RESEARCH HIGHLIGHT

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Benchmarking Home Energy Savings from Energy-Efficient Lighting

INTRODUCTION

Energy-efficient, compact fluorescent lighting (CFL) has been on the market for several years. Today's lower costs, easy availability and variety of configurations make CFL more appealing to homeowners.

Energy and cost-saving claims by CFL manufacturers are typically based on the difference in power consumption between CFL and incandescent bulbs with similar lighting performance. This approach does not take into account the "systems" effect of lighting energy consumption on space heating and cooling energy consumption.

To better understand the net overall energy impact of CFL in homes during heating and cooling seasons, Natural Resources Canada (NRCan) developed a detailed field research plan to monitor energy usage in the CCHT[1] test house with and without CFLs installed. The testing helped to develop and validate the internal gains model associated with lighting energy use.

RESEARCH PROGRAM

A 1997 NRCan study monitoring 134 homes generated profiles of lighting energy use in homes.[2] The average residential lighting energy use is 3.4 kWh per day or roughly 1,350 kWh/year—about 15 per cent of total electricity use. Lighting accounts for five to eight per cent of annual utility bills. Average peak demand is about 0.65 kW per house during winter months and about 0.5 kW during summer months.

While the monitoring provided insights regarding residential lighing energy use, it did not assess the impact of lighting energy use and CFL retrofits on overall residential energy use. While CFL retrofits can be expected to increase space heating energy use, it will also reduce space cooling energy use. To better understand how lighting and energy-efficient lighting retrofits impact on household energy use, NRCan initiated a lighting study at the CCHT.

The research program had three objectives:

1. Benchmark testing of CFL and incandescent lighting using a reference house and a test house.
2. Verify internal gains model for residential energy analysis program.
3. Estimate the "take-back" effects[3] of CF lighting in homes in various regions. Benchmark testing included measuring power demand and lighting performance of conventional lighting and CFL and comparing the impact of CFL retrofits during the heating season.

1 The Canadian Centre for Housing Technology (CCHT) is a partnership. The Centre is jointly operated by the National Research Council (NRC), Natural Resources Canada (NRCan) and Canada Mortgage and Housing Corporation (CMHC). The CCHT research and demonstration facility features two highly instrumented, identical, two-storey houses with full basements. The houses, each 210 m^2 (2,260 sq. ft.), are built to R-2000 standards and use simulated occupancy to evaluate the whole-house performance of new technologies in side-by-side testing. The CCHT also has an Info Centre that includes a demonstration of FlexHousing™.
For more information about CCHT, go to http://www.ccht-cctr.gc.ca

2 Based on data from 134 existing homes monitored between 1990 and 1994. Nova Scotia report (NRCan) 1993; Efficiency Housing Database – Alberta (NRCan) 1993; Field Energy Audit Survey (NRCan) 1994, BC; Espanola Energy Efficiency Housing Retrofit Program, Ontario Hydro, Scanada 1989, ON; Airtightness and Energy Efficiency of New Conventional and R2000 Housing in Canada (NRCan) 1997.

3 The "take-back" effect refers to the increased space heating requirements in winter (or reduced cooling energy use in summer) caused by the reduced lighting energy use and lower internal gains from CFL.

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METHODOLOGY

At the CCHT facility, conventional lighting included incandescent lamps, fluorescent ceiling fixtures, halogen flood lights and exterior high-wattage security lamps, for an average of 27 fixtures per house—some with multiple lamps. All light bulbs were checked and the voltage, power, light intensity, power factor (PF), volt-amps reactive, volt-amps and harmonics, were measured and recorded.

To analyze the internal gains and heat loss, the daily total heat losses were established for the test and reference houses. Hourly energy analysis was performed for the duration of the test period using the measured weather data (mainly outdoor temperature and solar contribution).

During heating season testing, two modes of HRV ventilation were used.

1. Continuous ventilation: as might be used in new homes. The HRV kept ON throughout the test period, running at full capacity when the furnace was operating and at half capacity when there was no call for heating.
2. Intermittent ventilation: The HRV was operated at full capacity only during the heating periods.

The cooling season tests compared air conditioning loads, temperature profiles and the energy use for both test and reference houses, keeping all aspects identical. The set-up for CFL lighting was similar to the heating season testing of two different lighting fixtures, using all previously calibrated lamps for the test period.

Using energy analysis software, a base case model was created for 33 locations in North America (11 in Canada and 22 in the U.S.). This was a two-storey house (about 186 m^2 [2,000 sq. ft.]) with five conventional bulbs of 77 W used three hours a day. The conventional lighting was then replaced by 19 W CFL. Table 1 shows the impact of CFL.

FINDINGS

Benchmarking

The measured power draws for the incandescent and CFL compare well with the manufacturer's specifications. The power factor of the incandescent lamps was 1.0, while that of the CFL ranged from 0.56 to 0.59. However, at the household level the decrease in power factor due to CFL ranged from 0.04 to 0.10. The CFL decreased the overall power factor for the house from 0.04 to a maximum of 0.10.

