Illinois Smart Energy Design Assistance Center

Level III Feasibility Report

Energy Evaluation

and

Recommendations

[redacted]

8/13/09

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

dceo ILLINOIS DEPARTMENT OF COMMERCE AND ECONOMIC OPPORTUNITY

Table of Contents

Index of Tables

Index of Figures

Acknowledgements

The Smart Energy Design Assistance Center (SEDAC) would like to thank [redacted], for participating in the Smart Energy Program and for assistance in providing access to information necessary to develop this report. Jean Ascoli of SEDAC was the architect responsible for the analysis and is the primary author of this report. Additional assistance in report preparation by Adrian Gurga, Eileen Westervelt, Andy Robinson, Kristine Chalifoux and the rest of the SEDAC staff is gratefully acknowledged.

Executive Summary

SEDAC has performed an energy audit of [redacted] High School in [redacted], Illinois. As part of this process, SEDAC conducted a site inspection of [redacted] High School on [redacted]. This report presents the results of the analysis of the information gathered during this site visit, as well as additional energy data, and building and equipment information provided by school personnel. Our goal is to identify promising energy cost reduction measures (ECRMs) to be pursued for implementation. Our work does not replace engineering design which may be necessary for project implementation. Our suggestions do not override local building code requirements which should be consulted prior to investments.

The school administration and maintenance staff have kept energy efficiency as an important goal and clearly recognize the benefits of reducing energy costs. Some of the energy conservation practices that have already been implemented in the main building complex are listed below:

- Lighting upgrades from T12 to T8 for most fluorescent lighting fixtures.
- Window replacements to double pane thermally broken frame.
- Upgrade/replacement of all unit ventilators to air-to-air heat pumps.
- Well maintained energy management system controlling peak shedding, set-back scheduling (3:00 PM to 5:00 AM), and comfort temperature settings (68F Heating; 74F Cooling with 3 degree float). CO_2 control for ventilation.

SEDAC has identified $25,719 in potential additional annual savings from an investment of about $226,624 with cost reductions from incentives and considering the incremental cost to upgrade equipment whose service life is coming to an end. Altogether the energy savings amount to a potential 314,819 kWh which equals a 12 percent reduction in the school's total energy use (16 percent of the energy by cost). This report considers seven energy cost reduction measures (ECRMs) plus two packages of multiple ECRMs. The savings associated with these ECRMs are reported in Table 1. The recommended strategies include:

- Replacing metal halide gym lighting with high-bay fluorescent lighting.
- Adding daylighting and daylighting controls to the <u>west gym</u>.
- Adding occupancy sensors to turn off lighting when spaces are not in use.
- Replacing <u>west gym</u> HVAC with ground source heat pump.
- Adding vending controls to turn off vending machines when they are not in use.
- Upgrading site lighting to more efficient fixtures and lamps.

Additional efficiency measures are also identified in the report for which cost and savings have not been specifically calculated in detail. These additional measures include:

- Referencing Energy Star® and ASHRAE guides for all building upgrades.
- Select Energy Star equipment and appliances for all new purchases.
- Increasing wall and roof insulation at the time of future renovation projects.
- HVAC upgrades and programmable thermostats in the auxiliary buildings.
- Once building energy consumption has been reduced by 20 percent from current levels, consider renewable energy strategies including wind and solar.

Implementing the recommended measures will enhance the school's bottom line and reduce vulnerability to fuel price fluctuations. This report details our findings and can be used as a tool for obtaining financing from a lender to finance these measures. Information on incentives, grants, and other funding opportunities are also provided.

The reader should also be aware that the first cost pricing used herein was developed only for budgeting purposes and will vary according to the final design of the retrofits. Keep in mind that, for most of these strategies, the cost of doing nothing may be lower now but it will be higher than implementation over time.

Energy Cost Reduction Measure (ECRM)	Annual Cost Savings ($/yr)	Initial Investment	Internal Rate of Return (IRR)	Net Present Value (NPV)
ECRM 1 – Gym Lighting Upgrade - NO Incentives	$3,256	$27,360	1.4%	(-$4,013)
ECRM 2 – Gym Lighting Upgrade plus Daylighting and Controls - NO Incentives	$4,702	$53,760	3%	(-$6,870)
ECRM 3 – T12 to T8 Lighting Upgrades - NO Incentives	$2,638	$8,718	27%	$9,555
ECRM 4 – Occupancy Sensors - NO Incentives	$1,801	$10,200	10%	$2,477
ECRM 5 – Replace West Gym HVAC w/ Ground Source Heat Pump - FULL Cost – NO Incentives	$13,460	$385,380	(-4%)	(-$212,111)
ECRM 6 – Vending Controls - NO Incentives	$1,630	$2,000	81%	$9,129
ECRM 7 – Site and Parking Lot Lighting - NO Incentives	$1,488	$9,505	7%	$1,020
Package 1: ECRM's 2, 3, 4, 6, 7 – NO Incentives	$12,259	$84,183	11%	$35,398
Package 2: ECRM's 2, 3, 4, 5, 6, 7 – WITH Incentives and using INCREMENTAL cost for ECRM 5	**$25,719**	**$226,624**	**7%**	**$26,627**

Table 1: Summary of ECRM Savings

Notes to Table 1:

(1) NO incentives are included in the summary above except for Package 2 as noted. Package 1 includes some ECRMs which have a negative NPV with NO Incentives but which as a package has a positive NPV even without incentives. See Table 17 for a summary including the individual ECRM savings WITH incentives.
(2) Discount Rate is assumed to be 5%; ECRMs with IRR less than 5% will show a negative NPV.
(3) This analysis does not include a likely increase in energy prices. Results are in today's dollars on a pre-tax basis based on $0.08 per kWh and $1.16 per therm.
(4) When multiple ECRMs are implemented together, results vary from application of individual ECRMs

Detailed descriptions of each ECRM appear later in the report. We recommend implementing the package of ECRMs represented in Package 2 to begin saving energy dollars.

In order for SEDAC's energy audit program to demonstrate its effectiveness to the State of Illinois, we are asked to compile quarterly reports documenting implementation of energy efficiency measures. We ask that you keep us apprised of all work completed to allow us to accurately represent savings recommended. We will also contact you periodically to discuss, answer questions and review status.

1. Introduction

Most buildings use 10 to 30 percent more energy than necessary and have abundant opportunities for improvement. Engaging in energy efficiency strategies is a proven method of controlling costs. Cutting a building's energy use increases the market value of the building, reduces vulnerability to fuel price fluctuations, and reduces environmental impact.

Organizations that take a systematic and strategic approach to energy management enjoy a broad array of tangible and intangible benefits. We have entered an increasingly complex and volatile energy marketplace requiring a new emphasis on measuring and maximizing energy productivity. Enterprise-wide energy management has become an effective method of improving performance and is an important element of sustainability policy.

The resurgent focus on energy efficiency has been brought about by rising energy costs. In today's volatile energy markets it is impossible to predict energy cost increases. Since 2000, commercial natural gas prices have increased 70 percent, while commercial electric prices have increased 40 percent.[1] Although energy price increases lead to inflation, they also typically surpass the inflation rate. Given this phenomenon, energy costs savings secured today will probably increase in value over time.

1.1 SEDAC Background

The objective of the Smart Energy Design Assistance Center (SEDAC) is to encourage building owners and operators, design professionals, and building contractors to incorporate energy efficiency practices and renewable energy systems. SEDAC supports the Smart Energy program to increase the efficient and effective use of energy by for-profit businesses and public buildings throughout Illinois. SEDAC is sponsored by the Illinois Department of Commerce and Economic Opportunity and is managed by the School of Architecture at the University of Illinois at Urbana-Champaign.

Our goal is to identify energy cost reduction measures (ECRMs) for owners to employ as they manage their facilities. Our work does not replace engineering design which will be necessary for project implementation. Our suggestions do not override local building code requirements which should be consulted and may dictate prioritization of investments.

This report details our findings and can be used as a tool for obtaining financing from a lender.

1.2 Energy Management / Implementation Strategy

Energy conservation is best achieved through a multifaceted approach involving load reduction, efficiency improvements, and renewable generation. Addressing any one of these pathways will conserve energy; however a strategic and integrated approach involving all methods is the most cost effective energy solution.

[1] Energy Information Administration August 2009 http://www.eia.doe.gov/emeu/mer/contents.html

Load reduction can have no cost or low cost and should be the first step. It involves managing energy consumption by turning things off when not needed or using controls systems to manage unnecessary energy use.

Energy efficiency improvements provide the greatest opportunities for energy conservation and should be considered before use of renewable energy sources on site because they are typically more cost effective than implementing renewable energy technologies. Efficiency improvements involve upgrading the building envelope and replacing old or failing systems with modern technologies, which perform the same function while consuming less energy.

The final step is energy generation. This offsets a portion of the remaining energy consumption with onsite energy generation using renewable energy sources. This is recommended only after load reduction and efficiency improvements because expensive renewable generation systems can be downsized after other energy saving measures are already in place.

1.3 Analysis Approach

The basic analysis approach involves several steps. First, initial information is collected from the client in regards to current building usage, energy consumption and project design goals. Then, during the site visit, detailed data and observations are recorded by SEDAC team members. Utility consumption is input into a spreadsheet and examined for anomalies and graphed with annual heating and cooling degree day data to see if there is a correlation between energy usage and climate.

Subsequently, the SEDAC team performs computer analyses of energy cost reduction measures (ECRMs). For the analysis of utility costs, electricity and gas prices are estimated from recent utility bills provided by the client.

