electrical uses; consequently, there is no way to tell for sure how much energy is actually consumed for lighting. Rewiring buildings for separate meters for lighting is extremely difficult. Therefore, the only way to tell how much energy lighting uses is by estimate.¹⁵⁹ This problem appears insoluble.

Minimum Percentage Cutback in Lighting Level, Power, or Energy

Instead of specifying levels of illumination, power, or energy, percentage cutbacks could be required or encouraged. Two major limitations make this approach inappropriate for use in a mandatory program for public buildings and unattractive for a voluntary program. First, a few

buildings are already as dimly lit and energy-conserving as can be reasonably expected. A percentage cutback would be easy for energy wastrels but unfair to those who already conserve.

The second limitation is the difficulty of proof. Under the standards discussed earlier, a state building inspector can measure lighting levels, survey connected lighting power, or estimate actual lighting use (admittedly this last is problematic). Once cutbacks are made (or said to have been made), how is an inspector to know what lighting levels, connected power, or energy usage were previously? Such a standard is suitable only for a voluntary program or for a state's program to control energy use in its own buildings, as it would be easier to monitor changes carried out by the state's own employees than by others'.

Some states have adopted or proposed delamping and relamping programs to reduce lighting levels in their own buildings. Such programs have low initial costs and pay for themselves within months. In some states this can be done by executive order or regulation, without new legislation.¹⁶⁰

Although we have seen no proposals requiring a percentage cutback in lighting power, this strategy makes more sense than one requiring cutbacks in lighting levels or lighting energy: this is for the same reasons that a lighting power budget is more workable than lighting level or lighting energy budgets. Lighting energy is hard to estimate, but changes in lighting energy are doubly hard to compute. A program requiring cutbacks in connected lighting power would, however, still have the problems of proof mentioned earlier.

There have been proposals for standards to cut lighting energy use by certain percentages. A Connecticut proposal calls for a decrease in lighting energy use of at least 15 percent below a base year, depending on the year a building was built.¹⁶¹ The procedure requires a survey of the connected lighting power and an estimate of the number of hours per day and the number of days per year that each type of lamp is used.¹⁶² It is not clear how one figures what lamps were used and for how many hours in a building with a base year as far back as 1976. If one were crafty, one might guess that at least 15 percent more was used in the base year than is being used

now; this would show one to be in compliance and earn a "certificate of achievement."¹⁶³ This standard is voluntary in effect, though mandatory by its terms (there is no penalty); its purpose is to assess the amount of energy conservation that can be achieved without setting forth cost-effectiveness criteria.¹⁶⁴

If a cutback in lighting energy use is mandated, the only workable plan would mandate a percentage cutback in all electricity use.¹⁶⁵ Examination of utility bills would then disclose compliance or noncompliance. Even so, if a building changed its use to one requiring more light, it would need to consume more energy. If weather got colder in the winter or hotter in the summer than the base year, more energy would again be needed. How a standard can effectively, and fairly, treat such variations in energy needs is not clear. As indicated earlier, no standard with percentage cutbacks is recommended for general application.

Fixed Utility Budget

Since utility rates generally and electricity rates in particular are rising steadily, a temporary fixing of utility budgets at current levels will force energy conservation. It would not specifically force lighting efficiency improvements, but that would be one likely result. Fixing the electric utility budget would be more likely to be effective in reducing lighting energy use than fixing overall utility budgets. This way of forcing less energy use is better applied by a state to itself than to existing public buildings generally, since some buildings are already conserving energy adequately. This approach has the same risk of problems when building use or weather calls for more energy as with a standard for direct cutbacks in energy use. At least one state, Delaware, plans to limit state utility budgets to force energy conservation.¹⁶⁶

Mandating or Prohibiting Certain Hardware or Maintenance Procedures

Hardware mandates. In a standard for existing public buildings generally, the one kind of hardware that should be mandated is controls (switches and possibly dimmers). It would be unfair to mandate controls without a cost-effectiveness criterion, however, since wiring in buildings

varies greatly and the costs of rewiring and adding controls would vary accordingly.

Just how much area each control should cover is not clear. The North Carolina standard for new buildings requires a switch and dimming for each 200 square foot area.¹⁶⁷ California's standard for new buildings requires that dimming be available for areas over 100 square feet and that in effect each switch be limited to 16 amps for lighting,¹⁶⁸ which would mean almost 2,000 watts of lighting fixtures. This latter feature is lenient, as it would light over 600 square feet at 3 watts per square foot, or three times the area of the North Carolina standard. ASHRAE 90-75 requires switches but does not specify how many.¹⁶⁹ If controls are required only where they are cost effective, a very stringent requirement such as North Carolina's can be justified even for existing buildings.

Standards that specify hardware other than controls are probably not a good idea for public buildings generally, as they will rarely be technically and economically feasible for most buildings. Some state procurement regulations do specify efficient kinds of lamps and ballasts and some life cycle costing, which gives efficient hardware a competitive edge over less efficient hardware that may cost less initially.¹⁷⁰ Such procurement rules might be used as extra requirements for government buildings, but performance standards should be the general rule for all public buildings.

Hardware prohibitions. The decorative gas lamp is the only likely candidate to be banned in general; the federal government has already moved against its use.¹⁷¹ If reasonable overall standards of performance are met, it should not matter that a user has some inefficient equipment. (Government buildings may be an exception.) Next to gas lamps, the most wasteful lamp is the long-life incandescent bulb; a state may wish to prohibit such lamps except where their use can be clearly justified by the difficulty and high cost of replacement. Other inefficient light sources (the standard incandescent lamp and mercury lamps) might be prohibited in some situations, especially in outdoor applications, in favor of high-efficiency sources such as metal halide or sodium lamps.

Mandating maintenance. Efficient lighting systems need regular cleaning and changing of lamps. It may be wise to require such maintenance

where a lighting level standard is used, so that standards are not met by wasting lighting energy through poor maintenance. For power and energy-based standards, such a requirement would not be needed. States may wish to provide for more frequent lighting system maintenance for their own buildings and provide funding adequate for this purpose.

Options in Adoption and Enforcement

Having described various substantive standards to reduce energy use in lighting, the report in this section turns to alternative ways of adopting and enforcing standards. The options that a state may want to take will depend on existing state laws and on the relationship between state and local authorities. No one way can be recommended as the best, but alternatives to the usual assumptions about how lighting standards can be adopted do exist.

