Lighting and Thermal Operations

Energy Management Action Program for Commercial•Public•Industrial Buildings

Guidelines

Federal Energy Administration
Office of Conservation and Environment
Washington D.C. 20461

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Foreword

Today's energy problems, which were intensified by the oil embargo to the U.S. in the winter of 1973-74, have developed from trends in the production and consumption of energy that have persisted for some time. Energy consumption grew at an average rate of about 3.5 percent per year from 1950 to 1965 and then increased to 4.5 percent annually. Domestic energy production grew at an annual rate of 3 percent between 1950 and 1970, but has been at a virtual standstill since then.

Essentially, then, the most basic energy problem we face is a growing gap between growth rates in production and supply. There are two approaches to closing this gap and meeting the Nation's energy needs: First, discovering and developing both new and traditional energy sources (increasing the supply) and, second, decreasing the rate of growth in the demand for energy.

Commercial, public, and industrial buildings, and the people and activities they house, represent the most rapidly increasing demand for energy. In response, the Office of Energy Conservation and Environment of the Federal Energy Administration is working with representatives of this sector to seek their voluntary cooperation in reducing energy consumption. Initially, this effort will address indoor lighting and temperatures and modes of building operation.

This publication contains guidelines which represent desirable targets with regard to illumination levels, efficiency in lighting, and operating heating and cooling systems. Many organizations have attained these levels successfully; others have adapted the targets suggested to meet their unique characteristics and needs. Broad cooperation with the principles of energy conservation represented by these guidelines will have a significant effect on decreasing energy demand and will make a vital contribution to assuring sufficient energy supplies in the future.

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Energy Conservation and Environment

Glossary

Balance temperature	The outdoor temperature at which the internal heat gain of a building (from lighting, people, and machines) equals the losses through walls, roof, and windows.
Ballast	A device used with gaseous discharge lamps and tubes to limit current flow and to provide voltage control at proper design levels.
Btu	British thermal unit, a unit of heat energy. Classically, the heat required to raise 1 pound of water 1°F.
Commercial space	Offices, schools, stores, administrative space, public space, hospitals and other health and laboratory space, and warehouses.
Contrast	The relationship between the luminances of an object and its immediate background.
Footcandles	A measure of illuminance produced on a surface all points of which are 1 foot from a directionally uniform point of 1 candela. That illuminance is 1 lumen/ft^2 or 1 footcandle.
Glare	The sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which eyes are adapted to cause annoyance, discomfort, or loss in visual performance or ability.
Heat redistribution system	A system which transfers excess heat from one zone of a building to another zone which requires heat, as from the interior zone to the perimeter zone. This usually minimizes the total energy required for heating.
Industrial space	Space in buildings or other structures in which fabrication or other manufacturing is performed.
Interior zone	In a multistory building, the interior space beginning about 15 feet from the outside wall and including all floors except the top. This space is not affected by outside temperature.
Lamp	A generic term for a manmade source of light.
Luminaire	A complete lighting unit consisting of a lamp or lamps together with parts designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply.
Lumen	A unit of luminous flux.
Nonuniform lighting	Task lighting only where needed within a space, in contrast to task lighting levels provided generally throughout the space.
Occupied hours	The time when a commercial, industrial, or institutional building is normally occupied by people functioning in their jobs.
Setback temperature (or night setback)	In the interest of economy and energy use, temperature in the winter may be set back to 60°F during the unoccupied hours instead of maintaining 68°F, as during occupied hours.
Static Luminaire	A conventional lighting fixture having no air flow (other than normal convection) through the lamp compartment.

Unoccupied hours	The time when a commercial, industrial, or institutional building is normally empty of people, except for a few attendants or maintenance personnel.
Veiling reflections	A reduction in task contrast due to light rays which are reflected specularly from the surface of tasks rather than absorbed and reradiated diffusely in the observer's eye.
Watt	A unit of electric power or heat power. 1 watt equals 3.4 Btu/hr.
Work area	Circulation area within work space but not at work station.
Work station	Space (such as a desk top) where task is actually being performed.

