Overcoming barriers to residential energy-efficient lighting: Results of research for *The Lighting Pattern Book for Homes*

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1. SYNOPSIS

Research supporting the publication of a comprehensive book on energy-efficient residential lighting is summarized. The research includes occupant behavior, lighting quality, and economic feasibility analyses.

2. INTRODUCTION

Many barriers exist to the use of efficient lighting in the home. Utility companies, manufacturers, and environmental advocates have lacked statistically reliable quantitative and qualitative information about residents' attitudes and behaviors toward lighting, about the types of products presently used in the homes, and about the economic feasibility of energy-efficient lighting technologies.

3. METHODOLOGY

A questionnaire survey of nearly 3 000 persons' attitudes towards and beliefs about fluorescent lighting (Beckstead and Boyce 1993) suggests that lighting conservation programs that encourage the use of fluorescent lighting by promoting the cost and energy-efficient benefits will not be as effective as programs that focus on overcoming people's negative beliefs about fluorescent lighting. Surveys, roundtables, and a focus group of lighting decision makers indicate that objective, easily accessible information about lighting is necessary to encourage the use of energy-efficient lighting (Conway and Leslie 1992).

The Lighting Pattern Book for Homes illustrates prototype designs for energy-efficient lighting suitable for dwellings of low- to middle-income residents. The book addresses people's negative stereotypes about fluorescent lighting by clearly describing, illustrating, and analyzing lighting technologies, techniques, and designs. Residential energy-efficient lighting is not limited to the use of compact fluorescent lamps; for example, full-size fluorescent lamps, appropriate lighting controls, luminaire placement, and daylighting are effective alternatives.

Table 1. ***Hours of Lamp Operation and Occupancy Sensor Reduction Factor, by Room***

Room	Hours of use	Occupancy sensor reduction factor
Kitchen Area	4	0,7
Kitchen Dining Area	3	0,8
Kitchen Food Preparation Area	3	0,7
Living/Family Room	3	0,8
Main Bathroom	2	0,6
Main Bedroom	1	0,7

Research was conducted to assure that the prototype lighting designs were objective and in a format easily understood by people who influence decisions. The research included a telephone survey of 2 445 residents to establish hours of operation of lighting in five areas of the home and to determine occupancy of the lighted rooms; examination of national building data and the conduct of 40 building audits to determine typical room sizes, types of luminaires, and wattages of lamps; design sessions in which twelve experts proposed typical and energy-efficient lighting designs; comparative and economic analyses of the proposed

designs; and roundtable critiques of a draft of the book held in four different geographic regions of the United States.

Thirty-six typical rooms and lighting designs were identified. Energy-efficient design alternatives were generated to replace lamps, controls, and luminaires or to remodel the typical designs. The lighting experts and the roundtable participants evaluated whether or not the alternatives would provide equivalent lighting quality.

To evaluate the economic effectiveness, a database of typical lamps costs was created and an electricity rate of USD $0.10 (approximately 0,07 ECU) per kilowatt hour was assumed. Energy costs assumed the hours of use listed in Table 1, representing the authors' judgment and interpretation of the results from the telephone survey.

Table 2. ***Lamp Life Multipliers for Fluorescent Lamps***

Hours of Lamp Operation per Start	Lamp Life Multiplier
continuous	1,8
12	1,5
6	1,2
3	1,0
2	0,9*
1	0,7*
0,5	0,5*
0,25	0,4*

*For some compact fluorescent lamps with "soft-start" electronic ballasts, these values may be higher.

The change in average rated lamp life for fluorescent lamps due to frequency of switching was estimated using Table 2, and was derived from full-size fluorescent lamp mortality curves (Sorcar 1982).

The impact of dimming on incandescent lamps life was estimated using Table 3. Table 3 also indicates the power reduction assumptions for both fluorescent and incandescent lamps.

Table 3. ***Power Reduction Factors and Lamp Life Multipliers for Dimmers***

% of Full Light (as perceived by eye)	100	90		75		50	
% of Full Light (as measured)	100	80		56		25	
% of Time on Dimmer	0	100	50	100	50	100	50
Incandescent Lamps							
Power Reduction Factor	1	0,9*	,95	0,8*	0,9	0,5*	,75
Lamp Life Multiplier	1	2	1,3	8	1,8	20	1,9
Fluorescent Lamps**							
Power Reduction Factor	1	0,8	0,9	0,5	,75	0,3	,65

*If dimmers are used only for occasional reduction in illuminance, enter 1.0.
**Fluorescent lamp life is not significantly affected by dimming, so enter 1.0.

4. RESULTS

The typical spaces that were analyzed included 3 dinettes or dining rooms, 5 kitchens, 5 bathrooms, 3 bedrooms, 7 living or family rooms, 1 home office, 7 foyers, stairs, or hallways, and 5 outdoor spaces. For these rooms, 43 relamping designs, 16 replacements of controls, 24 replacements of luminaires, and 27 remodeled or new designs passed the quality evaluation review and had reduced annual operating costs compared to the 36 typical designs. The average percentage reduction in annual operating cost for the 110 alternative designs compared to the typical designs was 47 percent. Figure 1 compares the average annual operating costs of the typical designs versus the alternatives.

