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Pacific Northwest National Laboratory
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Energy Effective Courtroom Lighting: An Analysis of Existing Conditions and Recommended Improvements

Carol C. Jones, IALD, LC
Eric Richman, LC

March 2006

Prepared for the
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Federal Energy Management Program
Under Contract DE-AC06-76RLO 1830

and the U.S. General Services Administration
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Richland, Washington 99352

Executive Summary

Providing high quality *and* energy efficient lighting in courtrooms is a complex task, and it represents a greater challenge than most other Federal space types. Energy efficient lighting in courtrooms must be accomplished with no sacrifice in quality; efficiency must be effectively invisible to the occupants. The Whole Building Design Guide (WBDG) eloquently states the architectural goals of courthouse design: "As the preeminent symbol of Federal authority in local communities, a Federal courthouse must express solemnity, stability, integrity, rigor and fairness." The courtrooms themselves must have a sense of majesty and be aesthetically inspiring. When paired with the visual needs in a courtroom—given the wide variety of tasks and the critical nature of the courtroom proceedings—one has a challenge indeed.

In consideration of these issues, this report reviews existing conditions in courtrooms and provides specific guidance about solutions that will accomplish the dual objectives of high quality and energy efficiency. The material covers all aspects of courtroom lighting, including design criteria, design and application strategies, energy efficient technologies, procurement and team selection, design process and implementation, and education.

A detailed energy analysis was performed to develop a baseline for energy consumption in courtroom lighting, and the primary root cause for excessive energy use was found to be a high incidence of incandescent technology. Incandescent lighting was responsible for 54% of the energy consumption but is the least efficient of all the technology options. Point-by-point calculations were completed to provide an energy efficient alternative to the incandescent that met the high level of criteria for performance in courtrooms. Energy modeling was completed based on redesigns that included the use of dedicated compact fluorescent downlights with dimming electronic ballasts and high performance T8 systems, resulting in an average potential savings of 27.6% and 1.2 watts per square foot. A life-cycle cost analysis was performed to provide one example of the type of energy cost savings that is available. The findings showed a Savings-to-Investment Ratio (SIR) of 5.57, and Adjusted Internal Rate of Return (AIRR) of 10.32%, and a simple payback period of four years. The national energy savings potential has been estimated at 13,328,837 kilowatt-hours.

Additional detailed design guidance has been provided in the spirit of a holistic solution. It is hoped and anticipated that the recommended solutions will transform courtroom lighting towards both energy efficiency and high quality lighting. This is more important than ever before given the passage of the Energy Policy Act of 2005, which significantly changes the energy usage requirements in Federal buildings. Ultimately it is possible to support the critical and high stakes proceedings in courtrooms while still meeting the civic duty of designing for energy efficiency and sustainability.

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1.0 Background

This project originated from the 2005 Technical Assistance (TA) Call for Projects from the U.S. Department of Energy Federal Energy Management Program (FEMP). The General Services Administration (GSA) Sunbelt Region requested guidance on energy efficient lighting in courtrooms from a technical assistance team at the Pacific Northwest National Laboratory (PNNL). Because the GSA Public Buildings Service Office of Applied Science (OAS) and the Administrative Office of the U.S. Courts (AOUSC) were conducting similar work under a separate contract, it was later determined to align the efforts, with the lighting energy analysis conducted by PNNL and the data collection and engineering conducted by Ove Arup & Partners Consulting Engineers PC (hereafter referred to as Arup Lighting).

The impetus of the project was related to frequent problems with courtroom lighting. The question at hand was to determine the nature and source of the continuing problems and determine the best course of action to fix the root cause. Was the basis of the problems the guidance in the written criteria (or lack thereof), or the inability to apply the guidance correctly?

This report addresses these questions and provides a focus on achieving energy efficiency and high quality courtroom lighting. To this end, the focus of Arup Lighting was primarily to gather physical lighting measurements from six district courtrooms and determine what did or did not work well with respect to lighting quality and the relationship to the design criteria. The focus of the PNNL team was to perform a detailed analysis of the energy efficiency issues in consideration of the lighting quality requirements and the complexities of design criteria, procurement and construction by GSA. Arup Lighting and PNNL shared documentation and had meetings as necessary to support their mutual goals in service of GSA, AOUSC and FEMP. The revised goal of the effort was to provide guidance to GSA Public Building Service (PBS) and the AOUSC, in the hopes of improving their design criteria in both lighting quality and energy efficiency. The data collection and analysis by Arup Lighting is included in their report under separate cover.

1.1 Objectives

The objective of this work, with respect to lighting in courtrooms, is to accomplish the following:

(1) Determine the most frequent and significant lighting design problems, with respect to both energy efficiency and lighting quality.

(2) Perform an energy analysis to determine the root cause for excess energy consumption.

(3) Recommend changes to lighting criteria, and provide relevant strategies to improve lighting in courtrooms to improve energy efficiency and lighting quality.

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2.0 Analysis of Existing Conditions

The first task was to identify the design guidance provided by the two primary agencies – GSA and AOUSC – along with other relevant technical information, the existing conditions in courtrooms, and the process by which designs are developed and installed.

2.1 Relevant Design Criteria and Standards

Data was gathered to determine what the prevailing criteria and standards are for courtroom design, as well as the existing conditions in the courtroom sample set. Sources included the following list:

(1) U.S Courts Design Guide (US Courts),

(2) GSA PBS Facilities Standards for the Public Building Service (PBS P-100),

(3) IESNA[1] Lighting Handbook, 9th Edition (IESNA),

(4) Energy Policy Act of 2005 (EPACT),

(5) ANSI/ASHRAE/IESNA[2] Standard 90.1-2004 (ASHRAE),

(6) Federal commercial building energy code 10 CFR Part 434 (10 CFR Part 434).

2.1.1. U.S. Courts Design Guide

The U.S. Courts Design Guide (USCDG) provides guidance about lighting in courtrooms, summarized as follows.

- Footcandle levels range from 40 to 75 footcandles (fc) (430 to 800 lux).
- Acceptable lighting is identified by source and distribution. Fluorescent can be used for direct or indirect applications. Incandescent is only allowed in direct luminaires, while metal halide is only allowed in indirect applications.
- Specific control requirements are provided, including the minimum “scenes” that will be required of the control system.
- Additional general guidance calls for lighting that is sensitive to the needs of video display and recording, evidence display, and computer usage. Good color rendering is called for, as well as vertical footcandles. Caution is suggested with respect to bright sources because of the possibility of glare. Concerns about noise from voltage fluctuation of high wattage lamps are also raised.

2.1.2. GSA PBS P-100

The most recent update to the Facilities Standards for the Public Buildings Service (GSA P-100) was issued in March of 2005. In particular, Chapter 6, Section 6.8 on Interior Lighting has incorporated changes from the IESNA Lighting Handbook 9th edition, and has been thoughtfully updated with respect to issues related to energy efficiency, sustainability and daylighting.

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[1] Illuminating Engineering Society of North America.

[2] American National Standards Institute, American Society for Heating, Refrigeration, and Air Conditioning Engineers.

However, Chapter 9, Design Standards for U.S. Court Facilities, has not been similarly updated and remains vague with respect to courtroom lighting. The guidance is consistent with the USCDG and IESNA resources, but offers little advice about how to accomplish the goals.

2.1.3. IESNA Lighting Handbook, 9th Edition

The IESNA Lighting Handbook provides the most specific guidelines for lighting in courtrooms, and does provide explanations in the handbook on strategies to achieve the criteria. A summary is provided here.

- Visual tasks are listed and include reading, audiovisual (A/V) presentations, and video and camera use.
- Special considerations include low-glare luminaires, dimming with preset levels for typical courtroom functions, and aesthetically appropriate luminaires to enhance the dignity of the courtroom.
- Color rendering is indicated as important because of evidence display.
- Horizontal and vertical illuminance levels are referenced in Chapter 10.
- Wall luminance must be reduced so it does not interfere with A/V presentations.
- Judge, jury and attorneys must still be able to take notes during the A/V presentations.
- Lighting control must be flexible and user friendly so it may easily accommodate the variety of activities in the courtroom.

Design standards for lighting are synthesized in the Lighting Handbook in the Chapter 10 Lighting Design Guide. The Guide provides a matrix that prioritizes the design issues for different spaces. Additional guidance on how to address these objectives can be found in a courtroom design example in the IESNA publication entitled “Lighting for People: A Guide to Designing Quality Lighting in the Built Environment.” (IESNA DG-18) The highest design priorities for courtrooms are as follows:

(1) Appearance of Space and Luminaires
(2) Color Appearance (and Color Contrast)
(3) Daylighting Integration and Control
(4) Direct Glare
(5) Light Distribution on the Task Plane (Uniformity)
(6) Modeling of Faces or Objects
(7) Source/Task/Eye Geometry
(8) System Control and Flexibility
(9) Horizontal Illuminance
(10) Vertical Illuminance.

Further details on illuminance are also provided for the different areas of the courtroom.