Under EPCA, a state may either adopt lighting standards itself or force localities to do so; in either case, standards that meet the guidelines must be in place in all political subdivisions of the state.¹⁷² State legislation would be needed to adopt standards or to mandate that they be adopted in most states. The legislation might be a highly specific piece of state legislation, a narrow mandate to a state agency, a narrow mandate to local agencies statewide, a broad mandate to a state agency, or a broad mandate to local agencies statewide.

Building codes. The usual assumption is that lighting standards as regulations on buildings belong in the building code. If the building code is a state code, lighting standards would be adopted by the state in that code; if the codes are locally adopted, states would mandate standards to be adopted (or enforced) by each local building authority. This approach is difficult unless all jurisdictions have adopted a building code or are in a position to enforce a state-promulgated code. Some states indicate that they have no statewide mechanism for enforcing lighting standards under EPCA.¹⁷³

Building codes are an apt mechanism to control the equipment that goes into a building when built, altered, or renovated. A building official can enforce a lighting standard for new work by refusing to issue a permit to build, alter, or renovate unless plans comply with the lighting standard, and

by inspecting the work as it progresses and when it is completed to see that it is done according to plan. But for existing buildings where no new work is to be done, no building permit is needed.

Compliance report. A new enforcement mechanism is needed. The simplest would be a program that required the owner of each regulated building to file a report on what lighting level, power, or energy (as applicable) is used for lighting and a proposal on how the building will be brought into compliance if it is not already. The Massachusetts standard contains such a program, based on connected lighting power. Although it is nominally a part of the state building code,¹⁷⁴ the enforcement mechanism is not by traditional building code means (permits, inspections, and certificates of occupancy). This kind of lighting standard could be adopted whether or not there is a state building code.

The Massachusetts standard requires that building owners file by a certain date a report of lighting power load for every building covered, with the local building official and with the State Building Code Commission.¹⁷⁵ (Jurisdictions with no state building authority might require filings instead with the state energy office.) If the current lighting power exceeds the budget calculated according to the prescribed method, the building owner must file a plan to achieve compliance by a certain date fixed in the code.¹⁷⁶ The building official may require certification of the lighting power by a registered engineer or architect.¹⁷⁷ Because this standard is part of the state building code, the usual administrative procedures and penalties under that code apply; this includes a misdemeanor penalty of one year of imprisonment and a \$1,000 per day fine for willful noncompliance.¹⁷⁸ The code's definition of "owner" applies as well, so that tenants in subject buildings must each file reports and comply for the space they occupy.¹⁷⁹ Massachusetts officials interpret compliance to require removal or disconnection; turning off lights, pulling fuses, or disconnecting circuit breakers, which are actions that are too easy to undo, are not enough.¹⁸⁰

Adopted as is in another state, the Massachusetts standard would not necessarily obtain the same result, because the Massachusetts State Building Code contains unique provisions for definition and enforcement. A code adopted elsewhere with the same intended effect would generally need further provisions.

Writing and adopting standards. Massachusetts wrote its own standard and adopted it at the state level. Another approach is to adopt an external standard by reference. This is what Minnesota did when it adopted ASHRAE 90-75 by reference as its lighting standard for all public buildings where "economically feasible" under a formula developed by the state energy agency.¹⁸¹ The agency developed an implementation manual with economic feasibility formulas and the simplified power budget approach described earlier. A report on connected power before and after compliance must be filed.¹⁸² The energy agency has the power to subpoena records of building owners to check compliance with the standard.¹⁸³

Some states have formed (or proposed) special committees or designated a state agency to write lighting standards for submission to the legislature.¹⁸⁴ Some have required an agency to develop a standard based on an existing or proposed standard.¹⁸⁵ Other states have considered passing the buck completely to localities by requiring the localities to adopt lighting standards without guidance from the state.¹⁸⁶ One bill would go so far as to require localities without a building code to enact one just so that they could enforce state lighting standards.¹⁸⁷

It is better if a single statewide standard is adopted by the legislature or the state energy or building authority. As long as reasonable cost-effectiveness criteria are met for all required modifications, no hardships should be imposed. Since states themselves have had difficulties devising and adopting satisfactory regulations for lighting efficiency in existing buildings, they should not expect localities to do better. It is possible, however, that a state may wish to leave enforcement to the localities. In this case, the state should reimburse localities for enforcement costs.

Voluntary versus mandatory standards. Although EPCA on its face calls for mandatory lighting efficiency standards, the regulations cite the voluntary ASHRAE 90-75 standard as a criterion of stringency for new buildings, and the regulations relax the requirement for standards with the qualifier, "the elements deemed appropriate" by the state for existing buildings.¹⁸⁸ Some standard is required, but almost anything suffices under the current regulations.

Two approaches are promising: either a mandatory standard such as Massachusetts' (with refinements), or standards that do not require

compliance but that do require the filing of audit reports, including an estimation of savings from compliance. If owners are forced to audit their buildings and see how they could save money, it may not be necessary to force them to take cost-effective steps. A purely voluntary standard does not seem sufficient, however, because it is too easy for apathetic building owners to assume that energy conservation, although wise in theory, would not pay in their buildings. If a voluntary approach with a mandatory audit is selected, it could be superceded by mandatory standards if voluntary compliance turns out to be insufficient to meet a state's long-term conservation goals.

Some states may prefer purely voluntary standards, seeking to rely on a public education program.¹⁸⁹ Many excellent sources of information and materials for such a program are discussed earlier. States may also wish to offer free or cut-rate technical assistance or energy audits to demonstrate the technical and economic feasibility of saving energy in lighting.¹⁹⁰

A special problem for mandatory standards is how to treat leased buildings. A building owner often does not pay for utilities, so that if the owner must pay for modifications to comply with the standards, the lessee may reap unfair benefits in utility savings during the remainder of the lease. If the lessee must pay, the lessee under a short-term lease may not recoup costs from utility savings, and the owner may reap unfair benefits after the lease expires. For leased buildings, then, there are complex problems of equity regarding who should bear costs of compliance.¹⁹¹

Monitoring compliance and penalties. Whether mandatory or voluntary, states will want to monitor compliance with adopted standards. This could be done through:

- o required submission of electric utility bills
- o subpoena of other records
- o random checks by specially trained lighting efficiency analysts (state or state-trained and -funded local building or energy officials)
- o random required audits by certified private lighting efficiency analysts (such as registered engineers)

Using electric utility bills poses the difficulty of figuring how much is for lighting and how much is for other uses. Subpoenaing other records¹⁹² may

help if records are kept that would aid in monitoring. The most universally applicable method appears to be state or local monitoring by lighting efficiency analysts, even though they may be costly.¹⁹³ Some or all of these costs might be passed on to the parties monitored.¹⁹⁴ If state or local staff are not available, private lighting analysts could be used.