Lighting & Thermal Operations Guidelines

ENERGY MANAGEMENT ACTION PROGRAM

LIGHTING

Background

Total energy consumption for direct lighting in the United States in 1972 was slightly over 20 percent of the total electricity generated for all uses. This percentage amounts to

360 billion kWh (kilowatthours)
or 3.6 quadrillion Btu's (British thermal units)
or 1.7 million barrels of oil per day
or 5 percent of the total national energy consumed.

Estimates of possible energy savings by implementing energy conservation measures are as high as 43 percent of lighting usage, or about 2 percent of the total energy consumption nationwide.

Because energy for lighting consumes an especially large fraction of electricity and because recent trends in lighting contribute to increased electricity consumption, the Federal Energy Administration is releasing these guidelines for indoor commercial and industrial lighting to encourage efficient lighting practices. The fact that virtually all artificial light is produced by electricity makes efficient lighting practices especially important in alleviating a number of national problems, which include: (a) present and future projected shortages of energy resources generally, (b) special difficulties in providing for increased electricity generating capacity, and (c) problems of additional peak electricity demands created by air-conditioning equipment which must remove waste heat from lighting systems.

Commercial, public, and industrial buildings account for approximately 70 percent of total lighting energy consumption. Energy conservation measures affecting lighting practices in these buildings are therefore likely to be especially important to progress toward goals of energy reduction. Recent lighting design practices have favored higher and higher levels of illumination and have seldom taken full advantage of energy saving opportunities principally because the formerly abundant, economical supply of electricity and fuel provided little incentive to conserve energy.

Energy conservation in lighting systems design and operation

Design, installation, and operation of effective lighting systems have complex scientific, management, engineering, and architectural components. Of the many elements that must be considered in providing an adequate visual environment at acceptable cost, energy conservation is only one, but recent events and future prospects for the demand and supply of energy have underscored the necessity of giving conservation greater weight. Other elements that must be taken into account are the visual tasks to be performed, the physiological state of the observer's eyes, the psychological state and perceptual skill of the observer, the design of task and surrounding areas, the availability of daylight, the level of illumination, and the lighting system quality with regard to spectral characteristics, glare, veiling reflections, and geometrical factors.

These complexities limit the degree to which simple guidelines for energy conservation in lighting can be applied in all cases. However, in most situations they are very useful in providing the guidance necessary to achieve substantial savings in lighting energy and cost while also providing an adequate visual environment.

Variations in visual requirements for different tasks for different observers and other considerations are responsible for some situations where additional analysis is needed. The objective of the guidelines is to provide useful assistance in the design and operation of lighting systems to minimize energy consumption, including direct and indirect effects. There are some situations where measures beyond those specified in the guidelines may result in additional energy savings. The expert assistance of architects and lighting engineers can provide additional guidance.

Illumination levels guidelines

The following illumination levels are recommended as desirable target levels for modifications to existing systems or for design of new ones, under the condition that energy savings are thereby effected. See Tables 1 and 2 and Glossary for details.

Commercial buildings

Office buildings, administrative spaces, retail establishments, schools, and warehouses. During working hours, illumination levels should be reduced to 50 footcandles at occupied work stations, 30 footcandles in work areas, and less than 10 footcandles in areas that are seldom occupied or which have minimal visual requirements such as hallways and corridors. Where needed, because of exceptional individual requirements or because of the difficult nature of a specific task, nonuniform supplemental lighting may be provided for the task duration not to exceed levels indicated in Tables 1 and 2. Individual switches should be provided to permit maximum control over both standard and supplemental lighting when not needed. Lights should be switched off whenever daylight can be used.

Industrial buildings

Factories and plants. For industrial lighting, levels at the work station should be no greater than those recommended by American National Standards Institute Practice for Industrial Lighting A11.1-1973 (June 1973), no greater than 30 footcandles in work areas, and no greater than 10 footcandles in nonworking areas, except in a few special cases specified by the Occupational Safety and Health Administration. Daylight, when available, and switching should be used to the greatest degree possible to reduce energy consumption.

