Update From North America: U.S. and Canadian Lighting Regulations and U.S. Fluorescent Ballast Standards

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ABSTRACT

In the first section of the paper, we give a brief review of major Canadian and U.S. lighting regulatory activities since 1995. In Canada, the U.S. lamp regulations were adopted and progress was made on the national energy code. Fluorescent ballasts were already regulated. In the U.S., the Energy Policy Act of 1992 (EPAct) inspired a voluntary fluorescent luminaire program, lamp test procedures, and adoption by the states of the ASHRAE/IES[1)] 90.1-89 building code. We discuss the harmonization efforts between the two countries on lighting regulations.

Fluorescent lamp ballasts returned to the regulatory spotlight in the United States beginning in 1994 and are a high priority product for the Department of Energy (DoE). The second section of the paper covers a history of the existing and proposed standards and describes the current process for developing standards including changes due to 1996 legislation. This section presents an overview of the ballast analysis methods, and results of the engineering/economic (life cycle cost) analysis, the analysis of variability of parameters, and the national energy forecasts of electricity consumption for lighting.

NORTH AMERICAN LIGHTING REGULATIONS UPDATE

Canada: Lighting Product Regulations

Canada's *Energy Efficiency Act* was proclaimed in January 1993. This authorizing legislation gives the government broad regulatory powers to select energy-using equipment for regulation, prescribe energy efficiency levels and labels for this equipment and specify compliance requirements.

Natural Resources Canada (NRCan) is responsible for the development and administration of the *Energy Efficiency Regulations* for energy-using equipment. NRCan conducts widespread consultation with equipment manufacturers and suppliers, industry associations, electric utilities, consulting firms and other governments during the development of equipment energy efficiency regulations.

NRCan utilizes Canada's National Standards System (NSS) for consultation on equipment test procedures and possible minimum efficiency levels and as a component of the regulatory compliance program. The Canadian Standards Association (CSA) is part of the NSS and is accredited by the Standards Council of Canada (SCC) to develop National Standards of Canada for electrical products. NRCan supports and participates in the work of the CSA equipment energy performance technical committees.

Fluorescent lamp ballasts were regulated in the first *Energy Efficiency Regulations* ("the Regulations") which came into effect on February 3, 1993. Regulations for fluorescent lamps and incandescent reflector lamps came into effect on February 1, 1996 and April 1, 1996 respectively. Regulated ballasts manufactured on or after February 3, 1995, cannot be imported into Canada or shipped between provinces unless they meet the requirements. Regulated lamps are subject to the same conditions, regardless of their date of manufacture. The Regulations apply to all regulated lighting products, regardless of whether they are shipped as stand-alone products or as components of lighting fixtures.

The provincial regulations apply at the point of sale within the particular province. In Canada, federal regulations do not take precedence over provincial regulations. Therefore, products that are imported into a province with regulations have to comply with both the federal and provincial regulations. In the U.S., in contrast, federal regulations preempt state regulations.

Five Canadian provinces, Ontario, British Columbia (B.C.), Quebec, Nova Scotia and New Brunswick have similar regulations for fluorescent lamp ballasts. Ontario and B.C. have also implemented regulations for incandescent reflector lamps and are looking at adopting the regulations for fluorescent lamps. In addition, Ontario and B.C. have regulated compact fluorescent lamps and cobra head luminaires based on recently published CSA standards for compact fluorescent lamps and roadway lighting (cobra head, dusk-to-dawn and high mast luminaires).

The Regulations apply to fluorescent lamp ballasts designed for an input of 120, 277 or 347 volts and intended for operation with: (1) 1220 mm (4 foot) lamps: F32T8 (26 mm diameter), F40T12/ES (38 mm reduced wattage or "energy saver), F40T10 (32 mm) or F40T12 (38 mm) rapid-start lamps and (2) 2440 mm (8 foot) 38 mm diameter lamps: F96T12 instant start, F96T12ES, F96T12HO (high output) or F96T12HO/ES lamps. The regulations specify standards only for 1- and 2-lamp ballasts. [2)]

Fluorescent lamp ballasts must meet the minimum ballast efficacy factors established in the CSA standard [3)]. The Canadian standards for fluorescent lamp ballasts are similar to the existing U.S. standards. The two exceptions are that Canada regulates ballasts that drive F32T8 lamps, and established standards for ballasts designed for an input of 347 volts.