Table 1. Courtroom Illuminances

Courtroom Area	Horizontal Illuminance	Vertical Illuminance
Judge and clerk	50 fc	10 fc
Litigant's table and podium	50 fc	10 fc
Witness chair	30 fc	5 fc
Spectator area	10 fc	3 fc

2.1.4. Energy Policy Act of 2005

The most significant and immediate impact of the Energy Policy Act of 2005 (EPAct) is that new Federal buildings will soon be required to achieve energy savings of at least 30%, (if cost-effective) below that required by ANSI/ASHRAE/IESNA Standard 90.1-2004. This savings has not been defined. The Department of Energy is required to issue a rule to this effect by August 2006. Stakeholders are encouraged to provide input.

It is important to note that the 30% savings requirement does not indicate a linear reduction of energy usage across the entire standard. The impact on lighting power density (LPD) numbers may be greater or lesser than the impact on the building envelope or mechanical systems, for example. If LPD's are reduced, it does not necessarily mean that the courtroom LPD will be reduced by 30%; it may be more appropriate to reduce the power allowance for other space types.

In addition to those mentioned above, there are a number of other relevant provisions.

- Sustainable design principles be applied to the siting, design, and construction of all new and replacement buildings. (Section 109)
- When newer versions of the ASHRAE Standard 90.1 or IECC (ICC) Code have been passed, EPAct 2005 encourages state and local government buildings to meet these newer versions. (Section 125)
- Technology use in Federal buildings is addressed by requiring the procurement of Energy Star® products, FEMP-designated products, and National Electrical Manufacturers Associations (NEMA) Premium® electric motors. (Section 104)
- An overarching goal for reducing energy consumption on a gross square foot basis has been set for *existing* Federal buildings. The requirement is that consumption be decreased by two percent per year, reaching a 20 percent decrease by 2015 as compared to a baseline established in 2003. (Section 102)

2.1.5. ANSI/ASHRAE/IESNA Standard 90.1-2004

ANSI/ASHRAE/IESNA Standard 90.1-2004 (ASHRAE) provides power limits for both the interior and exterior lighting of a building, along with mandatory controls requirements and some lighting source efficacy limits. Only interior lighting issues are discussed in this report.

Standard 90.1 provides lighting power density (LPD) limits in two ways. One performance path (called the "Building Area Method") is to comply with an LPD that applies to an entire building, such that average LPDs for the entire building do not exceed this number. For courthouses, the LPD limit is 1.2 watts per square foot.

Another performance path (called the "Space-by-Space" method) is to develop an "energy budget" by applying a room-specific power density for each room in the courthouse building. The LPD number for courtrooms is 1.9 watts per square foot. A variety of LPDs would apply to other areas of the courthouse. For example, the LPD number for offices is 1.1, while restrooms are 0.9, and corridors are 0.5. The room-specific power densities would be calculated for each space resulting in a power allowance for the entire building, which is likely to be different from the allowance specified under the whole building method of compliance.

The Space-by-Space method accommodates the particulars of an actual building, which would be advantageous for courthouses that have a higher density of courtrooms than is typical.

Mandatory automatic lighting controls are required. This means that the lighting controls system in the courtroom must be capable of automatically turning off the lights when the room is not in use.

2.1.6. Federal Energy Code

The current applicable rule for Federal commercial buildings (including courthouses) is entitled "10 CFR Part 434, Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings." The final rule was published on October 6, 2000 and the regulation became effective on October 8, 2001. The current Federal code is effectively superseded by the Energy Policy Act of 2005.

2.2 Design, Procurement and Construction

Information about the design, procurement and construction process was gathered. Written guidance on these topics is excellent, but practical application of the guidance cannot be reliably determined.

2.2.1. GSA Design Excellence Policies and Procedures

The GSA is deeply committed to architectural excellence, as evidenced by the Design Excellence program (GSA Design Excellence), which has been in place since 1994. This program provides explicit guidance about procurement for government design projects including courthouses, and establishes very high standards for professional expertise. The focus is primarily on architectural services and the program is mostly silent on the topic of lighting services and energy usage. While the use of a lighting design consultant is not explicitly required, it is common practice on courthouse projects for architects to have a lighting consultant as a member of the design team.

2.2.2. Whole Building Design Guide

The Whole Building Design Guide (WBDG) is not a design guide in the traditional sense; rather it is a website that offers useful links to resources on topics related to building and construction in the Federal sector. For example, links are provided to the U.S. Courts Design Guide and relevant energy codes, but the website does not have any specific requirements per se. The web pages offer basic information about sustainability, courthouses and lighting, but there is no specific guidance about lighting in courtrooms.

2.3 Courtroom Data and Project Background

Data was collected in two ways. Information about specific courtrooms was gathered and analyzed, and GSA staff members were consulted to gain their professional experience about managing courtroom lighting projects.

2.3.1. Courtroom Data

Courtroom data collection started with a review of courthouse drawings and specifications provided by GSA, including Tampa, FL; Tallahassee, FL; Montgomery, AL; Columbia, SC; Central Islip, NY; and New York, NY.

Written documentation was supplemented with an actual lighting audit data provided by Arup Lighting. This additional data resulted in enough information to complete a reasonable energy analysis (see below). The information and results of Arup Lighting's work is published in a separate study. (Arup)

2.3.2. GSA Staff Interviews

Phone meetings were held with GSA project managers and staff to gather input on successes and failures of specific courtroom projects, as well as issues related to the process of running a courtroom lighting project. Based on these discussions, a number of issues arose as the most frequent and serious problems in courtroom lighting.

2.4 Design Problems

The most prevalent and systematic lighting problems and challenges were identified both by the audit data and by GSA project managers. The issues are listed below, and suggested solutions to these problems are found in the recommendations section of this report.

2.4.1. Synthesis of Findings from Arup Lighting Report

- Many of the courtrooms were either overlit or underlit.
- There was insufficient "bounce" light in some circumstances caused by the lack of indirect lighting, resulting in excessive shadows and poor facial modeling.
- Most courtrooms had dark wood finishes at the walls, resulting in low room surface brightness, insufficient "bounce" light, and excessive power density.

- Metal halide fixtures created problems because of color appearance, color rendering, and ballast and transformer noise.
- Insufficient daylighting control (less than optimal window shades).
- Task areas were often not treated differently than non-task (e.g., audience) areas, resulting in higher power density than is necessary.

2.4.2. Synthesis of Findings from GSA Staff Interviews

- Insufficient light at the walls (luminance), largely resulting from the use of dark finishes, primarily wood walls.
- Insufficient vertical illuminance, resulting in complaints from judges about facial modeling and evidence display.
- Spaces are *perceived* as underlit because of the low room surface brightness. This has required expensive relighting projects subsequent to initial construction, which usually increases power density.
- Control systems that are not user-friendly.
- There have been problems with ceiling plane and room geometries, where the lighting design did not respond to the architectural requirements of the space.
- Glare from lighting fixtures and occasionally windows as well.
- Color rendering issues have occurred, where finishes appear differently under the courtroom lighting than expected, resulting in changing the lighting or the wood finishes.
- Misunderstandings by the project participants can occur over design issues, often related to a lack of awareness about lighting design principles and technologies and a lack of priority for energy efficiency.

2.5 Energy Analysis

The energy analysis first focused on determining the severity of the problems related to energy usage. To do this, it was necessary to determine the power density for each of the courtrooms based on the best data available. Once this was done, possible solutions were investigated.

2.5.1. Existing Power Density Analysis

Energy data collection and analysis for the selected courtrooms involved several steps aimed at assessing the lighting characteristics. The methodology is detailed below, and the findings are compared against EPAct 2005 requirements.

2.5.1.1. Methodology

For each set of available drawings, those specific to the chosen courtroom were separated and enlarged to identify room characteristics and lighting fixture codes to match the lighting schedule where available. Audit data from Arup Lighting was applied where necessary to supplement missing information. Input wattages were multiplied by fixture quantities to get overall wattage used, which was then divided by the square footage to get the lighting power density (LPD) for each courtroom.

With a characterization of each courtroom in place, a summary of the current lighting power density was completed to represent energy use and provide a basis for potential improvements.

2.5.1.2. Summary of Lighting Power Density

Lighting power densities are listed in the table below.

Table 2. Lighting Power Densities for Selected Courtrooms

Courthouse Location & Courtroom Description	Wattage	Square Footage	ACTUAL Lighting Power Density (1, 2)	TARGET Lighting Power Density (3)
Tampa, FL 801 North Florida Ave Gibbons Courthouse- District Courtroom, 13B	9,896	2,287	4.3	1.9
Tampa, FL 801 North Florida Ave Gibbons Courthouse- District Courtroom, 14B	11,976	2,287	5.2	
Tallahassee, FL 111 North Adams St. US Courthouse- District Courtroom	12,920	2,439	5.3	
Montgomery, AL One Church Street Johnson Courthouse- District Courtroom	7,005	2,196	3.2	
Columbia, SC 901 Richland Strreet Perry Courthouse- District Courtroom 13B	17,360	3,840	4.5	
500 Pearl Street Manhattan, NY Moynihan Courthouse- Foley Square, Rm 15A	11,310	3,168	3.6	
Central Islip, NY 100 Federal Plaza Alfonz D'Amato Courthouse- 9th floor Courtroom	7,260	2,210	3.3	
Average Totals	11,104	2,632	4.2	N/A
NOTES: (1) Data was based on the most reliable information available at the time of analysis, and is subject to change should additional information become available. (2) Lighting Power Density is Watts per Square Foot. (3) The target LPD value shown here is taken from ANSI/ASHRAE/IESNA Standard 90.1-2004. Per the Energy Policy Act of 2005, a new Federal rule is due out from DOE in August 2006 requiring further energy savings of 30%, if cost effective. Impacts on individual LPD's cannot be anticipated at this time.				

