ENERGY CONSERVATION IN RELATION TO LIGHTING

by

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Dedicated to my

parents

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INTRODUCTION AND PHILOSOPHY

There is little doubt that an energy crisis exists in this country. Energy conservation is one of the important and more practical approaches towards the short-term solution of the problem. At a first glance energy conservation seems both easy to define and incontestable as a social goal. For, in the sense in which it currently figures as a public issue of growing prominence — promising undiminished human satisfaction, but with dampened energy use – energy conservation addresses a host of attractive objectives, it basically signifies the reduction or elimination of waste. This waste provided the stimulus for this work.

This work specifically deals with lighting conservation. It was initiated in September 1976 when a federal grant was allocated to the College of Engineering, Kansas State University for the preparation of the Kansas energy conservation plan, which was completed in March 1977. This thesis is an extention of the lighting section of the plan (Kansas Energy Conservation Plan, 1977) but is more detailed.

The thesis aims at a systematic approach towards lighting conservation techniques, energy and cost savings, economic and technical feasibility and modes of implementation of these techniques. It explores public and industry reaction and attitudes towards energy conservation in general and lighting conservation in particular. The next section, adapted from Dumas (1976, Chapter 1), explains the reasons which should make this work more than just an academic product.

The Energy Crisis and Energy Conservation

The abundance of energy has for some time been considered a keystone of economic growth and increasing material prosperity. The industrial, mining, and agricultural sectors of developed nations consume prodigious amounts of energy in the production of the bewildering variety of goods that have come to be associated with modern economic activity. Vast and expanding quantities of energy are also consumed in the production of services, often considered the hallmark of an advanced economy, as well as in the use of the entire spectrum of goods and services by ultimate consumers. Without large quantities of energy, modern economic societies would simply cease to exist.

It is therefore no surprise that when the leaders of some of the world's most important energy supplying nations drastically reduced that supply in the fall of 1973, enormous shock waves propagated through the economies of much of the developed world. The shock was more than economic — it was social and psychological as well. The economies of the developed world had been built on the assumption that abundent and relatively inexpensive energy would continue to be available into the indefinite future. Now that assumption was suddenly called into question — not by a Malthusian - style academic treatise - but by hard physical reality which could neither be debated nor ignored.

Nowhere was this shock more strongly felt than in the United States, for although it was among the nations least seriously threatened because of its sizable domestic energy supplies, energy had always been so abundant and so cheap in the United States that many Americans had almost come to regard plentiful, inexpensive energy as a birthright. Inevitably, the first reaction was to begin the search for alternate supplies, particularly supplies not subject to arbitrary political interruptions. By developing new supplies, it was assumed, life could go on as before, after only a relatively short period of disruption. To be sure, exhortations to save energy by lowering thermostats and turning off lights in unoccupied rooms were made. But, the emphasis was clearly on expanding the energy supply — build the trans-Alaska pipeline, drill for offshore oil, develop better oil shale and tar sand extraction techniques, speed the construction of nuclear power plants, use solar and wind energies. Unfortunately most of these were the dreams of the future. Only secondarily, and somewhat reluctantly, was attention turned to the problem of energy conservation.

The phrase "energy conservation", like the term "budgeting", has a certain ring of asceticism to it, which does not accord well with the quest for the more abundant life. It conjures up images of working by candlelight, shivering in the cold, and bumping along the streets in a dirty, overcrowded bus. It seems particularly unpleasant to generations of Americans taught to believe that living in an appliance-packed, single-family house in the suburbs was the key to happiness and that the ability to drive endless miles in your own oversized, overstuffed automobile was the meaning of freedom.

But energy conservation, like budgeting, has much to recommend it. It is a way of ensuring that we will get the most out of available resources, no matter how scarce or how abundant they may be. Energy conservation is the path to maintaining or improving the standard of living in the face of limited energy resources — a path that is also compatible with the reduction of environmental pollution and the conservation of other natural resour es.

Energy Conservation and Lighting

Although lighting accounts for less than two percent of the total energy consumed in the United States (Stanford Research Institute, 1972), it is responsible for nearly one-quarter of the energy consumed in the form of electricity (Stein, 1972). In commerce, the fastest growing energy-use sector, lighting plays a particularly important role. Lighting systems in office buildings not only typically contribute at least 20 to 30 percent of the electricity demand directly but account for as much as 60 percent of the air conditioning load (National Bureau of Standards, 1973), a load that is nearly always serviced by electrically driven machinery. On these grounds alone, lighting is an important point of focus for energy conservation.

Conservation of electrical energy in building is especially vital to our national energy goals since every unit of electrical energy saved in the building saves about three units of raw source energy. When lights are left on in areas which are unoccupied or unused for lengthy periods of the week – in religious buildings and outdoor parking lots, for example, the inadvertent waste of energy often approaches or exceeds the amount of energy used by other building systems much of the week; the cost of this waste energy for one year may equal the initial cost of installing automatic controls to eliminate the waste.

The basic approach to saving energy in building lighting is to save by eliminating waste in lighting while maintaining lighting suitable for performance of visual tasks, while maintaining visual comfort and while providing a pleasant visual environment. Virtually all of the techniques for saving lighting energy have been well known within the industry for some time. Energy saving, cost saving, education and legal compliance will lead to a widespread adoption. These techniques involve reduction of lighting levels where excessive, especially in areas without critical visual tasks, the adoption of procedures which make existing lighting equipment more efficient, the installation of new lighting equipment which is more efficient and the use of the by-product of lighting for heating.

In existing construction, the approach assures that since energy saving and cost saving are highly correlated, granted sufficient educational-extension activities, building owners and users will adopt lighting conservation measures for their own as well as national ends.

For new building construction and major renovation, the plan calls for the adoption of a state uniform building code based on the calculation of a lighting energy budget prescribed in American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 90-75. The illumination levels described in ASHRAE 90-75 are adapted from the Illuminating Engineering Society (IES, 1972) standards.

Illumination Standards and Practices

The current approach to lighting standards is to specify illumination levels in terms of worker performance. In the broadest sense, this should include consideration of such factors as age, fatigue, physiological and psychological effects, impairment of vision or health, economics, energy use and availability, and even cultural or emotional effects of light. A limited review of the literature shows that controversy exists concerning illumination standards.

Engineers adopt conservative approaches when there is uncertainty in their knowledge. Thus lighting levels are sometimes set above the minimum recommended lighting standards of the Illuminating Engineering Society by practioners. In addition, these recommended standards have been incorporated in various school codes, state codes, building codes and frequently ASHRAE standards. In the absence of other data or experience, they are frequently used by architects and design engineers in order to have guidelines for recommended illumination levels (Stein, 1972). Hence, the IES standards are widely adhered to as operational minima for the design of lighting systems throughout the United States.

Table 1 presents data from the IES(USA) and IES(British) illumination standards. It is interesting to note the difference between the two standards. In virtually every case, the US standards are two to four times as high as the British. The standards discrepancy suggest that either the British standards are too low or the American standards are too high. Work underway by the Commission Internationale L'Eclairage (1971) is moving to achieve international agreement in this area.

TABLE 1

Comparison of Illumination Recommendations for Schools

Areas	IES (USA)	IES (British)
Classrooms	70-150 fc	20-30 fc
Library Reading	30-70	30
Office	70-150	30
Drafting/Sewing	100-150	70
Washroom/Locker	20-30	7-10
Laboratory	100	30

Source: Adapted from Stein, R. G. and Stein, C. Research, design and evaluation of a low energy utilization school. National Science Foundation, Washington, D.C., 1974.

LIGHTING CONSERVATION TECHNIQUES

As part of the national effort to have the public realize the need to avoid wasting all forms of energy, especially during a time when shortages existed, the Illuminating Engineering Society (IES), in February 1972, prepared 12 recommendations for the better utilization of energy used for lighting (F. Clark, 1976). Later conservation measures for lighting were advocated by the FEA (Conservation Papers 20 and 21, 1975) which were more elaborate and detailed.

These FEA recommended conservation measures, discussed in the following pages, are technically feasible and economically wise. They have been classified into four categories, each of which in turn includes relevant conservation measures. Category A involves several measures for simply reducing excessive amounts of light. Category B calls for new procedures for reducing waste in existing lighting. Category C involves lighting installation changes to achieve greater efficiency. Finally, category D calls for the use of the by-product of light, i.e. heat. The specific conservation measures are listed and briefly described below.

A. Reduce Excessive Illumination Levels

Lighting levels in non-task and task areas are frequently excessive. Where this is so, they should be reduced at minimum cost. Conservation measures which would reduce excessive illumination levels are:

1. Reduce illumination levels. Conserve energy for lighting by reducing illumination levels in non-task areas where they need not be high and eliminating illumination where it is not needed at all. In areas surrounding task location, the average level of general lighting, for budget purposes, shall be one-third the levels for tasks performed in the area but in no case less

than 20 footcandles (215 lux). In circulation and seating areas, where no specific visual tasks occur, the average level of illumination shall be one-third of the average general lighting in the adjacent task spaces but in no case less than 10 footcandles (108 lux).

2. Remove unnecessary lamps. Remove unnecessary lamps when those remaining can provide the desired level of illumination. When removing fluorescent or high intensity discharge lamps, also remove the ballast.

3. Reduce lighting levels by relamping. Selecting lamps with higher lumens per watt could permit the removal of some lamps, providing the lumens produce the required footcandles. More efficient lamps also impose smaller heat loads on the air-conditioning system. It is also desirable to adopt a group relamping program, as labor costs are generally less for group relamping than for individual relamping throughout the year.

B. Establish Procedures to Eliminate Waste of Lighting

Certain procedures can be followed to reduce lighting waste without capital expenditures. These include:

1. Improve lighting maintenance. By maintaining a higher light output from existing fixtures it may be possible to reduce the wattage of lamps in each fixture and, in some cases, the number of fixtures in service without a reduction in illumination. Maintenance can be improved as follows:

- Replace existing lamps with new ones which have a lower lamp lumen depreciation over rated life.
- Clean fixtures and lamps more frequently by replacing lamps when light output drops to 70 or 75% of initial output.

2. Use daylight for illumination. Use windows and skylights effectively as a primary source of illumination in perimeter spaces. The amount of available daylight in a building is a function of operating hours, latitude, weather,

time of year, air quality, window size and location, shading and glazing details, reflectivity of interior surfaces and furnishings. Control of natural light, for effective use and integration with artificial light, is important, because the amount of natural light available varies.

3. Use existing switching to turn off unnecessary lights. When electric lighting is not required, switch it off.

C. Make Installation Changes Which Lead to Greater Efficiency

Many changes can be made in facilities to achieve greater efficiency in lighting. Some investment in capital facilities is needed in order to reduce operating costs. Such conservation measures include:

1. Increase room interreflectances. The larger a room the lighter the color of room finish and furnishings, the lower the light absorption by these objects, and hence less watts per square foot will be required to produce the same footcandles. Electrical consumption can be reduced by about 15% with an improvement from 50-30-20 to 80-70-50 wall, ceiling and floor reflectance values and by almost 35% with improvement to 80-70-50 from an original level of 50-10-10.

2. Use non-uniform lighting. Uniform lighting maintained at a level necessary for the most critical task in a given area wastes energy when other less critical tasks within the same area do not require the same amount of illumination. Non-uniform lighting can be accomplished by the following measures either individually or in combination with others.

