Lighting Industrial Facilities: An Untapped Source of Energy Savings

John Freeman, Elena Gryadovkina and Sandra A. Raitz, Ontario Hydro
Erik Haites and Paul Parfomak, Barakat and Chamberlin

Industrial lighting offers important conservation opportunities, but is too frequently overlooked by Demand Supply Management planners. This inattention is exacerbated by a serious lack of information regarding the characteristics of lighting systems in industrial facilities. Although lighting loads are smaller than other industrial loads, they are still substantial and have a very high potential for energy savings. This potential can be realized using programs that rely on skilled professionals to identify and install appropriate lighting efficiency measures and that provide cash rebates and financing arrangements to help overcome the financial barriers.

This paper reports the results of a comprehensive regional study of industrial lighting. It describes an innovative approach used to identify lighting system characteristics, market attitudes and conservation opportunities for every industrial sector in Ontario. Recommendations on developing industrial lighting programs are also represented. The lighting data were compiled through surveys of major lighting contractors, consultants, equipment vendors, and a random sample of nearly 200 industrial facilities in the province. These surveys were supplemented by on-site audit data for over 2,600 plants in the United States.

The results indicate that relatively inefficient fluorescent lighting is far more prevalent in industrial plants than is commonly believed. Although financial concerns and lack of education are major barriers to lighting improvement, many managers are aware of lighting efficiency opportunities. Of the 2,400 GWh consumed annually for industrial lighting in Ontario, savings of nearly 800 GWh, one-third of the consumption, could be achieved through lighting efficiency improvements. Industrial customers consider their utility the best source of information and assistance for upgrading their lighting systems.

Introduction

Ontario Hydro, Canada's largest public utility and the only producer and wholesaler of electricity in the province, is currently implementing a number of technology-based programs as part of its Demand Side Management strategy. One of the areas identified for demand side savings is lighting in industry. The utility's Energy Management and Corporate Relations Market Research Department was asked to quantify the potential savings that could be realized through lighting efficiency improvements in Ontario's industry and a research firm was retained to conduct the study.

The purpose of the study was to document the lighting systems currently in place in Ontario industry, evaluate the technical, economic and achievable efficiency improvement for industrial lighting systems, and identify the barriers to adoption of those improvements.

Technical, economic and achievable potential is defined as follows:

Technical Potential

Technical potential is the reduction in electrical demand that could be achieved in a given year if all technically possible improvements were made without regard for cost or people's preferences.

Economic Potential

Economic Potential is Technical Potential less savings that are not economic. In this situation, "economic" refers to energy savings where the total cost of the efficiency improvements measure to the customer and to the utility is less than the marginal cost of additional supply.

Achievable Potential

Achievable Potential is defined as the total cost effective electricity savings available in the market place (equivalent to complete replacement of eligible equipment) that are economic, yet require the utility's intervention to be attractive to customers. This intervention is required to overcome barriers to penetration of energy efficient technologies which exist in the market place. Intervention may be in the form of financial incentives or services or higher efficiency standards required by the utility. The energy efficient technologies usually face one or more significant barriers to penetration.

Research Approach

The study covered industrial lighting systems in all industry sectors including mining.

Telephone surveys were conducted with the following groups:

- Manufacturers and distributors of lighting products (16);
- Lighting contractors and consultants (14); and
- Industrial plants (196).

The number of plants in the mining and manufacturing sectors is estimated to be 22,392. A sample size of 200 was established for the plants and mines, and 196 plants were actually surveyed.

In addition, recommendations by type of lighting measure, estimated costs and savings by recommended measure, and implementation rates were obtained for over 2,600 on-site energy audits of small- and medium-sized facilities[1].

Highlights of Lighting Manufacturers and Consultants/Contractors Surveys

Manufacturers

- 75% sell to both industrial and commercial customers, the rest focus on the commercial sector;
- Only 25% sell directly to industrial customers, the rest sell to industrial customers via distributors;
- Site visits are considered to be the most effective sales method; and
- Most believe efficiency is a key consideration for industrial customers.

