Lighting Code Compliance in New Small Commercial Construction in Minnesota

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This study examines the current practice in lighting system design and installation in relation to requirements set forth in the Minnesota Energy Code. A two part survey was conducted. The first examined buildings constructed between May 1991 and September 1992. These were subject to code requirements equivalent to ASHRAE/IES 90.1-1989. The second examined buildings constructed after September 1992 which were subject to code revisions equivalent to ASHRAE/IES 90.1-1993. Following the 1992 revisions, the Minnesota Department of Public Service began offering lighting energy code training seminars in an attempt to increase compliance. The effectiveness of this training was evaluated.

A sample of thirty-eight commercial projects was selected. Electrical plans were collected when available, and site visits were performed to inventory the lighting equipment. This information was then analyzed to determine compliance with the appropriate code.

The results revealed that of the thirty-eight buildings surveyed, nineteen complied with the code. No substantial increase was noted following the training seminars. The twenty-two buildings from the 1991-1992 portion were reanalyzed assuming retrofits with efficient lamps and ballasts to determine if compliance could be achieved by simply using more efficient equipment. All twenty-two sites met the 1989 requirements.

Based on all results, utilities cannot assume that code requirements are being met simply because they have been adopted and training seminars have been conducted, especially in small commercial buildings. Small buildings account for 96% of commercial buildings and 56% of commercial energy use. Utilities and state code officials must find more effective ways to reach this market.

Introduction

On May 7, 1991 the first Minnesota Energy Code requirements were enacted. These requirements, equivalent to the Code of Federal Regulations (CFR) title 10, part 435.103 “1989” and the ASHRAE/IES 90.1-1989, included limits on the amount of power to be used for lighting and established a means of computing compliance. On September 6, 1992 the state replaced these limits with more restrictive “1993” requirements as established by the CFR and ASHRAE/IES. The purpose of these actions was to reduce the amount of energy being wasted by the use of inefficient or over-designed lighting systems and move the building industry towards the use of more efficient state-of-the-art lighting equipment to realize an overall savings in energy as well as a reduction in CO_2 emissions. After the “1989” code had been in affect for one year, CEE was funded to conduct a survey to determine the level of compliance and the current practice in lighting system design. Following the introduction of the “1993” code, and during this initial survey period, the Department of Public Service (DPS), funded by the Environmental Protection Agency, initiated a lighting energy code educational program in which training seminars for designers, contractors and building officials were conducted at fifteen sites across the state. The goal of this program was to increase code awareness and compliance through education. In response, CEE performed a second survey to again evaluate the level of compliance for before and after the training.

Methodology

Code Awareness, Compliance and Enforcement

Awareness, compliance and enforcement issues relating to the lighting provisions of the energy code were first investigated through informal discussions with designers, design-build contractors, and code officials. These were followed by a formal phone survey of twenty-five lighting designers.

Site Selection Criteria

Date of Construction. The first phase of the study examines sites for which the building permits were issued between May 7, 1991 and September 6, 1992. These buildings were legally required to be in compliance with the “1989” commercial lighting requirements of the Minnesota Energy Code. The second phase of the study examined buildings with permits issued after September 6, 1992. These buildings were legally required to comply with the Minnesota “1993” commercial lighting requirements.

Communities/Designers Contacted. For the first phase of the study, forty-eight communities in the metro area were contacted to request lists of new commercial construction and major additions permitted during the time period under study. Lists were obtained from twenty-three communities. For the second phase, twenty-four designers who had attended the DPS lighting energy code educational seminars were contacted to comprise a participant study group. A second group of nine designers who had not attended a seminar were contacted as a control group. Each designer was asked to provide lists of commercial projects which were under 100,000 square feet and were completed after September 1992. Of the thirty-three designers contacted, sixteen participant and five control designers responded with building lists.