2.5.1.3. Energy Code Compliance

Clearly the power densities shown in Table 2 do not even approach compliance with the ASHRAE/IESNA Standard 90.1-2004 (see Sections 2.1.4 – 2.1.6). The average calculated power density is 4.2 watts per square foot (w/sf), while the target power density limit is 1.9 w/sf for courtrooms.

2.5.1.4. Energy Usage – Kilowatt-hours

It is important to note that power density is actually a limited method of determining actual energy usage because it does not assess hours of use. District courtrooms are not used as frequently as most other spaces, and so the high connected load is not likely to be as severe a problem as it could be. Unfortunately the lighting section of Standard 90.1-2004 does not have an equivalency system to determine the relative importance of different spaces with respect to energy consumption. It is important to recognize that true energy consumption is reflected in kilowatt-hours, which consider both connected load and hours of use.

The issue of energy use over time and code language related to lighting controls is being discussed in depth in the most recent ASHRAE 90.1 Lighting Subcommittee meetings. Should the U.S. Courts want to provide data about the relative energy use of courtrooms over time or have input to the code development process, feedback is always welcomed by the ASHRAE Standard 90.1 Lighting Subcommittee.[3]

2.5.2. Energy Modeling

The immediate challenge was to determine if the use of energy efficient technologies could sufficiently reduce consumption. Two methods of energy modeling were used to determine possible solutions to high energy consumption. The first method was a fairly high level and simplified investigation into the substitution of more efficient technologies. The second method was a detailed computer modeling using point-by-point ray tracing software, to provide a more focused solution to the obvious overuse of incandescent downlights.

2.5.2.1. ANSI/ASHRAE/IESNA Standard 90.1-2004 Models

The energy analysis utilized a pre-existing methodology that models different types of lighting equipment in a variety of spaces. These models form the basis for lighting power density values in the national energy standard, ANSI/ASHRAE/IESNA Standard 90.1-2004. PNNL is actively involved in supporting USDOE with respect to the development of Standard 90.1, and as such, has experience in using these models. The goal was to perform a broad strokes re-design in the courtrooms to determine how much energy could be saved.[4] The energy savings were roughly estimated by assuming a replacement of the lighting technologies.

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[3] For information on how to provide input to the ASHRAE Standard 90.1 Lighting subcommittee, email carol.jones@pnl.gov or eric.richman@pnl.gov.

[4] The modeling process is not a simple wattage reduction or replacement; rather, it requires an application of lighting equipment (using published data and coefficients of utilization) along with an IESNA approved lumen method of calculating lighting levels.

This methodology kept the existing design solutions but calculated the use of more efficient equipment. In some cases where the actual audit data revealed that the courtroom was overlit, the redesign model was able to save energy by adjusting the light output down to IESNA recommended light levels. In all but one of the courtrooms downlights and wallwashers using compact fluorescent lamps (CFL) were substituted for incandescent PAR lamps. In four of the seven courtrooms it was also possible to retrofit the linear fluorescent fixtures by replacing standard T8 electronic technology with high performance T8 systems.

Table 3 provides a summary of the initial lighting power characteristics for each courtroom location and the potential re-design power characteristics and savings. The table shows an average potential savings of 27.6% and 1.2 watts per square foot.

Table 3. Modeled Re-design Showing Savings from Efficient Technologies

Courtroom Description	Wattage	Square Footage	Lighting Power Density (1,2)	Proposed Re-Design Technlogy	Re-design wattage	Re-design Power Density	Percent Power Reduction
Tampa, FL 801 North Florida Ave (Gibbons Courthouse- District Courtroom, 13B)	9,896	2,287	4.3	CFL Wallwash (in place of Quartz wallwash) & partial retrofit to HPT8	7,006	3.1	29.2%
Tampa, FL 801 North Florida Ave (Gibbons Courthouse- District Courtroom, 14B)	11,976	2,287	5.2	CFL Wallwash (in place of Quartz wallwash) & partial retrofit to HPT8	9,086	4.0	24.1%
Tallahassee, FL 111 North Adams St. (US Courthouse- District Courtroom)	12,920	2,439	5.3	CFL Downlight Open (in place of PAR38 incandescent downlight)	8,453	3.5	34.6%
Montgomery, AL One Church Street (Johnson Courthouse- District Courtroom)	7,005	2,196	3.2	CFL Downlight Open (in place of PAR38 incandescent downlight)	6,081	2.8	13.2%
Columbia, SC 901 Richland Strreet (Perry Courthouse- District Courtroom 13B)	17,360	3,840	4.5	CFL Downlight Open (in place of PAR38 incandescent downlight) & partial retrofit to HPT8	8,273	2.2	52.3%
500 Pearl Street Manhattan, NY (Moynihan Courthouse- Foley Square, Rm 15A)	11,310	3,168	3.6	CFL Downlight Open (in place of PAR38 incandescent downlight)	7,786	2.5	31.2%
Central Islip, NY 100 Federal Plaza (Alfonz D'Amato Courthouse- 9th floor Courtroom)	7,260	2,210	3.3	Retrofit from standard T8's to High Performance T8	6,613	3.0	9%
Averages	11,104	2,632	4.2	Averages	7,614	3.0	27.6%

NOTES: (1) Data was based on the most reliable information available at the time of analysis, and is subject to change should additional information become available. (2) Lighting Power Density is Watts per Square Foot.

2.5.2.2. *Defining the Gap*

The most significant problem as shown above is the use of PAR lamps as a downlight solution in spaces with high ceilings. The severity of the problem is revealed in Table 3, which shows the relative energy use of incandescent as compared to the rest of the connected load in the courtrooms. On average, 54% of the total connected load is direct incandescent lighting—the most inefficient type of lighting.

Table 4. Relative Energy Use of Different Types of Light Sources.

Courthouse and Courtroom Description	% Incandescent	% Linear Fluorescent	% Compact Fluorescent	% Metal Halide
Tampa, FL 801 North Florida Ave Gibbons Courthouse- District Courtroom, 13B	42%	9%	49%	0%
Tampa, FL 801 North Florida Ave Gibbons Courthouse- District Courtroom, 14B	35%	7%	14%	43%
Tallahassee, FL 111 North Adams St. US Courthouse- District Courtroom	90%	0%	10%	0%
Montgomery, AL One Church Street Johnson Courthouse- District Courtroom	34%	0%	66%	0%
Columbia, SC 901 Richland Strreet Perry Courthouse- District Courtroom 13B	93%	7%	0%	0%
Central Islip, NY 100 Federal Plaza Alfonz D'Amato Courthouse- 9th floor Courtroom	0%	74%	0%	26%
500 Pearl Street Manhattan, NY Moynihan Courthouse- Foley Square, Rm 15A	81%	0%	19%	0%
Subtotal	54%	14%	23%	10%

2.5.2.3. *Point-by-point Calculations*

Given the results in Table 4, the first challenge was to find a substitute for incandescent lighting that would meet the strict criteria of courtroom lighting, including excellent color rendering and dimmability, while providing sufficient horizontal light levels. To identify possible solutions, point-by-point calculations were performed using five different downlight options.

In contrast to the lumen method of calculation used in the Standard 90.1 models, point-by-point calculations are a very accurate way to determine the distribution of light in a space. The target illuminance was 25 footcandles, because the direct component should contribute to roughly half of the overall illuminance in the space. The remainder of the horizontal illuminance would be provided by linear fluorescent sources or indirect metal halide. Table 4 shows the results of 15 calculations, using 5 of the most applicable types of luminaires at three different ceiling heights.

Table 5. Calculation Results using Downlight Luminaires at Three Mounting Heights

	Vertical Lamp Fixture Triple Tube CFL 42 Watt			Horizontal Lamp Fixture Triple Tube CFL 42 Watt			Horizontal Lamp Fixture Triple Tube CFLs 2 lamp-42 Watt			PAR38 HIR Halogen InfraRed (Incandescent) 100 Watt			PAR38 Metal Halide Ceramic, Pulse Start 70 Watt, electronic		
Ceiling Height: (1)	**12'-0"**	**16'-0"**	**20'-0"**	12'-0"	16'-0"	20'-0"	12'-0"	16'-0"	20'-0"	12'-0"	16'-0"	20'-0"	12'-0"	16'-0"	20'-0"
Average Illuminance (fc)	**29.7**	**26.6**	**23.9**	28.6	25.3	27.9	29.2	25.7	29.9	31.1	28.8	26.6	25.5	24.3	32.5
Lighting Power Density	**0.72**	**0.72**	**0.72**	0.85	0.85	1.07	0.93	0.93	1.24	2.67	2.67	2.67	0.67	0.67	1.00
LPD Normalized	**2.4**	**2.7**	**3.0**	3.0	3.4	3.8	3.2	3.6	4.1	8.6	9.3	10.0	2.6	2.8	3.1
Maximum Illuminance	**37.4**	**34.8**	**32.1**	36.1	34.6	37.9	36.1	34.6	39.7	49.8	35.3	32.5	94.7	49.6	39.3
Minimum Illuminance	**17.8**	**16.1**	**15.1**	15.1	14.0	16.9	16.8	15.1	18.6	16.6	18.8	15.6	3.8	7.2	20.8
Max/Min Illuminance	**2.1**	**2.2**	**2.1**	2.4	2.5	2.2	2.1	2.3	2.1	3.0	1.9	2.1	24.7	6.8	1.9
Uniformity	**0.6**	**0.6**	**0.6**	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.7	0.6	0.1	0.3	0.6
NOTES: (1) Metric equivalencies for ceiling heights are as follows: 12'-0" equals 3.7 meters, 16'-0" equals 4.9 meters, 16'-0" equals 6.1 meters.															