Figure 1 Compact fluorescent lamp in a test house

Heating Season Monitoring Results

With conventional lighting, between 89 to 96 per cent of lighting energy use is converted to heat and contributes to space heating as internal gains. The few losses associated with lighting energy occurred mainly where lights were located close to windows. When the conventional lighting was replaced, there was a 68 per cent reduction in daily lighting energy use during the heating season. The resultant space heating energy increase was due to the decrease in internal gains of about 28.6 MJ per day. The reduction in the lighting energy use was almost offset by the increase in the space-heating energy use. Ventilation, continuous or intermittent, had no appreciable impact on the overall energy savings associated with CFL.

Cooling Season Monitoring Results

The CFL reduced the lighting energy consumption by about 68 per cent. The energy consumption of the air conditioner compressor and the air distribution fan was reduced to 2.1 from 3.8 kWh per day, depending on ambient conditions, with an average 14 per cent daily reduction. As a result of the reduction in internal heat gains the energy consumption of the air conditioner compressor and the air distribution fan was reduced on average by 14 per cent depending on ambient conditions, for a saving of 2.1 to 3.8 kW per day. The use of CF lighting also reduces the on-time of the cooling equipment by 20 per cent or more. The energy analysis showed that about 78 per cent of the internal heat gains from lighting are associated with cooling energy needs. Reductions in the lighting energy also reduced the space cooling requirements. The resulting energy-efficiency benefits associated with the lighting energy savings and space cooling energy savings are additive.

Internal Gains and Heat Loss Analysis

On average, there is about 93 per cent utilization of heat from conventional lighting over the heating season. Electrical energy savings are about 318 kWh per year — a reduction of about 26 per cent in lighting space heating season energy consumption.

For heating-dominated regions, the increase in annual space heating energy consumption (due to reduced internal heat gains) is about 0.6 to 1.7 per cent.

For cooling-dominated regions, the reduction in space-cooling energy consumption ranged from four to 9.5 per cent, while the reduction in on-time operation of cooling equipment ranged from 15 to 22 per cent. The CFL reduced the peak electric power demand by 0.2 to 0.4 kW.

In a heating-dominated region, the "take-back" effect associated with CFL reduced the cost benefits by up to 40 per cent, whereas in a cooling-dominated climate, there was an "additive" effect, increasing the savings by up to 30 per cent (see Table 1). Assuming a retrofit cost of $40 for the five CFLs modelled in this analysis, the simple payback period is two to six years.

Table 1 Impact of lighting energy reduction (of 318 kWh a year), due to CFL retrofit

	Space Heating Increase	Space Cooling Decrease—kWh/yr.	Cost savings—Lighting only—$/yr.	Overall cost benefits—$/yr.	Take-back effect
Vancouver	22 m^3	49	20	12	60%
Vancouver	201 KWh	49	20	10	50%
Edmonton	28 m^3	38	26	22	85%
Saskatoon	25 m^3	59	29	24	83%
Winnipeg	26 m^3	61	19	11	58%
Toronto	23 m^3	63	27	22	81%
Sudbury	222 KWh	26	27	10	37%
Ottawa	24 m^3	53	27	21	78%
Montréal	182 KWh	54	20	12	60%
Quebec City	184 KWh	55	20	12	60%
Saint John	25 L	60	24	9	38%
Saint John	233 KWh	60	24	11	42%
Halifax	22 L	52	31	20	65%
Halifax	220 KWh	52	31	15	45%
St. John's	30 L	40	28	11	39%
St. John's	270 KWh	40	28	8	25%
Fairbanks, Alaska	29 m^3	18	38	27	71%
Los Angeles	5 m^3	72	38	44	116%
San Francisco	14 m^3	34	38	36	95%
Denver	18 m^3	37	26	20	77%
Miami	0 m^3	96	27	35	130%
Chicago	18 m^3	38	27	21	78%
Boston	20 m^3	32	37	32	86%
Minneapolis	20 m^3	33	25	18	72%
New York	17 m^3	40	45	43	96%
Madison, Wisconsin	20 m^3	34	28	21	75%
Seattle	21 m^3	25	20	12	60%
M^3 – natural gas, kWh – electricity, L – litres of fuel oil					

CONCLUSIONS AND IMPLICATIONS FOR THE HOUSING INDUSTRY

Energy-efficient lighting systems do affect space-conditioning requirements. During the heating season, CFL increases the space-heating energy use. During the cooling season, CFL reduces the space-cooling demand and energy requirements.

Overall, the cost savings are positive in all climates, although the interaction effects reduce savings in most cases. Actual energy savings depend on the climate in which the house is located. The findings indicate the importance of the "House as a System" approach in evaluating the overall energy-efficiency impacts and benefits from CFL in Canadian and U.S. homes.

A full report on this project is available from the Canadian Centre for Housing Technology.

The Canadian Centre for Housing Technology (CCHT)

Canada Mortgage and Housing Corporation (CMHC), The National Research Council (NRC) and Natural Resources (NRCan) jointly operate the Canadian Centre for Housing Technology (CCHT). CCHT is a unique research, testing and demonstration resource for innovative technology in housing. CCHT's mission is to accelerate the development of new housing technologies and their acceptance in the marketplace. CCHT operates a Twin-House Research Facility, which offers an intensively monitored, real-world environment. Each of the two identical, two-storey houses has a full basement. The houses, 210 m^2 (2,260 sq. ft.) each, are built to R-2000 standards. For more information about the CCHT Twin-House Research Facility and other CCHT capabilities, visit http://www.ccht-cctr.gc.ca

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

To find more ***Research Highlights*** plus a wide variety of information products, visit our website at

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