In mandatory standards, penalties are necessary for cases of willful noncompliance, and optional for negligent or grossly negligent noncompliance.¹⁹⁵ Penalties could range from small fines to the very serious penalties of the Massachusetts standard—one year imprisonment and \$1,000 a day fine. This latter penalty would not often be justified, but penalties should not be so small as to invite noncompliance. Penalties could be imposed under the building code if the standard were made a part of that law (as in Massachusetts) or else under the state's perjury statute for willful misrepresentation in lighting energy audit forms.

Recommendations

Because of the wide variety of lighting standards and enforcement programs that have been proposed, states may have difficulty choosing the right combination. The following criteria for comparison should be helpful:

- o How substantially can the standard be expected to reduce wasted energy in lighting?
- o Is the standard simple enough to be easily understood and applied by the regulated parties as well as the regulators?
- o Is it technically and economically reasonable?
- o Does it allow for exemptions where necessary without offering loopholes?

The need for the first criterion is obvious; the purpose of the EPCA program is for states to adopt measures that reduce energy use. Its application is not so simple, however. This much is clear: a voluntary program backed by little funding to educate the public cannot be expected to yield the results of a well-funded voluntary program; nor can a voluntary program (especially if reports of lighting audits and potential savings are not required) be expected to be as effective as a mandatory program with adequate monitoring of compliance. Widely differing results can be

expected with the same substantive set of lighting standards, depending on the means of enforcement. The stringency of the illumination, power, or energy levels permitted will also affect the results. With a given kind of standard, the particular figures used can be varied from state to state and within a state from one kind of use to another according to the objectives of and conditions in the adopting state.

The criterion of simplicity is easier to judge. Simplicity is necessary to maximize the participation of the building owners, operators, and tenants themselves. Some standards virtually require a business to hire outside lighting consultants to figure the lighting budget and to recommend means of compliance with the standard. Others call for such simple measurements and calculations that a small business could do them without expert assistance. Unless a more complex standard can be clearly shown to produce greater energy savings (or some other substantial benefit) without imposing undue hardship, a simpler sort is preferable. A simple standard should save money in administration for both the government and the regulated parties and interfere less in private businesses. A more technically complex standard would require greater expertise in the government's enforcement personnel or reliance on outside lighting engineers; it would thus be more expensive than a simpler one. Any additional cost ought to be justified by greater benefits.

Technical and economic reasonableness would be a problem for standards that mandate use of specific hardware that is not cost effective or standards that try to impose reductions in use of lighting energy that are not achievable with currently available technology at reasonable cost, consistent with lighting levels needed for visual tasks. Sophisticated lighting controls and extensive use of daylighting, for example, may be easily incorporated into new buildings, but not into existing buildings. Almost any mandatory standard strictly applied to existing public buildings will result in severe economic hardship for some and no hardship for others. A lighting standard should only require measures that are economically justified for the parties affected—in other words, the measures should pay for themselves in a few years. Any measures that are cost effective would necessarily be technically feasible and also be reasonable unless calling for lighting levels so low as to interfere with productivity.

All of the lighting standards reviewed in this report include exemptions for special cases. Some exempt small buildings, stage lighting, and certain task lighting. Others exempt all buildings that are not heated or cooled or all task lighting regardless of the lighting energy used. Some of these exemptions—the latter two, for example—create unnecessary loopholes. In addition to a few exceptions for classes of cases, a variance procedure may be needed to provide for exceptional cases of genuine hardship; it should not allow more exemptions than are truly justified.

The spectrum of substantive lighting standards surveyed here runs from the almost impossibly complex to the excessively simple. None of these standards is fully satisfactory, but a composite lighting power budget standard could best meet the above criteria. It should include the following elements:

- o Allowed unit power densities should vary with the nature of the task or area use. There should be enough power level categories and different task categories to allow for realistic lighting needs. Although hundreds of categories (as in the IES standards) may not be needed, a few (as in Massachusetts' 37) are probably not enough.
- o Corrections should be made for room size so that large rooms have less allowance than small rooms (as in the IES standards, the California standard for new buildings, and the New Jersey standards).
- o Special task lighting power should be limited to a wattage allowance per person or work station (as in the California standard for existing buildings).
- o Only cost-effective modifications with a reasonably short pay-back period (say, 3 to 5 years) should be required. The formula to determine cost effectiveness should be simple, taking into account the building's life and the costs of figuring the required modifications as well as hardware and installation costs (as in ASHRAE 100.4P). The methods for estimating costs should include bona fide bids from contractors (as no proposal so far does).
- o All criteria and procedures should, as far as possible, be gathered in one document, rather than scattered in manuals of practice and standards. There should be no open-ended references to the accepted procedures of any private group.

Assuming adequate means of enforcement, it should be possible to reduce wasted energy in lighting as much as is needed by adjusting lighting

power densities allowed in such a standard. Although this is not the simplest of standards, it can be understood easily enough and be applied without outside technical consultants, given good explanatory materials (as in Massachusetts). Economic and technical reasonableness would depend on the stringency of the allowed power densities and the reasonableness of specified payback periods.

In addition to a lighting power budget substantive standard, we recommend that the owners of all public buildings above a certain size be required to submit to the state reports of lighting energy audits and estimates of energy savings from modifications to comply with substantive standards. While these reports should be mandatory, substantive compliance need not be, if owners can see by their own calculations that lighting efficiency pays. If expectations are not borne out by a state's compliance monitoring, mandatory standards are recommended. They should include a fair allocation of responsibility for compliance between owners and lessees.

The main argument against mandatory lighting standards is that they may not be cost effective¹⁹⁶ and may cause unreasonable economic harm to some individuals or businesses. Cost-effectiveness criteria with a payback period within the recommended range should satisfy this objection. In rare cases, there may be economic hardship to an individual or business with insufficient capital to make the required modifications, even though the modifications would soon pay for themselves in reduced operating costs. For such cases, a variance could be made available, or an extended period for compliance could be negotiated informally by the enforcing authority. Legislation to handle such exceptional cases may or may not be needed, depending on the relationship between the lighting standard and other laws (building codes, for example, usually have some variance procedure built in). We recommend exemptions and variances be limited to small buildings and serious hardship cases.