- Install switches to turn off unnecessary lights.
- Use lamps with light output required for specific tasks.
- Relocate or install new fixtures to suit specific tasks.

— Control lamp intensity with dimmers.

— Use multi-level ballasts to obtain light level required for specific tasks.

— Use furniture mounted lighting fixtures.

In order to select the most appropriate measures make a careful analysis of task requirements, expected duration, the possible future relocation, the quality of illumination required for specific tasks, and the frequency with which they may change.

3. Use furniture mounted task lighting. Furniture mounted (supplemental) lighting provides illumination of specific tasks to the extent necessary; circulation between tasks and the background can be maintained at lower levels. The operating costs for electricity for lighting and air-conditioning when using furniture mounted fixtures may be reduced in many installations from 30 to 60%.

4. Lower the fixture mounting heights. Lowering the mounting height of ceiling mounted lighting fixtures can result in fewer watts required to illuminate given tasks - since the lumens/watt that reach the task increase as the distance between light source and task decreases. For example, the energy saved by dropping the mounting height from 14' to 9'; in a 30' x 40' space while maintaining the same illumination level would be 10% of the energy consumed for lighting the area.

5. Provide switches to turn off unnecessary lights. Turning off lights which are not needed will conserve energy and reduce expenditures for electricity. When sufficient switches do not exist, add them.

6. Modify existing fixtures to accommodate more efficient lamps. Energy savings can often be amplified by modifying an existing fixture to accept a

different type and higher efficiency lamp. When this is not possible, consider replacing the fixture with one that will accept a lamp of greater efficiency. More efficient lamps save energy by permitting use of lower wattage lamps or a reduction in the number of fixtures used. Modify fixtures of site lighting, parking lots, canopies, advertising signs, display containers and other special applications as well as fixtures for interior lighting.

7. Install new efficient fixtures. The lamp and fixture efficiency together determine the quantity of light transmitted into a space for each watt of power consumed. When a more efficient lamp source would suit the application but conversion of the fixture to handle this source is not possible, consider replacing the fixture itself. Select the most efficient light source for the application then choose a fixture with higher efficiency performance.

8. Utilize daylight for illumination. Install reflectors at windows to increase the amount of daylighting. Horizontal and vertical reflectors located on the exterior of the building can often be added without significantly changing the appearance of the building. The effectiveness of windows for daylighting can be increased by 25% or more with proper reflector devices.

9. Reduce power for lighting by replacing ballasts. When the standard ballasts in existing systems fail or must be replaced, substitute high efficiency types.

10. Install dimmers to reduce light levels. When frequent light level changes are required in areas of transient occupancy, dimmers are a better alternative to multi-level switching, multi-level ballasts, or lamp replacement.

11. Use multi-level ballasts. In office buildings or stores, portions of a single large space may be used for different purposes each week or month. Multi-level ballasts with 2 or 3 levels of lamp control are available for 430 milliamp fluorescent lighting fixtures; they allow reduction in illumination levels without sacrificing the symmetry of the lighting fixture pattern.

12. Add timers to shut off lights. Provide time switches for areas which are commonly used for short times, and in which lighting is inadvertently but frequently left on.

13. Use efficient lenses. Remove lenses where they are not required for glare control (such as corridors, toilet rooms) thereby improving the fixtures coefficient of utilization and permitting a reduction in the wattage required without an attendant reduction in the number of footcandles. Replace inefficient lenses and consider both efficiency and quality when choosing them for new fixtures.

14. Install high frequency lighting. When remodeling or expanding all or a portion of an office building or store with fluorescent lighting (or when changing from incandescent lighting to fluorescent consider high frequency lighting. The advantages as compared to 60 Hertz systems, include the following:

— Lamps produce about 10% more lumens/watt

— Ballast life is increased

— Ballast can be located out of the air-conditioned area, reducing the load on the air-conditioning system.

— In a new addition to the building, fewer lighting fixtures are required.

D. Use the Waste Heat From Lights

The major advantages of a "heat-of-light" system lies in its reduction of heating, cooling and heating, ventilation and air-conditioning system and distribution loads, rather than in savings in electrical energy for lighting. Although "heat-of-light" system can conserve energy and reduce operating costs, the installation for such systems will be quite costly unless renovations to the building, requiring completely new lighting and duct work systems, are contemplated.

Reduction in Energy Use

Estimated energy reduction from each of the conservation measures are listed in Table 2. These estimates were obtained through calculations based on the application of specific conservation measures in public buildings.

The Stanford Research Institute (1976) estimated approximate reduction potential for commerical buildings shown in Table 3. The basis for these estimates is not known, but they do take into consideration the fact that all conservation measures cannot be applied at the same time to a particular lighting situation.

Social, Environmental and Economic Assessments

Because the conservation approach taken is to maintain lighting effectiveness while improving lighting efficiency there should be little social impact. The use of nonuniform lighting techniques should improve the aesthetic quality of most large installations. Once designers have assimilated the changes more innovative, effective lighting should result.

There should be no direct environmental impact of the conservation program for lighting. Of course, since energy and hence money will be saved, there will be the various effects of that.

The Arthur D. Little study (1975), sponsored by the FEA assesses the impact of ASHRAE 90-75 on lamp and fixture manufacturers.

TABLE 2

Estimated Percentage Energy Reduction Due to Particular Conservation Measures

		% Reduction
A.	Reduce Excessive Illumination Levels	
	1. Reduce illumination level (in non-task areas)	30 to 50
	2. Remove unnecessary lamps	20 to 35
	3. Reduce lighting by relamping	10 to 30
B.	Establish Procedures to Eliminate Waste of Lighting	
	1. Improve lighting maintenance	5 to 25
	2. Use of daylight	—
	3. Utilize existing switches	—
C.	Make Installation Changes Which Lead to Greater Efficiency	
	1. Increase room reflectances	25 to 40
	2. Non-uniform lighting	—
	3. Use furniture mounted lighting	30 to 60
	4. Lower the fixture mounting heights	10 to 15
	5. Provide switches to turn off unnecessary lights	20 to 40
	6. Modify existing fixtures	—
	7. Install new efficient fixtures	50 to 60
	8. Replacing ballasts	15 to 35
	9. Install dimmers	—
	10. Use of multilevel ballasts	30 to 40
	11. Add timers to shut off lights	—
	12. Install high frequency lighting	—
D.	Use of Waste Heat	10 to 25

TABLE 3

Estimated Reduction Potential for Commercial Buildings

	Existing Buildings	New Construction
Office Buildings	0.2	0.5
Retail Stores	0.3	0.5
Schools	0.2	0.5
Hospitals	0.2	0.4
Other	0.2	0.5

Impact on electric lamp manufacturers. While incandescent and fluorescent lamps will continue to dominate the market, high intensity discharge lamps, which have a small share of the total building illumination lamp market, are expected to take increasing market share due to their higher efficiency. It is estimated that ASHRAE 90 will result in an average reduction of 23% in designed wattage per square foot in commercial buildings. The impact will be decidedly different on demand for incandescent versus fluorescent or high intensity discharge lamps.

Impact on lighting fixtures manufacturers. Arthur D. Little estimates that ASHRAE 90 could cause an immediate 21% reduction in the number of fixtures sold to the combined residential, commercial, and industrial fixture markets in new construction. Because ASHRAE 90 does not deal with remodeling or alternations, to which 15% of the fixtures are sold, the impact on total sales volume will be an 18% reduction. Two factors will affect, and in some cases mitigate, the apparent impact of ASHRAE 90 on lighting fixture manufacturers. More efficient lighting forms will replace less efficient forms in new and renovation construction heighting the impact of the standard on manufacturers of components of the less efficient forms, and diluting the impact on manufacturers of the more efficient forms. It is expected that substitution of HID lamps for fluorescent and incandescent lamps will continue due to their immediate operating economies and greater efficiencies. Similarly, fluorescent lighting is expected to grow at the expense of incandescent, because it is expected that in new construction, architects will design the most efficient lighting type available wherever possible. This shift in market share of the lighting technologies will adversely affect shipments of incandescents and increase shipments of HID.

It appears that the energy crisis has created sufficient economic incentives for owners of existing buildings to convert their present incandescent or fluorescent fixtures to more efficient fluorescent or HID fixtures and thus reduce their electricity bills. This conversion market is apparently large enough to more than compensate for the expected reduced demand for lighting fixtures due to the 12-13% decline in new commercial construction. Thus, projected declines in consumption of commercial lighting fixtures due to ASHRAE 90 may be largely compensated for by increased sales of lighting fixtures for existing construction or renovation work.

Special Safety and Health Considerations

Certain energy conservation actions could result in a conflict with applicable safety and health standards such as the Federal Occupational Safety and Health Act (OSHA) reguations or a company's fire insurance requirements. For example, electricity can be conserved by reducing illumination levels but the OSHA regulations prescribe minimum lighting levels for certain categories of space and activities. The following sections from the OSHA regulations as printed in the Federal Register are the pertinent ones related to potential energy conservation measures. These OSHA and ANSI standards are lower than the present recommendations.

1910.142(g) "....Lighting levels in toilet and storage rooms shall be at least 20 foot-candles 30 inches from the floor. Other rooms, including kitchens and living quarters shall be at least 30 foot-candles 30 inches from the floor.

This section also refers to temporary labor camps, and may be understood to be no less than the requirements in more permanent installations. The levels correspond to those found in ANSI std A11.1-1965 which is the reference cited.

1910.142(b)(2)(vii) "....Lighting shall be provided with an intensity of no less than 10 foot-candles, 30 inches above the floor."

This minimum cited for non-water privy installations is probably a more realistic minimum requirement.

1910.178(h) and

1910.219(c)(5) "....Controlled lighting of adequate intensity shall be provided in operating areas (See ANSI a11.1-1965)"

1518.55 "Illumination. (a) General. Construction areas, ramps, runways, corridors, offices, shops, and storage areas shall be lighted to not less than the minimum illumination intensities listed in Table 4, while any work is in progress."

In 1973, the FEA, in cooperation with the General Services Administration (GSA), had initiated a policy for reducing the illumination levels in all Federal office space. The illumination levels were limited to 50 footcandles in the working area (on the desk top), 30 footcandles in the general office environment, and 10 footcandles in hallways, corridors and other seldom occupied areas (50/30/10 standard). Because the reduction in illumination levels has raised questions regarding health and safety, NIOSH was requested to make an initial evaluation of the potential problem. The findings of the symposium provided no scientific evidence to indicate that eye disease or permanent impairment of visual function will be caused by working at the GSA illumination limits (NIOSH, Proceedings of Symposium, 1974).

The illuminance levels recommended by IES and ANSI for safety alone range from 0.5 to 5.0 footcandles, depending on the level of activity and the degree of hazard presented to the worker. These levels represent the absolute illumination for safety of personnel at any time and at any location on any place where safety is related to seeing conditions.

Thus the conservation measures, discussed earlier, do not pose any health or safety problems.

TABLE 4

Minimum Illumination Intensities in Footcandles

Foot-Candles	Area or Operation
5	General construction area lighting
3	General construction areas, concrete placement, excavation and waste areas, accessways, active storage areas, loading platforms, refueling, and field maintenance areas.
5	Indoors: warehouses, corridors, hallways, and exitways.
5	Tunnels, shafts, and general underground work areas: (Exception: minimum of 10 foot-candles is required at tunnel and shaft heading during drilling, mucking, and scaling. Bureau of Mines approved cap lights shall be acceptable for use in the tunnel heading.)
10	General construction plant and shops (e.g., batch plants, screening plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active store-rooms, barracks or living quarters, locker or dressing rooms, mess halls, and indoor toilets and workrooms).
30	First aid stations, infirmaries, and offices.