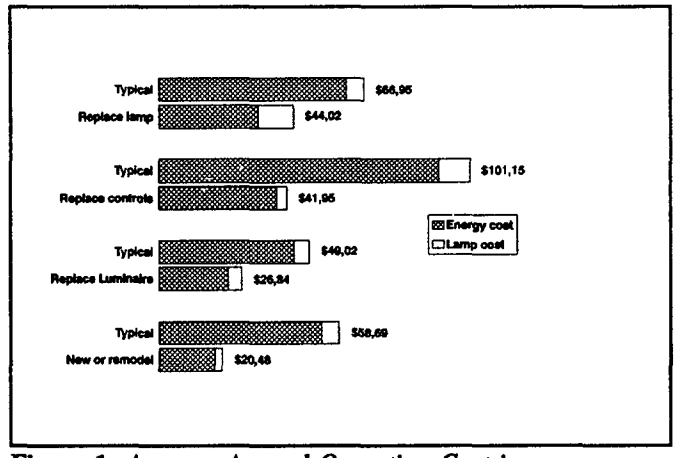

Figure 1. ***Average Annual Operating Cost in $USD for Residential Lighting Designs***

The relative effectiveness of the alternatives, however, is largely dependent on energy and lamp replacement costs, hours of operation, and frequency of switching. For example, consider one of the typical designs: a small bathroom containing a vanity light with three 60-watt G-25 incandescent lamps controlled by a wall mounted switch.

Replacing the existing lamps with electronically self-ballasted 15-watt globe compact fluorescent lamps provides slightly lower illuminance. Replacing the wall switch with a manual on-automatic off occupancy sensor is a control option. Alternatively, the luminaire could be replaced with another luminaire containing two 18-watt fluorescent twin lamps. A remodeling option uses a soffit light with one 32-watt T-8 rare-earth linear fluorescent lamp. Figure 2 compares the annual operating costs of these alternatives.

Relamping with compact fluorescent lamps saves a significant amount of energy compared to the typical design. However, the short time of operation per start (assumed to be half an hour per start) reduces lamp life, yielding only a modest decrease in annual operating costs. Although some manufacturers are offering "soft start" compact fluorescent lamps, the impact of switching on compact fluorescent lamps is still not well understood.

The potential operating cost savings for compact fluorescent lamps controlled by occupancy sensors are also reduced when the lamps are switched frequently. Installing an occupancy sensor on the typical design, however, reduces annual operating cost by 40%, assuming that the occupancy sensor reduces the daily operating hours from 2 hours to 1,2 hours.

A more efficient luminaire is a larger initial investment than relamping but should be considered. In this example, the luminaire reduces annual operating costs by 60%, even though the lamp replacement costs are similar to those of the typical case.

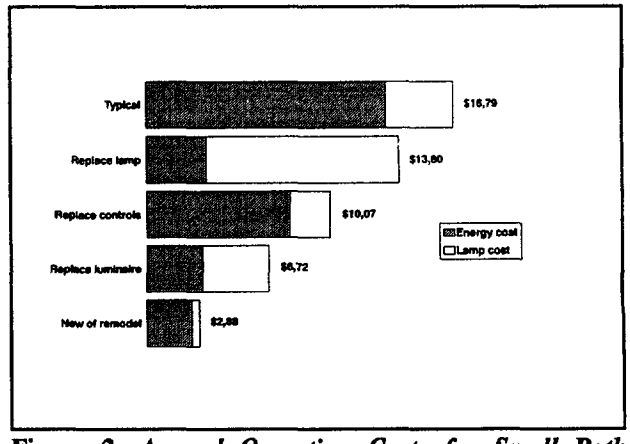

Figure 2. ***Annual Operating Costs for Small Bath Design at USD$0.10 per kWh***

Where one is able to relocate the luminaire during remodeling or new construction, further savings are realized by using full-size fluorescent lamps, available in higher efficacies and lower cost compared to compact

fluorescent lamps. The savings in annual operating costs is 83% over the typical case for this design.

As the annual operating costs are reduced, the potential impact of occupancy sensors is also reduced. They are best used to switch multiple incandescent lamps.

5. CONCLUSION

The Lighting Pattern Book for Homes offers viable strategies for simple relamping, control and luminaire replacement, and new or remodeled rooms. In general, the more an owner is willing to replace and/or relocate luminaires, the greater the potential for annual operating cost savings. Products such as interval timers and night lights can also provide high potential savings.

The roundtables and the research also indicate the need for new products available for residences. For example, "soft start" compact fluorescent lamps that can reduce the impact of short time of operation per start on lamp life are important for achieving full cost savings with compact fluorescent lamps. Many of the designs use full-size fluorescent lamps installed in soffits, valances, or coves. A commodity-grade strip luminaire that holds T-8 lamps and electronic ballasts and is available through residential distribution channels will facilitate energy-efficient lighting in homes.

The analysis methodology and research results provide a framework for economic and qualitative analysis of alternative designs for residential energy-efficient lighting.

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