The standards for fluorescent lamps and incandescent reflector lamps are harmonized with the standards specified in the U.S. EPAct. Regulated fluorescent lamps include: most standard 1220 mm rapid start lamps, 560 to 635 (2 foot) U-shaped rapid start lamps, 2440 instant start lamps, and 2440 high-output rapid start lamps. As in the U.S. regulations, the full wattage halophospor T12 lamps are effectively prohibited.

Regulated incandescent reflector lamps have R, PAR or similar shapes (elliptical reflector – ER and bulged reflector – BR shapes are excluded), E26 medium screw bases, diameters greater than 70 mm, a nominal voltage or a voltage range at least partially between 100 and 150 volts and a nominal power of 40 to 205 watts. [4)] As in the U.S. regulations, standard and reduced-wattage reflector lamps are effectively prohibited, while halogen reflector lamps and others that are more efficacious comply.

There are no lamp labeling requirements in Canada that are similar to those in the U.S. EPAct legislation. However, regulated lighting products must carry a verification mark indicating that the energy performance of the product has been verified. The verification mark is from an SCC-accredited certification organization that administers an energy performance verification program for the product. This requirement for third party verification of the energy performance of regulated lighting products is significantly different from the U.S. requirements. The U.S. regulations require manufacturers to certify the energy performance of their products using energy performance information obtained from National Voluntary Laboratory Accreditation Program (NVLAP) accredited testing laboratories.

The Regulations also contain requirements related to reporting of the products' energy performance information to Natural Resources Canada (NRCan) as well as information to be provided on customs documents. NRCan maintains a database of complying products for use in compliance monitoring, inspection activities and publications.

NRCan plans to initiate a study to evaluate the establishment of energy efficiency standards for ER and BR shaped incandescent reflector lamps. This study will also include an examination of an issue raised regarding an increased energy efficiency standard for incandescent reflector lamps falling in the 61–66 Watt range. In addition, NRCan intends to recommend the adoption of the U.S. procedures and definitions for specific types of exempted fluorescent lamps and incandescent reflector lamps (see U.S. incandescent reflector lamp standards below). NRCan may also investigate the feasibility of establishing energy efficiency standards for other lighting products including roadway lighting and exit signs.

Harmonization with existing energy efficiency regulations in other jurisdictions is a major consideration during the development of equipment energy efficiency standards. Although there are a few exceptions, Canadian regulations are essentially harmonized with those in effect in the U.S., prescribing the same equipment and specifying the same energy efficiency standards for this equipment. For lighting product regulations, it is NRCan's policy to harmonize with the U.S. regulations to the greatest extent possible. In addition, NRCan carries out extensive economic analyses to ensure that proposed equipment energy efficiency standards will provide positive economic benefits for Canada.

NRCan is actively involved in identifying energy-using products that might be suitable for regulation through the establishment of energy efficiency standards. To this end, NRCan has conducted a study examining the energy savings potential for certain commercial and industrial energy-using equipment. Lighting products were included in this study.

Communication and consultations with affected parties are key to the promotion of standards. NRCan has learned that it cannot rely solely on the Canadian National Standards System to promote energy efficiency standards and initiates a number of communication activities during the development of product standards including large information mailings, regulation workshops and one-on-one meetings. NRCan sees the current interest in regional/international harmonization as another means to promote standards and advocates increased participation in the global standards making process through the IEC. NRCan is also involved in the activities of APEC, the Free Trade of the Americas and Hemispheric Trade Liberalization.