NOTE: The table indicates very much lower lighting levels for active storage areas, hallways, warehouses, corridors and indoor toilets.

PROJECTIONS ON ENERGY AND COST SAVINGS

Methodology and Calculations

Using projections developed by the FEA for the Midwest region and Kansas, estimates of the savings possible with available conservation measures were made, assuming the adoption of an extension-education program and a uniform building code effective January 1, 1978. Expected energy savings calculations were made for 1978, 1979 and 1980.

To estimate energy savings in 1978-79-80 from lighting efficiency standards, a step-wise methodology was formulated. Separate calculations of energy savings for each of five FEA designated, building types — offices, retail stores, schools, hospitals and others — were made, for 1978-79-80 and each quarter of 1978. The step-wise methodology, which is self-expanatory, is shown in Table 5. The calculations for each of the five types of buildings are shown in Appendix A. Total estimated savings for the target years are shown in Table 6. Table 7 gives the energy consumptions in old and new buildings without the conservation measures.

Data sources. The data used and their sources were as follows:

Projected energy for lighting in public buildings:

Table 1C FEA unpublished document (1976)

Population by state and region:

Table 1A FEA unpublished document (1976)

Average potential reduction (percentage reduction by application of conservation measures):

Table 3

Fraction of floor space affected (degree of compliance):

Questionnaire

TABLE 5

Step-wise Methodology for Calculation of Energy Savings

Wooksheet for Total Electricity Savings in Terms of Source Fuel (in trillion Btu's) for the following building type:

___Office ___Retail Stores ___Schools ___Hospitals ___Other

Step 1: Projected 1978-79-80 electrical consumption for lighting in buildings in region built prior to and following effective date of program, in trillion Btu's

a. 1980 energy consumption for lighting in buildings built pre-1971 in region ______ $(x10^{12})$

b. Energy for lighting in additional buildings built in region each year since 1971 ______ $(x10^{12})$

c. Number of years program in effect ______

d. No. of years between beginning of 1971 and time program into effect ______

e. State/Region population ratio ______

Step 2: Electrical energy savings for 1978-79-80 in State by buildings built prior to program effective date, in trillion Btu's

a. Projected lighting energy for existing buildings in State in 1978 [(line 1b x 1d) + line 1a][line 1e] ______ $(x10^{12})$

b. Projected lighting energy for existing buildings in State in 1979 [line 2a + 1b(line 1e)] ______ $(x10^{12})$

c. Projected lighting energy for existing buildings in State in 1980 [line 2b + 1b(line 1e)] ______ $(x10^{12})$

d. Fraction reduction in lighting in existing buildings (Table 3) ______

e. Fraction of floor space affected in 1978 (Table 8) ______

f. Fraction of floor space affected in 1979 (Table 8) ______

g. Fraction of floor space affected in 1980 (Table 8) ______

h. Electricity savings in existing building in 1978 (line 2a x 2d x 2e) ______ $(x10^{12})$

TABLE 5 (continued)

i. Electricity savings in existing building in 1979 (line 2b x 2d x 2f) ________ $(x10^{12})$

j. Electricity savings in existing building in 1980 (line 2c x 2d x 2g) ________ $(x10^{12})$

Step 3: Electrical energy savings for 1978-79-80 in State by buildings built since time of program effective date, in trillion Btu's.

a. Projected annual lighting energy for new building in State in 1978-79-80 [line 1b x 1e] ________ $(x10^{12})$

b. Fraction reduction in lighting in new buildings (Table 3) ________

c. Fraction of floor space affected in 1978 (Table 7) ________

d. Fraction of floor space affected in 1979 (Table 7) ________

e. Fraction of floor space affected in 1980 (Table 7) ________

f. Electricity savings in new buildings in 1978 (line 3a x 3b x 3c) ________ $(x10^{12})$

g. Electricity savings in new buildings in 1979 (line 3a x 3b x 3d) ________ $(x10^{12})$

h. Electricity savings in new buildings in 1980 (line 3a x 3b x 3e) ________ $(x10^{12})$

Step 4: Total electrical energy savings by new and existing buildings in the State, in trillion Btu's.

a. i) Aggregate savings in 1978 (lines 2h + 3f) ________ $(x10^{12})$

ii) Savings per quarter of 1978 (line 4a/4) ________ $(x10^{12})$

b. Aggregate savings in 1979 (lines 2i + 3g) ________ $(x10^{12})$

c. i) Aggregate savings in 1980 (lines 2j + 3h) ________ $(x10^{12})$

ii) Energy for existing and new buildings in 1980 with no energy conservation [(line 1b x 9) + line 1a][line 1e] + [line 1b][line 1e] ________ $(x10^{12})$

iii) % savings in 1980 [(line 4c i/4cii) x 100] ________

Table 6

Estimated Energy Savings in 1978-79-80 from Lighting Efficiency Standards for Public Buildings in trillion Btu's

	1978	1979	1980
Office Buildings	.021	.070	.124
Retail Stores	.045	.153	.271
Schools	.021	.072	.125
Hospitals	.017	.056	.098
Other	.045	.149	.260
Subtotal:	.150	.501	.879
Total Savings*:	.500	1.668	2.93
% Savings†:	2.35%	7.50%	12.57%
At 4¢/Kwh Savings#:	$1,758,000	$5,868,000	$10,305,000

Total Savings for 1980 = 2.930 $(\times 10^{12})$Btus

Total Savings for 1979 = 1.668 $(\times 10^{12})$Btus

Total Savings for 1978 = 0.500 (10^{12}) Btus

Savings/Quarter of 1980 = 0.732 (10^{12})Btus

* Subtotal multiplied by 3.33, factor to correct for generating efficiency.
† For details see Table 8.
# Subtotal multiplied by 2.928×10^{-4} (factor to convert Btu to Kwh).

Table 7

Energy for Lighting in Old and New Buildings, in trillion Btu's (no conservation measures)

From Table 5:

Energy for each bldg. type in 1978:

[(line 1bx7)+line 1a](line 1e]+line 1bx1e

Energy for each bldg. type in 1979:

[(line 1bx8)+line 1a](line 1e]+line 1bx1e

Energy for each bldg. type in 1980:

[(line 1bx9)+line 1a][line 1e]+line 1bx1e

	1978	1979	1980
Office Buildings	.957	1.009	1.06
Retail Stores	1.453	1.541	1.63
Schools	1.019	1.062	1.104
Hospitals	.826	.860	.894
Others	2.131	2.218	2.304
Total	6.388	6.691	6.995
Energy Saved*	.150	.501	.879
%Savings	2.35%	7.50%	12.57%

* from Table 6

Degree of compliance. Engineering faculty at Kansas State University were given descriptions of the conservation measures. They were asked to estimate the degree of compliance which might be expected during the time period for new and existing construction. An analysis of the data gathered resulted in the degrees of compliance, prorated over the years, shown in Table 8. These estimates were used in the calculations.

Revised Savings Calculations

The final report of the Kansas Advisory Committee of Statewide Building codes, January 1, 1976, stated that approximately one third of Kansas population is presently without the protection of a building code. As a followup of this energy conservation study, a legislative act will be written which would form a uniform building code for Kansas. It is assumed that this code would include efficiency lighting standards and conservation techniques.

Since the building code, covering about two-thirds of Kansas population, the target calculations are modified to take this into account. However since the annual construction rate is much smaller than the existing buildings of the five types, the modified percentage savings do not significantly differ from those derived previously.

Methodology for revised calculation. Lines 3f, 3g, 3h of the methodology (Table 5) were multiplied by 2/3, to give the energy saved in new construction (covered by the building code) for 1978, 79, 80 for the five types of buildings. Energy saved in existing buildings remain unchanged. Calculations are summarized in Table 9.

Cost Effectiveness

The minimum condition motivating adoption of an energy-saving practice is lower, or at least unchanged, monetary costs. Two types of costs, associated

TABLE 8

Degree of Compliance — Fraction of Floor Space Affected

	1978	1979	1980
New Construction (Building-code)	10%	50%	90%
Existing Construction (Extension-education)	10%	30%	50%

TABLE 9

Revised Estimated Energy Savings in 1978-79-80 from Lighting Efficiency Standards for Public Buildings, in trillion Btu's

	1978	1979	1980
Office Buildings	.019	.066	.116
Retail Stores	.043	.145	.257
Schools	.021	.068	.119
Hospitals	.016	.054	.094
Other	.043	.142	.247
Subtotal:	.145	.476	.835
Total Savings*:	.483	1.586	2.781
% Savings†:	2.27%	7.1%	12%
At 4¢/Kwh Savings#:	$1,700,000	$5,579,000	$9,783,000

Total Savings for 1980 = 2.781 $(x10^{12})$Btus

Total Savings for 1979 = 1.586 $(x10^{12})$Btus

Total Savings for 1978 = 0.483 $(x10^{12})$Btus

Savings/Quarter of 1980 = .695 $(x10^{12})$Btus

* Subtotal multiplied by 3.33, factor to correct for generating efficiency.
† For details see Table 8.
# Subtotal multiplied by 2.928×10^{-4} (factor to convert Btu to Kwh).

with lighting conservation, are of importance--capital or 'first' costs, and operating costs. In general both of these promise savings to builders and operators in the case of lighting conservation.

Capital or 'first' costs involve the cost of lighting equipment and installation. Generally, most efficient lighting systems are more expensive and this has deterred their usage. Using a systems approach, the lighting goals are adopted based on needs, fewer of the more efficient fixtures can meet the needs previously met by a large number of less efficient fixtures. By avoiding excessive lighting levels, for example in hallways, fewer fixtures can be used. More switching and other control equipment may increase costs but in most cases this can be offset. For example, a large space might have three-way switching for lights for the entire space. Instead, three switches each controlling a third of the space might be used. Non-uniform lighting, where furniture mounted lighting is used in place of more expensive ceiling fixtures will reduce capital costs as well as operating costs. Avoidance of popular recessed ceiling fixtures will reduce costs. Because these are direct lighting sources with little contribution to ambient lighting, these lights cause glare. To prevent glare special lenses are used to cover the fixtures. These lenses reduce glare. They also reduce the usable light by about 50 percent and they are quite expensive.

Building cost savings. The modification of the conventional buildings to meet the criteria set forth in ASHRAE 90-75 has impact on both the initial (capital) and annual operating costs of the buildings. Changes in these costs and impact on building economics were assessed by Arthur D. Little, Inc. (1975) for the midwest region. Component cost was considered by building type and region expressed as cost per unit floor area. Construction costs are estimated using recognized industry practices and represent the cost to the owner including contractor's overhead and profit.

Based on projections on the annual square feet construction in the Midwest region and Kansas, estimates of the savings possible in construction costs are summarized in Table 10.

Operating cost savings. Since the energy savings reduces the energy expenditure operating costs will be reduced for the target years. These savings are given in Table 11.

Effects of Compliance on Savings

In order to assess the effect of compliance on savings a sensitivity analysis was made based on the projections made earlier in this chapter. The methodology and calculations were the same, only the compliance in new and existing buildings were changed. The projections were made for 1980. The maximum compliance considered was 100% for new buildings and 60% for existing building, the minimum was 60% for new building and 20% for existing buildings. The results are shown in Figure 1.