The results of these calculations show that the "Vertical Triple CFL 42 Watt" luminaire provides the best overall results, and is acceptable for each of three mounting heights. The power density is low at 0.72 watts per square foot, the fixtures do a good job of providing the target illuminance of 25 fc, and the uniformity is good at 0.6. The luminaire is a low glare fixture because the lamp sits up high in the housing of the fixture, which also results in an efficient vertical distribution. The luminaire has a dimmable electronic ballast, and the lamp is available in a variety of colors (including the popular 3000K or 3500K) and has a Color Rendering Index (CRI) of 82.

For additional background information on the calculations and the "Vertical Triple CFL" see Appendices A, B, and C.

2.5.3. Energy Cost Savings

Energy costs have escalated dramatically in the recent past, creating a renewed concern and commitment to the reduction of energy costs. Implementation of the recommendations in this report will result in lower utility bills.

Courtroom lighting design varies dramatically and it is not feasible or appropriate to provide any guarantee of energy cost savings. However, for the purposes of providing an example a life-cycle cost analysis was completed to show possible energy cost savings in a typical courtroom. District Courtroom 13B in the Perry Courthouse, Columbia, SC was considered the most typical and representative and was chosen for the analysis. For this report the estimated energy savings is based on a redesign that included the replacement of PAR incandescent downlights with dedicated dimming compact fluorescent downlights, and a retrofit of the non-dim linear fluorescent T8's to high performance T8 systems. The energy and cost savings are shown in Table 6.

Table 6. Present Value Costs and Energy Savings Summary

Description	Average Annual Consumption (kWh) and Costs ($)			Life Cycle Savings
	Base Case	Alternative Design	Savings	
Electricity	40,622 kWh 138.6 Mbtu	19,358 kWh 66.1 Mbtu	21,264 kWh 72.6 Mbtu	531, 527 kWh 1,814 Mbtu
Future Costs	$88,303	$32,838		$55,466
Present Value Life-Cycle Costs	$88,303	$42,799		$45,505

NOTES: (1) Comparative analysis was completed using Building Life-Cycle Cost (BLCC) software version 5.3-05 from the National Institute of Standards and Technology (NIST), and is consistent with Federal life-cycle cost methodology and procedures, 10CFR, Part 436, Subpart A. (2) Future Costs include energy consumption costs, and recurring and non-recurring operation, maintenance and replacement (OM&R) costs. (3) See Appendix D for the complete output of the BLCC analysis.

Additional findings from the life-cycle cost analysis include the following:

- Savings-to-Investment Ratio (SIR) of 5.57
- Adjusted Internal Rate of Return (AIRR) of 10.32%
- Payback period of four years.

2.5.4. Energy Savings Summary

The above analysis clearly defines the nature of the energy consumption problem in typical courthouses and provides a basis for making energy efficiency improvements while meeting the strict quality criteria at the same time. To summarize the national energy savings potential an estimate is provided in Table 7.

Table 7. Summary of the Impacts of the Energy Conservation Measures

Description of Energy Conservation Measure	Energy Metric	Unit Savings / Year (Kilowatt-hours)	Unit Cost Savings ($/year) Current Dollars	O&M Cost Decrease ($/year)
(1) Replace incandescent downlights with pin-based compact fluorescent lamps and electronic ballasts, and (2) Replace non-dimmed Standard T8 fluorescent with High Performance T8 fluorescent systems.	Electric consumption	13,328,837 kWh	$1,066,307	$432,824
NOTES: (1) Typical courtroom size is 2,160 square feet, based on average of typical courtroom sizes noted in the 1997 U.S. Courts Design Guide, (2) Number of courtrooms in the U.S is 2,158, per telephone conversation with Fred Miller, GSA, 2/24/06, (3) Courtrooms usage is estimated at 9 hours per day, 5 days per week, (4) Typical power density savings is 1.22 Watts per square foot, (5) Average Federal kWh cost is applied at $0.08, (6) O&M cost is based on typical retrofits of standard T8 to High Performance T8 and incandescent PAR lamp to Triple tube CFL.				

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3.0 Recommendations

No single recommendation would be sufficient to close the gap between existing practice in courtroom lighting and energy efficient practice. The problems are systemic, and thus the solutions must also be applied systematically. The following suggestions attempt to cover additional areas critical to overall success, including: design criteria, examples of design strategies, energy efficient technology guidance, procurement and team selection, design process, implementation practices, and education.

3.1 Criteria Revisions

This section contains specific suggestions as to how the design criteria could be revised to improve both lighting quality and energy efficiency in courtroom lighting. It is important to continue the coordination between the U.S. Courts Design Guide and the GSA P-100 Chapter 9 to ensure consistency and avoid discrepancies or confusion. The technical basis for the lighting criteria should be based on the IESNA Lighting Handbook, 9th edition, per Section 2.1.3.

3.1.1. U.S. Courts Design Guide

- Table 4-4, "Heating Ventilating, and Air Conditioning (HVAC) and Lighting," should be revised to show more specific footcandle and lux requirements for the different task areas in the courtroom (see Section 2.1.3). If it is not feasible to break out the separate task areas in the existing table, provide a separate table for lighting guidance.
- As a supplement to Table 4-4, additional detail should be provided in Chapter 4 to explain more clearly the luminaire options.
- Guidance on finishes (page 4-57) should be revised to specifically *require* high wall and ceiling reflectances in courtrooms. As it stands, the guidance could be misinterpreted. While there is a mention of light reflectance ("consider acoustics and light reflectance"), there is also guidance to use hardwood veneer paneling. The interplay and relationship between lighting perception, energy efficiency and the choice of the color of wall, floor, and ceiling finishes should be more clearly defined.
- The lighting guidance on pages 4-64 and 4-65 should be revised to include IESNA design guidance. The "Lighting System" section should break out the critical issues in a bulleted or listed format as found in Section 2.1.3 (e.g., (1) Appearance of Space and Luminaires, (2) Color Appearance, (3) Daylight Integration and Control, etc.). As desired, examples of design strategies could be added.
- A commitment to energy efficiency and sustainability should be specifically called out in this section, and references to complementary sections or resources should be considered.
- The "Lighting Levels" section on page 4-64 should be revised to show more specific footcandle and lux requirements for the different task areas in the courtroom (similar to Table 4-4).
- The word "incandescent" in the "Lighting Controls" section should be replaced with the word "dimming," to allow for the use of dimming compact fluorescent fixtures. Digital controls should be added to the list of options, to allow use of the latest technology.

3.1.2. GSA P-100, Chapter 9

The guidance in the "Lighting System" section of Chapter 9 could be incrementally improved to more specifically incorporate the guidance in this section.

3.2 Design and Application Strategies

Practical application of the most appropriate energy efficient technologies in a high quality lighting design involves many variables including technology, tasks, visual performance, human preferences and comfort, costs, architecture, and implementation. This section provides specific suggestions for consideration about the art and science of energy efficient lighting in a courtroom. As a general rule, the lighting design should be responsive to the task activities in the courtroom.

3.2.1. Light for the Task

Lighting solutions should vary depending on task needs. In the case of courtroom lighting, the tasks vary significantly between the well of the courtroom where the judge, jury, and legal counsel are located, and the spectator areas.

3.2.1.1. Judge, Jury and Legal Counsel

The lighting in the well of the courtroom is where the most important and varied activity of the courtroom takes place, and the design and lighting levels should reflect this. Because the activities change throughout the courtroom proceedings and the lighting levels will need to be raised and lowered accordingly, control systems need to be adequately integrated with the lighting design. Critical tasks include viewing of witnesses, evidence, A/V presentations, paper and computers.

3.2.1.2. Spectator Areas

In most of the courtrooms reviewed for this report, the design solutions for the well and audience seating area were similar. Energy savings will be improved by lowering the lighting levels in the spectator areas, as the illuminance requirement is significantly less than in the courtroom well. If the design team wants the same "look and feel" throughout the courtroom, the luminaire can look similar while still consuming less wattage. For instance, if a suspended luminous bowl luminaire is used, the lamps and ballasts for the spectator area can be reduced from those the courtroom well, or the size of the bowl can be smaller but the style can be the same.

3.2.2. Layers of Light

To achieve better energy efficiency in the courtroom, the design strategy of using layers of light is a necessity. These different layers can be accomplished with a variety of different luminaires, but each layer has a mission-critical task. This section will cover the following types of layers: direct, indirect, wall washing, and task lighting.