Canada: National Energy Code For Buildings

The *Model National Energy Code for Buildings* (MNECB) establishes minimum standards of construction for building components and features that affect a building's energy efficiency. The Code includes envelope requirements based on life cycle costing that are sensitive to regional energy and construction costs. Optional compliance paths similar to those found in ASHRAE/IES 90.1 give flexibility to the designers.

Produced by the Canadian Commission on Building and Fire Codes, the MNECB is a model code that can be used by building designers, developers and contractors across Canada to design cost-effective, energy-efficient buildings. Research to support its development has been provided by NRCan, provincial energy ministries, the Canadian Electricity Association and the National Research Council of Canada. As with the National Building Code of Canada (NBCC), this code can be adopted (or adapted) by any Canadian province or territory. Several provinces are currently considering the adoption of the MNECB as part of their building regulations. If adopted by a province, territory or municipality, the provisions of the MNECB will become law in that jurisdiction.

The MNECB is intended to be used in conjunction with the NBCC. In contrast to ASHRAE/IES 90.1, the code references Canadian standards and regulations, uses metric (SI) units, and includes only enforceable requirements (it can be determined that a building meets the specified efficiency requirements). The code contains five technical sections related to building envelope, lighting, heating, ventilating and air conditioning systems, service water heating systems and electric power requirements. The MNECB also provides tables of minimum efficiencies for equipment that is not covered by federal, provincial or territorial regulations.

The technical section on lighting contains:

1) mandatory requirements for exterior lighting including power allowances for exterior entrances/exits, a maximum limit for connected lighting power for facade lighting and a minimum luminous efficacy requirement for other exterior lighting;

2) mandatory requirements for exterior lighting controls;

3) mandatory requirements for interior lighting including a maximum power limit for exit signs;

4) prescriptive requirements for interior lighting calculated as per the building's Interior Connected Lighting Power (ICLP) and Interior Lighting Power Allowance (ILPA); and 5) mandatory requirements for interior lighting controls.

Final decisions about the content of the MNECB were made by the Standing Committee on Energy Conservation in Buildings in September 1995. Based on comments received as a result of public consultation, technical changes, improved wording and expansion of appendix material to clarify requirements were recommended, approved, and implemented. The MNECB was published in 1997.

United States Equipment and Building Regulations

This is a brief status update on active lighting programs under the U.S. Energy Policy Act of 1992 (EPAct), as well as the current version and the revision of the ASHRAE/IES 90.1 building code. The authors have published summaries of all U.S. lighting regulations in the Proceedings of the Right Light 2 and 3 conferences[5), 6)].

Voluntary Luminaire Program

The voluntary luminaire testing and rating program received provisional approval from the Department of Energy (DoE) in March 1996. DoE found the program in its beginning stages to be well positioned to achieve its objectives. DoE will make a final determination by the end of 1998 on whether the program has continued to progress and whether the outstanding issues have been resolved. These issues include the ongoing expansion of the program and assurance of the reliability of test data. Progress may be demonstrated, in part, through surveys on manufacturer participation, consumer awareness, and publicity efforts; tracking of Bureau of Census data collection; and the addition of rating methods for other luminaire types. See the paper "Voluntary Luminaire Efficacy Program: A Model for Collaboration," in these *Proceedings* for more information.

Fluorescent, Incandescent Reflector, and High Intensity Discharge Lamp Standards

Current fluorescent and incandescent reflector lamp standards set in the EPAct legislation have been in effect since 1994 and 1995 respectively. The lamp test procedures were published in May 1997; these include definitions of rough and vibration service lamps and colored lamps that clarify which lamps are exemptions to the lamp standards.

A determination of whether standards are warranted for high intensity discharge (HID) lamps called for in EPAct has been designated low priority by DoE. A preliminary analysis that would be a basis for such a determination is in the early stages. The EPAct update to the present fluorescent and incandescent lamp standards, and the analysis of standards on additional lamps, are also considered low priority and their schedule is undefined.

