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Michigan State Code Adoption Analysis: Cost-Effectiveness of Lighting Requirements- ASHRAE/IESNA 90.1-2004

EE Richman

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Prepared for the
U.S. Department of Energy
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Summary

The state of Michigan has asked the U.S. Department of Energy to analyze the potential energy effect and cost-effectiveness of the lighting requirements in ASHRAE/IESNA 90.1-2004 as they consider adoption of this energy code in place of the 90.1-1999 Standard currently in effect. The primary change of interest in the lighting section of the 90.1-2004 Standard is the set of revised interior lighting power densities (LPD) that provide for more stringent lighting compliance levels. Another major change with the 2004 version is the greatly expanded set of exterior LPDs. Finally, there are some additional and revised control requirements including limited mandatory occupancy sensor use and some exceptions to existing control requirements aimed at making the standard easier to apply. The potential effect of the new 2004 LPD values is analyzed as a comparison with previous values in the 1999 version. The basis for the analysis is a set of lighting models developed as part of the ASHRAE/IESNA code process. The use of the models allows for an effective comparison of values for various building types of interest to Michigan state. The potential effect of the new exterior LPD requirements are discussed, but no numerical analysis is available because there was no comparable set of requirements in the previous version of the standard with which to compare directly. Potential effects from control requirements changes are also discussed, and available case study analysis results are provided, but no comprehensive numerical evaluation is provided in this limited analysis effort.

The numerical LPD analysis concludes that the change in weighted average power density requirements across all building types is estimated to be a decrease of 0.39 watts per square foot. The corresponding estimated change in installation costs to meet these requirements is a decrease of \$0.63 per square foot as a result of reduced fixture requirements. The new controls requirements are found to be cost effective on a whole building weighted basis at a payback period under 5 years on average.

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Interior Lighting Power Densities – Cost Effectiveness

The adoption of the ASHRAE/IESNA 90.1-2004 Energy Standard will include a set of Lighting Power Density (LPD) values that were completely revised as a result of various changes in the lighting industry since the adoption of the 1999 version of the standard. These changes included a revised set of light level recommendations from the Illuminating Engineering Society of North America (IESNA 2000) found in the 9th edition handbook, as well as updated lighting equipment efficiencies, revised light loss factors and changes in common design practice. These changes in the lighting industry are the driver for the efficient yet achievable lighting power limits reflected in the new 90.1-2004 LPD values.

It is important to note that this kind of code-to-code analysis is a point-to-point comparison, where a fixed level of real world activity is assumed. It is understood that buildings are not built precisely to code levels, and that actual percentage of compliance above and below codes will vary among individual buildings and building types. However, without specific knowledge of this real world activity for all buildings in existence and in the future (post-code adoption), it is not possible to analyze actual effects of code adoption. However, it is possible to compare code levels and determine the potential effect of changes from one code requirement level to another. This is the comparison and effectiveness assessment provided by this analysis.

Analysis Method

The basis for this analysis is the set of models that are used to derive the LPD values in the 90.1 Standards. The basic models are mathematical representations of typical “good quality” lighting designs for approximately 120 different space types commonly found in buildings. The output of these models is a LPD for each space type, which forms the space type LPD requirements in the standards. These space type LPDs are further applied to a dataset of detailed space type square footage data take-offs for 246 individual, recently constructed real buildings from across the nation. This application generates whole building LPDs based on the weighting of space type LPD values in real buildings. The dataset contains multiple individual buildings for each building type, and the LPD results for these are averaged to represent a typical building type LPD requirement.

Cost Analysis Basis

These 90.1 LPD models are modified for the Michigan State analysis to generate cost effectiveness data. The original models provide information on generic lighting technology types and the relative quantities of each that represent the lighted space type. This lighting technology information is directly used to develop a typical cost for each space type model for both the 90.1-1999 and the 90.1-2004 sets of models. These derived space type costs can then be compared and combined with estimated energy savings to develop the cost-effectiveness of the adoption of the new LPD values.