Finally, the estimated savings and the additional costs of implementing ECRMs are evaluated in a life cycle cost analysis. This analysis assumes a ten or twenty year life cycle and calculates the internal rate of return (IRR) and the net present value (NPV) of each ECRM and package of ECRMs. IRR is essentially the annual yield on an investment. A project is a good investment if its IRR is greater than the rate of return that could be earned by an alternative investment (other projects, bonds, bank accounts, etc.). For public projects we assume 5 percent as the minimum acceptable rate of return, but you may wish to use a different rate.

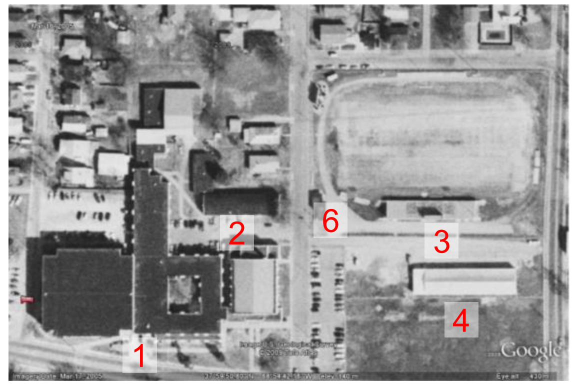
The NPV calculation uses a discount rate to find the present value of savings occurring at a future date. The discount rate is your minimum acceptable rate of return, or your time value of money. Investments have positive NPVs when their IRR is greater than the discount rate. Therefore, projects with IRR greater than the discount rate (assumed to be 5 percent) and a positive NPV are considered to be good investments.[2]

---

[2] http://en.wikipedia.org/wiki/Internal_rate_of_return & http://en.wikipedia.org/wiki/Net_present_value

2. Existing Building and Conditions

[redacted] High School is a consolidated district high school located in [redacted], Illinois. The main building complex includes the classroom and administration building constructed in 1974 (including the west gym), the vocational wing constructed in 1984, and the east gym which was part of the original school constructed on this site in 1939. The east gym is the only portion of the 1939 structure which was preserved when the new school was built in 1974. In addition to the main building complex, there are five other structures which comprise the districts' buildings at this site. An aerial view of the school is shown in Figure 1.[3] The superintendent's bldg. is directly across the street to the west on [redacted] St. The school has about 550 students and 60 staff. This report will focus primarily on the main building complex. Unless noted otherwise, details and descriptions will be in reference to the main building complex.



Key:

1) Main Bldg. Complex ~131,500 sf
2) Ag Building ~8,500 sf
3) Stadium Bldg. ~6,500 sf
4) Bus Barn ~11,000 sf
5) Superintendent's Bldg. ~3,800 sf (not shown)
6) Concessions

Figure 1: Aerial view of [redacted] High School

2.1 Building Envelope

The exterior wall construction of the 1974 and 1984 portions of the main building complex consist of 4" concrete block, 1 ½" rigid insulation, and 4" face brick with a ~1 ½" air space. The walls are thermally bridged at the foundation where solid concrete foundations walls are not insulated above grade and at windows, floor-wall, and roof-wall intersections due to the design of the concrete window sills and the waffle slab construction. SEDAC would estimate the average R-value of these walls to be R-5.

The east gym, built in 1939, is solid reinforced concrete construction with walls varying from approximately 12"-24" thick. It is assumed for the purposes of this report that the walls are not insulated. The mass of the building construction does provide benefit at certain times of the year. For example it was noted during the site visit that the building construction provides significant thermal storage and the interior space, without mechanical cooling, was cool on a day with high outside temperatures. SEDAC would estimate the R-value of the east gym wall construction to be between R-1 and R-2.

Including the east gym, SEDAC would estimate the overall would estimate the overall R-value of the main building complex wall construction to be between R-3 and R-4.

All portions of the roof were replaced during the time period between 1995 and 2008. The type and thickness of roof insulation is unknown. Given the vintage of the buildings and re-roofing work and the general construction type, SEDAC would estimate the R-value of this construction to be between R-8 and R-10.

[3] Google image.

2.2 Heating, Ventilation and Air Conditioning

Equipment:

The main classroom-administration portion of the main building complex, built in 1974, is heated and cooled by 49 individual unit ventilators. Ten of these units were replaced in 1996 (two split units and eight thru-wall air-to-air heat pump unit ventilators with integral backup resistance heat), the remaining 39 units were replaced in 2006 with thru-wall air-to-air heat pump unit ventilators with integral backup resistance heat. The 39 units replaced in 2006 have CO_2 sensor controls for modulating outdoor air. The older units have fixed outdoor air dampers.

The west gym, also built in 1974, has heating only. Heat is provided by two 180kW, 6 stage, electric duct heaters original to the 1974 building. The client is interested in exploring the replacement of this equipment, which is reaching the end of its useful life, with a ground source heat pump system providing some cooling to the space as well as more efficient heating. This system is controlled by the building automation system (BAS).

The vocational education wing, built in 1984 is heated using a gas-fired hot water boiler supplying unit ventilators in the classrooms and ceiling-hung terminal unit heaters in the shops. This wing of the building is partially cooled (restrooms, storage rooms, vocational shops, and corridors are not cooled) using split system DX cooling units. The equipment in this wing of the building is original to the 1984 construction. This system is controlled by the building BAS.

The east gym, built in 1939, is heated using a gas-fired low pressure steam boiler with four ceiling-hung terminal unit heaters in the main gym space. The age of this equipment in not known—though it appears that it is at least 35 to 40 years old. The east gym does not have air conditioning.

Controls:

The facility has a central energy management system or building automation system (BAS) which manages the electrical demand (peak shedding) and temperature controls. The system is tied to the space conditioning equipment in the classroom-administration building, the west gym, and the vocational education wing. Temperature settings through the BAS are 68F during the heating season and 74F in cooling season with a three degree float for individual control. The units are set to minimal building maintenance temperatures at night (between 3:00 PM and ~5:00 AM for most portions of the building) and on weekends and holidays. The east gym is *not* controlled by the building BAS. Thermostats in the east gym are manually set and are left at 65F 24–hours per day during the heating season.

Based on analysis of [redacted] High School gas and electric consumption patterns, SEDAC estimates space heating represents 43 percent of the total energy (gas and electric) used by the school. Since natural gas is used for heating a portion of the space, and natural gas is currently less expensive than electricity, this represents a somewhat lower percentage (36 percent) of the current total energy cost annually. Based on our analysis SEDAC also estimates that space cooling represents 13 percent of the total energy used by the school (15 percent of the cost).

2.3 Domestic Hot Water

In the main classroom-administration portion of the main building complex and the west gym hot water is provided by three electric water heaters (2 @ 500gal and 1 @ 100gal), while the vocational education wing and east gym have natural gas water heaters. Based on Energy Star data for typical school energy use combined with analysis of [redacted] High School gas and electric usage patterns, SEDAC estimates domestic hot water represents 6 percent of the total energy usage (5.5 percent of the energy cost) annually.

2.4 Lighting

The majority of the space lighting is provided by a combination of T8 four-lamp 17-watt 2-foot (17W 4x2') and T8 two-, three-, or four-lamp 32-watt 4-foot (32W 2x4', 3x4', 4x4') linear fluorescents with electronic ballasts. However, there are a significant number of T12 lamps with magnetic ballasts, which have not yet been upgraded in storage/maintenance spaces: under the west gym auxiliary seating bleachers on the second floor; in the east gym stage area and support spaces; as well as in some of the other buildings on the property (see section 2.7 Auxiliary Buildings).

In addition to the linear fluorescent fixtures, the east gym has 250-watt mercury vapor fixtures lighting the main space and the west gym has a mixture of 400-watt metal halide and 400-watt mercury vapor fixtures, plus some compact fluorescent can lights (CFLs). There are a few incandescent lamps still in use however these are being replaced with CFLs as they burn out. Exit signs use LED lights.

Space lighting power density (LPD)[4] was estimated to be approximately 1.4 W/sf overall for the whole building. Calculated separately, the west gym has an (LPD estimated to be approximately 2.3 W/sf—providing a significant opportunity for energy savings.

Site lighting is a mixture of fixture and lamp types. Poles and fixtures are leased from Ameren. The client is interested in looking at any opportunity to reduce energy and cost of site lighting.

Based on fixture and lamp data for [redacted] High School, SEDAC estimates that space lighting represents 21 percent of the school's energy usage (24 percent of the energy cost) annually.

2.5 Additional Loads

Additional energy loads include computers, printers, scanners, monitors, kitchen equipment, office equipment, and beverage vending machines. Based on Energy Star data for typical school energy use combined with analysis of [redacted] High School gas and electric usage patterns, SEDAC estimates the draw of these remaining devices to be approximately 13 percent of the school's total energy consumption and 14 percent of the energy cost annually.

2.6 Occupancy Schedules

The school is open for classes from around 7:00 AM to 3:00 PM with varying occupancy at the beginning and end of each day with athletic activities extending the scheduled

---

[4] Lighting power density is the ratio of the power used by lighting and the floor area it illuminates (W/sf).

use of both gyms on a regular basis during the school year. There are approximately 600 people in the building during a typical school day. The school year runs from mid-August to June first. There are summer camps and institutes which use the facilities on a part time basis during the summer. The administrative wing of the main building complex is open ~7:00 AM to 5:00 PM year-round.

2.7 Auxiliary Buildings

In addition to the main school building, there are five other structures which comprise the districts' buildings at this site. They include the ~8,500 sf agriculture shop building (ag building) which also includes the grounds maintenance garage and wrestling facilities; the ~6,500 sf stadium locker room building (stadium; the ~11,000 sf bus storage and maintenance building which includes the football team weight room (bus barn); the ~3,800 sf superintendent's office building (superintendent's bldg.); and a small concessions building located adjacent to the football field.