ASHRAE/IESNA-90.1 Building Code

Following the EPAct mandate, more than half the U.S. states have adopted a commercial building code with provisions at least as strict as those in the current ASHRAE/IES code. This code contains various lighting requirements. DoE is involved in activities to assist the remaining states to comply, including the development of compliance software and training programs.

The revision of this code, ASHRAE/IES 90.1-R, is undergoing public review. The process of publishing the final code revision will take several years, after which DoE will decide whether to accept the revised code as part of the EPAct requirements. The lighting section of the code contains updated lighting power density values as well as mandatory controls requirements. It is written in code language, and regulates additions and alterations as well as new construction.

U.S. Fluorescent Ballast Standards History and Process

Existing U.S. ballast standards have been in effect since 1990. Under the National Appliance Energy Conservation Amendments (NAECA-1988) [7)], a consensus standard was formulated by the U.S. Congress, energy conservation advocates, and ballast manufacturers that effectively prohibited the sale of standard magnetic ballasts. The ”energy-efficient” or ”low loss” magnetic ballast meets this current standard.

The existing and potential amended standards are set in the form of a minimum ”ballast efficacy factor” (BEF). This metric was developed to compare the performance of different ballast types used with the same lamp or lamps. The BEF is defined as the relative light output (ballast factor) divided by the input power to the ballast.

In 1992, DoE began analyzing possible revisions to the ballast efficiency standard. The Energy Policy and Conservation Act, as amended [8)], states that a new or amended standard must achieve the maximum improvement in energy efficiency that DoE determines is technologically feasible and economically justified. Seven factors must be considered:

(1) the economic impact on manufacturers and consumers;

(2) the savings in lifetime operating costs compared with the increase in product price (including installation and maintenance);

(3) the total amount of projected energy savings;

(4) any reduced utility or performance;

(5) the impact of reducing competition in the industry;

(6) the need for national energy conservation; and

(7) other factors DoE considers relevant.

The analysis for the ballast standard revision has been performed for the Department of Energy by Lawrence Berkeley National Laboratory (LBNL). LBNL has developed computational analysis tools to calculate the economic impacts on individual end-users and forecasting models to project the energy and economic impacts on the nation as a whole. [9)]

In 1994, DoE issued an ”Advance Notice of Proposed Rulemaking” for fluorescent lamp ballasts. High-frequency electronic ballasts were proposed as the standard. The analysis generated considerable public comment and criticism in part because of an error that overstated the efficiency levels. In response to this and critiques of other proposed appliance energy-efficiency standards, DoE undertook a review of the standards process. DoE, manufacturers, consultants, and energy-efficiency advocates participated in the development of the process improvements. These include

(1) earlier involvement of stakeholders,
(2) increased predictability of the rulemaking timetable,
(3) increased use of non-government technical expertise,
(4) earlier elimination of impractical or problematic design options,
(5) more in-depth analyses of impacts,
(6) use of more transparent and robust analytical methods,
(7) support of efforts to build consensus on standards,
(8) greater consideration of non-regulatory approaches, and
(9) establishment of an advisory committee on standards.

In the meantime, DoE directed LBNL to undertake a re-analysis of potential life-cycle costs and national energy savings from the ballast technology options. These options are cathode cutout (hybrid), high frequency electronic rapid start, and electronic instant start ballasts. There was much more stakeholder input and public review for this round, particularly from the ballast industry. Additional sensitivity analyses were performed on key input parameters. The forecasting model was revised and better documented.

After several public workshops, the final draft of the analysis was released in 1997 [10)]. Fluorescent ballasts operating in the commercial and industrial sectors for interior lighting were covered in the study. Discussion and draft results are presented below.

U.S. Fluorescent Ballast Analysis

Engineering/Economic Analysis

Parameters such as wattages, ballast factors, ballast prices, operating hours, equipment lifetimes, and electricity prices received much attention, professional input, and public review.