Cost data for commodities such as lighting are always very difficult to apply to analysis efforts because of the great variability. Lighting products that provide similar light at similar efficiencies and distribution characteristics can come in a wide variety of styles and formats that have greatly varying costs. This is unlike other major building energy components such as mechanical systems and envelope materials,

where the cost is generally driven by the efficiency or quantity of the material. Lighting, however, includes a very large decorative or visible art component that impacts cost.

To make this analysis a fair and reasonable comparison, a set of equitable costs was required. The basis for these depends on the use of basic light producing equipment (minus any decorative or art components) at a nationally consistent and recognizable cost structure. The LPD models are already based on standard basic equipment representing good quality but low decorative components. The source for consistent cost data is centered on the R.S. Means cost data reference (RS Means 2005) and the Grainger Supply catalog (Grainger 2004). The R.S. Means data is a well recognized and used source for building construction cost estimating that provides material, labor, and overhead estimates for a variety of lighting products. R.S. Means also tracks location-specific cost indexes for adjusting basic cost data. The Grainger Supply catalog represents a major retail source of lighting equipment with nationally consistent prices. The Grainger catalog provides additional detail on specific equipment that is not available in the Means data source and is used to supplement the base Means estimates.

Each of the LPD models is populated with lighting fixture data from 1 to 3 different fixture types from a list of 34 defined fixture types. Fixture costs for each of the 34 types were developed from the two cost sources, which are in turn applied to the space type models. This development included deriving a base fixture cost and associated installation labor, adjustment to Michigan cost indexes, and assignment of a wattage for cost assignment. The Means and Grainger sources were used, where applicable, to derive an installed cost for each fixture. The Means city cost indexes for Michigan cities were used to derive a weighted Michigan state index using city population data from the U.S. Census. The resulting costs used for this analysis include material plus labor adjusted by the weighted Michigan state index but do not include any overhead/profit adders. The Grainger catalog was used to assign a typical wattage to each fixture type. These wattages are used to apply the appropriate cost for each of the one to three fixture types in the model based on the model's use of them based on wattage and efficacy.

The individual space type model formulas were modified to derive costs (instead of LPD) based on the developed fixture costs and index. While the set of 90.1-1999 and 2004 models are the same, some of the characteristics of the models are different, including different fixture choices and, of course, the quantities of fixtures needed to provide the lighting represented by the LPD value. These differences drive the difference in cost for each model from the 1999 to 2004 sets of models. For consistency of the analysis, the efficiencies of the fixtures applied in the models and the building set data used to develop the whole building values were based (for both code levels) on the latest data used in the 2004 Standard development. This provides a consistent basis because new construction designed to meet either code would apply the same equipment at current efficiencies.

Energy Cost Comparison

The models provide detailed data that can be used to compare individual space type characteristics and changes. However, these individual comparisons cannot provide an overall effect on code adoption at a state level. Therefore, the whole building cost data derived in the analysis is used for comparisons. The models are used to derive both difference in cost and difference in energy (power density) between the application of 90.1-1999 and 90.1-2004 LPD levels to each building type. The cost difference is the difference between the whole building lighting cost per square foot derived using the 90.1-1999 models

and the 90.1-2004 models. The energy difference is the wattage (power density) difference per square foot. These values for the 32 building types are shown in Table 1.