Traditions of home rule (e.g., strictly local building regulation) and lack of state authority for enforcement may be problems for some methods of enforcement, such as state building codes for lighting. The recommended filing of self-audit reports with a state agency (most likely, the energy agency) need not interfere with traditional local authority over buildings.

(This is a great advantage of these reports over building code approaches.) State reporting requirements should also be much simpler to coordinate than local enforcement of standards that are state adopted or locally adopted under a state mandate.

Lack of adequate state or local staff to enforce a mandatory standard might be another barrier for some methods of enforcement. This is more likely to be a problem where a state intends to use monitoring by lighting efficiency analysts as the primary means of checking compliance, as with a traditional building code. In the recommended program using self-certification reports (with perjury penalties as back up), the vast majority of buildings need not be checked, so that a smaller work force should suffice. Widespread compliance without much monitoring is also likely where a standard calls for only genuinely cost-effective modifications as recommended, whether they are mandatory or voluntary standards.

NOTES

1. This report was written at the Environmental Law Institute by Frank Meeker, with research by Wendy Smith and Laura Hedall, and editing by Margaret Hough, all under supervision of Gail Hayes. Richard Klimkos of DOE was the project officer under this contract, EM-C-01-5255.
2. 42 U.S.C.A. § 6201 et seq.
3. See 42 U.S.C.A. §§ 6321-26.
4. 42 U.S.C.A. §§ 6322(c)(1).
5. 42 U.S.C.A. §§ 6322(d)(1). While this could be part of a program to save lighting energy, it is not discussed in this report.
6. 42 U.S.C.A. §§ 6322(d)(2). Some states have acted to prohibit decorative gas lamps. See, e.g., Minnesota Statutes § 1164.12.32 (Ch. 333, 1976). The Economic Regulatory Administration recently adopted regulations to outlaw such lights under § 402 of the Powerplant and Industrial Fuel Use Act of 1978 (P.L. 95-620, Oct. 14, 1978). See Fed. Reg., Vol. 44, No. 92 (Thursday, May 10, 1979), p. 27606. The regulations delegate enforcement authority to the states (10 C.F.R. § 516.30).
7. 42 U.S.C.A. § 6322(d)(4).
8. 42 U.S.C.A. § 6322(d)(5).
9. 10 C.F.R. Part 420.
10. 10 C.F.R. § 420.23(a) as of January, 1978. The regulations were revised in 1979; see Fed Reg., Vol. 44, No. 66 (Wednesday, April 4, 1979), p. 20055. Hereinafter cites to 10 C.F.R. Part 420 are to these new regulations. This percentage goal is no longer in the regulations (10 C.F.R. 420.6), but DOE reports current state targets are averaging 6 1/2 percent nationally, with few below 5 percent.
11. Of the 4.8 percent, 1.5 percent is residential and 3.3 percent commercial. Primary energy consumption is roughly 32 percent for buildings, 25 percent for transportation, and 43 percent for industry. The greatest use of energy in buildings is for space conditioning and water heating: 15.3 percent for space heating, 2.5 percent for space cooling, and 3.2 percent for water heating.
12. Estimates vary. For an estimate of 30 percent possible reduction in all lighting in five years, see Robert T. Dorsey, "The Potential for Energy Conservation in Lighting," Lighting Design & Application, Vol. 8, No. 7 (New York: Illuminating Engineering Society, July 1978), p. 25. DOE has suggested savings of 20 to 50 percent are possible with little, if any, capital expense. See, e.g., U.S. Department of Energy, "Lighting" (Washington, D.C.: U.S. DOE, Fact Sheet No. DOE/CS-0006, January 1978), p. 1.
13. This report was written in spring of 1979.
14. 10 C.F.R. § 420.7(a)(1).
15. 10 C.F.R. § 420.7(a)(2).
16. 10 C.F.R. § 420.7(a)(3).
17. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., ASHRAE Standard 90-75: Energy Conservation in New Building Design (New York: ASHRAE, 1975). This standard is also known as EMS-1 of the Illuminating Engineering Society of North America (IES), which actually wrote the standard for ASHRAE.
18. 10 C.F.R. § 420.7(a)(4). A DOE regulatory reform includes an initiative to provide more practical guidance to states to help them develop lighting standards. Revised, more detailed regulations will soon be available. See Fed. Reg., Vol. 44, No. 2 (Wednesday, January 3,

1979), p. 1032, at p. 1038, Initiative 13. This ELI report should also provide guidance to states. Given the wide range of reasonable options that have been developed, it is just as well that earlier regulations did not severely limit what states might do.

19. This standard has also been adopted to apply to existing buildings.
20. 42 U.S.C.A. § 6326(7).
21. 42 U.S.C.A. § 6326(2).
22. 10 C.F.R. § 420.2.
23. Id. (emphasis added).
24. Id.
25. Massachusetts, for example, allows 1/4 of a watt per square foot for indoor parking and 1/10 of a watt for outdoor parking. Massachusetts State Building Code § 2207, Table 22-12.
26. This latter point appears to be an error in writing the regulations (EPCA would not exclude buildings with hot water systems), and it is not consistent with the definition of "building" in the regulations themselves.
27. U.S. Constitution Art. IV, § 3. See also Robert M. Anderson, American Law of Zoning, 2nd ed., 5 vols. (Rochester, N.Y.: Lawyers Cooperative Pub. Co., 1976), p. 2:416, § 12.07.
28. 42 U.S.C.A. § 6361(a)(2); also see Executive Order No. 11912 (April 13, 1976), Fed. Reg., Vol. 41, No. 74 (Thursday, April 15, 1976), p. 647, and Executive Order No. 12003 (July 20, 1977), Fed. Reg., Vol. 42, No. 141 (Friday, July 22, 1977), p. 37523.
29. New Jersey Annotated Code § 14A: 3-9.1.
30. Massachusetts State Building Code § 2207.2.
31. This exemption may have its origin in ASHRAE 90-75 § 2.1.2.
32. ASHRAE 100.3P § 2.6.1, recognizing this, does not exempt buildings with lighting systems.
33. Also in ASHRAE 90-75 § 2.1.2.
34. 10 C.F.R. § 420.7(2)(2).
35. For example, instead of exempting all buildings under 5,000 square feet, a state might exempt such buildings provided they had less than 15,000 watts (or perhaps 20,000 watts) of connected lighting power, if the state's usual maximum allowed lighting power were 3 watts per square foot. This seems to be the intent of a Colorado proposal to exempt buildings with less than "50 kilovolts [sic] of power" (presumably 50 kilowatts, rather than kilovolts, is intended). Part 10.C of the Colorado State Energy Conservation Plan (1977).
36. Florida Statutes § 553.89(2)(2). This provision regulates only new construction, but the same principle applies. Incidentally, this law just adopted the public buildings and exemptions definitions from the federal regulations, as do a number of other laws and bills.
37. Minnesota Laws Ch. 381 § 15, Subdiv. 2 (1977).
38. West Virginia HB 75 (1978), § 47-18-5.
39. This is done in Connecticut draft Lighting Efficiency Standards for Public Buildings § 16a-3(9)(3).
40. See the text following note 173 below.
41. See, e.g., Building Officials and Code Administrators International, Inc., BOCA Basic Building Code (Chicago: BOCA, 1975) § 106.0. See also Nebraska LB 820 (1978) § 8 for a somewhat simpler rule for a lighting standard.
42. Georgia HB 1310, Act 1470 of 1978, § 316.