For every 10 percentage points change in compliance for new and old buildings a savings of 48.019×10^6 Kwh could be made. At 4 cents per Kwh, this would mean a savings of approximately $2,000,000 to the consumer. The calculations assumed the reduction potential and cost of electricity to be constant. Technological advancement in the field of new and more efficient conservation techniques and possible increases in electricity prices would mean an even greater savings as compliance increased.

TABLE 10

Estimated Costs of Conventional vs. ASHRAE 90-75 (illumination standards only) Modified Buildings and Associated Savings for the State of Kansas

	Conventional ($\$/ft^2$)	ASHRAE 90-75 ($\$/ft^2$)	Saving/Ft^2 ($\$/ft^2$)	New Construction Each Year ($10^6 ft^2$)	Savings per Year ($)
Office	2.20	2.17	0.03	2.6403	79.209
Retail Store	0.98	0.95	0.03	4.2666	127,998
School	1.53	1.46	0.07	2.53836	177,685
Hospitals	-	-	0.05*	0.891	44,550
Others	-	-	0.03*	4.173	125,190

Total Estimated Savings for each of the years 1978 - 1979 - 1980 (total compliance) = $554,632

*Estimated

TABLE 11

Estimated Operating Cost Savings in Commercial Buildings

	Total Energy Saved (in Btus)	Operating cost savings ($) (at 4¢ KWH)
1978	.482	$1,700,000
1979	1.586	$5,579,000
1980	2.781	$9,783,000

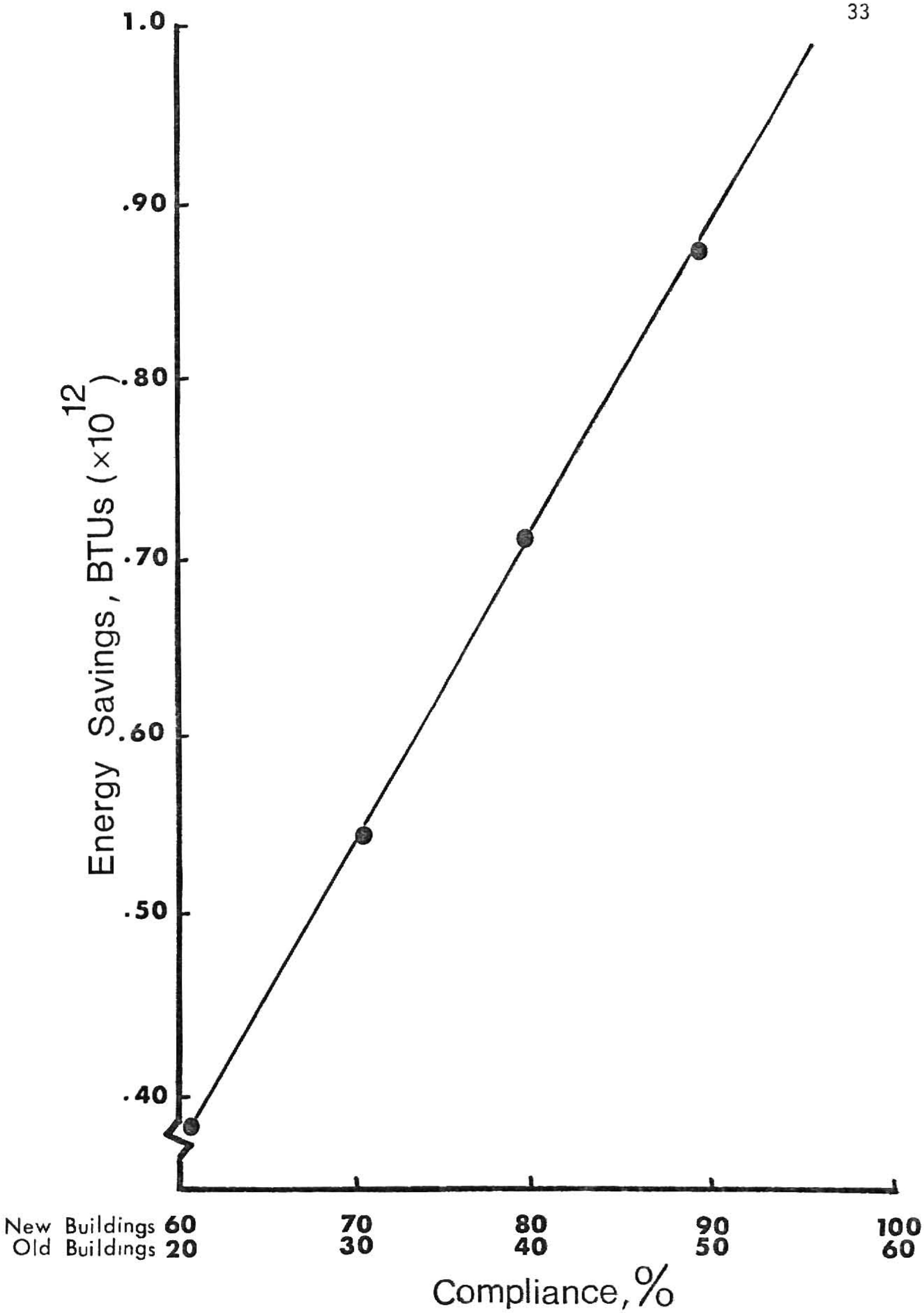

Figure 1. Energy savings at various combinations of compliances for new and old buildings.

LIGHTING CONSERVATION MEASURES FOR RESIDENCES

There are many steps which can be taken to conserve electricity from lights in homes. A simple act like turning off unneeded lights saves energy. Following are some conservation measures which although not at all technically complex, would bring about considerable savings in the electricity bill. These conservation measures are based on the IES 12 recommendations (F. Clark, 1976).

1. Maximum Light for the Dollar

Lumens are a measure of light output. Lamp manufactures are now required to state the tested lumen output of a lamp on the outside of the corrugated cardboard sleeve or wrapper on incandescent lamps. Given the choice between a 60-watt lamp producing 860 lumens and a 60-watt lamp delivering 765 lumens, the 860-lumen lamp should be selected; since it will shed more light while drawing no more electricity.

2. More Light from Fewer Lamps

Where it makes sense around the house, the number of bulbs should be reduced and more light gained. Drawing the same amount of electricity, one 100-watt incandescent lamp glows with nearly 50 percent more light than four 25-watt lamps (and costs only one-quarter as much). However, 25-watt lamps last about 2500 hours, while the 100-watt has a 750-hour life.

3. Fluorescent Tubes

Fluorescent tubes are a proven way by which the light level in a space can be raised and at the same time energy saved. A comparison between a 75-watt incandescent and a 30-watt fluorescent clearly illustrates the point, in Table 12.

TABLE 12

Energy Comparison of Incandescent Lamps and Fluorescent Tubes

	Incandescent lamp	Deluxe fluorescent tube	Advantages of fluorescent
Watts	75	30 (44 total input watts)	31-watt (or 41 percent) energy saving
Rated life	750 hours	15,000 hours	Lasts 14,250 hours more (or 20 times longer)
Amount of light	1180 lumens	1530 lumes	350 more lumens, or 30 percent more light

Comparing lamps and tubes of the same nominal wattage is even more startling. A 40-watt deluxe warm white fluorescent tube (54 total input watts) produces 2190 lumens. A 40-watt incandescent lamp produces only 20 percent of that light - 455 lumens. And the fluorescent tube lasts 12 times as long. Deluxe fluorescence is strongly recommended for use in kitchens and baths, since besides the above mentioned advantages, the quality of light produces a pleasing appearance in food and facial complexions. Standard tubes should be used in workshops and garages to gain more light output than that of the deluxe type.

4. Long-life Lamps

Long-life incandescent lamps make good sense where replacement is inconvenient — like a high ceiling fixture in the front hall. There is no doubt about the fact that it will last longer than a standard lamp (2500 hours or more compared to about 750 hours) and therefore needs changing less often. However the light output from a long-life lamp is less than from a standard lamp. From an energy-saving standpoint, standard lamps are a better choice for seeing tasks. For example, a 75-watt standard lamp could be the choice to replace a 90 to 100-watt long-life lamp of the 75-watt lamp produces the amount of light needed. The lumen rating should be checked on the light lamp sleeve. Table 13 shows the lumen output of standard and long-life incandescent lamps.

5. Three-way Lamps

Three-way lamps provide a choice of lighting levels — high for more difficult seeing tasks, medium for less demanding activities and low for safety. At the low level, much less energy is consumed.

Table 13

Lumen Output of Standard and Long-life Incandescent Lamps

	Watts	Lumens	Hours life	Lumen/watt
Standard lamps*	100	1740	750	17.4
	75	1180	750	15.7
Long-life lamp**	100	1690	1150	16.9
	100	1490	2500	14.9
	100	1470	3000	14.7
	92	1490	2500	16.2
	90	1290	3500	14.3

* Industry averages

** Manufacturer's data

6. Out-door Lights

For all night security and safety out-of-doors, the use of Mercury lamps is recommended. A 40-watt deluxe white mercury lamp (about 50 total input watts) provides 1350 lumens (27 lumens/watt) compared to 455 lumens from a 40-watt white coated incandescent lamp (11.4 lumens/watt) — more light for the electricity drawn. Mercury is more than twice as efficient — it lasts over 10 times longer too. The lights should be attached to a dusk-to-dawn photocell light control.

7. Dimmers

In living, dining and sleeping areas, the use of dimmers can be an excellent esthetic advantage for environmental pleasure. Action of the dimmers reduces the light level when higher amounts are not needed by damping down the flow of power to the fixture, thus saving electricity. The lamps will last longer too.

8. Avoid the use of a Higher Wattage Lamp than Recommended

On or attached to a lighting fixture is the manufacture's recommendation for the most efficient lamp. In some cases, the label clearly states maximum wattage. This is done for safety's sake and/or to meet the Underwriters laboratories' requirement. The advice given should be followed.

9. Avoid the use of a Higher Wattage Lamp than Really Needed

In a ceiling fixture or wall sconce along a bedroom hall, enough light for safe passage might be needed. If the hallway is small, a 40-watt lamp sheds enough light for that purpose — a 75-watt lamp should not be used. That is an unnecessary energy drain.

10. Planning Lighting

Good planning means the most efficient combination of light sources, equipment designed to use light sources best, and proper placement of the equipment (taking into account the type and color of reflective surface around the fixture). The closer the light source can be to the work area, the better the results. Table and floor lamps with shades that allow light out through the sides of the shade as well as out of the top and bottom produce more useful light than lamps with opaque shades. In most cases, common sense will tend to the right combination of source, fixture and placement.

11. Lighting Maintenance

This involves keeping fixtures, lamps and tubes clean and in working order. A blackened lamp sheds less light than a new one, but it also draws the same amount of electricity as a new one. To gain maximum light output, blackened lamps should be changed before they burn out. The fixtures, shades and reflectors should be kept clean, too. They collect dust and the dust reduces light output.

12. Switches

When leaving a room, it is easier to turn lights off in a room if the switch is along the door. When a room has two exits, a switch control should be provided at both exits. Also, if there is more than one lighting system in the room, each should be switched separately.

13. Room Interreflectances

The larger a room and the lighter the color of room finishes and furnishings, the lower the light absorption by these objects, and hence less watt per square foot will be required to produce the same footcandles. White surfaces reflect the maximum amount of light. Keeping these facts in mind, decorating schemes should be adjusted to take full advantage of reflection in a space where it makes sense.