In ***all cases*** the color rendering should be attractive and consistent across the different sources, with a Color Rendering Index higher than 80. The layers are comprised of several components:

- The **direct** component is necessary for the critical tasks of evidence inspection and seeing people clearly. This will generally be accomplished with recessed downlights, such as dimming compact fluorescent fixtures.
- The **indirect** component creates inter-reflections of light (also called bounce light), which are important with respect to vertical illuminance and for softening what otherwise would be harsh shadows on faces and evidence. The indirect component can be accomplished with architectural cove lighting, suspended luminous bowls, suspended architectural luminaires with an indirect element, or wall or cove mounted sconces.
- A layer of **wall washing** is necessary for acceptable room surface brightness. This is a significant factor that contributes to the impression of the majesty of the courtroom. Often the best way to accomplish wall washing is with linear fluorescent coves or linear wall wash fixtures, although it can also be accomplished with compact fluorescent downlights with a wall wash distribution.
- **Task lighting** should be provided as necessary for the attorney's tables. If there is task lighting for the attorney's tables, and dedicated recessed downlights for the jury and judge/witness areas, then it may be possible to reduce the overall direct element in a good portion of the room. In addition to saving energy, this has the added aesthetic benefit of keeping the ceiling mostly "clean," with fewer downlights.

3.2.3. Daylighting

Daylighting is consistently well-received in almost all environments, if, and only if, appropriate controls are utilized. Used well, it can dramatically improve the quality of a courtroom and truly heighten the experience of the room for all of the end users. Managed poorly, daylighting can be a problematic source of glare and thermal discomfort. In situations where windows are the primary or singular source of natural light, this usually means the use of controllable shade systems at the windows. In new construction buildings daylighting strategies may be more complex, possibly including clerestories, light shelves, and other strategies. To save energy with the use of daylight, the electric lighting must be tied into photocells that can sense the amount of daylight and adjust the electric lighting accordingly. Care should be taken to ensure that there is adequate attention to the cost benefit of the daylighting, as the costs associated with daylighting control can be significant, depending on the design. Daylighting design is considered a specialty in its own right, so it is important to look for deep and proven experience in the selection process of the lighting designer.

3.2.4. Flexibility and Control

Lighting control systems and dimming are a necessity for the courtroom well areas. Continuous dimming is preferred, but step-dimming can be sufficient in some cases. Audiovisual presentations are one of the tasks where the need for lighting control becomes most evident. For example, when a front projection system is used, it becomes important to dim the light that would otherwise wash out the screen. It is important to have a user-friendly control system with preset scenes that are easy to change. The required "scenes" are listed correctly in the USCDG. Security is important so that only the appointed courtroom staff can have access to the lighting controls. (More detail is provided on lighting controls technology in Section 5.3.4 below.)

3.2.5. Lighting for Videoconferencing

While audiovisual presentations are quite common in courtrooms, videoconferencing and filming with the use of cameras is less common. The lighting requirements for videotaping and filming are considerably different than what is provided throughout the rest of this report. For detailed information on this topic, guidance is provided from the IESNA in their newly completed design guide entitled "Lighting for Videoconferencing" (IESNA DG-17). Basic guidance is outlined here.

Vertical illumination is the most important lighting element for videoconferencing. 30-50 fc of vertical illuminance is necessary for videoconferencing. Keep in mind that there is a ratio of approximately 2:1 between horizontal and vertical illuminance. This means that 50 vertical footcandles is often equivalent to 100 horizontal footcandles (the exact ratio depends on the lighting design and photometric distribution of the fixtures). This would double the energy consumption in these areas.

Contrast ratios are very important in lighting for cameras. Cameras will exaggerate contrast, so it becomes important to ensure that the perimeter walls are dimmable, and to minimize scallops on the walls by using linear fluorescent wall washing.

Lighting for videoconferencing would impact all aspects of the lighting design—including increased costs for the equipment, the look and feel of the courtroom, and the energy consumption. Therefore, permanently installed lighting for videoconferencing should only be provided if it's deemed truly necessary based on the intended use of a particular courtroom.

For infrequent videoconferencing or occasions when camera filming is necessary, consider the option of using portable equipment that is employed only for the duration of the proceedings. Television crews often provide their own lighting, but it will be necessary to plan access to a large enough power supply. Another solution would be to install powered track in the courtroom so that theatrical lighting fixtures could be added as necessary.

3.2.6. Courtroom Finishes

The reflectances of the surfaces in the courtroom are integrally related to the aesthetic success of the courtroom and the energy efficiency issues as well. It is important to understand the relationships between the variables to make informed decisions.

- Lighter finishes allow for improved inter-reflection, which improves the visibility of faces and evidence.
- Darker finishes require more lighting and thus more wattage, which will make it difficult (if not impossible) to meet energy code limits and will also add to the lighting equipment costs.
- The use of wood finishes is traditional in courtrooms and contributes to the ambiance and majesty of the space.

- The use of wood must be considered in the context of sustainable design, which becomes more relevant given the new requirements in EPAct 2005.

One approach that has been applied with success in recently built courtrooms is to use less wood in the upper portions of the walls, and more wood toward the lower portions of the room. Well-designed accents and details in wood can contribute significantly to the ambience and quality of the courtroom.

3.3 Energy Efficient Lighting Technologies

One of the ways to close the gap between the audited energy consumption and the connected load required by code is to use the most advanced energy efficient equipment available. A few possibilities are mentioned below, along with some caveats and cautions.

3.3.1. Compact Fluorescent Lamps

Compact fluorescent lamps come in larger lumen packages than when they were first introduced, and often use amalgam technology to help with heat and durability. As of February 2006, 70- and 80-watt compact fluorescent lamps have become available; however, the heat of these lamps may prove to be a durability issue and it is best to wait to ensure that they are reliable in the marketplace before applying them in a courtroom. The highest wattage lamp recommended is the 42-watt triple tube to be used with a dimmable electronic ballast.

3.3.2. High Performance T8 Systems

For areas where dimming is not required (e.g., spectator areas), high performance T8 lamp and electronic ballast systems (HPT8) provide approximately 23% savings as compared to the commodity T8 lamp and ballast system. (ESource) The best performing luminaire components should be specified as part of an energy efficiency strategy. DOE FEMP has guidance on HPT8 technologies on their website at www.eere.energy.gov/femp, and the Consortium for Energy Efficiency has performance specifications listed on their website at www.cee1.org.

3.3.3. Ceramic and Pulse Start Metal Halide

Metal halide in direct applications in courtrooms is not recommended primarily because of dimming constraints and the potential for color shifting in dimming applications. However, consideration should be given to metal halide in indirect applications. The newest metal halide technologies are vastly improved from prior generations of this technology. The quality of the lamps (specifically ceramic and pulse start lamps) have improved with respect to Color Rendering Index (greater than 80 CRI), color temperature (available down to 3000K), and color consistency between lamps and across life. Lamp life is long and lumen depreciation has been reduced. Electronic ballasts are also currently available. Metal halide is a very energy efficient light source and comes in a variety of wattages that can be helpful in the large spaces of a courtroom.

3.3.4. Lighting Controls

The newest lighting controls are digital, which provide for almost any type of control arrangement. Lighting controls with continuous or step dimming should be applied in the front areas of the courtroom. When specifying lighting controls, focus should be on system integration between ballasts, controllers, and any central energy management systems that may be planned for the whole building. It is advisable to verify that the software protocols communicate reliably between the different components, especially if different manufacturers are being used. The lighting specifier should have extensive experience with the use of control systems and should have high confidence in their recommended solution. Experienced commissioning services are also critical to success.

3.4 Credentials, Certifications, Experience Review

The GSA Design Excellence program requires an LC certification (an LC indicates Lighting Certified through the National Council for Certifying the Lighting Professions), which should indeed be required and is useful as a minimum credential. The IALD (International Association of Lighting Designers) appellation should also be considered, along with a portfolio of successful lighting design applicable to courtrooms when choosing the design team. Look for extensive and proven experience with respect to daylighting and advanced lighting control systems.

3.5 Design Process and Implementation Practices

The design process is an integral element of a successful project, and even more so in sustainable design. A few suggestions will ratchet up the chance of success on a courthouse project.

- Engage lighting design services early, and have them involved as a primary team contributor to the integrated design process.
- Lighting calculations should be required, for both horizontal and vertical illuminance and the luminances of all surfaces. Calculations should be performed with the different layers of the lighting system "turned off" so that it is clear exactly how much each layer is contributing to the overall design.
- Serious consideration should be given to a virtual mock-up of the courtroom to evaluate lighting design. With the software and virtual rendering tools that are now available, it is possible to cost effectively preview the visual experience of the courtroom from all visual perspectives.
- Carefully consider any adjustments to courtroom lighting that are considered during value engineering or from contractor requests for substitutions. Substitutions to the original lighting design are risky and are not advised unless thoroughly reviewed and approved by the lighting designer. To avoid diminishing the effectiveness of the lighting design during the construction phase, proposed substitutions should be accompanied by lighting calculations that meet the original design intent.
- Commissioning services to assure compliance with the design intent should be required in the contract documents. Operations and maintenance manuals to train and educate the staff are recommended and are essential for the ongoing success of the lighting design. Where possible, try to keep lamp types to a minimum, and keep the location of the luminaires accessible for servicing by the maintenance staff. Remember that the post-installation phase is also a mission-critical part of the success of the project.

3.6 Education and Communication

To help facilitate understanding by the participants in the design process, consideration should be given to creating educational tools targeted to the needs of specific groups.