Lighting Consultants/Contractors

- 43% of their business is with industrial facilities;
- Most of their industrial work centers around the design or installation of new systems;
- Fluorescent, high pressure sodium and metal halide each represent 25-30% of business; and,
- Contractors/consultants estimate that 18% of industrial space is overlit, a lower percentage than in the commercial sector.

Contractors and vendors estimate the potential energy savings for the types of lighting systems found in industrial plants to be approximately 33% of the lighting load.

Highlights of End-user Surveys

Industrial Lighting Electricity Use

- Industrial lighting represents 850 MW in demand and 2,400 GWh of electricity consumption and accounts for 5.5% of total industrial load.
- Lighting accounts for about 1% of the total load for energy-intensive industries such as mining, pulp and paper, and petroleum refining.
- Lighting represents over 40% of total load for tobacco, machinery and printing industries. Table 1 provides further information on the industries with the largest lighting loads.

Lighting System Electricity Use

- High-intensity discharge systems (mercury vapour, metal halide, high pressure sodium) make up the largest loads, provide the greatest illuminance and have the longest operating hours. These are followed by fluorescents and incandescent in that order. This is consistent with efficient lighting design[2].

Table 1. Industries with Largest Lighting Loads

SIC	Industry	Total MW	Total GWh	Average KW/Plant
31	Machinery Industries	150	400	40
30	Fabricated Metal Products	125	350	45
35	Non-Metallic Minerals	85	190	110
15/16	Rubber & Plastic	80	260	80
28	Printing & Publishing	80	240	30

- Lighting system electricity use is summarized in Table 2.

Electrical Efficiency Improvement Potential for Industrial Lighting

The consultants used the study results, Energy Analysis and Diagnostic Center data, other studies and their own best judgement to arrive at the estimates presented in Table 3. Technical potential is estimated at 60% of lighting load, economic potential is estimated at 80% of technical potential and achievable potential, given Ontario Hydro's programs, is estimated at 65 to 70% penetration of the economic potential.

Electrical Efficiency Improvement Potential by Lighting System. Although the manufacturers, contractors and consultants were requested to provide estimates of technical potential, the utility's consultants believe that the estimates actually provided represent achievable potential. The electrical efficiency improvement potential of 33% of lighting load (which equals 280.5 MW) estimated by this group agrees with the achievable potential estimate (250 MW) presented in Table 3. The achievable potential estimate is also consistent with the audit results, which had an average of a one year payback and a 70% implementation rate.

The graph in Figure 1 illustrates the estimated savings by type of lighting system.

Profile of Lighting System Users

The survey of industrial customers found industry to have the following characteristics:

- average of 33.5 employees per plant;
- average plant operates 10 hours per day, 5 days per week, 50 weeks per year; and

Table 2. System Electricity Use

	Fluorescent	Incandescent	Mercury Vapour	High-Pressure Sodium	Metal Halide
Average Lamp Wattage (W)	57.3	169.6	783.9	376.8	395.7
Average Ballast Wattage (W)	11.5	0	78.4	47.1	49.5
System Demand (KW)	10.0	2.9	27.7	21.6	23.4
Annual Hours	2,720	2,903	2,877	3,636	3,400
System Energy (MWh)	27.2	8.4	79.7	78.5	79.6
% of System Lighting	10%	3.1%	29.1%	28.7%	29.1%

Table 3. Technical, Economic, and Achievable Potential for the Utility System

Technical Potential 60% of Lighting Load	500 MW	1,450 GWh ±20%
Economic Potential 80% of Technical Potential	400 MW	1,150 GWh ±20%
Achievable Potential 65-70% Penetration	250 MW	750-800 GWh ±20%