These auxiliary buildings are heated with individual natural-gas fired furnaces ranging from 100 to 125 kBtu. The stadium locker rooms are cooled by two window air conditioning units. The ag building classroom and superintendent's building are cooled by split systems. The bus barn is not air conditioned.

Approximately 40-60 gallon natural gas water heaters provide the domestic hot water for these auxiliary buildings.

Lighting in these buildings is largely T12 linear fluorescents with the exception of the stadium which has been upgraded to T8.

3. Benchmarking

A good method for benchmarking a building's energy efficiency is to determine its energy use intensity (EUI, measured in kBtu/sf/yr) and energy cost intensity (ECI, given in $/sf/yr). A summary of the energy efficiency benchmark information for the main building complex at [redacted] High School is given in Table 2 below.

2008/09	Annual Consumption		Annual Costs		Average Unit Cost	
Electricity	1,285,372	kWh	$104,047	84%	$0.08	$/kWh
Natural Gas	17,358	therms	$20,125	16%	$1.16	$/therm
Total	$ 124,172					
Floor Area	131,510	sf				
Energy Use Intensity	47	kBtu/sf/yr	**Energy Cost Intensity**		$0.94	$/sf/yr

Table 2: Energy Intensities

Using the U.S. EPA Energy Star Target Finder tool[5] to compare this building with other similar facilities in the Midwest, we find that the main building complex at [redacted] High School performs quite well. The school has a site energy use intensity of 47 kBtu/sf/yr. The school falls in the 77th percentile which makes the school eligible for an Energy Star label (a minimum rating of 75 required). This is a direct result of the district's energy efficiency efforts to date which have included high quality double pane windows installed in 2007, upgrade of unit ventilation to heat pumps in a significant portion of the building (1996 and 2006), building energy management system installed in 1996, and lighting upgrades completed within the past 5 years. Staff at the school and district have demonstrated an admirable commitment to energy efficiency. In order to further reduce the school's energy use we looked at energy targets which would put the school into the top 10 percent (90th percentile). This can be achieved through an 18 percent reduction in energy over the current building's consumption resulting in an EUI of 38 kBtu/sf/yr. Table 3 below contains a summary of the Target Finder results compared with the current school's energy data.

Target Energy Performance Results (estimated)		
Energy	**Current**	**Top 10%**
Energy Performance Rating (1-100)	77	90
Energy Reduction (%)	-	18%
Site Energy Use Intensity (kBtu/sf/yr)	47	38
Total Annual Source Energy (mBtu)	16,466	13,429
Total Annual Site Energy (mBtu)	6,121	4,993
Total Annual Energy Cost ($)	124,240	101,331

Table 3: Energy Star® Target Finder Performance Results

We also looked at energy use intensities in some of the additional buildings on the site. While these structures consume a small portion of the school's overall site energy, it is

[5] http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder

worth noting that upgrades to these buildings could result in significant savings. Table 4 below provides the Target Finder results, energy intensity, and percentage of energy cost for each of the five major buildings on the site.

Target Energy Performance Results (estimated)					
Facility Name	Target Finder Facility Category	Energy Performance Rating (1-100)	Bldg. Energy Use Intensity (kBtu/sf/yr)	Annual Energy Cost ($)	% of Total Site Energy Cost ($)
Main Bldg. Complex	K-12 School	77	47	$124,270	77.6%
Ag Bldg (~11,000 sf)	K-12 School	75	85	$13,885	8.7%
Stadium (~6,500 sf)	K-12 School	67	95	$9,790	6.1%
Supt.Bldg.(~3,800 sf)	Office	16	57	$5,450	3.4%
Bus Barn (~11,000 sf)	(Unavailable)	N/A	25	$6,720	4.2%

Table 4: Target Energy Performance Results (Estimated) for all Buildings

3.1 Utility Rates

Electricity is provided by Ameren Energy Marketing and natural gas is provided by AmerenCIPS. For the analyses in this report average utility costs were estimated from bills provided by the client. Electricity costs were estimated at $0.08/kWh, while natural gas costs were estimated to be $1.16/therm for total charges on the main building complex account. The average natural gas costs for all three accounts (including the accounts for the stadium and the ag building) is $1.22/therm. This is due to the fact that the smaller additional buildings pay basic usage fees on a smaller number of units (therms). For financial comparisons the 2008/09 rates for the main building complex of $0.08/kWh and $1.16/therm are used throughout this report.

3.2 Energy Usage Profiles

Utility bills for both electricity and natural gas were provided for June 2008 through May 2009. Analyzing the utility bills indicates the following overview of the building's performance at the present time.

Figure 2 shows the reported monthly electric energy consumption profile compared to cooling degree days and heating degree days which are indicative of the duration and intensity of the cooling and heating seasons respectively. The figure illustrates the fact that a significant portion of the electricity consumed by the school (~25 percent) goes to heating. The increase in the heating season months (increased heating degree days) is consistent with the use of electric resistance heat in the west gym and use of the backup resistance heating elements in the main building complex heat pumps. The increased use of the backup resistance heat is due to decreasing efficacy of standard heat pumps as the outside temperature drops.

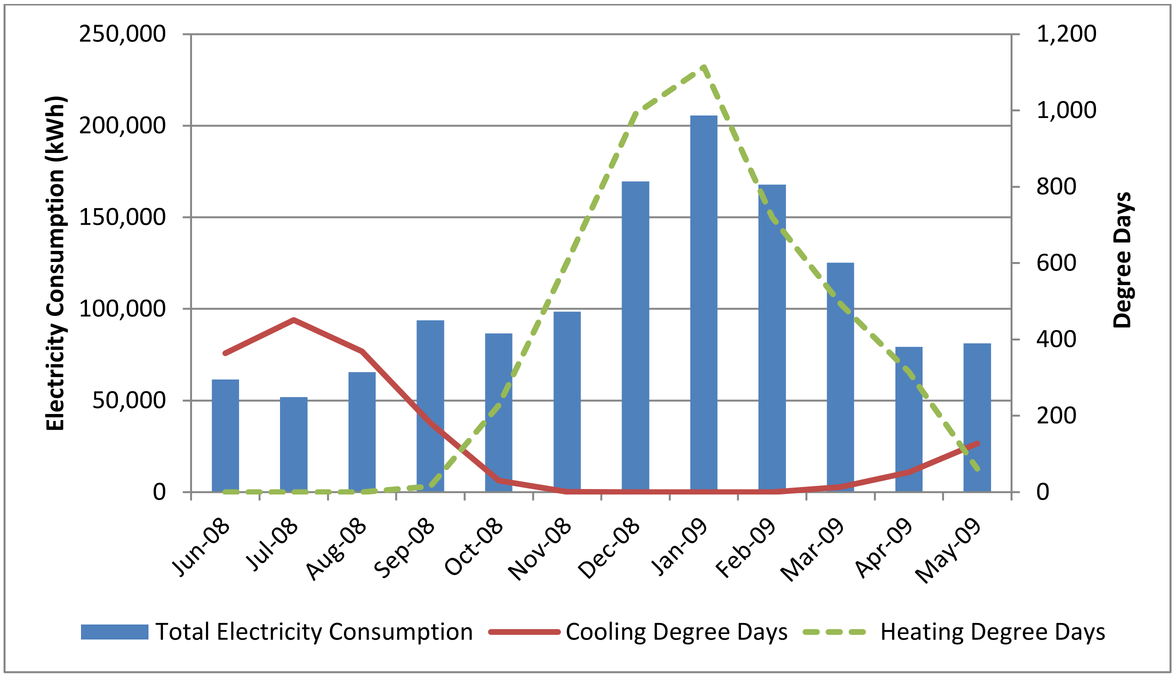


Figure 2: One Year Electric Energy Consumption Profile

Figure 3 shows reported monthly natural gas energy consumption profile compared to heating degree days, which are indicative of the duration and intensity of the heating season. Generally natural gas consumption follows the heating degree days closely, which indicates that by far the largest component of gas usage is space heating.

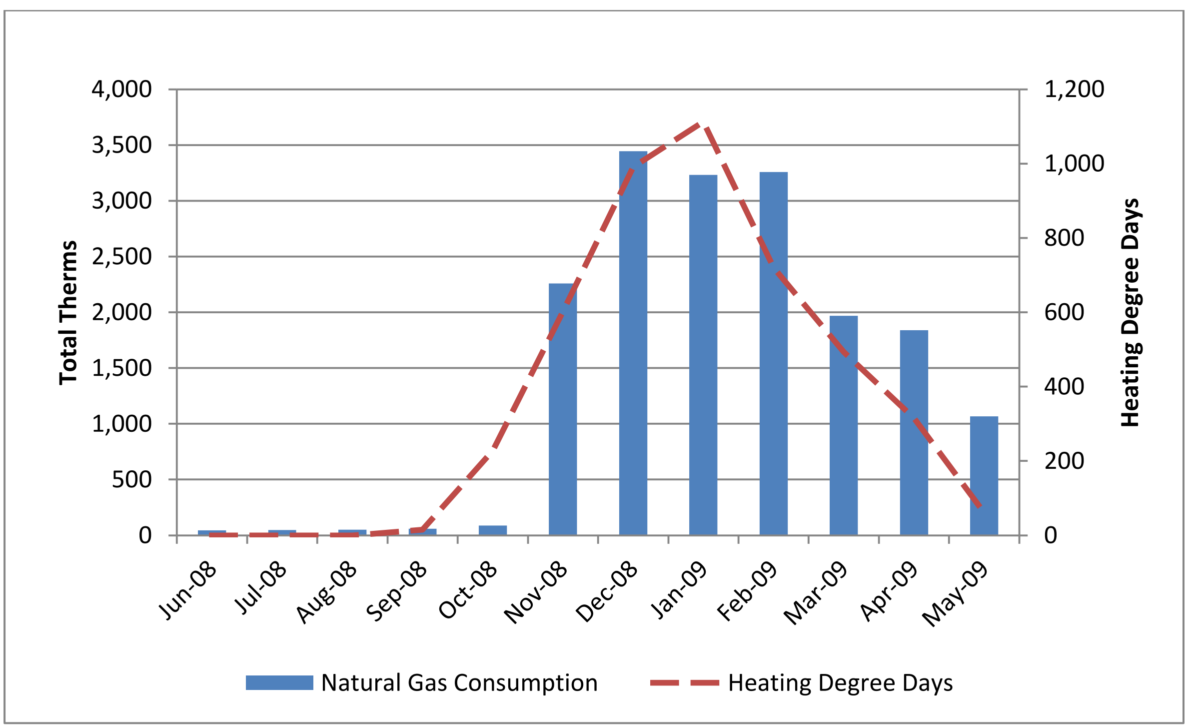


Figure 3: One Year Natural Gas Energy Consumption Profile

3.3 Breakdown of Energy Consumption

Determining where and in what quantities energy is used throughout the building helps to prioritize energy improvement efforts to maximum effectiveness.