Hospitals

Illumination levels at the task should be no greater than those recommended in Illuminating Engineering Society Lighting Handbook (fifth ed., 1972, p. 84-85) and no greater than 10 footcandles in nonworking areas such as hallways and corridors.

Discussion

No conclusive evidence is available to show harmful effects from either too much or too little light within the range found in commercial and industrial buildings. However, there are differences in lighting requirements for individuals; for example, older people generally need more illumination because of degenerative effects on pupil size, corneal transmission, visual acuity, scattered light, and muscular response. Both level and quality of illumination are important, however, since glare and other factors can make lighting offensive at both high and low levels.

Placement and orientation of luminaires and work stations with respect to each other are important in realizing energy savings. Work stations, places where the principle visual tasks are performed, are to be distinguished from general work areas, which surround work stations and which usually have lower illumination level requirements. Wherever possible, nonuniform lighting that is task oriented, with respect to both placement and illumination level, should be used. Uniform lighting systems which light large general areas independently of the task locations within them do not usually make the most effective use of energy. Coincidentally, the esthetic appearance of indoor space can often be improved by following nonuniform lighting practice.

Guidelines for efficiency in lighting

Selection of efficient lighting equipment

In the design of new lighting systems, and in modifying existing ones, the most efficient light sources that can provide the illumination required should be selected. As a general rule the efficiencies of some available lamp types rank according to the following list, with the most efficient first: high pressure sodium vapor, metal halide, fluorescent, mercury, and incandescent. In many cases replacement of existing low-efficiency lamp types with lower wattage, more efficient types will result in reduced total costs and improved lighting. See Table 3 for detailed examples.

Control and scheduling

Maximum control over lighting systems can be accomplished by having switches to permit turning off unnecessary lighting. Large general areas should not be under the exclusive control of a single switch if turning off small portions would permit substantial energy savings when they are not occupied. Lights should be turned off as a regular practice when buildings are not occupied, such as after working hours or on weekends and holidays. When opportunities for using daylight exist, natural light should be used whenever possible, and artificial lights should then be turned off. Occupants of buildings should be educated and periodically reminded to adopt practices which will save lighting energy, such as turning off lights when leaving a room.

Proper luminaire placement in the design of new lighting systems and the removal of unnecessary lamps in existing installations are examples of energy-saving measures. Luminaires should be positioned to minimize glare and veiling reflections, and work stations should be oriented and grouped to utilize light most effectively. Daylight should be used when available, maximum switching control should be provided to the user, and light colors should be used on walls, ceilings, and floors. Tasks should be designed to present high contrast to the observer.

Deterioration in illumination level due to dirt accumulation on lighting equipment should be prevented by adequate maintenance programs, cleaning lamps and luminaires, and replacement of lamps. As a part of maintenance programs, periodic surveys of installed lighting with respect to lamp positioning and illumination level should be conducted to take advantage of energy conservation opportunities as user requirements change.

Indirect impact of lighting energy on heating and cooling of buildings

The adoption of lighting energy conservation methods should be considered in conjunction with the operation of the heating and cooling systems. As a rule of thumb, when air-conditioning equipment is operating, each watt of lighting causes the expediture of about one-half watt of air-conditioning power. Substantial cooling energy can be saved by reducing electrical lighting loads to a minimum. Moreover, substantial savings in initial cost may be realized by reflecting the reduced heat load from an energy-conservative lighting system in the design of the air-conditioning system. Where possible, heat removal techniques should be considered to conduct waste heat from lighting systems out of the building without imposing an additional load on air-conditioning equipment.

The heat gain from lights should be included in calculating heat load; in addition, schemes utilizing waste heat from lighting are encouraged. Reliance on heat produced by lighting systems, beyond that produced by systems operated in normal energy-conservative ways, is not generally encouraged.