<u>Product Classes</u>

Ballasts driving one and two F40T12 lamps, two F96T12 lamps, and two F96T12HO lamps are presently regulated. In the new analysis, additional ballast types have been added; they drive three and four F40T12 lamps and one, two, three, and four F32T8 lamps. A ”product class” is the set of ballasts (technology options) that drive one of these lamp types. Within each product class, technology options may include energy-efficient magnetic ballasts (EEM, usually the baseline), cathode cutout (CC), electronic rapid start (ERS), and electronic instant start (EIS) ballasts. For some product classes, only some of these technology options are available. F40T12 and F96T12 ballasts are assumed to operate primarily in the commercial sector, and F96T12HO ballasts in the industrial sector.

Life-Cycle Cost

The life-cycle costs for each product class are presented in Table 1. Life=12.5 years. The results are calculated for an 8% real discount rate in 1995 U.S. dollars. The lowest life cycle cost (LCC) for each product class is shown in bold type. In all cases this is a high frequency electronic ballast technology option.

Variability Analysis

An analysis of the impacts of variation of important inputs was performed. The life-cycle cost analysis reported above represents the impact of the energy efficiency levels on the average consumer. However, electricity prices vary by region of the country and annual lighting hours vary by building type. At low electricity prices or low lighting hours, some fraction of consumers may be negatively affected by moving from the baseline to the technology option. The ”variability analysis” demonstrates the size of this fraction. It also shows which parameters have the most effect on life-cycle cost. The 2-lamp F40T12/ES product class was studied, since it represents the majority

Table 1. Life-Cycle Costs for Fluorescent Ballast Product Classes ($1995)

Ballast System	LCC ($)	Ballast System	LCC ($)	Ballast System	LCC ($)
1-F40T12		**1-F32T8**		**2-F96T12**	
EEM	157	EEM	135	EEM	459
CC	160	ERS	**126**	EIS	**437**
ERS	**146**	EIS	131		
1-F40T12/ES		**2-F32T8**		**2-F96T12/ES**	
EEM	136	EEM	214	EEM	358
CC	136	CC	209	EIS	**337**
ERS	**126**	ERS	**200**		
2-F40T12		EIS	**204**	**2-F96T12HO**	
EEM	243	**3-F32T8**		EEM	526
CC	237	ERS	**262**	CC	518
ERS	**234**	EIS	263	ERS	**511**
2-F40T12/ES		**4-F32T8**		**2-F96T12HO/ES**	
EEM	202	ERS	326	EEM	452
CC	195	EIS	**323**	CC	439
ERS	**191**			ERS	**431**

EEM = Energy Efficient Magnetic CC = Cathode Cutout
ERS = Electronic Rapid Start EIS = Electronic Instant Start

of the market for magnetic ballasts. The results for this product class are described below.

Electricity Price

In addition to the inputs for the engineering/economic analyses, the variability analysis requires a distribution for the parameter under study. The range of U.S. electricity prices is derived from 1995 investor-owned electric utility (IOU) sales and revenue data combined with the 1994 publicly-owned electric utility (POU) rates. More than 95% of electricity sales occurs at prices ranging from $0.04/kWh to $0.11/kWh.

The variability model was run keeping all other input parameters constant, generating results from a large sample of electricity prices from the distribution. The results show that for 99.5% of electricity sales (prices higher than $0.032/kWh), there is a net savings in LCC for CC ballasts compared to EEM ballasts, and for only 0.5% of electricity sales there is a net cost to the consumer. For ERS ballasts compared to EEM ballasts, for 99% of electricity sales (prices higher than $0.036/kWh) there is a net savings, while for 1% of electricity sales there is a net cost.

Annual Lighting Hours

The data source for the national distribution of the lighting hours is the Xenergy audit database.[11] About 86 percent of ballasts operate between 2000 and 7000 hours per year (98% operating at less than 7000 hours/year, minus 12% operating at less than 2000 hours/year).