Figure 4 shows a breakdown of the building's energy use by equipment type as estimated from equipment documentation, utility bill analysis, and data on end-use energy profiles from Energy Star. This breakdown gives an indication of possible areas for improvement. Focusing efficiency efforts in the appropriate areas are likely to produce the greatest results and therefore recommendations described later in this report focus on these areas of improvement.

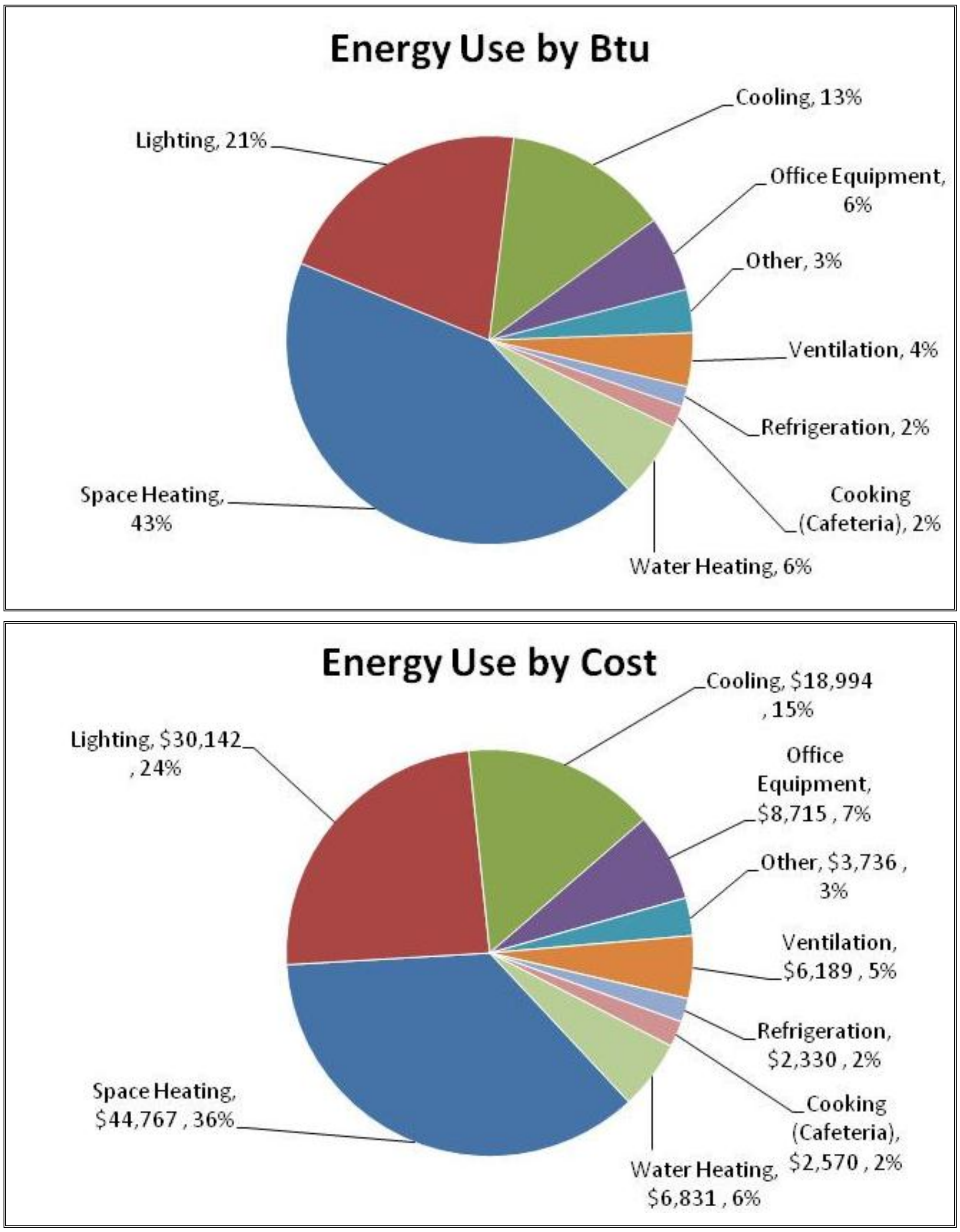


Figure 4: Breakdown of Annual School Energy by Energy Use (Btu) and by Energy Cost ($)

4. Energy Cost Reduction Measures (ECRMs)

The following section lists and describes all considered ECRMs and packages of ECRMs. The goal of these ECRMs is to reduce load and improve efficiency. Each subsection provides estimated annual utility use and utility cost reduction, potential incentives, and any other pertinent considerations. It should be noted that calculations used the aggregate of the past year's utility data. The economics of most strategies will improve greatly as increases in utility rates occur in the future

4.1 ECRM 1 – Gym Lighting Upgrade

The west gym is lit by a mixture of (48) 400-watt metal halide over the main floor and (63) 400-watt mercury vapor fixtures over the second floor auxiliary seating. The client indicated that the mercury vapor fixtures over the auxiliary seating are used some but not very much. This reduces the potential for payback on replacement of those fixtures. For the purposes of this ECRM we looked only at replacement of the 400-watt metal halide fixtures over the main west gym floor. In the east gym the main space is lit by (16) 400-watt metal halide lamps over the main space and (12) 250-watt metal halide lamps over the seating. A typical 250-watt metal halide fixture with magnetic ballast actually draws 295 watts, a typical 400-watt metal halide fixture with magnetic ballast actually draws 460 watts.[6] High-bay fluorescent fixtures designed for this type of application will consume about 150 watts per fixture for the 250-watt metal halide replacement and about 225 watts for the 450-watt metal halide replacement fixtures. Replacing the metal halide fixtures with can reduce lighting energy consumption in these spaces by 50 percent or more while maintaining or even improving upon the existing light levels. SEDAC recommends replacing the existing fixtures as shown in Table 5 below:

Location	Ct	Existing Fixtures		Recommended Replacement Fixtures		
		Fixture / Lamps	**Watts Per Fixture**	**Fixture / Lamps**	**Watts Per Fixture**	**Ballasts**
West Gym Main Floor	48	400-watt Metal Halide	460	6-lamp F32 T8, with Industrial Reflector[7]	226	Very High Output Electronic Ballasts (Ballast Factor ≥1.15 (Note: Use Program Start for dimming in ECRM 2)
West Gym Auxiliary Seating	63	400-watt Mercury Vapor	454	*No Replacement Unless Usage Significantly Increases in Future* [4-lamp F32 T8, with Industrial Reflector.]	148	
East Gym Main Floor	16	400-watt Metal Halide	460	6-lamp F32 T8, with Industrial Reflector	226	
East Gym Seating	12	250-watt Metal Halide	295	4-lamp F32 T8, with Industrial Reflector	148	

Table 5: Recommended Gym Lighting Upgrades

In addition to the per fixture wattage savings, this retrofit would allow the lights to be turned on only when needed without long start times, reducing unnecessary on-time of the system. Metal halides have a relatively long re-strike time, which requires ten to

[6] http://www.xcelenergy.com/SiteCollectionDocuments/docs/retail/busmrkts/LightingWattageGuide.pdf
[7] http://www.1000bulbs.com/High-Bay-Fluorescent-Power-Bay-Fixtures/31118/

fifteen minutes of warm up time for the lamps to reach their full lumen capacity. It is easier to leave these lights on than turn them off for short periods of time in which they are not needed. With the new fluorescent fixtures, the lights could be turned on and off with no waiting or downtime. This will also create the potential for adding daylighting and dimming controls to further reduce lighting energy consumption for this space as described in ECRM 2. See Appendix C for additional information and detail on retrofits for high-bay lighting applications.

SEDAC estimates that retrofitting the metal halide fixtures will save ~$3,256 per year. This ECRM has an estimated initial cost of ~$27,360 ($360/fixture installed) *without incentives*. Using a ten year life cycle, the internal rate of return (IRR) is ~1.4 percent and the net present value (NPV) is (-$4,013). It should be noted that SEDAC conservatively assumed time of use for the gyms to be 13 hours a day for five days a week for only nine months of the year, not including any use weekends or during the summer. Also the savings were calculated assuming the new lights left on the same number of hours. Should the actual usage be greater (weekend or summer usage) and/or the new fixtures be turned off regularly when the gym is not in use, the economics of this ECRM will improve.