43. See, e.g., Pennsylvania Energy Conservation Plan, p. 6, based on BOCA Basic Building Code § 106.8.
44. Colorado Rev. Stat. § 29-12-102(5) and (6) and § 29-12-104(2)(G).
45. Ohio adopted mandatory lighting standards that originally applied to all public buildings. They were revised to mandatory for state buildings and voluntary for others. Ohio HB 46 (1979).
46. Maryland SB 1270, Ch 302 (1978) would apply voluntary standards to state, county, and municipal buildings over 10,000 square feet.
47. See 42 U.S.C.A. § 6322(d)(4) and (5).
48. There are .1076 footcandles to the lux.
49. There are 3,412 Btus to the kilowatt-hour.
50. Illuminating Engineering Society, IES Lighting Handbook, 5th ed. (New York: IES, 1972), fig. 9-80, pp. 9-81 et seq. Some examples are given in the appendix to this report.
51. Ross & Baruzzini, Inc., Lighting Systems Study (n.p., March 1974).
52. Ross & Baruzzini, Inc., Energy Conservation Applied to Office Lighting (St. Louis: R & B, Inc., April 15, 1975).
53. Lighting Systems, pp. 18-22; Office Lighting, p. V-6. See these studies for the differences between the recommendations, not relevant here.
54. Government Services Administration, Energy Conservation Guidelines for Existing Office Buildings (n.p., n.d.—1975?), p. 61.
55. Federal Energy Administration, Lighting and Thermal Operations (n.p., n.d.—Conservation Paper No. 3, 1975?).
56. This was expressed in several letters from IES-member lighting professionals to ELI during this study.
57. See Resource Planning Associates, Inc., Recommendations for Enforcing & Administering Lighting Efficiency Standards in Existing Public Buildings in New York State (Washington, D.C.: RPA, Inc., December 1977), p. 1-7.
58. Illuminating Engineering Society, IES Recommended Lighting Power Budget Determination Procedure—EMS-1 (New York: IES, September 1978).
59. Minnesota Building Code rule MCAR § 1.16005. Minnesota has also adopted an alternative simplified approach as an optional procedure. Minnesota Energy Agency, Implementation Manual of Illumination Standards for Existing Public Buildings (n.p., January 1978); it is discussed later in the text accompanying notes 134 to 153.
60. EMS-1 § 2.1, ASHRAE 90-75 § 9.2.1. Since section numbers are parallel in EMS-1 and ASHRAE 90-75 (the 90-75 sections have a "9." prefix), cites hereinafter are to EMS-1 alone.
61. This is not to say that a lighting design professional will not honestly strive to come within the budget; it is simply that even if this standard is law he or she need not do so.
62. ASHRAE 90-75 § 8.5; emphasis in original. Unfortunately, rewiring for retrofit of dimming and switching controls would often not be feasible in existing buildings. So the one mandatory lighting standard feature of 90-75 may be inapplicable. But see the comments in the appendix on energy technology for switching.
63. This crucial term is inexplicably undefined.
64. The room cavity ratio is a factor that allows the designer to consider the relative balance between floor space and wall area. As walls absorb light, large rooms are easier to light than small rooms, per square foot of floor space. Rooms with tall ceilings are harder to light than those with low ceilings.

65. Although this standard, as ASHRAE 90-75, as been assessed by A.D. Little as potentially saving over 20 percent in lighting energy in new buildings, it is generally ignored that ADL's assessment assumed that, when the standard recommended rather than required measures, the recommendations would be taken as requirements. Arthur D. Little, Inc., Energy Conservation in New Building Design: An Impact Assessment of ASHRAE Standard 90-75 FEA Conservation Paper No. 43B (Washington, D.C.: U.S. GPO, n.d.), p. 4.
66. Jointly prepared by Building Officials & Code Administrators International, Inc. (BOCA) International Conference of Building Officials (ICBO), National Conference of States on Building Codes and Standards, Inc. (NCSBCS), and Southern Building Code Congress International, Inc. (SBCCI), December 1977. EMS-1 corresponds to § 505.3 of this code.
67. See p. 11 of EMS-1 (September 1978 version.).
68. EMS-1 § 3.5.1c and Appendix B, Part I, 2d; ASHRAE 90-75R (1977) § 9.3.5.1c and Attachment B to § 9.3.5 B, Part I, 2d.
69. See William Tao, "Systems Approach for Energy-Conserving Power Budget: Lighting Design & Application, Vol. 8, No. 3 (March 1978), p. 29 for a comparison of budgets under EMS-1 and EMS-1R as well as under some other standards.
70. "IES Recommended Procedure for Lighting Energy Management of Existing Buildings," Lighting Design & Application, Vol. 9, No. 4 (April 1979), p. 30.
71. Id., pp. 31-38.
72. Id., p. 31.
73. Id., pp. 39-47.
74. Under 42 U.S.C.A. § 6322(d)(4). Such a checklist procedure is not recommended for a mandatory program; a mandatory standard should require performance at a specified level and leave the means and procedures to the regulated parties.
75. We also recommend the "IES Twelve Point Recommendations—Energy Conservation and Design Practices," Lighting Design & Application, Vol. 2, No. 8 (August 1972); and the amplifications of the twelve points in John E. Kaufman, "Optimizing the Uses of Energy for Lighting," Lighting Design & Application, Vol. 3, No. 10 (October 1973); and "Energy-Saving Tips for Home Lighting," Lighting Design & Application, Vol. 4, No. 4 (April 1974), p. 40; and the state educational pamphlets cited below, especially those of Massachusetts as well as the ASHRAE 100.P series standards. Also see Howard Haynes, Energy-Related Material Published in Lighting Design & Application (New York: IES, 1979); this bibliography is updated several times a year.
76. New Jersey Annotated Code § 14A: 3-9.2, effective February 1, 1979, although EMS-4 was not published until April of 1979!
77. New Jersey Department of Energy, The R.E.M.* [Rapid Estimation Method] Way to Lower Lighting Costs (n.p.: N.J. DOE, February 1979), p. 19.
78. Id. This is discussed in the text accompanying notes 127 through 133 below.
79. See, e.g., ASHRAE 100.2P (May 1977 draft) § 10.8 for a short (1 1/2-page) discussion and 100.3P (May 1978 draft) § 9.8 for a much longer (11-page) discussion.
80. In the draft versions of the standards available to us: ASHRAE Standards 100.4P (May 1977 draft), 100.5P (November 1977 draft), and 100.6P (July 1978 draft), as Appendix C.
81. ASHRAE 100.1P (March 1977 draft) § 11.3.1.
82. ASHRAE 100.2P (May 1977 draft) § 4.3.
83. As Minnesota has done in its standard described below in the text accompanying notes 141 through 153.
84. ASHRAE 100.3P (May 1977 draft) § 12.4.