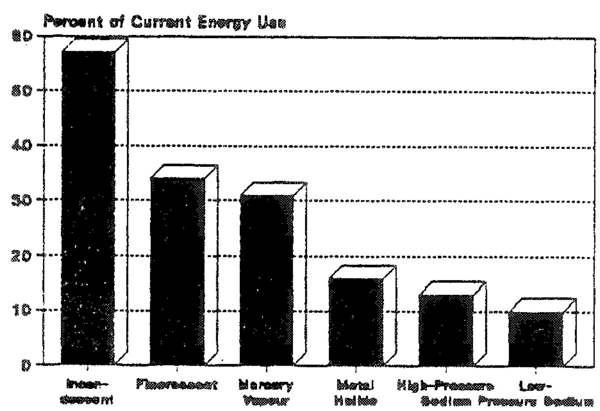

Figure 1. Estimates of Potential Savings from Consultants, Contractors, and Vendors

- average plant uses 2,826 lighting hours per year, (2500 lighting hours for plant operation and the remainder to provide lighting for cleaning staff, safety lighting etc.)

Profile of Lighting Systems Used

Fluorescent lighting is by far the dominant type of system in industrial facilities. Figure 2 shows the breakdown of connected load by lighting type.

Fluorescent lighting accounts for:

- 94% of "office" lighting;

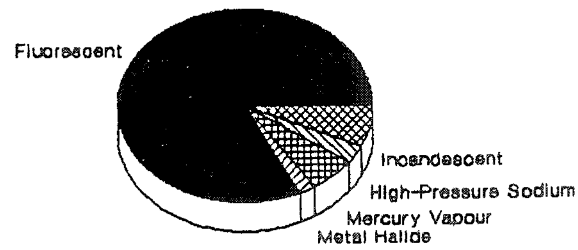

Figure 2. Lighting Systems Used in Industry

- 73% of the lighting in "small assembly" and "medium assembly" handling areas; and
- 55% in "storage/large assembly" areas.

Lighting System Operating Characteristics

The number of fixtures per lighting area varies with the type of lighting system[3]. Since areas are defined on the basis of lighting requirements, the floor space in each case can be different.

- 50-55 luminaires per lighting area for fluorescent, high-pressure sodium and metal halide;
- 32 luminaires per lighting area for mercury vapour; and
- 16 luminaires per lighting area for incandescent.

High pressure sodium and metal halide systems are newer:

- 10-12 year average age for fluorescent, incandescent, and mercury vapour; and
- 5-6 year average age for high-pressure sodium and metal halide.

Automatic controls and overlighting are relatively uncommon:

- 27% of the incandescent lighting load is used for task lighting, the remainder is used for general lighting;
- 27% of high pressure sodium systems are automatically controlled while only 3% of fluorescent systems are similarly controlled; and

- fewer than 26% of end-users felt that they could reduce their lighting level.

Satisfaction with existing lighting systems is high; over 75% of end-users are satisfied with their lighting system, regardless of system type.

Selection of Lighting Systems

Decisions Makers

In all plants, senior management approves the majority, (68%) of lighting projects. However, senior management only initiates lighting projects 14% of the time. In larger plants (over 50 employees), maintenance managers and plant managers share the responsibility for initiating lighting projects. Consultants were only cited as project initiators in smaller plants (10-50 employees).

Decision-Making Criteria

The following were equally important to end-users when selecting lighting systems:

- longer equipment life;
- low maintenance;
- higher energy efficiency;
- lighting quality; and
- frequency of maintenance.

The initial cost of the lighting system was not rated as important as the above characteristics, which suggests that customers are willing to pay a premium for improved performance. Most industries are not concerned about the choice of manufacturer as long as the equipment is approved by an independent product testing agency.

Operating cost is the most common economic criterion for lighting projects, followed by capital cost, payback and life-cycle cost.

Awareness of Energy Efficiency Improvements

The lighting efficiency measure most often considered by Ontario industry is an increase in wall and ceiling reflectance, which 58% of the plants in the survey claimed to have considered and which 84% of those who considered this measure claim to have implemented. The next most common measure is increased use of daylighting, which nearly 40% of plants considered and 87% implemented. This contrasts sharply with the recommendations in the Energy Analysis and Diagnostic Center audits which found painting to improve reflectance and increased use of daylight to be the measures with the longest paybacks and the lowest implementation rates.