DCEO's PSEE program currently has an incentive of $0.44 per watt reduced for high bay T5 and T8 applications. For this ECRM, the estimated incentive available from DCEO is ~$7,365. This improves the financial model significantly – giving the ECRM an estimated initial cost of ~$19,994, an IRR of ~8.4 percent and an NPV of ~$3,002. Table 6 below shows a sample DCEO application worksheet entry for obtaining incentive funds. See section 6.2 Energy Efficiency Portfolio Standard for further details about this program.

T8/T5 Highbay Fluorescent Fixtures with Electronic Ballast ***(Pre-approval application is required)***	**Incentive Per Watts Reduced**	**Unit**	**Watts Reduced**	**Incentive Subtotal**	**Existing Fixture Wattage**	**Number of Existing Fixtures**	**New Fixture Wattage**	**Number of New Fixtures**
Total Existing Fixture Watts less Total New Fixture Watts	$0.44	Connected Watt Reduction	14,976	$6,589.44	460	64 (48+16)	226	64
Total Existing Fixture Watts less Total New Fixture Watts	$0.44	Connected Watt Reduction	1,764	$776.16	295	12	148	12

Table 6: Sample Lighting Incentive Worksheet Entry
DCEO Public Sector Energy Efficiency Program - Year 2

The economic analysis of this ECRM is summarized in Table 7 below. SEDAC recommends implementing this ECRM ***only if incentives are obtained***. (see ECRM 2 for a combination of this ECRM with daylighting and controls).

Energy Cost Reduction Measure (ECRM)	**Annual Cost Savings ($/yr)**	**Initial Investment**	**Internal Rate of Return (IRR)**	**Net Present Value (NPV)**
ECRM 1 – Gym Lighting Upgrade - NO Incentives	$3,256	$27,360	1.4%	(-$4,013)
ECRM 1 – Gym Lighting Upgrade - WITH Incentives	$3,256	$19,994	8.4%	$3,002

Table 7: ECRM 1 - Economic Analysis

4.2 ECRM 2 – Gym Lighting Upgrade plus Daylighting and Controls

Installation of targeted daylight tubes in the west gym with the daylight dimming controls will result in a significant reduction in lighting energy consumption for this area.

A cost effective way to achieve significant daylighting in an existing building is to use daylighting tubes rather than more traditional rectangular skylights. These tubes can provide a very high quality of light and can be located to provide the majority of the overall space lighting during daylight hours. Products available for this include the Solatube 750 DS Daylighting System.[8]

Figure 5: Daylighting Tube[6]

Coupled with a daylight dimming system controlled by photo sensors which measure light levels provided by the daylighting tubes, this system can significantly reduce the overall lighting load for this area. Daylighting controls should be used on all gym lighting high-bay fluorescent fixtures in the proximity of skylights to keep them off when daylight is adequate for lighting needs. This ECRM can only be applied if metal halides are changed to fluorescent fixtures with dimming ballasts.

This ECRM models daylighting tubes along with fixture changes recommended in ECRM1 above. SEDAC estimates this ECRM will save a total of ~$4,702 (an additional ~$1,446 per year in addition to the ~$3,256 savings outlined in ECRM 1). This is accomplished by using savings from lighting retrofits discussed in ECRM 1 and adding skylights and dimmers to dim or turn off those new fixtures when foot candle levels from the sun are adequate for the space needs. This ECRM has an estimated initial cost of ~$53,760 (~$26,400 for the daylight tubes and dimming controls in addition to the $27,360 for lighting upgrades described in ECRM 1). This is the estimated capital cost *without incentives*. Using a fifteen year life cycle, the internal rate of return (IRR) is ~3 percent and the net present value (NPV) is (-$6,870).

The estimated incentive available from DCEO for this ECRM includes the incentives described for ECRM 1 (~$7,365) plus $1,550 additional incentive funding which may be available through DCEO's "Custom" incentive program ($0.08 per additional kWh reduced). SEDAC Estimates the total incentive funding available for this ECRM to be approximately $8,915. This improves the financial model significantly – giving the ECRM an IRR of 5.6 percent and an NPV of ~$1,621.

The economic analysis of this ECRM is summarized in Table 8 below. SEDAC recommends implementing this ECRM *only if incentives are obtained*.

Energy Cost Reduction Measure (ECRM)	Annual Cost Savings ($/yr)	Initial Investment	Internal Rate of Return (IRR)	Net Present Value (NPV)
ECRM 2 – Gym Lighting Upgrade plus Daylighting and Controls - NO Incentives	$4,702	$53,760	3%	(-$6,870)
ECRM 2 – Gym Lighting Upgrade plus Daylighting and Controls - WITH Incentives	$4,702	$44,845	5.6%	$1,621

Table 8: ECRM 2 - Economic Analysis

[8] http://www.solatube.com/commercial/com_750DS.php

4.3 ECRM 3 – T12 to T8 Lighting Upgrades

This ECRM addresses remaining fixtures which have not yet been upgraded from T12 to T8 in all of the buildings on the school property. In addition, the ECRM includes recommended de-lamping of specific fixtures where past upgrades resulted in overlit spaces.

T12 fluorescent fixtures were identified in the storage and maintenance spaces below the west gym auxiliary seating, in the ag shop, in the east gym (other than the main gym area), in the superintendent's bldg, and in the bus barn. For the analysis in this ECRM SEDAC identified 122 fixtures (50 @ 2x4', 62 @4x4' and 10@2x8'). There may be some additional fixtures which would increase the financial benefits of this ECRM.

In addition to further upgrades as noted above, SEDAC recommends checking light levels and de-lamping fixtures where it is possible to maintain recommended light levels[9] while realizing no-cost energy savings. The lighting in the art rooms is a good example where fixtures could be de-lamped to leave three lamps per fixtures. Currently the room light levels measure between 180-200 foot candles. Recommended levels for rooms with "Detailed Drawing Work, Very Detailed Mechanical Works" is 140 to 186 foot candles. Light levels for "Normal Office Work, PC Work, Study, Library…Laboratories" should be maintained at approximately 50 foot candles. Public spaces can be maintained at 5-10 foot candles. It is likely that many of the corridor and public space 4-lamp 2-foot T8 fixtures could be de-lamped to leave three lamps per fixtures.

SEDAC estimates that retrofitting the T12 fixtures with T8 fixtures with electronic ballasts plus selected fixture de-lamping (for the calculation of this ECRM only the lamps in the art rooms and the commons were included) will save ~$2,638 per year. This ECRM has an estimated initial cost of ~$8,718 *without incentives*. Using a ten year life cycle, the internal rate of return (IRR) is ~27 percent and the net present value (NPV) is $9,555. It should be noted that SEDAC conservatively assumed time of use for the gyms to be 8 hours a day (except the commons which assumes 13 hours a day) for five days a week for only nine months of the year, not including any use weekends or during the summer.

For this ECRM, the estimated incentive available from DCEO is ~$2,038. This improves the financial model – giving the ECRM an IRR of ~30 percent and an NPV of ~$9,366. Table 9 shows a sample DCEO application worksheet entry for obtaining incentive funds. See section 6.2 Energy Efficiency Portfolio Standard for further details about this program. Current standard incentives from DCEO are limited to de-lamping of 4-foot and 8-foot fixtures, however further incentive funding may be available for de-lamping of the 2-foot lamps through their "Custom" incentive program.

[9] Illuminating Engineering Society of North America (IESNA) Handbook

Equipment Type	Incentive	Unit	# of Units	Incentive Subtotal
Remove 4-foot lamp	$6.50	Lamp	49	$318.50
High Performance or Reduced Wattage 4-foot T8				
4-foot lamp and ballast	$7.50	Lamp	112	$840.00
4-foot lamp only	$1.00	Lamp	236	$236.00
Reduced Wattage 8-foot T8				
8-foot Lamp and Ballast	$11.00	Lamp	10	$110.00
8-foot lamp only	$1.00	Lamp	10	$10.00

Table 9: Sample Lighting Incentive Worksheet Entries
DCEO Public Sector Energy Efficiency Program - Year 2

The economic analysis of this ECRM is summarized Table 10 below. SEDAC strongly recommends implementing this ECRM.

Energy Cost Reduction Measure (ECRM)	Annual Cost Savings ($/yr)	Initial Investment	Internal Rate of Return (IRR)	Net Present Value (NPV)
ECRM 3 – T12 to T8 Lighting Upgrades - NO Incentives	$2,638	$8,718	27%	$9,555
ECRM 3 – T12 to T8 Lighting Upgrades - WITH Incentives	$2,638	$6,680	37%	$11,496

Table 10: ECRM 3 - Economic Analysis

4.4 ECRM 4 – Occupancy Sensors

Lighting currently represents approximately 24 percent of the energy cost for the main [redacted] High School building. To further reduce lighting energy consumption where fixtures have already been upgraded in most areas, SEDAC recommends installation of occupancy sensors in classrooms, offices, locker rooms, rest rooms, and storage rooms. The following provides some background on this ECRM.

A study completed by researchers with the U.S. EPA and the Lighting Research Center estimates potential energy savings from occupancy sensors at 54 percent for classrooms, 31 percent for private offices, 42 percent for conference rooms, 19 percent for break rooms, and 50 percent savings for restrooms, all based on a 15 minute time delay.[10] A brochure describing occupancy sensors can be found at http://www.wattstopper.com/getdoc/WallSwitchPSG.pdf.

Sensors can be mounted in place of a wall switch or on the ceiling to better 'view' the space. Sensors can be motion or dual sensors, which adds infrared detection to alleviate false turn-offs. It should be noted that some occupancy sensors may interfere with interactive white boards (e.g. SmartBoards) if they are used in the classrooms and

[10] VonNeida, Bill et al, An Analysis of the Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf

we recommend careful selection of sensors to prevent this interference. For these applications passive-infrared occupancy sensors with micophonics should be used.[11]

To calculate this ECRM, we assumed that there are 85 locations representing about half of the school's square footage, including classrooms, offices, restrooms, and other spaces, that can benefit from lighting occupancy sensors. It was assumed that occupancy sensors would turn off lights an average of 15 percent of the time during a typical 8 hour day (some spaces will be more, others less).