85. ASHRAE 100.4P (May 1978 draft) § 4.2.1.
86. Id., § 4.3.1.
87. Id., § 4.3.2. The standard is not quite clear on this point, but this seems to be the meaning.
88. Id., § 4.3.3.
89. ASHRAE 100.5P (November 1977 draft) § 4.2.
90. Id., § 4.3.3.
91. Id., § 4.3.3.2; emphasis added.
92. ASHRAE 100.6P (July 1978 draft) § 4.3.1.
93. A member of the drafting committee provided ELI with a copy of the October 1978 draft of this method. We do not cite sections here, as the draft is not yet generally available. See William Tao, "Systems Approach," for a description of this new method.
94. The same categories as in figure 9-80 of the IES Lighting Handbook are used.
95. There are some tasks that do not have an entry for the UPD key; perhaps these must be dealt with by the more complex method using light levels from the IES Lighting Handbook. This is not clear from the draft received.
96. California Energy Resources Conservation and Development Commission (CERCDC), Conservation Division Regulations Establishing Energy Conservation Standards for New Non-residential Buildings, CON-46A (as amended July 26, 1978), California Administrative Code, Title 24, Part 6, Article 2, Division 9.
97. CERCDC, Optional Lighting Standards for Existing Buildings, CON-19B (adopted June 12, 1978).
98. Standard for new buildings, § T20-1542, Table 9-1.
99. Id., note 2.
100. Id. This key phrase is unfortunately not defined.
101. A weakness shared by the IES draft version of the UPD standard.
102. Standard for new buildings § T20-1541(b)(3).
103. Standard for existing buildings, § 3, Category 1.
104. As in the Massachusetts standard; Massachusetts State Building Code § 2207.4.
105. Massachusetts State Building Code § 2207. This building code is a statewide mandatory code based mainly on the BOCA Basic Building Code.
106. Id., § 2207.2.
107. Id., § 2207.3 exempts one- and two-family buildings, dwelling unit portions of multi-family buildings, and the manufacturing portion of industrial plants, as noted earlier.
108. Id., Table 22-12.
109. Id., § 2207.7(a)(4).
110. Except California's optional standard for existing buildings.
111. Room cavity ratios are ignored, except that there is a 2 percent per foot allowance for ceilings over 20 feet up to a maximum of 70 feet, which doubles the normal allowance. § 2207(a)(5).
112. See, e.g., Massachusetts Energy Office, Saving Energy and Dollars in Retail Sales (n.p.: Mass. E.O., 1978), a manual prepared under EPCA funding on both lighting and heating, ventilating, and cooling.

113. Massachusetts Building Code 2207.0(c)(1). This is not the same meaning as "task lighting" under the IES standards.
114. Id., § 2207.4.
115. Id., §§ 2207.51 and 2207.8.
116. Ohio Chapter 4101: 2-87.
117. Ohio Code §§ 4101: 2-87-08 and -09.
118. Id., Appendix 87-A.
119. Id., § 4101: 2-87-03.
120. Id., § 4101: 2-87-04(D) and (E).
121. Ohio HB 46 (1978); this was reportedly enacted and signed March 16, 1979. Energy User News (New York: Fairchild Publications, Monday, March 26, 1979), p. 21.
122. Wisconsin Administrative Code, Regulations of the Department of Industry, Labor & Human Relations §§ Ind. 63.40 to 63.42.
123. Id., § Ind. 63.001.
124. Id., Table 63.41.
125. Id., § Ind. 63.41(1)(2)1.
126. Note to Id., § Ind. 63.41.
127. N.J. DOE, The REM* Way.
128. Id., pp. 10, 11. The New Jersey scheme has about the same number of listed kinds of area use as, but many more power levels than, Massachusetts.
129. Although tables only cover 10 X 10 to 300 X 300 foot rooms. Id., pp. 11-15.
130. Id., p. 3.
131. Id., pp. 3, 4.
132. This factor is taken from a set of tables, Id., pp. 11-15. This has the effect of correcting for room dimensions as do the IES's room cavity ratios.
133. Id., pp. 4-7.
134. Minnesota Building Codes rules § 1.16005.
135. Minnesota Energy Agency, Implementation Manual of Illumination Standards for Existing Public Buildings (n.p.: Minn. EA, January 1978), pp. 8 et seq.
136. Id., p. 8; see the table reproduced below.
137. Id., p. 3.
138. Id., p. 9.
139. Id., p. 10.
140. Id., p. 8.
141. Id., p. 4.
142. Id., p. 19.