Building Classification and Site Selection. The lists provided by the twenty-three communities were reviewed to eliminate residential, industrial and remodel projects. This left 141 eligible permits for this time period. Though it was not possible within the budget to select a sample of buildings large enough to be representative of new commercial construction in a statistical sense, sites were selected across the range of building types and valuations in order to give a sample that typified new construction in retail, office, public buildings and warehouses. Fifty-two sites were investigated to identify owners/occupants who would permit data to be gathered on site. Only occupied buildings were selected to assure that all lighting equipment, including task lighting, would be in place. A final sample of twenty-two sites was selected.

The lists received from the participant and control designers for the projects completed after September 1992 were reviewed and separated into pre seminar/post seminar lists. From these two groups, pairs of pre and post seminar projects were selected from each designer’s list, matching building types where possible. The designers were then asked to supply the lighting plans and specifications for each building selected and owners/occupants were contacted to obtain permission to gather data on site. A total of eighty-two projects were reviewed from which fifteen pairs (thirty sites) of participating projects and five pairs (ten sites) of control projects were chosen. At this time, data has been collected from four participant pairs and four control pairs.

Data Collection. Data collection for both parts of the survey included plan review and site visits. The plan review allowed the number and type of fixtures to be identified. The site visits identified any changes from the plans to the as-built conditions, including changes in the number of fixtures and additional task lighting. They also allowed for lamp and ballast model numbers and types to be determined.

To obtain permission to include a project in the study and to visit the site, the tenant of the site was contacted. Usually, the tenant was able to give permission for the visit. In some cases, it was necessary to obtain permission from both the tenant and the building owner, or from both the local manager and a regional or national manager.

Data Analysis

Code Compliance. Code compliance was determined using LTGSTD version 2.2, a software package developed for the U.S. Department of Energy by Pacific Northwest Laboratory, in partnership with ASHRAE and IES. Using the program greatly simplifies the designer’s task of performing the calculations needed to determine if a design complies with federal or ASHRAE/IES lighting standards. Lighting power budgets (LPBs) can be determined using both the prescriptive and system performance compliance methods, and the calculations duplicate the requirements and compliance calculations contained in the standard .

Economics of State-of-the-Art Lighting. In the first phase of the study, the economics of installing state-of-the-art lighting equipment was reviewed. To assess the economics of this equipment as it would actually be installed, information was needed on the annual energy cost savings and on the incremental cost of the state-of-the-art equipment. The annual energy cost savings are a function of the electric rates, the connected lighting load, the annual operating hours and the percent of the lighting load that occurs during the building peak demand period. The utility serving each business and the applicable rate class were determined by reviewing the business's electric bills and contacting the relevant utilities. The connected lighting loads were calculated from the detailed lighting schedules, plans and site visits and the annual operating hours were determined by interviewing the building owners/occupants. Information was gathered on a space by space basis to the extent possible. Emergency and security lighting (e.g., exit signs) were assumed to operate continuously.

Based on the information gathered about operating hours, lighting was generally assumed to be on during the building's peak demand period, except for intermittent use spaces such as storage areas. In addition, the primary analysis did not include the impact of using state-of-the-art lighting on heating and cooling energy costs. The combined effect of these two factors is to overestimate the peak demand slightly: Northern States Power (NSP) normally assumes connected lighting load to be 86% on-peak for commercial customers including the cross impact of air conditioning. In the sample of buildings selected, the peak coincidence of the lighting systems including the cross impact of air conditioning loads would be assumed, based on NSP default values, to range from 40% for the 2 public spaces, 85% for the warehouses, 101% for the retail spaces, and 112% for the offices. Furthermore, at Minnesota electric rates, demand charges are a substantially smaller fraction of lighting operating costs than energy charges, so overall electric costs are not very sensitive to the likely range of variations in peak-coincidence.

Incremental equipment costs were determined from distributor (wholesale) pricing gathered from three lighting vendors. The three sets of prices were averaged and ten percent was added to adjust for contractor mark-up and determine the cost of the equipment to the building owner. (The prices may be slightly high due to small quantities with no volume price breaks.)

To assess the potential statewide impact of using state-of-the-art lighting in new construction, simple extrapolations were made from the sample data set to the state as a whole. Buildings in the sample were aggregated into four major types, office, retail, warehouse, and public buildings, and the total impact of state-of-the-art lighting for each group was calculated in terms of annual energy and demand savings, annual energy cost savings, and annual reduction in CO_2 emissions. (CO_2 emissions are based on Minnesota's statewide utility/fuel mix (1.561 lbs/MWh).)