SEDAC estimates that adding occupancy sensors as described above will save ~$1,801 per year. This ECRM has an estimated initial cost of ~$10,200 *without incentives*. Using a ten year life cycle, the internal rate of return (IRR) is ~10 percent and the net present value (NPV) is $2,477. It should be noted that SEDAC conservatively assumed time of use for all lights to be 8 hours a day for five days a week for only nine months of the year, not including weekends or any use during the summer. Implementation in spaces which have higher usage will increase the savings potential.

For this ECRM, the incentive available for occupancy sensors from DCEO is $0.11 per connected watt. Incentives for this strategy are capped at 75 percent of project cost. The estimated incentive for this ECRM is therefore ~$6,694. This improves the financial model significantly – giving the ECRM an IRR of ~70 percent and an NPV of ~$9,763.

The economic analysis of this ECRM is summarized Table 11 below. SEDAC strongly recommends implementing this ECRM.

Energy Cost Reduction Measure (ECRM)	Annual Cost Savings ($/yr)	Initial Investment	Internal Rate of Return (IRR)	Net Present Value (NPV)
ECRM 4 – Occupancy Sensors - NO Incentives	$1,801	$10,200	10%	$2,477
ECRM 4 – Occupancy Sensors - WITH Incentives	$1,801	$2,550	70%	$9,763

Table 11: ECRM 4 - Economic Analysis

4.5 ECRM 5 – Replace West Gym HVAC w/ Ground Source Heat Pump

This ECRM looks at an alternate HVAC system to replace the current west gym system.

Geothermal systems take advantage of the earth's mass to provide heating and cooling for facilities. Geothermal systems can be significantly more energy efficient when compared to conventional heating systems. A preliminary analysis of this system has shown it to be a good candidate for a geothermal conversion. The current all electric system allows for sufficient electric service and adjacent open space allows for a vertical well field to be installed under the existing parking area. It is recommended that if a vertical field is installed below the parking that a porous paving system be installed in place of standard concrete so that the bore field can be recharged more easily with rain water. This has been included in the calculations for this ECRM. Keep in mind that designers must consider the balance of heating load versus cooling load for this type of system. If it is very unbalanced, the system can develop problems with the heat sink over time.

[11] For example: SensorSwitch (www.sensorswitch.com) uses Passive Infrared and Microphonics for their sensors and this will not interfere with interactive white boards.

Benefits of geothermal systems are:

- Energy efficiency – Geothermal systems are significantly more efficient than electric resistance systems.
- Geothermal systems can provide cooling as well as heating with the same system.
- Environmentally friendly – Because the earth is used as a heat source, supplemental heating and cooling is significantly reduced thereby reducing the carbon footprint of the facility.
- Renewable energy source – Geothermal energy is considered renewable energy source.
- Reliability – the existing equipment is thirty-five years old. The reliability of the system is compromised as time passes. Installing new equipment would ensure reliable operation for the foreseeable future.

Geothermal heat pumps can be installed in place of the existing electric resistance units to provide conditioned air to the west gym.

To calculate this ECRM, we developed a computer model of the west gym replacing the existing system with a high efficiency geothermal system or ground source heat pump. SEDAC estimates that this ECRM will save 166,274 kWh annually, resulting in a ~$13,460 annual energy savings. SEDAC estimates a cost of $385,380 to install this system. With *no grant funding or incentives*, this ECRM has an IRR of (-4 percent) and an NPV of ($212,111). We would like to emphasize the fact that for this initial analysis no grants or incentives were included and financial calculations were made based on the full equipment cost. Given the fact that the existing equipment is reaching the end of its useful life, it is reasonable to consider the financial return on investment based on the incremental cost difference between geo thermal and conventional equipment. Taking into consideration the potential need to replace the equipment in the near future we recalculated the IRR and NPV using the cost parameters shown in Table 12 below.

Note that one of the benefits of using geothermal heat pump systems, *when run without night or weekend setbacks*, is the ability to significantly reduce the system size (tons).

Conventional Equip: Heating only	**Conventional Equip: Heating + Cooling**	**Geo Thermal Heat Pump: Heating + Cooling**	**Incremental Cost Increase for Geo H+C**
115 Tons		***52 Tons***	
$144,700		**$385,380**	**$240,680**
	$202,200		**$183,180**

Table 12: Comparison of Replacement Equipment Costs

For a second investment analysis we used the incremental cost difference ($240,680) between replacing the existing heating-only system with a new system of the same type ($144,700) and replacing it with a new geothermal heating and cooling system ($385,380). These calculations resulted in an IRR of ~.6 percent and an NPV of (-$74,301).

Since the district is already considering adding cooling to the gym in the future we also ran the analysis using the incremental cost difference ($183,180) between replacing the existing heating-only system with a new conventional split system with both heating and cooling ($202,200) and replacing it with a new geothermal heating and cooling system ($385,380). These calculations resulted in a somewhat more favorable financial model, with an IRR of ~3.6 percent and an NPV of (-$19,540). This is in part due to the fact that a new conventional split heating and cooling system would increase the energy use for the gym, meaning that the net reduction in energy going to geothermal would be even greater and the incremental cost difference is less.

There are currently no standard incentives for geothermal through DCEO's Public Sector Electric Efficiency Program; therefore it is eligible for a custom incentive of $0.08 per kWh reduced provided the investment has a payback of one to seven years. Though the total system cost does not have a payback of 7 years, this ECRM may still be eligible for this incentive using the incremental cost difference if favorable pricing for the geothermal system can be obtained. Budget costs for vertical geothermal systems range from $4,000 to $8,000 per ton. For the calculations in this ECRM we have used a mid range cost of $6,000 per ton, plus ~$73,400 for additional project costs including removal of existing equipment and parking lot demolition and resurfacing. You might be able to obtain better pricing locally. With the project budget numbers we used the payback does not meet the maximum 7 year payback period allowed by the DCEO custom incentive program. If incremental cost of this ECRM is reduced enough to achieve a seven year payback, then this ECRM would be eligible for a custom incentive of approximately $20,196 (based on $0.08/kWh times the difference between estimated kWh consumption for a replacement conventional split heating-cooling system and the estimated kWh consumption for the selected ground source heat pump system), further improving the economic model (see Table 13).

Additional grant funding for this type of project is also potentially available through the Illinois Clean Energy Community Foundation[12] or other funding agencies, including upcoming programs made available through federal stimulus funds. See 6.4 Database of State Incentives for Renewables and Efficiency for details and links.

The economic analysis of this ECRM is summarized Table 13 below. SEDAC recommends implementing this ECRM *only if equipment replacement is already being considered and incentives/grant funds are obtained*. Another option to consider for the west gym would be an air-to-air heat pump system. There are new developments coming on the market for cold climates that can reduce the need for backup resistance heat as well.

Energy Cost Reduction Measure (ECRM)	**Annual Cost Savings ($/yr)**	**Initial Investment**	**Internal Rate of Return (IRR)**	**Net Present Value (NPV)**
ECRM 5 – Replace West Gym HVAC w/ Ground Source Heat Pump - FULL Cost	$13,460	$385,380	(-4%)	(-$212,111)
ECRM 5 – Replace West Gym HVAC w/ Ground Source Heat Pump - INCREMENTAL Cost used WITH Incentives	$13,460	$162,984	5%	(-$305)

Table 13: ECRM 5 - Economic Analysis

[12] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=IL06F&re=1&ee=1

4.6 ECRM 6 – Vending Controls

There are four cold drink vending machines outside the school in the courtyard and at least three others inside the school buildings. In addition there are several beverage coolers in the facility (in the concessions, kitchen and home economics classroom). These devices run 24 hours a day and use considerable amounts of energy. Controllers for cold drink vending machines are available which sense when people are nearby and turn off the controlled machines when nobody is around. In order to maintain temperature levels, the controller cycles the compressor once every one to three hours. This results in substantial energy and maintenance savings. A cold drink vending machine controller called a VendingMisers® is available for ~$200 each and the installation is simple. The controller is placed between the plug of the machine and the outlet. An occupancy sensor is also attached to the top of the machine. USA Technologies[13] manufactures the VendingMiser as well as other controllers including the SnackMiser™ for unrefrigerated snack vending machines and the CoolerMiser™ for glass door display refrigeration units. We estimated the annual savings of ~$1,630, based on the manufacturer's estimated annual savings per device, for a total installation cost of ~$2,000.

Using a ten year life cycle, the internal rate of return (IRR) is ~81 percent and the net present value (NPV) is ~$9,129. DCEO's PSEE program currently has a "Beverage Machine Control" incentive of $100/unit and a "Snack Machine Control" incentive of $30/unit which further improves the financial performance of this ECRM (see Table 14). The economic analysis of this ECRM is summarized Table 14 below. SEDAC strongly recommends implementing this ECRM.

Energy Cost Reduction Measure (ECRM)	Annual Cost Savings ($/yr)	Initial Investment	Internal Rate of Return (IRR)	Net Present Value (NPV)
ECRM 6 – Vending Controls - NO Incentives	$1,630	$2,000	81%	$9,129
ECRM 6 – Vending Controls - WITH Incentives	$1,630	$1,210	135%	$9,882

Table 14: ECRM 6 - Economic Analysis

4.7 ECRM 7 – Site and Parking Lot Lighting

The existing site lighting is a mixture of fixture and lamp types. Poles and fixtures are leased from Ameren. The school is interested in looking at any opportunity to reduce energy and cost of site lighting. According to the AmerenCIPS representative we spoke with, the site lighting is a mixture of fixture and lamp types including: (1) 250-watt and (1) 400-watt sodium vapor; (7) 175-watt mercury vapor; (2) 250-watt and (9) 400-watt metal halide directional light fixtures. These pole mounted fixtures operate dusk to dawn, controlled by photosensors. The poles and fixtures are leased from Ameren. The school currently pays for both the energy use and leasing of these fixtures.