143. Id., p. 20.
144. Id., pp. 20, 21.
145. Id., p. 21.
146. Id., pp. 34-37.
147. Id., p. 35 to the contrary notwithstanding.
148. See id., p. 25-39.
149. Id., p. 37.
150. Id., p. 38.
151. Id., p. 38.
152. See id., pp. 31-33; only positive values of $K = i - r$ are considered.
153. Id., p. 39. Note, however, that rates of 8.5 to 10 percent are inconsistent with the assumptions in the analysis at pp. 31-33.
154. North Carolina State Building Code (revised December 13, 1977) § 3202.6.
155. Plan §§ 3203.1 and 3206.
156. This divided by 1,000 gives kilowatt-hours (or Kwh, the usual measure of metered electric energy) per square foot per year.
157. See Florida Department of General Services, Division of Building Construction and Maintenance, Florida Energy Conservation Manual (March 1975).
158. Under Title III of the Energy Conservation and Production Act (ECPA), P.L. 94-385, 1976, § 301 et seq. Proposed regulations for 10 C.F.R. Part 435, Advance Notice of Proposed Rulemaking, and Notice of Public Meetings, Fed. Reg., Vol. 43, No. 225 (Tuesday, November 21, 1978), p. 54512.
159. To some extent, calculations of payback periods for cost effectiveness are subject to the same problem; but the problem is less serious in figuring energy use of any particular modification or part of a building than for a whole building's lighting system.
160. For example, by executive order in Delaware; letter of December 28, 1978, to ELI from Robert P. Bartley, Director of the State Energy Conservation Plan with Delaware's Office of Management, Budget, & Planning.
161. Connecticut draft Lighting Efficiency Standards for Public Buildings, § 16a-4. See also National Electrical Manufacturers Association, "Proposal for Lighting Efficiency Standard for Existing Buildings," in open letter dated June 30, 1978, from Thomas J. Ryan, NEMA Executive Secretary; the NEMA proposal calls for a 5 percent cutback and is much simpler than the Connecticut proposal.
162. Connecticut draft, § 16a-6.
163. Id., § 16a-8(d).
164. Id., § 16a-1(c).
165. As proposed in Michigan's Energy Conservation Plan, p. 35-2.
166. Letter from Robert P. Bartley, cited in note 160 above, p. 2, indicates FY 1980 utility funding will be held to the same level as FY 1978.
167. North Carolina State Building Code § 3206(6).
168. California new building standard § T20-1541(6)(3).

169. ASHRAE 90-75 § 8.5.
170. See technical appendix to Joe W. Russell, Energy Efficient Procurement in State and Local Government (Washington, D.C.: Environmental Law Institute, July 1979), prepared for the U.S. Department of Energy under the same contract as the present report.
171. See note 6 above.
172. 10 C.F.R. § 420.7(2)(1).
173. E.g., Arkansas, Louisiana, and Missouri.
174. Massachusetts State Building Code § 2207.0.
175. Id., § 2207.91.
176. Id., § 2207.92.
177. Id., § 2207.93.
178. Massachusetts Energy Office and State Building Code Commission, "Memorandum on Massachusetts Lighting Power Code" (n.p., October 12, 1978), Q&A, p. 1. This memo suggests that prosecutorial discretion will be exercised and that minor violations, where there is evidence that a good faith effort at compliance is being made, will not be punished. Id., pp. 5, 6.
179. Id., pp. 4, 5.
180. Id., p. 4.
181. Minnesota Laws Ch. 381, § 15, Subdiv. 2 (1977).
182. Minnesota Energy Agency, Implementation Manual, pp. 3-5.
183. Id., p. 4.
184. E.g., Louisiana HB 1584 (1978), special member advisory group; Illinois SB 1328 (1977) § 5, Department of Business and Economic Development.
185. E.g., Maryland SB 1270 (1978), to be based on ASHRAE 100 standards, when promulgated.
186. E.g., Missouri HB 1522 (1977) § 4. But since not all localities in the state have building codes, this would not satisfy EPCA.
187. Illinois SB 1328 (1977) § 8.
188. 10 C.F.R. 420.7(a).
189. Such programs of public education to promote energy conservation are specifically mentioned in EPCA. 42 U.S.C.A. § 6322(d)(4).
190. Such programs may qualify for EPCA funding.
191. The New Jersey standard nicely sidesteps this issue by making the buildings themselves conform: "all existing buildings . . . shall conform to the lighting standards." New Jersey Annotated Code § 14A: 3-9.2. A study done for the state of New York suggests a fairly reasonable allocation of responsibility. See RPA, Inc., Recommendations for New York, pp. 2-6, 2-7. We suggest the following division of responsibility for compliance:

The building owner shall comply in all owner occupied buildings with requirements that pay back within [X, the payback period established under the standard] years.

If an existing lease of a building places the burden of compliance with state laws and regulations on the owner or on a lessee with [X] years or more remaining in the lease at the time the lighting standard becomes effective, the indicated party shall comply immediately with requirements that pay back within [X] years.

If an existing lease of a building places the burden of compliance with state laws and regulations on a lessee with less than [X] years remaining in the lease at the time the lighting standard becomes effective, the lessee shall comply immediately with requirements that pay

back within the remaining term of the lease, and the owner shall comply at the end of the current term of the lease with requirements that pay back within [X] years.

For other leased buildings, if the owner pays the electric bills for lighting, the owner shall comply immediately with requirements that pay back within [X] years; if the lessee pays the electric bills for lighting, the lessee shall comply immediately with requirements that pay back within the remaining term of the lease, and the owner shall comply at the end of the lease with requirements that pay back within [X] years.

192. As authorized under Minnesota regulations, Minnesota Energy Agency, Implementation Manual, p. 4.
193. See RPA, Inc., Recommendations for New York, p. B-6.
194. See Ohio Proposed Standards (Public Hearing Draft; Amendments Group VI) § 4101: 2-87-09 for an example of a proposed cost structure. Ohio officials do see compliance monitoring costs to the monitored parties as a barrier to adoption and enforcement, however. Letter to ELI dated February 16, 1979, from Thomas P. Ryan, Deputy Director, Conservation, Planning, Information & Forecasting, Ohio Department of Energy.
195. The Connecticut proposed standards have been termed "mandatory without penalty" by an official with that state's Office of Planning and Management. Energy User News (Monday, July 31, 1978), p. 20. They are better called voluntary.
196. See, e.g., Energy Engineering Associates, Inc., Assessment of Lighting Standards for Existing Buildings, prepared for the Texas Governor's Office of Energy Resources (Austin, Texas: EEA, Inc., February 1979), p. 5.