These totals were then divided by total building value to determine the savings per dollar of building value. These unit savings' numbers were then multiplied by the total value of commercial construction in Minnesota for each building category for 1990 (the latest year available) to determine the total annual savings potential resulting from buildings built in one year.

Results

Current Awareness, Compliance and Enforcement. The Minnesota Energy Code applies to the entire state, but it is only administered by those local jurisdictions in which the Building Code has been adopted. This is over 80% of the state. Discussions were held with lighting designers, design-build contractors and code officials from these jurisdictions.

Four major architectural firms were contacted. Each reported that they were aware of the Energy Code and that they designed to it because retention of their license depended on it. They felt that education was not needed because they were already aware of the code and that the code is easy to meet with available technologies. In fact, some commented that the code was so easy to meet that policy should require higher levels of efficiency. Several of the designers stated that they had not filled out compliance forms or provided lighting calculations in Minnesota because no one had asked for them. They had provided the calculations in other states where they were required to do so.

Five design-build contractors were contacted. They variously estimated the proportion of the new construction designed by design-build contractors at 5 to 50% of the small commercial market. At least four of the five contractors were unaware of the new Energy Code lighting requirements, and none of the five had ever filled out a compliance form.

Nine code officials were interviewed. Eight of the nine stated that their departments had not been checking or enforcing the lighting provisions of the code. In addition, two of the code officials stated emphatically that they knew the other officials around the state were not enforcing the code. Review of the permit files at several inspection departments confirmed that the data needed to determine compliance was not present and that designers were not addressing compliance in the materials they submitted.

The code officials saw a number of serious problems with enforcement. First, though they were capable of taking on the challenge, they needed to be educated on the new code provisions. The code had changed rapidly and it had been impossible for them to keep up to date. They did not have the time or money needed to educate their staffs. In addition, they did not feel they had the time to review everything that needed to be reviewed. Finally, they felt that the code had been established by a procedure that was too "top-down" and did not allow for enough input from them, did not place enough emphasis on simplicity, and did not provide enough training and education. ,

Taken together, these interviews raised significant questions about the level of compliance with the code. While design firms felt that education was unnecessary and enforcement would have no effect on their practices other than completion of an additional form, design-build contractors were totally unaware of the lighting code and code officials indicated that enforcement was nonexistent.

The second, more formal set of interviews, was a phone survey, comprised of forty questions, issued to twenty-five designers. The questions covered topics such as the. specifics of their current design practices versus those used before the code implementation, their familiararity with the code, and their views on the present state of compliance and enforcement. Ninety-six percent of those surveyed noted changes in their design practices since early 1992 with the most noted being an increased use of T8 lamps, electronic ballasts and occupancy sensors. Of the factors that affected these changes, the adoption of the September 1992 code revisions and utility rebate programs were recognized as the most important influences, while the DPS code training seminars were noted as having very little affect. Each of the twenty-five designers felt that they were at least somewhat familiar with the code. However, of the more than two thousand lighting designs completed by these designers in Minnesota in one year, only half are reportedly being put through the calculations to determine code compliance. (This is an increase from the estimated twenty percent in early 1992.) In order to relate this to the perception of the actual level of compliance regardless of calculations, the designers were asked to approximate the percentage of all buildings being built in Minnesota today which comply with the energy code. Seventy-four percent of the estimations were stated as fifty percent or less. When asked how this could be improved, the majority of designers felt enforcement was the key.

The results of this survey, as with the first phase of interviews, indicate a questionable level of compliance with the code. Although design practices have improved and the number of compliance calculations has increased, these designers indicated that actual code compliance is still far from standard practice.

Site Visit Information. Each of the sites was given an identification number in order to provide confidentiality. Detailed information about each site was assembled, including permit date and value, gross building area, operating hours, utility rates, and inventory of existing lighting equipment including type, location, wattages and number installed. The LPB's were determined from the tables in the code, and compared to the installed lighting power in order to determine compliance with the code. It was also noted whether there were changes in the installed lighting equipment from that specified on the plans.