When an EEM ballast is replaced with a CC ballast, a net savings in LCC occurs for lighting hours above approximately 900 hours/year. This represents 98% of consumers, with 2% experiencing a net cost. A net savings in LCC occurs above 1100 hours/yr when an EEM ballast is replaced with an ERS ballast. This represents 97% of consumers, with a net cost for only 3% of consumers.

Ballast Lifetime

Based on limited data on the range of ballast lifetimes, the average lifetime is around 45,000 hours, but the distribution is not well characterized. A minimum of 2000 hours and a maximum of 80,000 hours was assumed. The results show that for CC ballasts compared with EEM, 90% of consumers would have a net savings (lower LCC costs) and 10% would have a net cost. For ERS compared with EEM, there is a net savings for lifetimes above 16,500 hours, representing 98% of consumers.

Multiple Variables

Figure 1 shows the relative importance of the three variables discussed above on the total difference in LCC ("LCC change"). Figure 2 shows the results of simultaneous variation of all three parameters and the cumulative probabilities of the LCC change. A negative LCC change means that the more efficient design reduces the LCC. For CC compared with EEM, 87% of consumers have a projected net savings, and for ERS compared with EEM, 91% have a projected net savings.

National Energy Savings

National energy forecasts for the commercial and industrial sectors were performed with an upgraded version of the Electric Power Research Institute's forecasting model COMMEND version 4.0. The model projects lighting (and heating, ventilating, and air conditioning) energy consumption from the base year of 1992 through the year 2030. The COMMEND model projects future energy consumption based on floor space, desired lighting levels, lumen shares, technology characteristics, and lighting hours.