Table 1. Whole Building Model Comparison – 90.1-1999 to 2004

Building Type	Equipment Cost "Change" in \$/sqft	LPD Energy "Change" in W/sqft
Automotive Repair	(1.00)	(0.60)
Convention Center	(0.26)	(0.20)
Courthouse	(0.63)	(0.20)
Dining-Bar Lounge/Leisure	(0.22)	(0.20)
Dining-Café/Fast Food	0.09	(0.40)
Dining-Family	0.33	(0.30)
Dormitory	(2.60)	(0.50)
Exercise Center	(0.09)	(0.40)
Fire Station	(0.54)	(0.50)
Gymnasium	(0.07)	(0.60)
Healthcare-Hospital	(0.94)	(0.40)
Hotel	(1.97)	(0.70)
Library	(0.26)	(0.20)
Manufacturing	(1.01)	(0.90)
Motel	(2.38)	(1.00)
Multi-Family	(0.34)	(0.30)
Museum	(0.67)	(0.50)
Office	(0.79)	(0.30)
Parking Garage	0.04	0.00
Penitentiary	(0.55)	(0.20)
Police Station	(0.59)	(0.30)
Post Office	(1.15)	(0.50)
Religious	(1.17)	(0.90)
Retail	(1.56)	(0.40)
School-College	(0.26)	(0.30)
Sports Arena	(0.92)	(0.40)
Theater-Performing Arts	0.03	0.10
Theatre-Motion Picture	(0.39)	(0.40)
Town Hall	(0.67)	(0.30)
Transportation	(0.11)	(0.20)
Warehouse	(0.10)	(0.40)
Workshop	(0.16)	(0.30)

It is clear from the table that the majority of the building types (28) exhibit both a decrease in cost and a decrease in energy between the two code levels. For these cases, there is a clear advantage in both cost and energy to moving to the new code level. The remaining four building types are worth examining individually.

Dining - Cafeteria Fast Food

The energy savings of 0.40 watts per square foot for this building type will offset the additional equipment cost. This is calculated using an estimated weekly lighting operation time for this building type of 84 hours (EIA 1999, Commercial Bldg Energy Conservation Survey) and the 2004 yearly average Michigan State commercial electricity cost of 7.57 cents per kilowatt (EIA 2004). For this building type, the estimated energy cost savings per square foot per year based on the 0.40 energy savings is \$0.13 per square foot. This offsets the equipment cost increase of \$0.09 per square foot and the simple payback is less than 1 year (0.67 years).

Dining – Family

The estimated energy cost savings per square foot per year for this building type will also offset the additional equipment cost. In this case, the estimated simple payback is 3.35 years.

Parking Garage

The parking garage building type is the only one that experiences no change in lighting power density for whole building. The whole building values represent aggregations of multiple individual space types and building space characteristics. These combinations of changes in the models can produce a null effect such as this for energy with a definite effect in cost (or visa-versa). In this case, while there is no energy savings, there is a small increase in cost resulting from small changes in technology choices. Therefore, technically, the additional small cost per square foot will never be repaid with energy savings for this building type.

Performing Arts Theatre

In this case both the cost and energy are expected to increase with a change in code levels. The cost change is very small at \$0.03 per square foot with a moderate rise in energy use at 0.10 watt per square foot. Again in this case, there can be no repayment of the additional equipment cost for this building type.

To be able to evaluate the effect of the code change across Michigan, it is important to look at the weighted effect of all building type changes. Michigan State specific building type square footage data was provided¹ and used to develop Michigan specific weighted changes in equipment cost and energy density. The results of this analysis show a weighted decrease in equipment cost of \$0.63 per square foot for all buildings and a decrease in energy of 0.39 watts per square foot for all buildings.

Analysis Results

Primary results from this comparison analysis are:

- 30 of the 32 building types analyzed show a **decrease** in allowed power density with adoption of the new code. The Performing Arts Theatre building type increases by 0.1 watt per square foot allowed (1.5 to 1.6) and Parking Garage shows no change in energy.

¹ Spreadsheet data provided by John Sarver via email on 9/11/2006: "SQFT Validation2.xls"

- 28 of the 32 building types show estimated **decreases** in lighting installation cost in complying with the new IECC 2003 code LPD levels. This is primarily caused by the new models reflecting the current light level recommendations and applying current equipment efficiencies and design practices that allow less equipment to be able to provide the necessary lighting. Cafeteria/Fast Food Dining, Family Dining, Parking Garage, and Performing Arts Theatre building types experience small to moderate increases in equipment costs.
- The weighted average power density change across all building types is an estimated **decrease** of 0.39 watts per square foot in lighting power density across the state based on a typical nationwide building mix.
- The weighted average effect of the cost change across all building types is an estimated **decrease** in lighting installation costs of \$0.63 per square foot across the state based on a typical nationwide building mix.