After the data was collected the first task was to determine how well the existing lighting systems were complying with the code. After totaling all existing installed interior lighting wattages affected by the code, the sites were run through LTGSTD. For the first phase of the survey, fourteen of the twenty-two sites passed the code requirements which were in effect when they were built. In addition, the 1993 criteria were applied to these sites to determine what fraction of the buildings would pass the code that is in effect today. Using these numbers, only seven of the twenty-two sites would pass. See Table 1. Of the sites reviewed in the second phase, none of the four pre-seminar and one out of the four post-seminar control sites complied with the 1993 criteria. Of the participating sample, two out of the four pre-seminar and two out of the four post-seminar sites complied. See Table 2.

The lighting equipment installed at the majority of the first phase sites was standard fare. Of the twenty-two sites, ten were using standard fluorescent lamps and ballasts to provide the majority of their illumination. Only three sites incorporated T8 lamps and electronic ballasts and two used energy saving incandescent to provide most of their general lighting requirements. A slight increase was noted in the second phase. Seven out of the sixteen sites were using the most efficient equipment.

Significant changes were made to the buildings' lighting systems at the time of construction. For the first phase, the average increase in installed lighting wattage over designed lighting wattage (of the fourteen sites for which lighting plans were obtained) was 6,352 watts. The increases averaged 14.6%. Of the sites reviewed for the second phase, the increase averaged 7%. At the sites with significant increases, the majority was from either display lighting, task lighting or lighting for refrigerated cases. Several sources have suggested that changes in the efficiency of equipment installed relative to that specified by the designers can be significant. It was not possible to assess this factor due to a lack of efficiency-related specifications in the lighting schedules. In addition, the

Table 1. Lighting Code Compliance with Existing Equipment - May 1991 to September 1992

Compliance Method	1989 Pass	1989 Fail	1989 N/A	1993 Pass	1993 Fail	1993 N/A
Prescriptive Criteria	8	11	3	4	15	3
System Performance Criteria	11	11	0	6	16	0
Either	**14**	**8**	**0**	**7**	**15**	**0**

Table 2. Lighting Code Compliance Pre and Post Seminar - After September 1992

Participating Sample Compliance Method	Pre Pass	Pre Fail	Pre N/A	Post Pass	Post Fail	Post N/A
Prescriptive Criteria	2	2	0	2	2	0
System Performance Criteria	1	3	0	2	2	0
Either	2	2	0	2	2	0
Control Sample Compliance Method	**Pre Pass**	**Pre Fail**	**Pre N/A**	**Post Pass**	**Post Fail**	**Post N/A**
Prescriptive Criteria	0	4	0	0	4	0
System Performance Criteria	0	4	0	1	3	0
Either	**0**	**4**	**0**	**1**	**3**	**0**

majority of offices that were surveyed used fixtures provided by the base building owner as the general lighting source. These fixtures were usually taken from stock established when the main building was completed and included as part of the fit-up for a new tenant. Although the designer may have specified state-of-the-art equipment, the base building fixtures were always of less efficient technology.

State-of-the-Art Lighting. For the first phase of the survey, in order to determine the effect on the sample buildings of using the most energy-efficient lighting equipment available without changing the actual lighting design or layout, CEE developed state-of-the-art systems and performed energy use analyses. At the sites where the existing lighting consisted of standard or "energy-saving" four foot T12 lamps and ballasts, the fixtures were assumed to be replaced with T8 lamps and electronic ballasts. In many cases, an existing fixture containing three or four T12 lamps had two ballasts which could be replaced with a single electronic T8 ballast. Standard incandescent lamps were replaced with compact fluorescent lamps (CFLs) whenever possible, and energy-saving incandescent lamps were used when it was not feasible to use CFLs. At sites where eight-foot T12 lamps were installed, the energy saving T12 lamps and electronic ballasts were used.