Up to this point, most of the suggestions could require some capital expenditure. Three-energy saving ideas that call for nothing more than a slight change in habit.

a. Use of Daylight to its Best Advantage

Whenever or where ever possible, daylight ought to supplement or replace interior lighting. Light-passing draperies, curtains and shades help bring this about. To utilize daylight, the most difficult and tiring tasks should be located next to windows and performed during the daylight, for example, hand-sewing of dark material using dark thread.

b. Turning off Unneeded Lights

This may seem too elementary, yet it needs to be said for the sake of those who forget. An everyday example: A youngster finishes studying in his bedroom and comes downstairs for an hour or so to watch television, leaving all his bedroom lights blazing.

c. Why not Romance?

The energy crisis gives a fine opportunity to relearn the romance of coffee and conversation by firelight, or cold drinks and parfait by the setting summer sun. There is even something to be said for moonlight on the patio.

Summing up, one can contribute to energy conservation and save money at the same time if one uses light only where and when one need it.

PUBLIC INFORMATION AND ATTITUDES TOWARDS ENERGY AND LIGHTING CONSERVATION

Public Opinion Survey

In order to evaluate public information and attitudes towards energy conservation in general and lighting conservation in particular, a survey was conducted. This was achieved by means of a questionnaire. Specifically, the survey concerned the seriousness and awareness of the energy problem, responsibility for conservation of natural resources, sensitivity to fuel-prices and public awareness of specific FEA advertisements. In addition it tested public knowledge through a series of questions on simple lighting conservation measures.

The questionnaire was answered by 272 persons during the engineering open house at Kansas State University in April 1977. About 100 questionnaires were completed through an interview and the rest were filled in by the subjects themselves. The subjects were assured that their answers would be kept confidential, hence no biased answers were expected.

The public was classified into four general categories. The categories and the percentage of people belonging to each category were as follows.

Group 1:	Students	53%
Group 2:	Professional and managerial	24%
Group 3:	Semi-skilled (farmers etc)	10%
Group 4:	Unclassified (housewifes, retired etc)	13%

Analysis and Discussions

The questionnaires were analyzed through the Statistical Packages for Social Sciences (Nie, Hull, Jenkins, Steinbrenner and Bent, 1975) computer program. The questions and the results of the survey (all four categories combined) are shown in Table 14. Chi-square tests were made to check the differences among the groups for each question. No significant difference was found among the four groups for most of the questions at 5% significance level. There were significant differences among the groups on questions 5 and 7 (cost of energy), question 9 (awareness of the 'Don't be fuelish' slogan) and questions 15 and 16 (lower wattage lamps). In questions 5 and 7, the professional and managerial and unclassified groups were more conscious of the cost of electricity than the semi-skilled and students groups. In question 9, students and professional and managerial groups had a higher level of awareness of the slogan "Don't be fuelish" than the other two groups. In questions 15 and 16, the professional and managerial and unclassified were more knowledgable about the use of lower wattage lamps than the students and semi-skilled groups.

The survey showed that there was strong agreement that there was an energy crisis, of a serious nature, in this country (questions 1, 2 and 3). The public was conscious of the cost of energy and thought it was worth the effort to use less electricity (questions 7, 11 and 13). While the public held itself responsible for doing a poor job of energy conservation, it thought the Federal government and the business community were also doing a poor job (questions 4, 6 and 8).

A review of the reactions to the basic lighting conservation measures (questions 21a to 21j) showed that most of the people were familar with them. The best response was to question 21g, where 96% thought that using daylight through windows and skylights would save energy. The poorest response was to question 21i, where 32% of the subjects thought that installing dimmers would not save energy. However, the overall

TABLE 14

Questions and Results of the Public Opinion Survey

1. There is an energy crisis in this country 97% Agree 3% Disagree

2. The energy shortage is 60% very serious 39% somewhat serious 1% not serious at all

3. Energy conservation is one of the solutions to the energy problem 97% Agree 3% Disagree

4. How good a job do you think the Federal government is doing in meeting its responsibility to conserve our supplies of natural resources 4% Good 42% Average 54% Poor

5. If the cost of energy (such as gasoline, electricity, gas) gets considerably higher, would it matter to you 95% Yes 5% No

6. How good a job do you think the business community is doing in meeting its responsibility to conserve our supplies of natural resources 3% Good 40% Average 57% Poor

7. Do you use less electricity due to cost 70% Yes 30% No

8. How good a job do you think the public is doing in meeting its responsibility to conserve our supplies of natural resources 2% Good 30% Average 68% Poor

9. Have you heard or seen the slogan "Don't be fuelish" 95% Yes 7% No

10. What are some of the reasons why people don't try to save energy
36% People don't care 2% Really there isn't a shortage
38% Too hard/causes inconvenience 24% People really don't know what to do

11. Are you using less electricity in your home or apartment because of cost 64% Yes 20% No 16% Do not know

12. Have you heard the slogan "Last out, lights out" 40% Yes 60% No

13. Is it worth the effort to use fewer lights to conserve energy 94% Yes 6% No

14. Do you like your house lit up 45% Yes 55% No

15. Which type of lamp, giving the same amount of light, would save electricity and thus money 11% Incandescent 89% Fluorescent

16. Do light bulbs with lower wattage use less electricity 66% Yes 13% No 21% Don't know

17. Do you use fewer lights due to cost 72% Yes 28% No

18. Do you turn off lights in rooms which are not being used 96% Yes 4% No

19. Houses which are lighted up are secure and look nice. 61% Yes 39% No

20. Do you like the whole room to be lit up when you are working at your desk 40% Yes 60% No

21. Please indicate your opinion on the following conservation measures, which may or may not save energy.

	Will save energy	Will not save energy
a) Reduced illumination level	85%	15%
b) Raising mounting heights of ceiling fixtures	18%	82%
c) 2 or 3 levels of lamp control (dim, medium & bright)	84%	16%
d) Using higher wattage bulbs	12%	88%
e) Using furniture mounted fixtures such as desk lamps instead of ceiling fixtures	70%	30%
f) Dark color room and furnishing	11%	89%
g) Cleaning light fixtures periodically	81%	19%
h) Using daylight through windows and skylights	96%	4%
i) Installing dimmers	68%	32%
j) Using only one control switch instead of more than one for big rooms or corridors	20%	80%

reactions to the measures, does not necessarily indicate that people have adopted these measures at home or even if they knew how to apply these techniques. Among the groups, students were found to be most poorly informed, although as a group they did well. To question 21g, 80% of them thought that dark colored rooms and furnishings would not save energy, whereas the overall response to the question was 89%.

When asked about the reasons why people do not try to save energy, 36% said that people do not care (question 10). This illustrates the lack of motivation on the part of the public, although 98% of them had heard or seen the FEA slogan "Don't be fuelish" (question 9). When compared with the "Don't be fuelish" slogan, "Last out, light out" did not show as high a level of awareness (question 12).

Since knowledge of a particular area does not have a clear effect on attitudes within that area, it is reasonable to conclude that the first task is to educate people on factual information. According to question 10, 25% of the public thought people really did not know what to do. At the same time, since the more knowledgeable tend to be more educated and have higher incomes and thus use more energy per capita, a second task involving actual savings due to specific conservation measures rather than basic education might be aimed at the more knowledgeable groups. These points, along with the motivational aspects of publicity, are elaborated in the last chapter of the thesis.

It can be argued that the results of the energy survey cannot be universally applied. It can be assumed that only those persons would come to visit an engineering open house, who were at least interested, if not informed, in the developments in technology. However, in that case, the questionnaire did serve to test a group of people who can be classified as educated and informed. A fairly reasonable conclusion can be reached about the rest, making the advocation of an education-extension program even stronger.

Comparison with national survey. Some of the questions in the questionnaire were taken from a national survey (Opinion Research Corporation, 1975). The results of that survey are compared to the present one in Tables 15, 16 and 17. As evident from Table 15, the people of Kansas are more conscious of the energy crisis and are using less electricity in their homes or apartments, due to cost. Since the national survey was conducted in 1975, this is not very surprising as the attitudes and knowledge of people should have improved in two years, in light of the much publicized "energy crisis".

However, surprisingly, as shown in Table 16, the federal government, the business community and the public all are viewed as doing a much poorer job, in energy conservation, than they were in 1975.

A comparison of questions on lighting conservation measures (Table 17) showed improvement in public awareness and knowledge. While 76% of the public had heard the slogan "Don't be fuelish" in 1975, 93% claimed they heard it in the present survey.

However, besides the time changes, in all the comparisons made above, it should be noted that the Kansas survey was made through a selected group from the city of Manhattan and does not necessarily represent a larger population.

TABLE 15

Comparison Between National and Kansas Energy Survey

Q. The energy shortage is:

	very serious	somewhat serious	not serious at all
National Survey	37%	42%	18%
Kansas Survey	60%	39%	1%

Q. Are you using less electricity in your home or apartment due to cost

	Yes	No	Don't Know
National Survey	55%	40%	5%
Kansas Survey	64%	20%	16%

TABLE 16

Comparison Between National and Kansas Energy Survey

Q. How good a job do you think the Federal government, the business community and the public are doing in meeting their responsibility to conserve our supplies of natural resources

	Kansas Survey			National Survey		
	Good	Average	Poor	Good	Average	Poor
Federal government	9%	38%	44%	4%	42%	54%
Business community	14%	39%	34%	3%	40%	57%
Public	15%	41%	36%	2%	30%	68%

TABLE 17

Comparison Between National and Kansas Energy Survey

	National		Kansas	
	Yes	No	Yes	No
Q. Is it worth the effort to use fewer lights to save energy	68%	32%	94%	6%
Q. Have you heard or seen the slogan 'Don't be fuelish'	76%	24%	93%	7%
Q. Light bulbs with lower wattage use less electricity	60%	40%	66%	34%
Q. Do you like houses lit up	20%	80%	45%	55%
Q. Do you turn off lights in rooms which are not being used	96%	4%	96%	4%

INDUSTRY INFORMATION AND ATTITUDES TOWARDS ENERGY AND LIGHTING CONSERVATION

Industry Opinion Survey

In order to formulate a program of education-extension, it seemed appropriate to test industry information and attitudes towards energy and lighting conservation. This purpose was achieved through a questionnaire which was mailed to 182 industries of 38 diversified natures around Kansas. The 182 industries were selected as follows:

Category A.	Less than 10 employees	1.5% (44 industries)
Category B.	Between 10 to 49 employees	3% (39 industries)
Category C.	Between 50 to 99 employees	6% (18 industries)
Category D.	Between 100 to 249 employees	12% (21 industries)
Category E.	Between 250 to 499 employees	25% (19 industries)
Category F.	Between 500 to 999 employees	50% (21 industries)
Category G.	Over 1,000 employees	100% (20 industries)

These categories were listed in the Directory of Kansas Manufacturers and Products (1976). Samples from each category (except G) were picked at random.

The survey was conducted in May 1977, after President Carters fireside energy talk. Out of the 182, 42% of the questionnaires were returned back. The questionnaire was similar to the public questionnaire but tested industry knowledge on more sophisticated lighting conservation measures.