3.6.1. The Design Team

Consider a new technical report geared toward the design team, to capture many of the points found in this report and to help educate the lead architectural designer and lighting designer on the interplay and relationship between finishes and high quality, energy efficient courtroom lighting. The product should highlight successes in courtroom lighting and provide enough detail to add value to future projects.

3.6.2. The Judges

A different type of educational tool is merited for judges and other occupants of the courtroom. This document would be less technical in nature, and would address some of the most common mythologies about lighting. The information should focus on explaining the interplay between finish colors, perceived lighting, and the energy efficiency requirements of the building. The text should also explain the changes and improvements that have occurred in lighting technology, both in fixture and lamp improvements (color rendition, flicker, energy efficiency) and controls.

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4.0 Conclusion

In summary, this report has shown the need for improvements to courtroom lighting with respect to both lighting quality and energy efficiency. Newer technologies in lighting and software will provide improvements, but the human element is key. Lighting should not be considered simple, or easy, or the last thing to do on a project. Given proper respect and the right level of expertise and focus, courtroom lighting can obtain the highest quality and efficiency at the same time. Implementing the recommendations in this report will yield significant national energy savings while supporting critical courtroom tasks, reducing energy costs, and furthering compliance with the Energy Policy Act of 2005.

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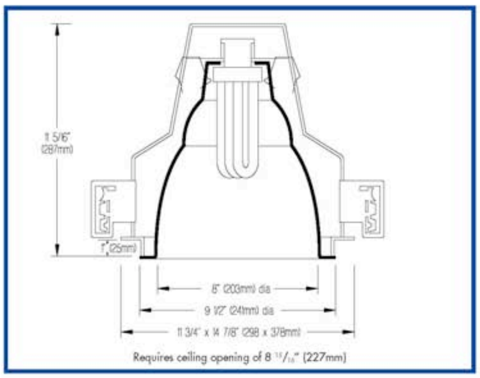
Appendix A: Example Lighting Fixture Cut

The following technical specification is presented as a sample of an appropriate energy efficient technology for use in high ceilings, and was utilized in point-by-point calculations shown in Appendix B. The product shown here is the "Triples-V 42/8" by Edison Price Lighting. Pacific Northwest National Laboratory, the General Services Administration and the U.S. Department of Energy do not specifically endorse this, or any specific product. ***This is intended as an example for illustration purposes only.***

recessed compact fluorescent downlight/wallwasher



PHOTOMETRIC REPORT

itl Report No. 44962. Original Independent Testing Laboratories, Inc. (ITL) test report furnished upon request.

Luminaire .... recessed compact fluorescent downlight with spun aluminum reflector, specular finish
Lamp .... Philips 42-watt triple-tube compact fluorescent, 4-pin GX24q-4 base, 3200 lumens
Efficiency 69.2%
Spacing Criteria .... 0°-1.1, 90°-1.1

BALLAST INFORMATION

Voltage	*120*	*277*
Input Watts	48	48
Line Current (A)	.42	.18
Power Factor (%)	>98	>98
THD (%)	<10	<10
Min. Starting Temp* (°F)	0	0

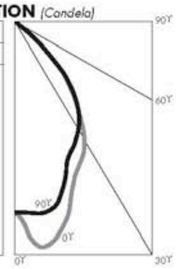
**Consult lamp manufacturers for specific temperatures.*

ZONAL LUMEN SUMMARY

Zone	*Lumens*	*% Lamp*	*% Fixture*
0 - 30°	1222	38.2	55.2
0 - 40°	1831	57.2	82.7
0 - 60°	2214	69.2	100.0
0 - 90°	2214	69.2	100.0
90 -180°	0	0.0	0.0
0 -180°	2214	69.2	100.0

CANDLEPOWER DISTRIBUTION (Candela)

Vertical Angle	*Horizontal Angle*		
	0.0	*45.0*	*90.0*
0	1659	1659	1659
5	1922	1788	1672
15	1759	1676	1560
25	1357	1278	1209
35	983	978	973
45	537	503	559
55	2	2	2
65	0	0	0
75	0	0	0
85	0	0	0
90	0	0	0



LUMINANCE DATA

(Candela/m²)

Vertical Angle	*Average 0° Longitude*	*Average 90° Longitude*
45	22012	22914
55	101	101
65	0	0
75	0	0
85	0	0

To convert cd/m² to footlamberts, multiply by 0.2919.

COEFFICIENTS OF UTILIZATION – ZONAL CAVITY METHOD

Effective Floor Cavity Reflectance 20%

Ceiling Reflectance (%)	*80*				*70*				*50*			*30*			*10*			*0*
Wall Reflectance (%)	*70*	*50*	*30*	*10*	*70*	*50*	*30*	*10*	*50*	*30*	*10*	*50*	*30*	*10*	*50*	*30*	*10*	*0*
Room Cavity Ratio																		
0	82	82	82	82	80	80	80	80	77	77	77	74	74	74	71	71	71	69
1	78	76	74	73	77	75	73	72	72	71	69	69	68	67	67	66	65	64
2	74	70	67	65	72	69	66	64	67	65	63	65	63	61	63	61	60	59
3	70	65	61	58	68	64	60	58	62	59	57	60	58	56	59	57	55	54
4	66	60	56	53	64	59	55	52	58	54	52	56	53	51	55	52	50	49
5	62	55	51	48	61	55	51	48	53	50	47	52	49	47	51	48	46	45
6	58	51	47	44	57	51	47	43	50	46	43	49	45	43	48	45	43	41
7	55	48	43	40	54	47	43	40	46	42	40	46	42	39	45	42	39	38
8	52	45	40	37	51	44	40	37	43	39	37	43	39	36	42	39	36	35
9	49	42	37	34	48	41	37	34	41	37	34	40	36	34	39	36	34	33
10	46	39	35	32	46	39	34	32	38	34	31	37	34	31	37	34	31	30

Appendix B: Point-by-Point Calculations

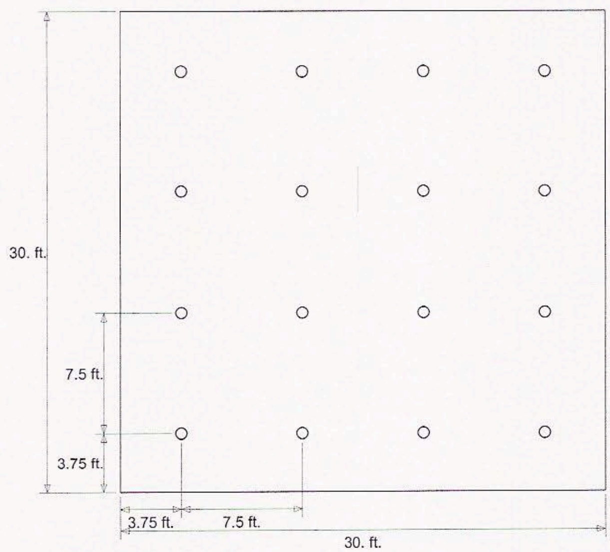
Edison Price Triples-V 42/8, at **12’-0”** Above Finished Floor

Summary for Layout #1: Ttt842.ies

Results

Average Illuminance:	30 fc	# of Rows:	4
Unit Power Density (UPD):	0.72 W/ft²	Row Spacing:	7.5 ft.
Spacing Criteria:	Acceptable	# of Cols:	4
		Col. Spacing:	7.5 ft.

16 luminaires provide 30 fc maintained.



Reflected Ceiling Plan

Scale: 0.12 in. = 1 ft.

Room Characteristics

Dimensions:	X: 30. ft.	Reflectances:	Ceiling:	0.8	Work Plane Height:	2.5 ft.
	Y: 30. ft.		Walls:	0.5	Target UPD:	
	Z: 12. ft.		Floor:	0.2	Target Illuminance:	25 fc

Luminaire Characteristics

Luminaire Description: Ttt842.ies

Suspension Length:	0.000 ft.	Wattage:		40.5W (connected)	
Total Light Loss Factor:	0.77	Aiming:	O: 0°	T: 0°	S: 0°
Efficiency:	69.2 %				

Lamp Description: One 42W triple-tube 4-pin

Lamps Per Luminaire:	1	Lamp Lumens:	3,200

Lighting Technologies, Inc.
5171 Eldorado Spgs Dr. Boulder, CO 80303

Page 1

Calculation Grid: Workplane (Layout #1)