Measurement of recommended lighting levels

Light levels can be determined with portable illumination meters such as a photovaltiac cell connected to a meter calibrated in footcandles. The light meter should be calibrated to a basic accuracy of ±15 percent over a range of 30 to 500 footcandles and ±20 percent from 15 to 30 footcandles. The meter should be color corrected (according to the CIE Spectral Luminous Efficiency curve) and cosine corrected. Measurements refer to average maintained horizontal footcandles at the task or in a horizontal place 30 inches above the floor.

Measurements of work areas and nonworking areas should be made at representative points between fixtures in halls, corridors, and circulation areas. An average of several readings may be necessary. Daylight should be excluded or corrected for during illumination-level readings for a determination of level when the system is operated without available daylight.

Table 1 shows levels for office work that are recommended when work stations are occupied; otherwise, consideration should be given to turning lights off or to switching to 30 footcandles if other workers remain nearby. For tasks requiring levels higher than 50 footcandles, switching to lower levels is desirable if the work changes to less critical tasks. Illumination at the task should be reasonably free of veiling reflections and body shadows. Refer to Table 2 for guidance in determining visual difficulty of office tasks. Levels for industrial work are from the American National Standards Institute A11.1-1973, June 1973, Practice for Industrial Lighting.

Table 2 may be used as a guide in evaluating the degress of visual difficulty for office work. It is based on the concept that visual difficulty for this kind of work is not only a function of the intrinsic characteristics of the task and the lighting system, but also of the length of time the task must be performed.

To use this table, multiply the difficulty rating, as shown in the table, for each task performed at a given work place by a single worker times the number of decimal hours per day it is performed, for example, 3 hours 15 minutes = 3.25 decimal hours. Add the products for each task. If the sum is greater than 40, provide 75 footcandles on the work station. If the sum is greater than 60, provide 100 footcandles on the work station. Multiply the difficulty factors by 1.5 if the operator is over 50 years of age, or if he has uncorrectable eyesight problems.

Relamping opportunities

Relamping to a lower wattage can save substantial amounts of energy. For example, relamping from a 150-watt to a 75-watt bulb saves 50 percent of previous use, or relamping fluorescents to smaller wattages called "watt misers" or "econo-watt" (industrial trade names) will save energy. Relamping two lamps with one can save also. For example,

Table 1: Recommended maximum lighting levels

Task or area	Footcandle levels	How measured
Hallways or corridors	10 ± 5	Measured average, minimum 1 footcandle.
Work and circulation areas surrounding work stations	30 ± 5	Measured average.
Normal office work, such as reading and writing (on task only), store shelves, and general display areas	50 ± 10	Measured at work station.
Prolonged office work which is somewhat difficult visually (on task only)	75 ± 15	Measured at work station.
Prolonged office work which is visually difficult and critical in nature (on task only)	100 ± 20	Measured at work station.
Industrial tasks	ANSI-A11.1-1973	As maximum.

Table 2: Relative visual task difficulty for common office tasks

Task description	Visual Difficulty Rating
Large black object on white background	1
Book or magazine, printed matter, 8 point type and larger	2
Typed original	2
Ink writing (script)	3
Newspaper text	4
Shorthand notes, ink	4
Handwriting (script) in No. 2 pencil	5
Shorthand notes, No. 3 pencil	6
Washed-out copy from copying machine	7
Bookkeeping	8
Drafting	8
Telephone directory	12
Typed carbon, fifth copy	15

replacing two 60-watt lamps with one 100-watt will save 12 percent of previous usage and will normally provide the same amount of light as before.

Table 3 lists some illustrative examples of changes that can be made in installed lighting systems. They result in roughly the same illumination levels, but reduced energy consumption.

THERMAL OPERATIONS

Background

Of all the energy consumed nationwide 16 percent is used to heat and cool commercial and industrial buildings. Increasing the efficiency of heating and cooling equipment and exercising better control over operating and temperature settings can save significant amounts of fuel oil, natural gas, and electricity.

By adjusting thermostat settings to less energy intensive levels, substantial energy savings can result. In heating, each degree drop in temperature can result in approximately a 3-percent energy savings. In cooling, each degree rise in temperature can result in approximately a 3-percent saving in energy.