These results make it clear that on a State level, adoption of the new lower LPD values found in the ASHRAE/IESNA 90.1-2004 Standard are cost effective at effectively any cost recovery base period.

It is important to note that while this analysis can do a reasonable job of comparing code levels, it is in no way a metric for actual practice, and, therefore, actual effects of the code. Builders have and will continue to design buildings (and lighting) based on client needs and desires, with energy code compliance, at best, a companion consideration. Therefore, it is probable that some (or many) buildings are already designed better than existing codes and may require minimal or no change to meet future codes.

Additional Adoption Considerations

Exterior Lighting Power Densities

One of the major additions to the 2004 version of the 90.1 Standard is a greatly expanded set of exterior lighting power density values. The previous standard (1999) only included specific power limits for four common exterior applications (building entrances and exits, canopies, and facades only) compared to 17 in the 2004 Standard (covering effectively all expected exterior applications). These values work in the same way as the interior LPDs in that they specify maximum power limits for specific exterior applications. The set of requirements includes tradable as well as non-tradable application LPDs. The tradable applications offer the same trade-off capability among applications as the interior LPDs. The non-tradable applications have specific power limits that must be used for the specific application and cannot be traded off to other applications.

This expanded set of power limits should have a similar energy saving and cost reducing effect as the revised interior LPDs analyzed in this report. The result of this expanded set of values is that large exterior areas previously unrestrained by a power limit must now comply with one. The actual energy savings will depend on the individual design application, but these requirements will have the effect of reducing exterior lighting energy use. The installation cost of exterior lighting will likely also be reduced because the power limits will cause designs to be re-evaluated with the likely result being fewer or smaller exterior fixtures.

Lighting Controls – Occupancy Sensors

One important addition to the 2004 version of the 90.1 Standard is a limited requirement for occupancy sensors in most classrooms, conference/meeting rooms, and employee lunch and break rooms. The existing automatic shutoff control requirement for lighting (in both 1999 and 2004 versions) allows the use of occupancy sensors as one compliance option. Note that the language for this requirement in the 1999 version is decidedly unclear. This language has been corrected in the 90.1–2001 and 2004 Standard.] This new requirement in the 2004 version makes the use of occupancy sensors mandatory for these spaces.

The savings potential from occupancy sensor control has been studied, and the results indicate large but quite variable potential. It is generally impossible to evaluate actual savings potential given the multiple variables of the building stock and use characteristics for an entire state. However, some discussion of the effect of this requirement can be useful.

Research finds that some building spaces are better candidates than others for these sensors both from a cost-effectiveness and operational standpoint. For example, most of the study results show that “common” type spaces such as lunchrooms, conference rooms, restrooms, and/or photocopy rooms provide the best energy savings opportunities. Conversely, those studies show that some but not all individual offices can provide little savings. While the conditions are extremely variable, the study results show potential payback periods for occupancy sensors in the range of 0.7 to 7.8 years (depending

on capacity of installed lighting) for “common” spaces and 4.0 to 9.1 years for office type spaces based on Federal energy rates of around \$0.08 per kWh (close to the average Michigan rate). Therefore, this new requirement for occupancy sensors in some common space types will be a cost-effective addition to energy code requirements for Michigan.

Compliance and Additional Lighting Power Allowances

In addition to the cost-effectiveness considerations for new code adoption, other factors may merit consideration. It is clear that in many building types, lighting can be an important part of design, art, and commerce.

It is also understood by code developers that the prominent art element of lighting (not found in envelope and mechanical energy concerns) creates potential problems with meeting specific code levels. This is the driver behind the additional lighting power allowances provided in the 90.1 Standard. Because of the unfamiliarity of codes and application, some interested parties may not have a full understanding of the use of the additional allowances. Therefore, the adoption of more stringent codes such as 90.1-2004 could be eased within the lighting design community by emphasis and education placed on these allowances.

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