Grid Summary

Grid Properties

Grid Type: Illuminance
Grid Height: 2.50 ft.
Units: English

Statistics

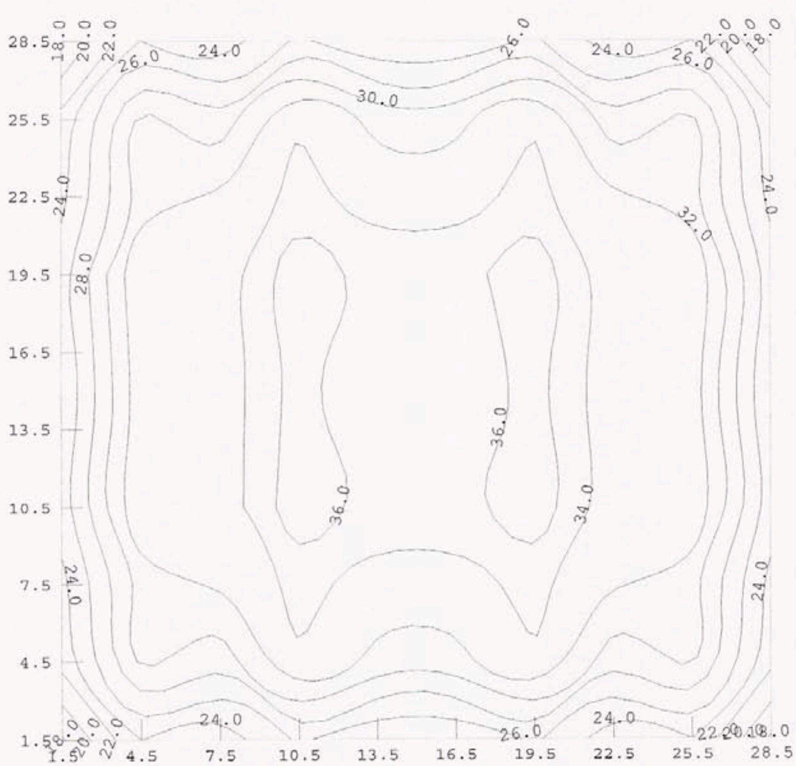
Average: 29.7
Max: 37.4
Min: 17.8

Max/Min: 2.1
Ave/Min: 1.7
Uniformity: 0.6

Grid Values

	1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5	28.5
28.5	18	24	23	26	24	24	26	23	24	18
25.5	23	30	29	34	31	31	34	29	30	23
22.5	23	31	32	35	33	33	35	32	31	23
19.5	25	34	33	37	35	35	37	33	34	25
16.5	24	33	33	37	34	34	37	33	33	24
13.5	24	33	33	37	34	34	37	33	33	24
10.5	25	34	33	37	35	35	37	33	34	25
7.5	23	31	32	35	33	33	35	32	31	23
4.5	23	30	29	34	31	31	34	29	30	23
1.5	18	24	23	26	24	24	26	23	24	18

Calculation Grid: Workplane (Layout #1)



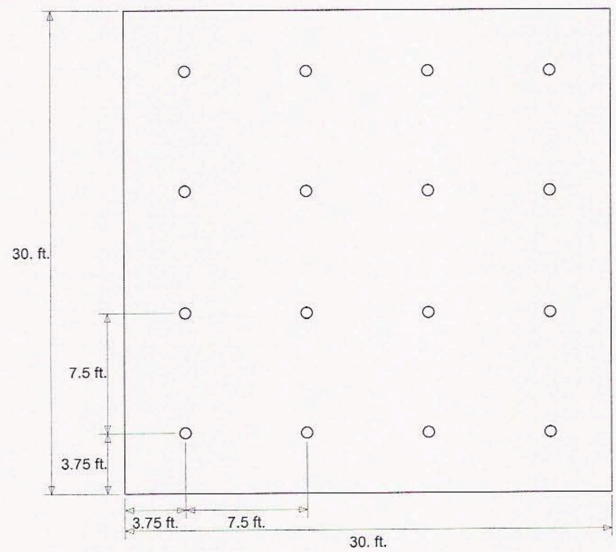
Edison Price Triples-V 42/8, **at 16’-0”** Above Finished Floor

Summary for Layout #1: Ttt842.ies

Results

Average Illuminance:	27 fc	# of Rows:	4
Unit Power Density (UPD):	0.72 W/ft²	Row Spacing:	7.5 ft.
Spacing Criteria:	Acceptable	# of Cols:	4
		Col. Spacing:	7.5 ft.

16 luminaires provide 27 fc maintained.



Reflected Ceiling Plan
Scale: 0.12 in. = 1 ft.

Room Characteristics

Dimensions:	X: 30. ft.	Reflectances:	Ceiling:	0.8	Work Plane Height:	2.5 ft.
	Y: 30. ft.		Walls:	0.5	Target UPD:	
	Z: 16. ft.		Floor:	0.2	Target Illuminance:	25 fc

Luminaire Characteristics

Luminaire Description: Ttt842.ies

Suspension Length:	0.000 ft.	Wattage:		40.5W (connected)	
Total Light Loss Factor:	0.77	Aiming:	O: 0°	T: 0°	S: 0°
Efficiency:	69.2 %				

Lamp Description: One 42W triple-tube 4-pin

Lamps Per Luminaire:	1	Lamp Lumens:	3,200

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Calculation Grid: Workplane (Layout #1)

Grid Summary

Grid Properties

Grid Type: Illuminance
Grid Height: 2.50 ft.
Units: English

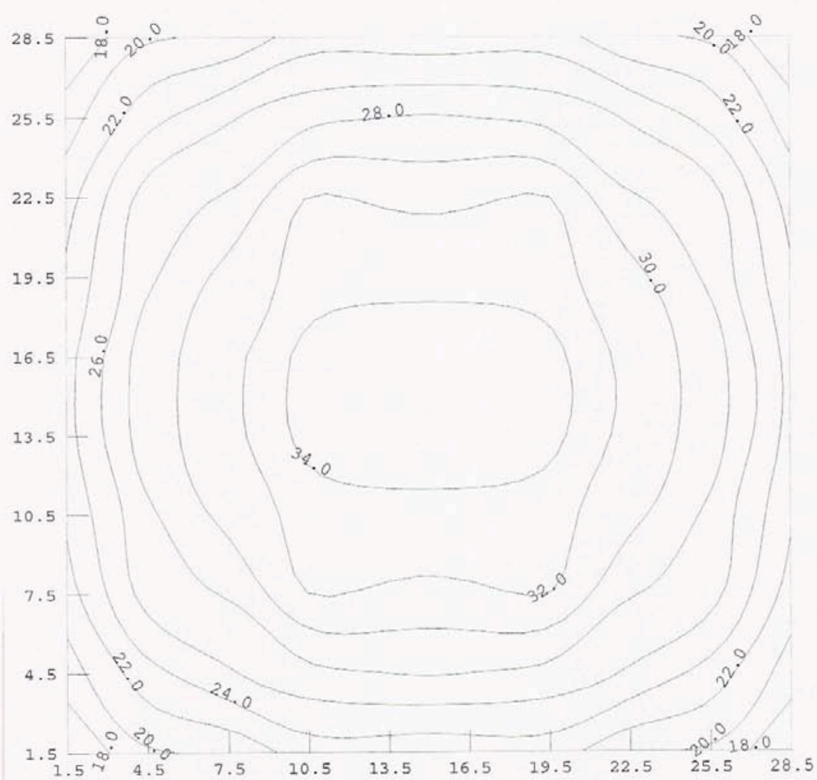
Statistics

Average:	26.6	Max/Min:	2.2
Max:	34.8	Ave/Min:	1.7
Min:	16.1	Uniformity:	0.6

Grid Values

	1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5	28.5
28.5	16	20	20	23	23	23	23	20	20	16
25.5	19	23	26	27	28	28	27	26	23	19
22.5	21	27	28	32	32	32	32	28	27	21
19.5	22	28	31	33	34	34	33	31	28	22
16.5	23	29	31	35	35	35	35	31	29	23
13.5	23	29	31	35	35	35	35	31	29	23
10.5	22	28	31	33	34	34	33	31	28	22
7.5	21	27	28	32	32	32	32	28	27	21
4.5	19	23	26	27	28	28	27	26	23	19
1.5	16	20	20	23	23	23	23	20	20	16

Calculation Grid: Workplane (Layout #1)



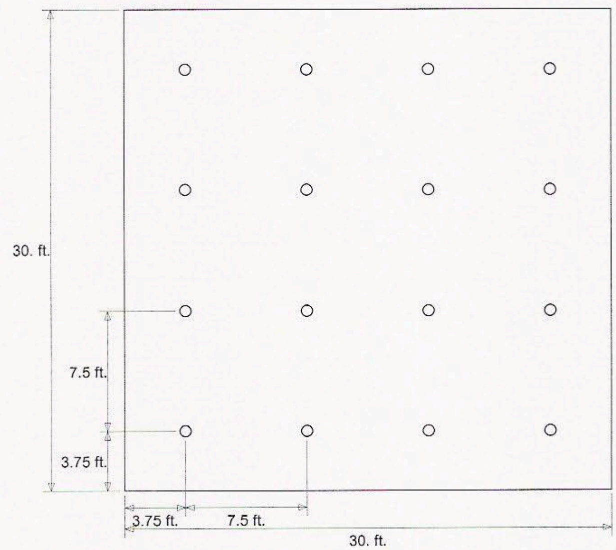
Edison Price Triples-V 42/8, **at 20’-0”** Above Finished Floor

Summary for Layout #1: Ttt842.ies

Results

Average Illuminance:	24 fc	# of Rows:	4
Unit Power Density (UPD):	0.72 W/ft²	Row Spacing:	7.5 ft.
Spacing Criteria:	Acceptable	# of Cols:	4
		Col. Spacing:	7.5 ft.

16 luminaires provide 24 fc maintained.



Reflected Ceiling Plan
Scale: 0.12 in. = 1 ft.