The heating and cooling guidelines outline measures that will normally result in appreciable energy savings. Modern heating and cooling systems are complex and interact with other aspects of buildings operations. Therefore, these guidelines can sometimes be supplemented with other measures after a detailed engineering survey of a particular building has been done by qualified experts.

Guidelines for energy conservation in operating cooling and heating systems

Cooling systems

During summer, air-cooling systems should be held at not lower than 78-80°F during working hours. Necessary adjustments should be made to cooling system controls so that space temperatures are maintained at 78-80°F with no reheat.

Humidity control

Humidity control on cooling systems should be eliminated for general office space. Requirements for humidity control in special types of space or locations should be handled on a case-by-case basis by the official responsible for the operation and maintenance of the facility; use of heating energy (other than waste heat) for such cases should be avoided.

Table 3: Relamping opportunities
[All costs are figured at 3 cents per kWh. The annual savings include normal ballast loss]

Change office lamps (2700 hours per year) from	to	to save annually
1 300-watt incandescent	1 100-watt mercury vapor	$14.58 (486 kWh)
2 100-watt incandescent	1 40-watt fluorescent	$12.00 (400 kWh)
7 150-watt incandescent	1 150-watt sodium vapor	$70.80 (2360 kWh)

Change industrial lamps (3000 hours per year) from	to	to save annually
1 300-watt incandescent	2 40-watt fluorescent	$18.69 (623 kWh)
1 1000-watt incandescent	2 215-watt fluorescent	$48.51 (1617 kWh)
3 300-watt incandescent	1 250-watt sodium vapor	$54.18 (1806 kWh)

Change store lamps (3300 hours per year) from	to	to save annually
1 300-watt incandescent	2 40-watt fluorescent	$20.55 (685 kWh)
1 200-watt incandescent	1 100-watt mercury vapor	$7.92 (264 kWh)
2 200-watt incandescent	1 175-watt mercury vapor	$20.10 (670 kWh)

Heating systems

In the winter, heating temperature control devices should be set to maintain temperatures of 65-68° F during working hours and should be set to maintain temperatures of not more than 55° F during nonworking hours. During working hours temperatures in warehouses and similar space should be adjusted lower than the 65-68° F range depending on the type of occupancy and the activity in the space. Cooling energy should not be used to achieve the temperatures specified for heating.

Humidity control

Humidity control should be eliminated for general office space. Requirements for humidity control in special types of space will be handled on a case-by-case basis by the official responsible for operation and maintenance of the facility.

Windows

Window draperies and blinds should be used to cut down heat losses by setting them to the closed position during nighttime and on cold, cloudy days and by setting them to the open position during periods of sunshine (subject to control of glare).

Heating blowers, threshold heaters, and portable space heaters

These devices should not be used unless there is no other heating source available.

Outside air intake

Outside air intake during heating and cooling seasons should be reduced to the greatest extent feasible. Under most conditions a 10-percent outside air intake will be adequate for general office space. Under certain outside air temperature and humidity conditions, the use of up to 100-percent outside air will be the most energy economical method of operation. Special purpose space such as laboratories or the like should have the outside air intake reduced to the maximum extent possible consistent with operating requirements.

Interior or core systems

Interior space in office buildings tends to have a heat build-up generated by lights, people, and equipment and does not require an added heat source during the heating season. Systems serving space of this type usually utilize recirculated air mixed with some outside air for ventilation. The amount of outside air should not be increased nor should refrigeration be introduced for the sole purpose of lowering the temperature which might otherwise exceed 68° F. Heat redistributed from the interior zone to the perimeter can be an important factor in energy conservation.

Perimeter zone systems

The function of perimeter zone heating is to offset the heat flow at exterior walls and windows and usually operates independently from the interior systems.

Exceptions

Exceptions to these techniques may be necessary to meet certain specialized requirements, such as for some kinds of equipment or other needs (for example, greenhouses, hospitals, and laboratories).

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