The state-of-the-art lighting systems were then analyzed using the DOE software to determine how much of an impact the equipment had on lighting power density and code compliance. The efficient equipment allowed each of the twenty-two buildings to meet the 1989 code, but only five passed the more stringent 1993 requirements. More involved redesign of the lighting type, layouts, or controls would be necessary. See Table 3.

The substitution of state-of-the-art lighting equipment in the sites of the first phase of the survey resulted in an average reduction in lighting power of 25.74%. Aggregate

Table 3. Lighting Code Compliance with State-of-the-Art Equipment - May 1991 to September 1992

Compliance Method	1989 Pass	1989 Fail	1989 N/A	1993 Pass	1993 Fail	1993 N/A
Prescriptive Criteria	15	4	3	12	7	3
System Performance Criteria	19	3	0	13	9	0
Either	**22**	**0**	**0**	**17**	**5**	**0**

power was reduced somewhat less, 16.8 %, because a few of the larger sites already had efficient lighting. In the majority of the sites, lighting power was reduced 15 to 35%. Table 4 illustrates how using state-of-the-art equipment can reduce connected lighting power.

The economics of using state-of-the-art lighting at the time of construction is also illustrated in Table 4. Secondary impacts on heating and cooling costs and maintenance/relamping costs are not considered, nor are refined estimates of peak coincidence. On this basis, the aggregate payback for all sites is 3.5 years.

Table 4. Reduction in Lighting Power and Economics of State-of-the-Art Equipment - May 1991 to September 1992

Type (Description)	Area (sq.ft.)	ALP/sq.ft. Existing	ALP/sq.ft. SOA	% Reduction in ALP	Material Cost	Energy Savings	Simple Payback (yrs)
Office	16,928	0.67	0.44	34.2%	$2,703	$700	3.9
Office	16,737	1.85	1.47	20.5%	$7,192	$1,294	5.6
Office	14,166	2.05	1.98	3.6%	$1,507	$318	4.7
Office	3,160	2.06	1.86	9.7%	$983	$156	6.3
Office	4,756	1.36	0.96	29.7%	$1,510	$208	7.2
Office	2,874	3.36	2.09	37.9%	$1,921	$727	2.6
Office	15,884	1.81	1.23	32.2%	$6,595	$1,923	3.4
Wrhs	32,661	1.12	0.84	25.3%	$14,251	$2,213	6.4
Wrhs	9,600	1.46	0.32	77.9%	$2,500	$361	6.9
Wrhs	5,168	0.41	0.36	13.4%	$66	$9	7.3
Retail	79,200	1.54	1.43	7.3%	$9,965	$3,180	3.1
Retail	12,544	2.41	1.84	23.8%	$4,239	$1,689	2.5
Retail	6,272	3.30	2.06	37.5%	$4,040	$2,816	1.4
Retail	67,478	2.04	1.97	3.1%	$1,982	$1,614	1.2
Retail	4,224	2.46	2.12	13.7%	$658	$649	1.0
Retail	3,804	3.61	2.27	37.0%	$2,663	$1,295	2.1
Retail	8,457	2.50	1.52	39.3%	$4,033	$2,624	1.5
Retail	3,168	0.54	0.38	30.2%	$451	$329	1.4
Retail	4,930	3.23	2.31	28.3%	$2,767	$2,202	1.3
Retail	1,428	3.14	2.61	17.0%	$970	$283	3.4
Public	25,625	2.02	1.69	16.0%	$19,737	$1,225	16.1
Public	45,136	0.92	0.82	10.9%	$2,339	$839	2.8
Averages		**1.99**	**1.48**	**25.8%**	**$4230**	**$1212**	**4.2**
Aggregate		**1.68**	**1.40**	**16.8%**	**N/A**	**N/A**	**3.5**

Comparing the incremental cost of using high-efficiency equipment in all of the sample sites to the total permit value shows that state-of-the-art fighting would add 0.57% to the total cost of construction for the sample. The average increase across the sample was 0.77% of the total value of the building.

To gain an understanding of how energy efficient lighting could affect new commercial construction statewide, factors were developed to apply to the value of major new building types across the state. Estimates were generated for the overall cost savings, along with the energy, demand, and CO_2 emission reductions, that would be realized by using the more efficient lighting equipment.