Table 4 lists lighting efficiency measures considered and the implementation rate for those that considered each measure:

Forty-three percent of industrial customers consider lighting to be a major load in their plant and 44% are aware of the utility's lighting efficiency program (Note that the sample was selected to exclude participants in the lighting program).

Only 17% of those surveyed made any lighting improvements in the past year and only 17% are planning to make lighting improvements in the coming year.

Barriers to Energy Efficiency Improvements

The greatest barrier to lighting efficiency identified by respondents is the requirement of major plant changes, which was cited by 77% of all plants. Although a lighting project may require a plant shutdown, most do not require a major change to the plant[4]. This reflects lack of knowledge about lighting system changes and retrofits on the part of the end-user.

Therefore, we feel that the actual fraction of plants where major plant changes are a barrier is probably much lower than 77%.

Cash flow and return on investment are virtually tied as the next greatest barrier, being cited by over 67% of all respondents. Since efficient lighting reduces operating costs, we conclude that these data make it clear that capital cost concerns are the dominant barrier to energy efficient lighting in plants in Ontario.

Although the awareness of the utility's program is relatively high (44% of the plants surveyed), the barriers to reaching the achievable potential are initial cost/cash flow and lack of knowledge/time on the part of plant staff.

The Utility's Industrial Lighting Program should address these barriers by:

- using skilled professionals to identify and install appropriate lighting efficiency measures; and

Table 4. Energy Saving Measures Considered and Implemented

Measure	Percent That Consider Measure	Percent of Those That Implemented
Paint walls & ceiling a more reflective color	58.3	83.5
Take advantage of available daylight	39.9	87.0
Use reduced-wattage equipment	30.2	55.6
Convert to more efficient light sources	22.1	35.3
Remove inefficient lamps from plant stocks	20.6	60.2
Use high-efficiency equipment	18.4	36.4
Switch from area lighting to task lighting	15.4	77.3
Install reflectors	13.2	56.8
Use timers, motion sensors & photocell controls	12.1	53.7
Reduce general overlighting	11.1	62.2

- providing cash rebates and financing arrangements to help address the financial considerations.

Conclusions

A survey of lighting in industrial facilities in Ontario found that about 2,400 GWh of energy, or 5.5 percent of industrial electricity use is for lighting. Relatively inefficient fluorescent lighting is by far the most prevalent form of lighting in industrial plants. Automatic controls and other efficiency measures are still relatively uncommon.

Savings of approximately 800 GWh, one-third of the lighting load, are estimated to be achievable with programs that offer lighting audits, contractor installation and financial incentives with an option for utility financing of the customer's share of the cost. An effective program for efficient lighting in the industrial sector must address the barriers of lack of technical knowledge of the available options and cash flow impacts of lighting retrofits. Implementation must be accomplished in a manner that does not disrupt production.

Endnotes

1. The results of the energy audits were obtained from the Energy Analysis and Diagnostic Centre (EADC) in Philadelphia.

2. The Illuminating Engineering Society of North America (IES) *IES Lighting Ready Reference* provides guidelines for efficient lighting design.

3. Lighting area definitions are based on definitions provided in the *IES Lighting Ready Reference.*

4. Barakat & Chamberlin. 1991. *Potential Energy Improvements for Industrial Lighting Systems in Ontario,* prepared for Ontario Hydro, Toronto, Ontario. p. 31.

References

1. Barakat & Chamberlin. 1991. *Potential Energy Improvements for Industrial Lighting Systems in Ontario,* prepared for Ontario Hydro, Toronto, Ontario.

2. Illuminating Engineering Society of North America. 1989. *IES Lighting Ready Reference.* Illuminating Engineering Society of North America, New York, N.Y.