The survey was concerned with the seriousness and awareness of the energy crisis, responsibility for conservation of natural resources, sensitivity to fuel-prices and responses to feasible conservation techniques in lighting. The questionnaire was addressed to the plant engineer/building superintendent/manager of the industries. They were assured that their answers would be kept confidential, hence no biased opinions were expected.

Analysis and Discussion

The questionnaires were analyzed through the SPSS computer program. The questions and the results of the survey are presented in Table 18.

An analysis of the survey showed that there was a strong agreement among the industries that there was an enery crisis, of a serious nature, in this country, which could be solved by energy conservation as one of the solutions (questions 1,2 and 3). A similar agreement was found in the public survey, however while 97% of the public agreed that energy conservation is one of the solutions to the energy problem, only 84% agreed to this among the industries. According to question 7, 53% of the industries said they used less electricity in their organizations, due to cost whereas 70% of the public thought they used less electricity, due to cost. While 83% of the industries thought it was worth the effort to use fewer lights to conserve energy (question 9), 94% of the public thought so. While the federal government and the public were viewed as doing a poor job of conserving our natural resources, only 40% of the industries thought that industry was doing a poor job in this respect (questions 4,6 and 8). As compared to this 68% of the public took the blame on themselves. To say the least, the comparisons, made above, indicate that the public is relatively more motivated than the industrial sector as far as energy crisis and energy conservation are concerned.

TABLE 18

Questions and Results of the Industry Opinion Survey

1. There is an energy crisis in this country 94% Agree 6% Disagree

2. The energy shortage is 56% Very Serious 38% Somewhat Serious 6% Not Serious At All

3. Energy conservation is one of the solutions to the high cost of energy for your plant 84% Agree 16% Disagree

4. Have you taken <u>definite</u> steps towards formulating an energy conservation plan in your organization since the energy crisis 65% Yes 15% No 20% Under consideration

5. How good a job do you think the public is doing in meeting its responsibility to conserve our supplies of natural resources 3% Good 20% Average 77% Poor

6. What are some of the reasons why some organizations don't try to save energy 20% Don't care 5% Really there isn't a shortage 35% Two hard/causes inconvenience 40% Really don't know what to do

7. Do you use less electricity in your organization, due to cost 53% Yes 47% No

8. How good a job do you think the Federal government is doing in meeting its responsibility to conserve our supplies of natural resources 3% Good 27% Average 70% Poor

9. Is it worth the effort to use fewer lights to conserve energy 83% Yes 17% No

10. How good a job do you think the business community is doing in meeting its responsibility to conserve our supplies of natural resources 8% Good 52% Average 40% Poor

11. Are your buildings lit up at night 9% Yes 32% No 59% Partially

12. Are rooms in your buildings where people are working at their desks, with table lamps, lit up 26% Yes 51 No 23 Partially

TABLE 18 (continued)

13. Please indicate your opinion on the following conservation measures dealing specifically with lighting. (View these as potential conservation measures for your organization)

	Technically & economically feasible	Technically unfeasible	Economically unfeasible	Technically & economically unfeasible	Don't know details to indicate opinion
a) Reduced illumination level in non-task areas	72%	8%	9%	5%	6%
b) Reduced illumination level in task areas	29%	42%	4%	19%	5%
c) 2 or 3 levels of lamp control (dim, medium, bright)	34%	7%	21%	16%	12%
d) More efficient sources of light (e.g Sodium, Metal halide)	54%	1%	14%	4%	26%
e) Using furniture mounted fixtures such as desk lamps instead of ceiling fixtures	33%	20%	25%	14%	8%
f) Light color room and furnishing	79%	5%	9%	1%	6%
g) Cleaning light fixtures periodically	92%	-	-	4%	3%
h) Installing dimmers	40%	17%	24%	11%	9%
i) Using daylight through windows and skylights	68%	12%	7%	12%	1%

Table 18 (continued)

	Technically & economically feasible	Technically unfeasible	Economically unfeasible	Technically & economically unfeasible	Don't know details to indicate opinion
j) Using more switches instead of one control switch for lights in big rooms or corridors	70%	4%	14%	6%	5%
k) Lowering ceiling fixtures mounting heights	43%	25%	13%	14%	4%
l) Use multi-level ballasts	28%	7%	13%	10%	42%
m) Use efficient lenses	55%	4%	4%	4%	33%
n) Add timers to shut off lights	55%	9%	17%	11%	8%
o) Install high frequencey lighting	22%	6%	7%	8%	56%
p) Use by-product of lighting i.e heat	41%	12%	17%	10%	20%
q) Reduce power for lighting by replacing ballasts	43%	5%	17%	1%	33%
r) Install new efficient fixtures	54%	-	25%	10%	11%

A review of the reactions to the lighting conservation measures showed that most of the industries thought those as technically and economically feasible (question 13a to 13r). The best responses were to question 13a (reduced illumination level in non-task areas), question 13g (cleaning fixtures) and question 13f (light color room and furnishing). Most industries did not know details to indicate their opinion on the following conservation measures, which are technically more complex than the rest; use of multi-level ballasts (question 13l) and installation of high frequency lighting (question 13o).

When asked if they had taken definite steps towards formulating an energy conservation plan in their organization, 65% of the industries said they had (question 4). To test the validity of this, chi-square cross-tabulations were run between question 4 (taking definite steps) and the first (technically and economically feasible) and fifth (no opinion) answers to questions 13 through 17 (on specific conservation measures). The chi-square cross tabulations indicated that in most cases the reaction to question 4 was justified at 5% significance level. In other words, the industries which had thought of the conservation techniques as technically and economically feasible, had formulated an energy conservation plan as indicated in question 4. The only conservation measures which did not match question 4 were question 16 (efficient sources of light) and question 26 (timers). This showed that either the two conservation measures were not included in the conservation plan or the industries did not have details to do anything about them.

About 40% of the industries thought that organizations do not try to save energy because they really do not know what to do (question 6). This suggests the need for an education-extension service as outlined in the next chapter. The fact that, presumably, technical personnel had filled out the questionnaires, supports the need of education even for a sophisticated audience.

DISCUSSION AND IMPLICATIONS

Implementation of Lighting Conservation Measures

One of the basic problems facing any serious review of the issue of lighting conservation is the difficulty of getting a broad consensus, among concerned parties, as to the implementation of the conservation program.

Although all lighting has been subject to review with respect to energy, the greatest interest and concern have been directed towards lighting for industrial, commercial and institutional buildings. This is because, undoubtly, most lighting is used indoors and mostly in public buildings. The residential sector of indoor lighting accounts for only a small fraction of all indoor lighting. Many of the decisions on implementation of lighting conservation measures, in public buildings, are fundamentally sociological and political rather than technological. Those who would impose life quality and value judgment are assuming great responsibility.

The National Electrical Manufacturers Association (NEMA) has been among those advocating the control of energy rather than "end use" controls. For buildings this suggests an energy budget as one approach. NEMA also prepared a program called Total Energy Management (TEM). G.W. Clark (1976) quotes from the building study report, "Two methods have been proposed to implement energy conservation in buildings. The first calls for end-use restrictions, proposed or imposed by the government, whereby energy is conserved by [specified] actions such as reduced lighting footcandle levels to specified maximums, and lowering the thermostat during the heating season. The second method is called Total Energy Management (TEM) and implies that building owners and managers accept responsibilities for instituting energy conservation modification (including the application of end-use options) to be integrated into the building systems".

The FEA has also advocated the control of energy rather than end use. Quoting from the FEAs Project Independence (1974), "The overall amount of energy used in a building would be limited, with each consumer within the building permitted to conserve energy according to his preferences, saving energy where he values its use least and continuing energy consumption where he values it most."

In the case of end-use requirements — prescriptive and simple as they seem to be — they have proven impractical as a measurable and enforceable standard. Although they seem easy to state, here are some of the questions this approach raises:

1. Minimum, maximum or average
2. New or old lamps
3. Clear or dirty lamps and luminaires
4. Accuracy of predictability
5. Practicality of design with finite lamps, luminaires & spaces
6. Disregard of other quality factors.

Foot-candles also have the deficiency that they do not directly correlate with energy, since neither efficiency nor usage is incorporated in the lumen/sq. ft. dimension.

One of the lighting tragedies of the past couple of years has been the tendency to reduce the benefits of lighting in favor of continued waste, largely because it seems easier and is accomplishable without any capital investment. Controlled usage of lighting systems is the key if proper lighting is to be maintained within the energy constraints that appear to be necessary. Controlled usage requires: the controller (human) and control devices. The controller provides the important input that sets the parameters for the devices, whether they be manual or automatic.

In the effort to promote energy savings, there are several paths open, including, voluntary guidelines versus mandatory requirements, and prescriptive end-use standards versus performance goals. At least until the energy needs are more precisely defined, the voluntary approach should be given the opportunity to function with the dollar playing its role. If and when mandatory regulations are eventually needed, they should be geared to mandate the conservation measures which do not involve personal preferences, like lower illumination levels in non-task areas.

The Kansas Energy Conservation Plan (1977) advocates legislative action for establishment of an illumination efficiency standard for existing buildings. However, it is felt that the voluntary approach should be at least given a chance before any mandatory action is taken for existing building. In the case of existing buildings, the conservation measures should be disseminated through extension-education activities to building owners and operators. This sort of activity would be required even for a mandatory plan. Because of operating cost savings it is anticipated that conservation measures will be widely adopted. Payback periods for capital expenditures tend to be three years or less. Government tax incentives could provide additional, although unnecessary stimulus. Indeed, private and industry employed energy consultants are already generally advocating these measures.

For new building construction and major renovations, the Kansas Energy Conservation Plan (1977) calls for the adoption of a state uniform building code. This code, in the case of lighting energy, would call for calculating a lighting energy budget based upon procedures described in ASHRAE 90-75, which puts certain limits on lighting efficiency standards. Basically, this budget will allow a specific amount of energy per square foot of building space. It is calculated based upon lighting needs: lighting needed to perform the tasks to be performed in the building. Then, efficient lighting approaches (using the conservation measures) provide for the lighting needs. This is the lighting budget. The designing engineers and architects would have complete freedom to provide necessary lighting, within the budget, as they see fit.

Program of Educational-Extension

While conservation of energy is important, it must be achieved in a manner consistent with other requirements, including those of productivity and visual comfort; aesthetics; federal, state and local codes and ordinances, etc. Moreover, it is especially important to recognize that major alternations to a lighting system can have a significant impact on heating and cooling system, most of which were designed to consider the amount of heat given off by the lighting system as originally designed. For these reasons, it is suggested strongly that competent technical assistance be obtained before any significant modifications are made. Such technical assistance could be provided through an education-extension service. This service could be based along the following lines.

For Residential and small business sectors. The extension service could train regional or county extension and home demonstration agents as a delivery mechanism for the conservation measures. Such a program could include:

1. Preparation of conservation material. As an integral part of transfering conservation ideas to the general public and small business, written material summarizing energy conservation techniques could be developed. This material would condense energy conservation technology, applications, energy saving potentials, costs and technical considerations from a variety of sources. Visual-aids like slides and short films could also be prepared.
2. Training of officials. Training to extension agents could be given through the extension service. Short courses could be offered.
3. Mass media. Media facilities including a statewide radio network, printed news network and television and film studios could be used to spread the message. All of these methods offer a large audience with a minimal man-day input.

For Existing Industrial, Public and New Buildings. Members of the industrial community and owners/operators of public buildings could be invited for half day or full day conferences at the extension center or at other locations. Such conferences could include; talks on energy conservation, factual answers to questions on energy conservation and usage, and advice on conservation measures. Seminars and courses could also be arranged through the extension service.