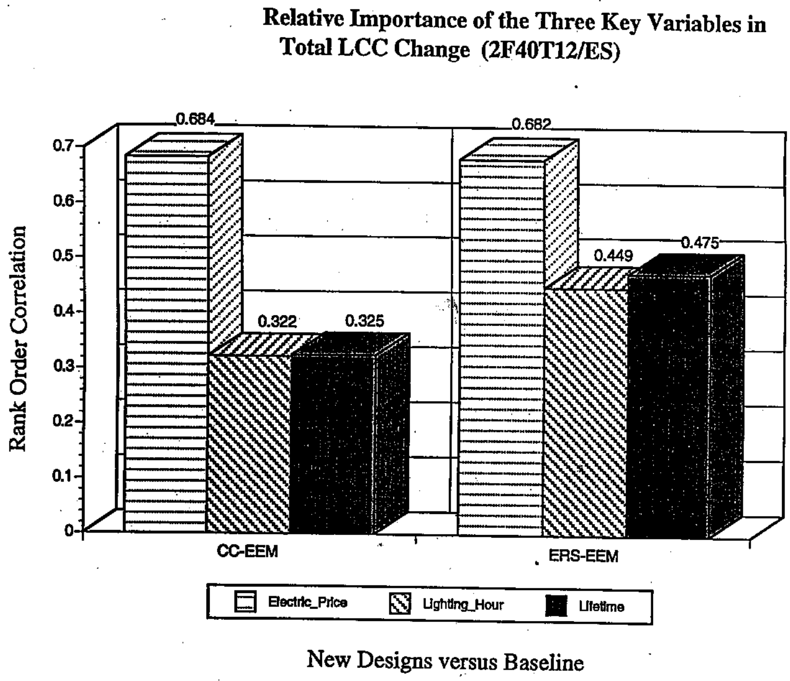

Figure 1. Relative Importance of the Three Key Variables in Total LCC Change

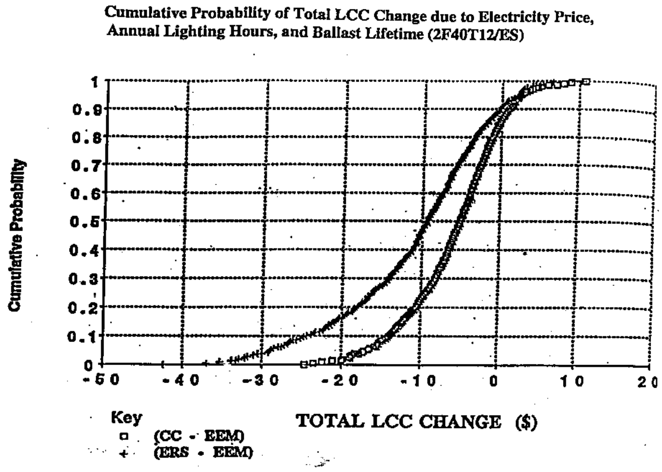

Figure 2. Probability of Total LCC Change by Intervals, Depending on Electricity Price, Annual Lighting Hours, and Ballast Lifetime

Three COMMEND base cases were created using different assumptions for the annual rate at which existing magnetic ballasts would be converted to electronic ballasts from 1995 through 2030. These conversions represent "early replacement" of magnetic ballasts in existing buildings as a result of incentive and voluntary programs and market forces in the absence of new federal policies. Between 1992 and 1995, the conversion rate to electronic ballasts was calculated based on sales data from the Bureau of Census as interpreted by the National Electrical Manufacturers' Association. These conversion rates for 1995 are 7.5 percent, 0 percent, and 3.5 percent for 4-foot, 8-foot, and 8-foot high output ballasts respectively. The three scenarios are:

(1) "Constant Conversion": conversion rates of remaining magnetic ballasts stay at 1995 levels throughout the forecast,

(2) "No Conversion": conversions of existing ballasts drop to zero after 1995, as if all conversions cease immediately, and

(3) "High Conversion": the 4-foot conversion rate climbs from 7.5% in 1995 to 20 percent in the year 2000 and remain at 20 percent throughout the forecast. The second and third scenarios represent low and high bounds or extremes; future consumption is likely to fall somewhere in between.

COMMEND was used to forecast energy impacts of several possible energy efficiency levels under the three base cases described above. A potential energy efficiency level was assumed to take effect in the year 2001. COMMEND output for aggregate energy savings and equipment costs was used to generate the national net present values for the three scenarios. Within each scenario, 4 energy efficiency levels were studied, each representing combinations of technology options with increasing energy efficiency. The energy and economic results are shown in Table 2. The energy savings include small net heating, ventilating, and air conditioning energy impacts. Net present values are reported for a 7 percent social real discount rate.

CONCLUSIONS

Lighting regulations are well-established in both Canada and the United States. While the institutional framework and the regulatory processes are different in the two countries, the basic policy approaches of equipment standards and building codes are used by both. Stakeholder input is

Table 2. Energy Consumption, Energy Savings and Net Present Value for Fluorescent Ballasts

Efficiency Level	Base Case	1	2	3	4
Cumulative Energy Consumption (Interior commercial and industrial lighting, primary quads 2001-2030)					
Constant Conversion Scenario	108.6	107.8	106.6	106.5	106.3
No Conversion Scenario	113.1	110.4	107.9	107.7	107.5
High Conversion Scenario	107.3	106.9	105.9	105.8	105.6
Cumulative Energy Savings from Potential Energy Efficiency Level (primary quads, 2001-2030)					
Constant Conversion Scenario		0.8	2.0	2.1	2.3
No Conversion Scenario		2.7	5.1	5.3	5.5
High Conversion Scenario		0.4	1.4	1.5	1.7
Net Present Value (Billion 1995 % at 7 percent)					
Constant Conversion Scenario		0.6	3.1	3.6	3.6
No Conversion Scenario		1.6	5.8	5.9	6.0
High Conversion Scenario		0.3	2.3	2.6	2.6

essential, and technical and economic analyses of potential savings and impacts are important in the establishment of regulations.