APPENDIX:

TECHNICAL OPTIONS FOR REDUCING ENERGY USED IN LIGHTING

There are many ways to reduce lighting energy used in existing buildings. These can be broadly divided into:

- o using less light
- o using more efficient lighting
- o using lights for shorter periods
- o a combination of these approaches

Using less light is often possible; many buildings are overlighted. Just how much light is needed for visual tasks, as opposed to lighting for aesthetic purposes, is a subject of dispute. The most widely recognized standard for recommended minimum lighting levels is found in the IES Lighting Handbook.¹ But the research and assumptions used by the Illuminating Engineering Society are now under question,² and the IES itself is reported to be reconsidering its recommended levels to include a range, rather than the current single number minima for each task. This may lead to higher or lower recommended levels in different instances.³

Under current figures for office lighting, for example, recommended light levels are at 30 footcandles for conferring, interviewing, or reading well-printed materials; 70 for reading handwriting in ink or medium pencil on good paper; 100 for reading handwriting in hard pencil or on poor paper, or fair reproductions; and 150 for reading poor reproductions or operating business machines.⁴ Inexplicably, minimum levels for tasks in general offices are 70 footcandles instead of the 30 footcandles recommended for private offices. It has been recently suggested that such high levels are no longer economically justified.⁵ Indeed, the federal government's standards for its office buildings are lower than IES's recommendations.⁶ A study by the Lawrence Berkeley Laboratories for DOE concluded that the quantity of lighting may be reduced (providing large energy savings) if the quality of light is improved by using polarizing panels.⁷ Yet because some studies show that production may fall when lighting is lowered, states should hesitate before mandating low light levels.⁸ All experts agree that high light levels are not needed for whole rooms, but only for areas where visual tasks, such as reading and writing, are done. With high levels in specific task areas, general lighting can be much less. Lighting need not—should not—be uniform. In any event, it appears that a change in illumination of about 26 percent is just barely perceived by the eye;⁹ a reduction less than this should hardly be noticeable, let alone troublesome.

Light levels can be reduced by several means. The easiest is to remove some lamps or turn them off. Dimmers offer another possibility, although they are often more cost effective for incandescent than for fluorescent and other high-efficiency lamps. It is also possible to substitute lamps of smaller wattages in the same fixtures.¹⁰ Delamping and relamping are flexible strategies that frequently pay for themselves in a few months by lower electric bills.

More efficient lighting devices to maintain present high light levels can be implemented several ways. The most obvious is to substitute more efficient lamps for less efficient ones. For example, fluorescent lamps can often be used in instead of incandescent and metal halide or high-pressure sodium lamps instead of fluorescent.

Efficiency varies considerably within particular kinds of lamps. In general, a few high wattage lamps will put out more light than many low wattage lamps. One 100-watt incandescent

lamp puts out more light than two 60-watt lamps, saving 20 watts. Standard incandescent lamps are more efficient than long-life lamps. Depending on the fixture and use, reflector lamps are generally more efficient than plain incandescent bulbs. Among fluorescents, efficiency varies greatly with the accuracy of color rendition; the standard cool or warm white lamp puts out nearly 50 percent more light than the corresponding deluxe lamp, which has better color rendition. The highest efficiency sources, sodium lamps, unfortunately have the poorest color rendition. Improvements are being made in sodium lamps, however, and they are beginning to find acceptance in commercial and industrial applications.

The light fixtures themselves (known as luminaries in the lighting trade) and ballasts can be improved. New fluorescent core ballasts, for example, can reduce the energy consumed by about 8 percent without loss of light. When used with dimmers, more energy can be saved with a proportional loss of light. New solid-state ballasts can actually increase light output at the same time as they save energy. Unless ballasts and fixtures are in need of replacement, this strategy may not pay if fixtures of the same kind (such as fluorescent for fluorescent) are used; when replacement is needed, or if a more efficient kind of lamp is to be used (such as fluorescent for incandescent), it pays to select more efficient ones.

Even if efficient lamps and fixtures are used, much light can be lost from dark surroundings and furnishings. Light finishes on ceilings, walls, floors, and furnishings reflect light and help distribute light more evenly, reducing glare. Any lighting system and surroundings must have regular maintenance to retain their effectiveness. Regular changing of lamps whose output has fallen, cleaning of dusty and dirty lamps and fixtures, and cleaning or refinishing of ceilings and walls are all crucial.¹¹

The third alternative, that of using lights for less time, is at once the easiest and hardest. Lights can and should be turned off when not in use. Since lighting is for people, not buildings, lights should be off in vacant rooms or vacant parts of rooms. While this appears simple, many existing public buildings do not have switching for each area within rooms; some only have switches for whole rooms, and others, only switches for whole floors. Until recently, the retrofit of more switches (standard wall switches) has called for costly rewiring and has not been considered practical in most cases. Recent developments in lighting controls allow for remote switching from a central transmitter to receivers in individual rooms, areas, fixtures, or even parts of fixtures by coded radio signals. With such systems, extensive rewiring is not needed. Other systems use ultrasonic signals to turn nearby fixtures on or off. It is not yet clear when such systems will be cost effective in general, but they are practical in some cases now and will become practical in more and more cases as energy prices rise.

The most difficult problem in lighting controls is not technical but psychological. For years, campaigns have been waged urging people to turn off unneeded lights. They have not met much success. Often those responsible for turning on and off lights do not pay the utility bills and have little motivation to act.

NOTES TO APPENDIX

1. IES Lighting Handbook, fig. 9-80, pp. 9-81 et seq.
2. Gary T. Yonemura, William M. Benson, and Robert Tibbott, Levels of Illumination and Legibility (Washington, D.C.: NBS, NBSIR 77-1306, November 1977); and Gary T. Yonemura and Toshimi Kohayakawa, A New Look at the Research Basis for Lighting Level Recommendations (Washington, D.C.: NBS, BSS 82, March 1976).
3. Elizabeth Pearson, "Possible IES Revisions May Cut Task Lighting," Energy User News (New York: Fairchild Publications, Monday, February 5, 1979), pp. 1 and 10.
4. Even higher levels are recommended for drafting. IES Handbook, p. 9-87.
5. Donald K. Ross, "Task Lighting—Yet Another View," Lighting Design & Application, Vol. 8, No. 5. (New York: IES, May 1978), p. 37.
6. The FEA and GSA standards are discussed in the text at notes 51 through 56.
7. "Berkeley: Less Lamps Possible," Energy User News, Vol. 3, No. 34 (Monday, August 21, 1978), p. 5.
8. P.C. Hughes and J.F. McNelis, "Lighting, Productivity, and the Work Environment," Lighting Design & Application, Vol. 8, No. 12 (December 1978), p. 22.
9. Donald K. Ross, "Brightness in dB's," Lighting Design & Application, Vol. 9, No. 4 (April 1979), p. 22.
10. See e.g., the excellent examples in Massachusetts Energy Office, Saving Energy and Dollars in Retail Sales (Boston: Massachusetts Energy Office, 1978), pp. 32-35.
11. See, the IES Handbook, pp. 16-11 et seq. for a detailed discussion of maintenance programs and light loss between times of maintenance.