For new buildings and major renovation, the Kansas Energy Plan calls for the adoption of a state uniform building code which are based on procedures described in ASHRAE 90-75. Since it envolves calculation of a lighting energy budget for all new buildings, training and education of contractors, architects and builders would be essential for the implementation of the code. A technical assistance program could be formulated by the extension service to help concerned personnel with the factual details of the plan. Demonstration buildings could also prove effective in conveying the practical aspects of the code. In short, for new buildings, the program aims at the organization of an effective training program for personnel involved in building design, construction and management.

The National Electrical Manufacturers Association (NEMA) and National Electrical Contractors Association (NECA) could also serve as useful conduits for the education-extension activities. Joint ventures with these associations could help propagate the program very effectively.

Program of Publicity

Until recently, the federal government had offered no formal plan of action, no sanction or incentives other than price increases, to encourage conservation by the consumer. Rather, the thrust of the policy had been to inform consumers about the importance of saving energy and methods for achieving savings. This may have lead to better informed consumers and to more favorable attitudes towards the conservation of energy, but is not likely in the short term to lead to effective change. Research has shown that it is easier for people to hold environmentally beneficial attitudes than to show environmentally beneficial behavior. Bickman (1973) attempted to investigate the behavioral and attitudinal aspects of littering and found that there was great disparity between the attitudes of people and their actual behavior. A study by Heberling (1974) of the electricity consumption of apartment dwellers indicated that the informational campaign of the federal government had no effect on the amount of electricity consumed. It is unlikely, therefore, that an informational campaign alone can successfully reduce energy consumption in the long run. What is needed is a program aimed at changing consumer behavior which can be partially achieved through the education-extension program discussed in the previous section.

Recent research has demonstrated that operant techniques can be used to modify environmentally relevant behaviors. Operant techniques are used for conditioning based on consequences to modify behavior. These consequences are contingent upon rewards, incentives, prompting or such other reinforcement. Modified environmentally relevant behaviors have included decreasing littering (Burgess, Clark, and Hendee, 1971; Clark, Burgess and Hendee, 1972; Kohlenberg and Phillips, 1973), increasing bus riding (Everett, Hayward and Meyers, 1974) and using returnable bottles (Geller, Farris and Post, 1973). Behavioral procedures have been used to delay the use of some electrical appliances until non-peak times of the day [Kohlenberg, Phillips and Procter (in press) cited by Palmer (1975)]. With decreased peaking, more electrical demands can be met without increasing plant capacity.

Another principle that could be applied to the reduction of energy consumption is that informational feedback facilitates behavior change. According to this principle, a person is best able to alter his behavior when he has specific knowledge of the consequences of his behavior. In a study by Palmer (1975) effects on electricity consumption of two feedback conditions, daily knowledge of electricity consumption and daily knowledge of electricity cost; and two prompt conditions, daily requests for conservation and a letter from a government official requesting a decrease in consumption were examined. In three months study period, electricity consumption was reduced in three of the four families evaluated. In a similar study, Seaver and Patterson (1976) increased fuel-oil conservation by providing consumption feedback plus social commendation for lowered consumption levels. Similar approaches could also be applied towards the conservation of lighting energy.

As discussed earlier, one of the solutions to impending energy shortages is to change consumers attitudes towards the consumption of energy. Public health organizations frequently stress upon the public the deleterious consequences of failing to adopt their recommendations. These types of communications have been termed fear appeals. There is evidence that fear appeals facilitate persuasion on health-related topics involving bodily injury (Higbee, 1969). Hass, Bagley and Rogers (1975) demonstrated that the magnitude of noxiousness of a potential energy crisis affected attitudes towards energy consumption, thus suggesting one method for coping with the energy crisis.

The FEAs widely publicized slogan, "Don't be fuelish", for example, does not really put any fear in the general public. It is the grim and dramatic consequences of being fuelish that should be publicized. Some of those consequences which could be readily understood by the layman can be publicized in terms of fuel-rationing, excessive taxation, reduced thermostat settings etc. A picture of the world without energy would really present a horrifying scene to the public, which has taken too much for granted. Thus a more forceful and fearful publicity campaign could be much more effective than the 'Don't be fuelish' approach.

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APPENDIX A

Step-wise Methodology for Calculation of Energy Savings for Five Building Types

Step-wise Methodology for Calculation of Energy Savings

Wooksheet for Total Electricity Savings in Terms of Source Fuel (in trillion Btu's) for the following building type:

_X_ Office ___ Retail Stores ___ Schools ___ Hospitals ___ Other

Step 1: Projected 1978-79-80 electrical consumption for lighting in buildings in region built prior to and following effective date of program, in trillion Btu's

a.	1980 energy consumption for lighting in buildings built pre-1971 in region	14 $(x10^{12})$
b.	Energy for lighting in additional buildings built in region each year since 1971	1.32 $(x10^{12})$
c.	Number of years program in effect	3
d.	No. of years between beginning of 1971 and time program into effect	7
e.	State/Region population ratio	.039

Step 2: Electrical energy savings for 1978-79-80 in State by buildings built prior to program effective date, in trillion Btu's

a.	Projected lighting energy for existing buildings in State in 1978 [(line 1b x 1d) + line 1a][line 1e]	.906 $(x10^{12})$
b.	Projected lighting energy for existing buildings in State in 1979 [line 2a + 1b(line 1e)]	.958 $(x10^{12})$
c.	Projected lighting energy for existing buildings in State in 1980 [line 2b + 1b(line 1e)]	1.01 $(x10^{12})$
d.	Fraction reduction in lighting in existing buildings (Table 3)	.20
e.	Fraction of floor space affected in 1978 (Table 8)	.10
f.	Fraction of floor space affected in 1979 (Table 8)	.30
g.	Fraction of floor space affected in 1980 (Table 8)	.50
h.	Electricity savings in existing building in 1978 (line 2a x 2d x 2e)	.018 $(x10^{12})$

i.	Electricity savings in existing building in 1979 (line 2b x 2d x 2f)	.057 ($x10^{12}$)
j.	Electricity savings in existing building in 1980 (line 2c x 2d x 2g)	.101 ($x10^{12}$)

Step 3: Electrical energy savings for 1978-79-80 in State by buildings built since time of program effective date, in trillion Btu's.

a.	Projected annual lighting energy for new building in State in 1978-79-80 [line 1b x 1e]	.051 ($x10^{12}$)
b.	Fraction reduction in lighting in new buildings (Table 3)	.50
c.	Fraction of floor space affected in 1978 (Table 7)	.10
d.	Fraction of floor space affected in 1979 (Table 7)	.50
e.	Fraction of floor space affected in 1980 (Table 7)	.90
f.	Electricity savings in new buildings in 1978 (line 3a x 3b x 3c)	.002 ($x10^{12}$)
g.	Electricity savings in new buildings in 1979 (line 3a x 3b x 3d)	.013 ($x10^{12}$)
h.	Electricity savings in new buildings in 1980 (line 3a x 3b x 3e)	.023 ($x10^{12}$)

Step 4: Total electrical energy savings by new and existing buildings in the State, in trillion Btu's.

a.	i)	Aggregate savings in 1978 (lines 2h + 3f)	.021 ($x10^{12}$)
	ii)	Savings per quarter of 1978 (line 4a/4)	.005 ($x10^{12}$)
b.		Aggregate savings in 1979 (lines 2i + 3g)	.070 ($x10^{12}$)
c.	i)	Aggregate savings in 1980 (lines 2j + 3h)	.124 ($x10^{12}$)
	ii)	Energy for existing and new buildings in 1980 with no energy conservation [(line 1b x 9) + line 1a][line 1e] + [line 1b][line 1e]	1.06 ($x10^{12}$)
	iii)	% savings in 1980 [(line 4c i/4cii) x 100]	11.69%

Step-wise Methodology for Calculation of Energy Savings

Wooksheet for Total Electricity Savings in Terms of Source Fuel (in trillion Btu's) for the following building type:

___Office X Retail Stores ___Schools ___Hospitals ___Other

Step 1: Projected 1978-79-80 electrical consumption for lighting in buildings in region built prior to and following effective date of program, in trillion Btu's

a. 1980 energy consumption for lighting in buildings built pre-1971 in region — 19.1 ($\times 10^{12}$)

b. Energy for lighting in additional buildings built in region each year since 1971 — 2.27 ($\times 10^{12}$)

c. Number of years program in effect — 3

d. No. of years between beginning of 1971 and time program into effect — 7

e. State/Region population ratio — .039

Step 2: Electrical energy savings for 1978-79-80 in State by buildings built prior to program effective date, in trillion Btu's

a. Projected lighting energy for existing buildings in State in 1978 [(line 1b x 1d) + line 1a][line 1e] — 1.364 ($\times 10^{12}$)

b. Projected lighting energy for existing buildings in State in 1979 [line 2a + 1b(line 1e)] — 1.453 ($\times 10^{12}$)

c. Projected lighting energy for existing buildings in State in 1980 [line 2b + 1b(line 1e)] — 1.542 ($\times 10^{12}$)

d. Fraction reduction in lighting in existing buildings (Table 3) — .30

e. Fraction of floor space affected in 1978 (Table 8) — .10

f. Fraction of floor space affected in 1979 (Table 8) — .30

g. Fraction of floor space affected in 1980 (Table 8) — .50

h. Electricity savings in existing building in 1978 (line 2a x 2d x 2e) — .041 ($\times 10^{12}$)

i. Electricity savings in existing building in 1979 (line 2b x 2d x 2f) — .131 $(x10^{12})$

j. Electricity savings in existing building in 1980 (line 2c x 2d x 2g) — .231 $(x10^{12})$

Step 3: Electrical energy savings for 1978-79-80 in State by buildings built since time of program effective date, in trillion Btu's.

a. Projected annual lighting energy for new building in State in 1978-79-80 [line 1b x 1e] — .088 $(x10^{12})$

b. Fraction reduction in lighting in new buildings (Table 3) — .50

c. Fraction of floor space affected in 1978 (Table 7) — .10

d. Fraction of floor space affected in 1979 (Table 7) — .50

e. Fraction of floor space affected in 1980 (Table 7) — .90

f. Electricity savings in new buildings in 1978 (line 3a x 3b x 3c) — .004 $(x10^{12})$

g. Electricity savings in new buildings in 1979 (line 3a x 3b x 3d) — .022 $(x10^{12})$

h. Electricity savings in new buildings in 1980 (line 3a x 3b x 3e) — .040 $(x10^{12})$

Step 4: Total electrical energy savings by new and existing buildings in the State, in trillion Btu's.

a. i) Aggregate savings in 1978 (lines 2h + 3f) — .045 $(x10^{12})$

ii) Savings per quarter of 1978 (line 4a/4) — .011 $(x10^{12})$

b. Aggregate savings in 1979 (lines 2i + 3g) — .153 $(x10^{12})$

c. i) Aggregate savings in 1980 (lines 2j + 3h) — .271 $(x10^{12})$

ii) Energy for existing and new buildings in 1980 with no energy conservation [(line 1b x 9) + line 1a][line 1e] + [line 1b][line 1e] — 1.63 $(x10^{12})$

iii) % savings in 1980 [(line 4c i/4cii) x 100] — 16.62%

Step-wise Methodology for Calculation of Energy Savings

Wooksheet for Total Electricity Savings in Terms of Source Fuel (in trillion Btu's) for the following building type:

___Office   ___Retail Stores   X Schools   ___Hospitals   ___Other

Step 1: Projected 1978-79-80 electrical consumption for lighting in buildings in region built prior to and following effective date of program, in trillion Btu's

a. 1980 energy consumption for lighting in buildings built pre-1971 in region — 17.1 ($x10^{12}$)

b. Energy for lighting in additional buildings built in region each year since 1971 — 1.08 ($x10^{12}$)

c. Number of years program in effect — 3

d. No. of years between beginning of 1971 and time program into effect — 7

e. State/Region population ratio — .04

Step 2: Electrical energy savings for 1978-79-80 in State by buildings built prior to program effective date, in trillion Btu's

a. Projected lighting energy for existing buildings in State in 1978 [(line 1b x 1d) + line 1a][line 1e] — .976 ($x10^{12}$)

b. Projected lighting energy for existing buildings in State in 1979 [line 2a + 1b(line 1e)] — 1.02 ($x10^{12}$)

c. Projected lighting energy for existing buildings in State in 1980 [line 2b + 1b(line 1e)] — 1.062 ($x10^{12}$)

d. Fraction reduction in lighting in existing buildings (Table 3) — .20

e. Fraction of floor space affected in 1978 (Table 8) — .10

f. Fraction of floor space affected in 1979 (Table 8) — .30

g. Fraction of floor space affected in 1980 (Table 8) — .50

h. Electricity savings in existing building in 1978 (line 2a x 2d x 2e) — .02 ($x10^{12}$)

i. Electricity savings in existing building in 1979 (line 2b x 2d x 2f) — .061 ($x10^{12}$)

j. Electricity savings in existing building in 1980 (line 2c x 2d x 2g) — .106 ($x10^{12}$)

Step 3: Electrical energy savings for 1978-79-80 in State by buildings built since time of program effective date, in trillion Btu's.

a. Projected annual lighting energy for new building in State in 1978-79-80 [line 1b x 1e] — .043 ($x10^{12}$)

b. Fraction reduction in lighting in new buildings (Table 3) — .50

c. Fraction of floor space affected in 1978 (Table 7) — .10

d. Fraction of floor space affected in 1979 (Table 7) — .50

e. Fraction of floor space affected in 1980 (Table 7) — .90

f. Electricity savings in new buildings in 1978 (line 3a x 3b x 3c) — .002 ($x10^{12}$)

g. Electricity savings in new buildings in 1979 (line 3a x 3b x 3d) — .010 ($x10^{12}$)

h. Electricity savings in new buildings in 1980 (line 3a x 3b x 3e) — .02 ($x10^{12}$)

Step 4: Total electrical energy savings by new and existing buildings in the State, in trillion Btu's.

a. i) Aggregate savings in 1978 (lines 2h + 3f) — .021 ($x10^{12}$)

ii) Savings per quarter of 1978 (line 4a/4) — .005 ($x10^{12}$)

b. Aggregate savings in 1979 (lines 2i + 3g) — .072 ($x10^{12}$)

c. i) Aggregate savings in 1980 (lines 2j + 3h) — .125 ($x10^{12}$)

ii) Energy for existing and new buildings in 1980 with no energy conservation [(line 1b x 9) + line 1a][line 1e] + [line 1b][line 1e] — 1.105 ($x10^{12}$)

iii) % savings in 1980 [(line 4c i/4cii) x 100] — 11.35%

Step-wise Methodology for Calculation of Energy Savings

Wooksheet for Total Electricity Savings in Terms of Source Fuel (in trillion Btu's) for the following building type:

___Office   ___Retail Stores   ___Schools   x Hospitals   ___Other

Step 1: Projected 1978-79-80 electrical consumption for lighting in buildings in region built prior to and following effective date of program, in trillion Btu's

a. 1980 energy consumption for lighting in buildings built pre-1971 in region — 13.9 ($x10^{12}$)

b. Energy for lighting in additional buildings built in region each year since 1971 — .87 ($x10^{12}$)

c. Number of years program in effect — 3

d. No. of years between beginning of 1971 and time program into effect — 7

e. State/Region population ratio — .04

Step 2: Electrical energy savings for 1978-79-80 in State by buildings built prior to program effective date, in trillion Btu's

a. Projected lighting energy for existing buildings in State in 1978 [(line 1b x 1d) + line 1a][line 1e] — .80 ($x10^{12}$)

b. Projected lighting energy for existing buildings in State in 1979 [line 2a + 1b(line 1e)] — .826 ($x10^{12}$)

c. Projected lighting energy for existing buildings in State in 1980 [line 2b + 1b(line 1e)] — .860 ($x10^{12}$)

d. Fraction reduction in lighting in existing buildings (Table 3) — .20

e. Fraction of floor space affected in 1978 (Table 8) — .10

f. Fraction of floor space affected in 1979 (Table 8) — .30

g. Fraction of floor space affected in 1980 (Table 8) — .50

h. Electricity savings in existing building in 1978 (line 2a x 2d x 2e) — .016 ($x10^{12}$)

i. Electricity savings in existing building in 1979 (line 2b x 2d x 2f) — .05 $(x10^{12})$

j. Electricity savings in existing building in 1980 (line 2c x 2d x 2g) — .086 $(x10^{12})$

Step 3: Electrical energy savings for 1978-79-80 in State by buildings built since time of program effective date, in trillion Btu's.

a. Projected annual lighting energy for new building in State in 1978-79-80 [line 1b x 1e] — .034 $(x10^{12})$

b. Fraction reduction in lighting in new buildings (Table 3) — .40

c. Fraction of floor space affected in 1978 (Table 7) — .10

d. Fraction of floor space affected in 1979 (Table 7) — .50

e. Fraction of floor space affected in 1980 (Table 7) — .90

f. Electricity savings in new buildings in 1978 (line 3a x 3b x 3c) — .001 $(x10^{12})$

g. Electricity savings in new buildings in 1979 (line 3a x 3b x 3d) — .006 $(x10^{12})$

h. Electricity savings in new buildings in 1980 (line 3a x 3b x 3e) — .012 $(x10^{12})$

Step 4: Total electrical energy savings by new and existing buildings in the State, in trillion Btu's.

a. i) Aggregate savings in 1978 (lines 2h + 3f) — .017 $(x10^{12})$

ii) Savings per quarter of 1978 (line 4a/4) — .004 $(x10^{12})$

b. Aggregate savings in 1979 (lines 2i + 3g) — .056 $(x10^{12})$

c. i) Aggregate savings in 1980 (lines 2j + 3h) — .098 $(x10^{12})$

ii) Energy for existing and new buildings in 1980 with no energy conservation [(line 1b x 9) + line 1a][line 1e] + [line 1b][line 1e] — .90 $(x10^{12})$

iii) % savings in 1980 [(line 4c i/4cii) x 100] — 11%

Step-wise Methodology for Calculation of Energy Savings

Wooksheet for Total Electricity Savings in Terms of Source Fuel (in trillion Btu's) for the following building type:

___Office   ___Retail Stores   ___Schools   ___Hospitals   X Other

Step 1: Projected 1978-79-80 electrical consumption for lighting in buildings in region built prior to and following effective date of program, in trillion Btu's

a. 1980 energy consumption for lighting in buildings built pre-1971 in region — 36.9 $(x10^{12})$

b. Energy for lighting in additional buildings built in region each year since 1971 — 2.22 $(x10^{12})$

c. Number of years program in effect — 3

d. No. of years between beginning of 1971 and time program into effect — 7

e. State/Region population ratio — .039

Step 2: Electrical energy savings for 1978-79-80 in State by buildings built prior to program effective date, in trillion Btu's

a. Projected lighting energy for existing buildings in State in 1978 [(line 1b x 1d) + line 1a][line 1e] — 2.045 $(x10^{12})$

b. Projected lighting energy for existing buildings in State in 1979 [line 2a + 1b(line 1e)] — 2.132 $(x10^{12})$

c. Projected lighting energy for existing buildings in State in 1980 [line 2b + 1b(line 1e)] — 2.218 $(x10^{12})$

d. Fraction reduction in lighting in existing buildings (Table 3) — .20

e. Fraction of floor space affected in 1978 (Table 8) — .10

f. Fraction of floor space affected in 1979 (Table 8) — .30

g. Fraction of floor space affected in 1980 (Table 8) — .50

h. Electricity savings in existing building in 1978 (line 2a x 2d x 2e) — .041 $(x10^{12})$

i. Electricity savings in existing building in 1979 (line 2b x 2d x 2f) — .128 ($x10^{12}$)

j. Electricity savings in existing building in 1980 (line 2c x 2d x 2g) — .222 ($x10^{12}$)

Step 3: Electrical energy savings for 1978-79-80 in State by buildings built since time of program effective date, in trillion Btu's.

a. Projected annual lighting energy for new building in State in 1978-79-80 [line 1b x 1e] — .086 ($x10^{12}$)

b. Fraction reduction in lighting in new buildings (Table 3) — .50

c. Fraction of floor space affected in 1978 (Table 7) — .10

d. Fraction of floor space affected in 1979 (Table 7) — .50

e. Fraction of floor space affected in 1980 (Table 7) — .90

f. Electricity savings in new buildings in 1978 (line 3a x 3b x 3c) — .004 ($x10^{12}$)

g. Electricity savings in new buildings in 1979 (line 3a x 3b x 3d) — .021 ($x10^{12}$)

h. Electricity savings in new buildings in 1980 (line 3a x 3b x 3e) — .039 ($x10^{12}$)

Step 4: Total electrical energy savings by new and existing buildings in the State, in trillion Btu's.

a. i) Aggregate savings in 1978 (lines 2h + 3f) — .045 ($x10^{12}$)

ii) Savings per quarter of 1978 (line 4a/4) — .011 ($x10^{12}$)

b. Aggregate savings in 1979 (lines 2i + 3g) — .149 ($x10^{12}$)

c. i) Aggregate savings in 1980 (lines 2j + 3h) — .260 ($x10^{12}$)

ii) Energy for existing and new buildings in 1980 with no energy conservation [(line 1b x 9) + line 1a][line 1e] + [line 1b][line 1e] — 2.304 ($x10^{12}$)

iii) % savings in 1980 [(line 4c i/4cii) x 100] — 11.31%

ENERGY CONSERVATION IN RELATION TO LIGHTING

by

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ABSTRACT

The thesis specifically deals with energy conservation in relation to lighting. It aims at a systematic approach towards lighting conservation techniques for public and residential buildings, energy and cost savings, economic and technical feasibility and modes of implementation of the conservation measures. It explores public and industry reaction and attitudes towards energy conservation in general and lighting conservation in particular.

Both operating and capital cost savings are possible as a result of adoption of the lighting conservation measures. Substantial operating and capital cost savings resulted in the five FEA specified public buildings, for Kansas, in 1978-79-80 if an energy conservation program is implemented. There are no safety and health problems associated with the suggested measures. Public and industry attitude towards energy conservation was found to be encouraging. The public was found to be more motivated than the industry. Public and industry reactions to the lighting conservation techniques indicated that these groups believed that most of them were economically and technically feasible.

The implementation program proposed was a voluntary approach for existing public building with education-extension services and a uniform building code incorporating the conservation measures for new public building construction. A forceful and fearful publicity campaign, based on consequences of energy waste, was advocated to encourage energy conservation.