While the annual cost savings represents only 0.15% of the total value of construction statewide, the 7.7 MW demand savings and almost 50 million pound reduction in CO_2 emissions is substantial. These estimates may be high, due to the small size of the buildings in our sample. If large buildings are all assumed to be using state-of-the-art lighting, and small buildings are assumed to account for half of annual floor space built, the statewide potential would only be half as great, but still significant. Since these savings would be realized *each year* for the buildings built in *one year,* the cumulative potential is very large.

Conclusions

The current level of compliance with the lighting provisions in the Minnesota Energy Code is poor. Although educational seminars sponsored by the DPS have increased awareness of the code, actual compliance calculations are not being performed. The efficiency of lighting equipment being installed in new small commercial construction is low: Of the entire thirty-eight sites analyzed in both phases of the survey, only twelve incorporated high efficiency equipment. Only nineteen of the thirty-eight passed the lighting code which was in effect when they were built.

The current situation represents a tremendous lost opportunity for the State of Minnesota. A conservative estimate indicates that compliance with the Energy Code in new small commercial construction would save 3.8 MW of peak demand, 15,000 MWh of energy, and 24 million pounds of CO_2 emissions in the first year alone. The DPS is currently in the process of amending state rules to clarify that the energy code applies to any remodeling affecting heat loss control, illumination and climate control. This will further increase the energy savings potential of the code.

More code officials must begin enforcement. The lack of a statewide process and schedule, leaves each jurisdiction to set its own criteria. More officials must begin this process. Compliance forms should be required and should include the signature of a registered design professional. Review of compliance forms during plan review is a good step toward increasing awareness and compliance, but many changes can occur between planning and final occupancy, in particular, equipment substitutions and addition of task lighting. Code officials must consider some type of field inspections to verify code compliance. To be cost-effective, this could probably only be done through "spot checks" of a random sample of buildings. Cities may want to contract this service out (as many do with electrical plan review), so that the work can be done efficiently by inspectors with specialized expertise.

Utilities must work far more aggressively to reach the small commercial market. The low level of code compliance and low market penetration of efficient equipment indicates clearly that current approaches are not reaching this market. Among the more aggressive strategies that could be considered are:

Low cost design assistance to help small commercial buildings meet the energy code. Lighting equipment selection and code compliance calculations are complex. Many design-build firms do not have the necessary expertise to carry out these tasks and will need one-on-one help even after a training workshop.

Rebates from those utilities not currently offering them.

Differential hook-up fees to force attention to energy efficiency at the time of construction. Fees could be zero for buildings meeting the code, negative (i.e., a rebate) for exceeding the code, and high enough for those buildings not meeting the code to make code compliance the most economical choice.

Loan programs structured to give a positive cash flow. Loans could be tied to the meter in a manner analogous to water and sewer assessments. This would circumvent the classic division of interest between the building owner and the occupants in a leased building by having tenants that are paying their own energy bills and realizing the savings from efficient equipment to pay for its cost. Tenants should be receptive to this, since they would not have to pay any unpaid balance were they to vacate (it would pass to the next tenant, who also would inherit the efficient lighting). It would also mitigate utility problems with qualifying small businesses for loans, since the loan would be paid off regardless of changes in tenancy.

Leasing of efficient equipment to spread out costs and achieve a positive cash flow for the occupant.

Design assistance is a rapidly growing field for utilities, and one Minnesota utility, Northern States Power Company, has been granted approval by DPS to include design assistance in its Conservation Improvement Program plan. However, as with almost all utility design assistance programs, the primary emphasis of the NSP program is on large buildings. This reflects the high cost of the engineering and architectural studies typically included in design assistance services, as well as the greater savings to be realized by working with the largest customers first.

A design assistance service for small commercial construction will need a much more streamlined, low budget approach, but can complement the full service program for large buildings.

It is clear that something much more effective than current approaches will be necessary to avoid losing a significant opportunity to reduce utility capacity requirements, statewide energy use and CO_2 emissions.