NRCan and DoE have been actively working together on harmonization. Two advantages of harmonization are that lower efficiency products are not "dumped" from a country with regulations to one without, and the manufacturers have essentially one market to plan for instead of two. Harmonization also decreases the regulatory burden and reduces costs. Harmonization of test procedures is the recommended first step. This is usually easier to accomplish, since most of the issues are technical. Harmonization of standards involves more political issues, but can be accomplished with manufacturer and stakeholder cooperation.

ACKNOWLEDGMENTS

To obtain copies of Canada's Energy Efficiency Act and Energy Efficiency Regulations or for more information on Canadian regulations for lighting products, contact Valerie Whelan at +1 (613) 947-1207, fax +1 (613) 943-1590 or e-mail vwhelan@nrcan.gc.ca.

For more information on the MNECB contact John Haysom at +1 (613) 993-0043, fax +1 (613) 952-4040 or e-mail john.haysom@nrc.ca. To order the MNECB, call +1-800-672-7990 or +1 (613) 993-2463 from countries other than Canada.

For more information on U.S. lighting equipment regulations, contact Anthony Balducci at +1 (202) 586-8459, fax +1 (202) 586-4617 or e-mail anthony.balducci@ee.doe.gov at the Office of Codes and Standards, U.S. Department of Energy. ●

ENDNOTES

1) American Society of Heating, Refrigerating, and Air Conditioning Engineers and Illuminating Engineering Society of North America

2) In these lamp codes, F designates fluorescent, the next number indicates the nominal wattage, T means tubular, and the number 8, 10, or 12 designates the lamp diameter in eights of an inch (e.g. T8 = one inch).

3) CAN/CSA-C654-M91, *Fluorescent Lamp Ballast Efficacy Measurements*, clause 4 Ballast Efficacy Factor. Canada.

4) The R lamp is a reflector lamp that is blown into a mold and has relatively imprecise reflector shape. R lamps are generally made from soft glasses (indoor service only) and do not have a facing lens.

The PAR lamp is a parabolic aluminized reflector lamp that has a precise reflector shape obtained by pressing molten glass into a mold. PAR lamps are generally made from hard glasses (outdoor or indoor service) and often have a lens cover to further shape and control the light distribution.

An E26 lamp has a nominal maximum bulb diameter of 26/8 inches; this is a common base type.

5) Atkinson, B.A., J.E. McMahon and S.M. Nadel. 1993. "U.S. Lighting Standards: a Review of Federal and State Lighting Efficiency Regulations," *Proceedings from Right Light Two, 2nd European Conference on Energy-Efficient Lighting*. Arnhem, The Netherlands.

6) Atkinson, B.A., J.E. McMahon, T.L. Logee, C.C. Jones, J. Lindsley. 1995. "U.S. Lighting Regulations: 1995 Update." *Proceedings from Right Light Three, 3rd European Conference on Energy-Efficient Lighting*. Newcastle-upon-Tyne, U.K.

7) National Appliance Energy Conservation Amendments of 1988 (Public Law 100-357) to the Energy Policy and Conservation Act (P.L. 94-163). U.S.

8) Energy Policy and Conservation Act (P.L. 94-163), as amended by the National Appliance Energy Conservation Act of 1987 (P.L. 100-12), by the National Appliance Energy Conservation Amendments of 1988 (P.L. 100-357). U.S.

9) Regional Economic Research, Inc. 1993. *COMMEND 4.0 User's Guide*, San Diego, CA, U.S.

10) Lawrence Berkeley National Laboratory. 1997. "Draft

Report on Potential Impact of Possible Energy Efficiency Levels for Fluorescent Lamp Ballasts," Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division, Technology and Market Assessment Group, prepared for U.S. Department of Energy, Office of Codes and Standards, July 1997. U.S.

11) Extract of Xenergy, Inc's XENCAP database showing lighting equipment and lighting hours of operation for over 24,000 commercial and industrial buildings from nationwide energy audits for the years 1990 - 1995. LBNL, U.S.