According to the AmerenCIPS representative we spoke with, they are phasing out usage of mercury vapor lamps altogether as those fixtures fail. The new fixtures

[13] http://www.usatech.com/energy_management/energy_vm.php

installed by Ameren will utilize lower wattage high pressure sodium lamps. While high pressure sodium lamps are considered highly efficient from the perspective of simple energy usage calculations (lumens per watt)—many people do not like the quality of light they produce. There can be a *perception* that the light level from high pressure sodium lamps is actually dimmer than the light produced by ceramic metal halide lamps with equal lumen output. This is due to poor color rendering from the high pressure sodium lamps which can impair facial recognition and other key factors in creating a secure environment.[14] According to the AmerenCIPS representative we spoke with, AmerenCIPS will install metal halide fixtures and lamps for customers who request them specifically.

The Illuminating Engineering Society of North America (IESNA) has published recommendations for a variety of outdoor sites.[15] It is a very useful source for determining the proper illuminance levels for given outdoor applications, including parking lots. The range given for parking lots is one to five foot candles, taking into account surrounding terrain and structures. See Appendix D White Paper on Outdoor Lighting Issues for a comprehensive explanation of the variables to be considered in selecting site lighting.

Making the broad assumption that reduced wattage lamps will provide adequate light levels based on the IESNA recommendations, we have evaluated the energy cost reduction potential of replacing the existing higher wattage fixtures (all fixtures except the 175-watt mercury vapor) with 150-watt pulse-start metal halide fixtures with high lumen maintenance lamps and energy saving magnetic ballasts. The proposed ECRM will result in an estimated annual savings of $1,488 in combined leasing and energy costs. At an estimated initial cost of $9,505 this ECRM has an IRR of 7 percent and an NPV of $1,020.

Some incentive funding may be available through DCEO's custom incentive program—based on $0.08/kWh reduced consumption of the new fixtures (see Table 21). SEDAC recommends either implementing this ECRM with replacement poles and fixtures or contacting Ameren and requesting fixture upgrades for all leased site lighting to pulse start metal halide 150-watt lamps. We would like to emphasize that current site light levels around the school should be carefully evaluated and light level calculations prepared for the suggested reduced wattage fixtures prior to implementation. The economic analysis of this ECRM is summarized Table 15 below.

Energy Cost Reduction Measure (ECRM)	Annual Cost Savings ($/yr)	Initial Investment	Internal Rate of Return (IRR)	Net Present Value (NPV)
ECRM 7 – Site and Parking Lot Lighting - NO Incentives	$1,488	$9,505	7%	$1,020
ECRM 7 – Site and Parking Lot Lighting - WITH Incentives	$1,488	$8,356	11%	$2,115

Table 15: ECRM 7 - Economic Analysis

[14] Transportation Research Board, Abstract: "Effect of Outdoor Lighting on Perception and Appreciation of End-Users"

[15] Illuminating Engineering Society of North America (IESNA) Handbook

4.8 Package 1: ECRM's 2, 3, 4, 6, 7 – No Incentives

Each of the recommended ECRMs discussed individually in this report offer a payback based on the investment and savings. We offer a package of ECRMs together (excluding ECRM 5) to account for any interaction between the strategies. The capital costs involved and the ability to finance these strategies *without any incentive funding* are provided in Table 16.

Energy Cost Reduction Measure (ECRM)	Annual Cost Savings ($/yr)	Initial Investment	Internal Rate of Return (IRR)	Net Present Value (NPV)
ECRM 2 – Gym Lighting Upgrade plus Daylighting and Controls - NO Incentives	$4,702	$53,760	3%	(-$6,870)
ECRM 3 – T12 to T8 Lighting Upgrades - NO Incentives	$2,638	$8,718	27%	$9,555
ECRM 4 – Occupancy Sensors - NO Incentives	$1,801	$10,200	10%	$2,477
ECRM 6 – Vending Controls - NO Incentives	$1,630	$2,000	81%	$9,129
ECRM 7 – Site and Parking Lot Lighting - NO Incentives	$1,488	$9,505	7%	$1,020
Package 1: ECRM's 2, 3, 4, 6, 7 – NO Incentives	$12,259	$84,183	11%	$35,398
Package 1: ECRM's 2, 3, 4, 6, 7 – WITH Incentives	$12,259	$63,640	17%	$54,962

Table 16: Package 1 - ECRM's 2, 3, 4, 6, 7

Notes to Table 16:

(1) This analysis does not include a likely increase in energy prices. Results are in today's dollars on a pre-tax basis based on $0.08 per kWh and $1.16 per therm.
(2) When multiple ECRMs are implemented together, results vary from application of individual ECRMs
(3) Individual ECRM return on investment reported with NO incentives. Package results are reported both with and without incentives.
(4) ECRM 2 includes ECRM 1 Gym Lighting Upgrade, therefore ECRM 1 is not listed separately in this Package.

SEDAC recommends implementing either this ECRM package or the following one.

4.9 Package 2: ECRM's 2, 3, 4, 5, 6, 7 – With Incentives

Finally we calculated a package of all the ECRMs, including ECRM 5, taking into account incentives and assuming incremental equipment replacement cost only for ECRM 5. Table 17 shows a summary of this package.

Energy Cost Reduction Measure (ECRM)	**Annual Cost Savings ($/yr)**	**Initial Investment**	**Internal Rate of Return (IRR)**	**Net Present Value (NPV)**
ECRM 2 – Gym Lighting Upgrade plus Daylighting and Controls - WITH Incentives	$4,702	$44,844	5.6%	$1,621
ECRM 3 – T12 to T8 Lighting Upgrades - WITH Incentives	$2,638	$6,680	37%	$11,496
ECRM 4 – Occupancy Sensors - WITH Incentives	$1,801	$2,550	70%	$9,763
ECRM 5 – Replace West Gym HVAC w/ Ground Source Heat Pump - INCREMENTAL Cost	$13,460	$162,984	5%	(-$305)
ECRM 6 – Vending Controls - WITH Incentives	$1,630	$1,210	135%	$9,882
ECRM 7 – Site and Parking Lot Lighting - WITH Incentives	$1,488	$8,356	11%	$2,115
Package 2: ECRM's 2, 3, 4, 5, 6, 7 – WITH Incentives/INCREMENTAL cost for ECRM 5	**$25,719**	**$226,624**	**7%**	**$26,627**
Package 2: ECRM's 2, 3, 4, 5, 6, 7 – NO Incentives and FULL cost for ECRM 5	$25,719	$469,563	-3.4%	($204,744)

Table 17: Package 2 - ECRM's 2, 3, 4, 5, 6, 7 – WITH Incentives

Notes to Table 17:

(1) This analysis does not include a likely increase in energy prices. Results are in today's dollars on a pre-tax basis based on $0.08 per kWh and $1.16 per therm.
(2) When multiple ECRMs are implemented together, results vary from application of individual ECRMs
(3) Individual ECRM return on investment reported WITH incentives. Package results are reported both with and without incentives.
(4) ECRM 2 includes ECRM 1 Gym Lighting Upgrade, therefore ECRM 1 is not listed separately in this Package.

SEDAC recommends implementing this ECRM package if incentives are obtained and the west gym equipment is planned to be replaced (incremental cost difference used for return on investment calculations).

5. Additional Energy Cost Reduction Measures

Savings associated with the following measures have not been quantified however these additional recommendations will achieve energy savings beyond those measures which have previously been mentioned.

5.1 Energy Star® Building Upgrade Manual and Other Resources

As a reference material for future renovations, SEDAC would recommend the Energy Star Building Upgrade Manual.[16] The Energy Star guides provide an integrated approach to building upgrades including retrocommissing, lighting upgrades, supplemental load reductions, and air distribution system upgrades, followed by HVAC upgrades.

SEDAC also recommends the ASHRAE Advanced Energy Design Guide for K-12 Schools. This guide provides recommended specifications for envelope, lighting, and HVAC systems. The guidelines are designed to achieve 30 percent energy savings over ASHRAE Standard 90.1-1999. SEDAC would strongly recommend obtaining a copy of the guide, which can be downloaded for free from their website.[17]

5.2 Energy Star® Appliances

Plug loads can account for a significant portion overall facility load. Purchase Energy Star equipment whenever possible. Energy Star certifies computers, office equipment, kitchen appliances (hot holding cabinets, fryers, ovens, ice makers), and other equipment. Such equipment should be purchased whenever possible to reduce energy consumption. Some of the appliances with Energy Star options are described below.

Energy Star copy machines use 25 percent less energy than conventional equipment. Energy Star refrigerators use 15 percent less energy than required by government standards and 40 percent less than conventional refrigerators sold in 2001. Energy Star freezers use at least 10 percent less energy than required by current federal standards.

For more information on Energy Star appliances and tools to estimate your buildings energy efficiency, see www.energystar.gov.

The DCEO Public Sector EEPS program also has funds available for certain Energy Star and high efficiency refrigeration equipment.

5.3 Building Insulation

SEDAC encourages increasing the level of building roof insulation and air tightness at the time of any future building upgrades or additions. Facilities in this climate zone and of this type of construction should, at minimum, have R-13 wall insulation and R-25 roof insulation. The greatest savings will be realized from adding insulation to the roof of the main school complex and adding insulation to walls and roof of the ag building, and superintendent's building.