Room Characteristics

Dimensions:	X: 30. ft.	Reflectances:	Ceiling:	0.8	Work Plane Height:	2.5 ft.
	Y: 30. ft.		Walls:	0.5	Target UPD:	
	Z: 20. ft.		Floor:	0.2	Target Illuminance:	25 fc

Luminaire Characteristics

Luminaire Description: Ttt842.ies

Suspension Length:	0.000 ft.	Wattage:		40.5W (connected)	
Total Light Loss Factor:	0.77	Aiming:	O: 0°	T: 0°	S: 0°
Efficiency:	69.2 %				

Lamp Description: One 42W triple-tube 4-pin

Lamps Per Luminaire:	1	Lamp Lumens:	3,200

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Calculation Grid: Workplane (Layout #1)

Grid Summary

Grid Properties

Grid Type:	Illuminance
Grid Height:	2.50 ft.
Units:	English

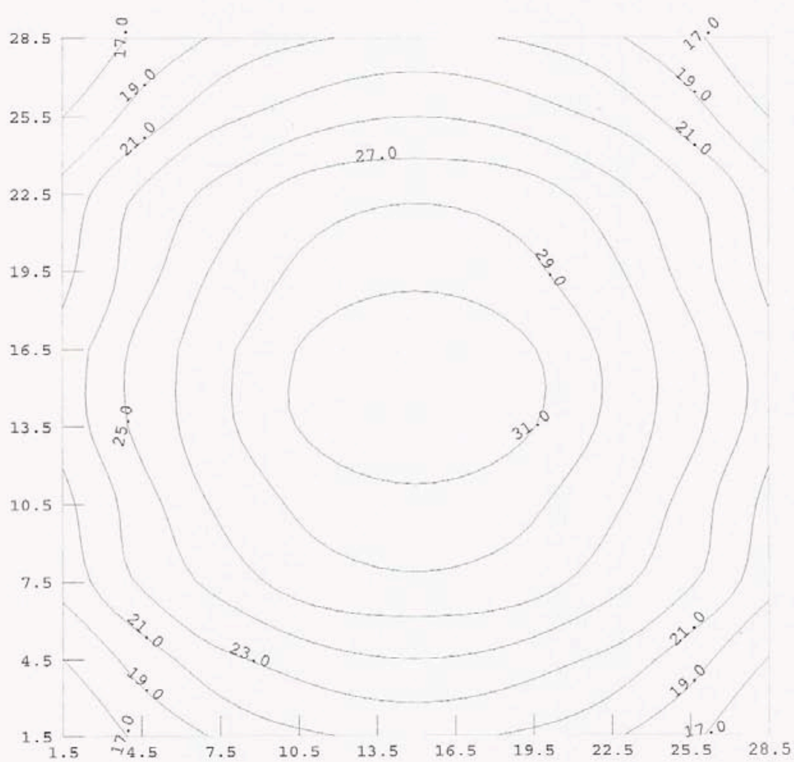
Statistics

Average:	23.9	Max/Min:	2.1
Max:	32.1	Ave/Min:	1.6
Min:	15.1	Uniformity:	0.6

Grid Values

	1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5	28.5
28.5	15	17	19	21	21	21	21	19	17	15
25.5	17	20	23	24	25	25	24	23	20	17
22.5	20	23	26	28	29	29	28	26	23	20
19.5	20	24	27	29	30	30	29	27	24	20
16.5	22	26	28	31	32	32	31	28	26	22
13.5	22	26	28	31	32	32	31	28	26	22
10.5	20	24	27	29	30	30	29	27	24	20
7.5	20	23	26	28	29	29	28	26	23	20
4.5	17	20	23	24	25	25	24	23	20	17
1.5	15	17	19	21	21	21	21	19	17	15

Calculation Grid: Workplane (Layout #1)



Appendix C: Comparison of Component vs. System Efficiencies

	Edison Price Triples-V 42/8 Vertical Triple 42 Watt CFL	Edison Price Triples-H 142/8 Horizontal Triple 42 Watt CFL	Edison Price Triples-H 242/8 Horizontal Double 42 Watt CFL	Edison Price Darklite 38/7 PAR38 100 Watt HIR	Edison Price Arclite 38/7 PAR38 70 Watt MH
Lamp lumens	3,200	3,200	6,400	2,070	6,700
Mean lumens	2,752	2,752	5,504	N/A	N/A
Lamp Lumen Depreciation	0.86	0.86	0.86	1.00	1.00
Ballast Factor	1.00	1.00	1.00	1.00	1.00
Lamp Lumen Factor	1.00	1.00	1.00	1.19	0.78
Luminaire Dirt Depreciation	0.89	0.89	0.89	0.89	0.89
LIGHT LOSS FACTORS	0.77	0.77	0.77	1.06	0.70
Center Beam Candlepower	N/A	N/A	N/A	6,300	16,000
CRI	82	82	82	100	85
CCT	3000-3500	3000-3500	3000-3500	2700-3000	3000
Lamp Life	12,000	12,000	12,000	3,000	10,000
Input watts	49	49	92	100	79
Lamp-Ballast Efficiency, lumens/watt	65	65	69	100	88
Fixture Efficiency (FE)	69.2	69.0	60.9	82.3	88.2
System Efficiency (FE+LLD+BF+LDD)	53.0	52.8	46.6	73.2	78.5
Fixture Zonal Lumens 0-30 degrees	38	29	27	79	84
Fixture Zonal Lumens 0-40 degrees	57	51	45	81	87
Fixture Zonal Lumens 0-60 degrees	69	69	61	82	88
Candlepower Distribution					
at Vertical Angle... 0	1659	934	1865	6338	10006
5	1922	902	1824	5374	8753
15	1759	839	1863	3298	6803
25	1357	963	1874	579	1969
35	983	836	1535	57	238
45	537	506	1031	6	31
55	2	7	21	2	0
65	0	0	2	0	0
75	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
Total	8219	4987	10015	15654	27801

Notes

(1)The cut sheet for Darklite 38/7 shows candlepower values for a 100-watt HIR, but the photometric report uses an old Q150 lamp with 1735 lumens. We used a Lamp Lumen Factor of 1.19 to bring the lamp lumens up to 2,070 lumens for the 100 HIR.

(2) The ballast for the 42-watt triple tube lamp is Sylvania Quicktronic Electronic CF DALI 51384, QTP 1x42CF/UNV DALI, 120-277, 42W DT/E, 3200 lumens, 1 lamp, 49 input watts, 65 lumens/watt..

(3) The ballast for the (2) 42-watt triple tube lamps is Sylvania Quicktronic Electronic CF DALI 51386, QTP 2x42CF/UNV DALI, 120-277, 42W DT/E, 3200 lumens, 2 lamp, 6400 lumens, 92 input watts, 69 lumens/watt.

(4) The ballast for the 70-watt PAR 38 Metal Halide lamp is Sylvania Quicktronic MH, 51913, QTP 1x70MH/UNV-J, 120-277, 70W T6, 6700 lumens, BF 1.0, 79 input watts, 88 lumens/watt.

(5) The candlepower values shown for the 70-watt metal halide are adjusted for accuracy using a Lamp Lumen Factor. The photometric report is for a 100 watt lamp, so we used a factor of .78 to take the candlepower values down to a 70-watt lamp.

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NIST BLCC 5.3-05: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: existing

Alternative: Lighting Retrofit

General Information

File Name:	C:\Program Files\BLCC5\projects\Courtroom lighting-2.xml
Date of Study:	Mon Mar 06 16:32:56 PST 2006
Project Name:	Courtroom Lighting
Project Location:	U.S. Average
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	EER
Base Date:	January 1, 2006
Service Date:	January 1, 2006
Study Period:	25 years 0 months(January 1, 2006 through December 31, 2030)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$0	$9,961	-$9,961
Future Costs:			
Energy Consumption Costs	$54,236	$25,846	$28,390
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$34,068	$6,992	$27,076
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0

	------------	------------	------------
Subtotal (for Future Cost Items)	$88,303	$32,838	$55,466
	------------	------------	------------
Total PV Life-Cycle Cost	$88,303	$42,799	$45,505

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$55,466
- Increased Total Investment	$9,961

Net Savings	$45,505

Savings-to-Investment Ratio (SIR)

SIR = 5.57

Adjusted Internal Rate of Return

AIRR = 10.32%

Payback Period

Estimated Years to Payback (from beginning of Service Period)

Simple Payback occurs in year	4
Discounted Payback occurs in year	4

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy	-----Average	Annual	Consumption-----	Life-Cycle
Type	**Base Case**	**Alternative**	**Savings**	**Savings**
Electricity	40,622.0 kWh	19,358.0 kWh	21,264.0 kWh	531,527.2 kWh

Energy Savings Summary (in MBtu)

Energy	-----Average	Annual	Consumption-----	Life-Cycle
Type	**Base Case**	**Alternative**	**Savings**	**Savings**

Electricity	138.6 MBtu	66.1 MBtu	72.6 MBtu	1,813.6 MBtu

Emissions Reduction Summary

Energy Type	-----Average Base Case	Annual Alternative	Emissions----- Reduction	Life-Cycle Reduction
Electricity				
CO2	35,958.27 kg	17,135.55 kg	18,822.72 kg	470,503.64 kg
SO2	93.12 kg	44.38 kg	48.75 kg	1,218.48 kg
NOx	75.47 kg	35.96 kg	39.51 kg	987.50 kg
Total:				
CO2	35,958.27 kg	17,135.55 kg	18,822.72 kg	470,503.64 kg
SO2	93.12 kg	44.38 kg	48.75 kg	1,218.48 kg
NOx	75.47 kg	35.96 kg	39.51 kg	987.50 kg