Architecture, Lighting, and Energy:

An evaluation of the perceptual and energy consumption implications of lighting standards in architectural design

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The invention of the incandescent light bulb in 1879 brought forth a proliferation in the use of electric lighting to illuminate building interiors, and in 1906, the field of illuminating engineering was created. Although it was theoretically possible shortly thereafter to precisely calculate the illumination levels at every point in any room, the complexity and enormity of the task made it practically impossible to utilize the accurate calculation method in the day-to-day practice of architecture and lighting design. In 1916, the *lumen method*, which compromised accuracy for simplicity, was developed to address the need for an empirically based lighting calculation method for use in the day-to-day practice. The then current rule-of-thumb methods, designed to increase the sales of lighting fixtures and electric power, were quickly displaced by the *lumen method*, which has since taken hold as <u>the</u> industry standard lighting calculation method.

The Arab Oil Embargo in the 1970's, which made the linkage between human activity and environmental impacts palpable, brought forth the need for building guidelines that specifically addressed energy and environmental considerations. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) responded by developing Standard 90.1-1979 *Energy Standards for Buildings Except Low-Rise Residential* in 1979, and in its 1999 revision, ASHRAE incorporated the *lumen method* to establish limits on building lighting power density into Standard 90.1-1999. The *Leadership in Energy and Environmental Design Green Building Guideline* (*LEED*™), the most prevalently used building environmental guideline in the United States, references ASHRAE Standard 90.1-1999 in its in defining building energy performance requirements. The somewhat crude *lumen method*, thus, establishes the environmental lighting requirements in the United States.

Throughout the 20th Century, the methods of calculating the coefficients and factors used in the *lumen method* were incrementally improved to increase the accuracy of the calculation. However, the *lumen method* cannot be improved beyond what it was designed to calculate: the average maintained uniform illumination level over a horizontal surface (typically 2'-6" above the floor). The introduction of environmental (and thus energy efficiency) considerations in lighting standards demands more accurate calculations than the *lumen method* allows.

The maturation of accurate lighting simulation methods coupled with significant advancements in computational power and speed offer an opportunity to empirically evaluate current lighting standards by simulating the lighting conditions resulting from adhering to them. Such an evaluation would be instrumental in identifying the aspects of current lighting standards that could be modified in order to improve lighting energy efficiency while maintaining (or improving) the resulting visual lighting conditions in buildings.

This paper presents a framework for evaluating the building lighting standards by:

1) Simulating the lighting conditions resulting from current lighting standards
2) Quantifying visual and perceptual characteristics resulting from current lighting standards
3) Defining the correlation (or lack thereof) between illumination levels and visual quality

The expected outcome from this evaluation is a framework for developing lighting standards and recommendations founded on the desired visual and perceptual conditions in a space rather than absolute illumination levels. It is further expected that this investigation will indicate that the application of this alternative standard could result in reduced energy consumption while maintaining or increasing the visual quality of spaces.