In addition to insulation, the air tightness of the wall and roof construction, including doors and windows can have a significant impact on the overall energy performance of

---

[16] http://www.energystar.gov/index.cfm?c=business.bus_upgrade_manual
[17] http://www.ashrae.org/publications/page/1604

buildings. The air tightness can be evaluated and remedies sought at the time of building envelope upgrades.

5.4 Energy Efficient HVAC Upgrades and Programmable Thermostats

SEDAC encourages increasing the energy efficiency of the natural gas boiler in the east gym as well as the individual gas furnaces in the ag building (3), and stadium (2). Given the age of the existing units, these systems are probably only 70-80 percent efficient. Consider installing units of minimum 90 percent efficiency at the time of any required replacements. Adding programmable thermostats to control temperature settings and schedule night time and weekend set-backs is encouraged for the ag building and stadium, as well as for the all-electric heating in the weight room of the bus barn. We understand that the superintendent's building already has a programmable thermostat.

5.5 Renewable Energy Sources

Once a minimum of 20 percent reduction in energy use has been achieved through the implementation of all of the recommended ECRM's plus additional measures found in this report, we encourage exploring renewable energy strategies (solar or wind). The reason for waiting to consider renewables until after all other conservation and efficiency measures have been implemented is that the cost of renewable energy is still quite high and the life cycle cost much less financially attractive when compared with the recommended energy cost reduction measures in this report.

The school has no unused land on the property. However, the building roof could be used as space for solar panels. SEDAC estimates that approximately 12,000 sf of space is currently available for this purpose. When the time comes to consider renewable energy, it is worth noting that the site is fairly well suited to roof-top solar and there are beginning to be small wind generation devices on the market which might be appropriate for this facility. There have been incentives and grant programs available to help support renewable energy projects. See Section 6 Funding Opportunities.

6. Funding Opportunities

These funding opportunities may help reduce the initial cost or improve the return on investment for the recommended ECRMs.

6.1 EPAct Tax Deduction

Building owners may be able to claim tax deductions for energy efficiency improvements put into service in 2006-2013. The 2005 Energy Policy Act (EPAct) provides tax deductions for buildings that are 50 percent more efficient than the 2001 ASHRAE Standard 90.1. In the case of energy efficient systems installed on or in government property (such as public schools), tax deductions will be given to the person primarily responsible for the systems' design. Deductions are taken in the year when construction is completed.

Businesses may also receive deductions if individual components of the building (lighting, envelope, HVAC) meet the requirements. A summary of incentives is shown in Table 18 below**.** For more information see Appendix B – EPAct 2005 Tax Deduction.

Category	**Energy Savings (vs. ASHRAE 90.1-2001)**	**Tax Deduction**	**Requires Energy Simulation?**
Whole Building	50%	Up to $1.80/sf	Yes
Lighting, HVAC, or Envelope	16.7 % per system	Up to $0.60/sf per system	Yes
Lighting savings of at least 25%	25-40%	Sliding scale: $0.30/sf for 25% savings to $0.60/sf for ≥40%	No, just lighting power density calculation

Table 18: Summary of Federal Tax Deductions

6.2 Energy Efficiency Portfolio Standard

On August 28, 2007 Senate Bill 1592 was signed into law which includes an Energy Efficiency Portfolio Standard (EEPS) and a Renewable Portfolio Standard (RPS) that are among the most ambitious in the nation. The EEPS required Illinois utilities to reduce overall electric usage by 0.2 percent of demand in 2008, escalating to 2.0 percent by 2015.

The RPS required utilities to supply 2 percent of their power from renewable energy sources in 2008 for certain "eligible customers," escalating to 25 percent by 2025.

This law creates a substantial budget for programs and incentives to reduce electrical energy usage and demand for customers of ComEd and Ameren. During the first year which ended in May of 2009, there was approximately $50 million devoted to various sectors of utility customers. ComEd and Ameren focused approximately $38 million on residential, commercial, and industrial customers and the Illinois Department of Commerce and Economic Opportunity (DCEO) utilized about $12 million on the low income and public sectors. For the second year of the program which began June 1, 2009, these budgets doubled, and in the third and fourth years of the program, the budgets will triple and quadruple respectively. This is by far the largest opportunity Illinois has had for funding energy efficiency and demand reduction efforts.

The implications of the EEPS and RPS for SEDAC clients is that clients in the Ameren and ComEd service territories can take advantage of incentives for energy cost reduction measures (ECRMs) which reduce electric energy consumption. Note that applications are now being accepted for the next funding cycle which began June 1, 2009. Incentives applicable to this facility are summarized in Table 19 below.

Application to Use	Measure Description	Unit Incentive
Selected Standard Lighting Incentives (See application for the complete list as well as specific requirements associated with these incentives)[18]	**Compact Fluorescent Lamps (Screw-in)**	
	15 W or Less	$1.50 per lamp
	16 W - 26W	$1.50 per lamp
	27 W or Greater	$2.00 per lamp
	Hardwired Compact Fluorescent Fixtures	
	29 W or Less	$27.50 per fixture
	30 W or Greater	$55.00 per fixture
	Delamp, Permanent Lamp Removal – *(Pre-approval application is required)*	
	Delamp, 4-foot Lamp, Ballast, Holders	$6.50 per lamp
	Delamp, 8-foot Lamp, Ballast, Holders	$8.50 per lamp
	Delamp, 4-foot Lamp, add Reflector	$13.00 per lamp
	Delamp, 8-foot Lamp, add Reflector	$17.50 per lamp
	High Performance or Reduced Wattage 4-foot T8	
	4-foot Lamp and Ballast	$7.50 per lamp
	4-foot Reduced Watt Lamp Only	$1.00 per lamp
	Reduced Wattage 8-foot T8	
	8-foot Lamp and Ballast	$11.00 per lamp
	8-foot Lamp Only	$1.00 per lamp
	Specialty T8 Lamps and Ballasts	
	4-foot U Tube and Ballast	$3.00 per lamp
	2-foot Lamp and Ballast	$3.00 per lamp
	3-foot Lamp and Ballast	$5.00 per lamp
	LED Lighting	
	LED T-1 Electroluminescent Exit Signs	$22.00 per sign
	LED Lamp/Fixture	$10.00 per lamp
	Metal Halide	
	Integrated Ballast Ceramic Metal Halide Lamps	$5.00 per fixture
	Pulse Start or Ceramic, 100W or Less	$22.00 per fixture
	Pulse Start or Ceramic, 101W – 200W	$38.00 per fixture
	Pulse Start or Ceramic, 102W – 350W	$44.00 per fixture
	Controls	
	Occupancy Sensors	$0.11 per watt controlled
	Plug Load Occupancy Sensor	$20.00 per sensor
	Bi-Level Stairwell/Hall/Garage Fixtures w/ integrated sensors	$25.00 per fixture
	T8/T5 New Fluorescent Fixtures with Electronic Ballast (Pre-approval application is required)	
	Total Existing Fixture Watts less total New Fixture Watts	$0.44 per watt reduction

[18] http://www2.illinoisbiz.biz/energy/PSEEG.pdf

Application to Use	Measure Description	Unit Incentive
Selected Refrigeration Incentives (See application for the complete list as well as specific requirements associated with these incentives)	Beverage Machine Control (Vending Miser)	$100 per unit
	Snack Machine Control	$30 per unit
	Energy Star® Vending Machine	$100 per unit
	High Efficiency Ice Makers	Varies by capacity: $150 - $400 per unit
HVAC System Incentives	Additional Standard Incentives	See application
Motor System Incentives	Additional Standard Incentives	See application
Custom Incentives	Max. $0.08 per kWh saved (1-7 year payback)	See application
NOTE: You must apply in advance, prior to completing the work of these incentives. See applications for details: DCEO Public Sector Electric Efficiency Programs [19]		

Table 19: Selected DCEO EEPS Incentives

6.3 DCEO Solar Energy Programs

DCEO is currently offering two funding programs for solar power. Projects with a total cost of less than $50,000 are eligible for the Solar Energy Rebate Program which offers a rebate of 30 percent of the total project cost capped at $10,000. Larger projects are eligible for the Solar Energy Incentive Program which offers an incentive of up to $3 per watt installed for LEED projects or up to $3.25 per watt installed for innovative use of PV. The maximum funding amount may be waived in cases where it is appropriate for the purposes of the Renewable Energy Resources Program.

For more information on DCEO's programs see:
http://www.commerce.state.il.us/dceo/Bureaus/Energy_Recycling/Energy/Clean+Energy

6.4 Database of State Incentives for Renewables and Efficiency

For information on state and federal rebates, see Database of State Incentives for Renewables and Efficiency (DSIRE): http://www.dsireusa.org/.

6.5 Smart Energy Design Assistance Center

SEDAC has developed a website for posting links to various funding opportunities: http://smartenergy.arch.uiuc.edu/html/info_loan.html

A list of service providers can be found at:
http://smartenergy.arch.uiuc.edu/html/info_serviceprovider.html

[19] http://www.illinoisbiz.biz/dceo/Bureaus/Energy_Recycling/Energy/Energy+Efficiency/

7. Conclusions and Recommendations

SEDAC has analyzed seven energy cost reduction measures (ECRMs). Together the ECRMs reduce annual facility energy use by 314,819 kWh which equals a 12 percent reduction in the school's total energy use. This results in $25,719 annual savings (16 percent of the school's annual energy costs) from an investment of about $226,624 with cost reductions from incentives and considering the incremental cost to upgrade equipment whose service life is coming to an end. Consider funding opportunities mentioned in this report to help cover a portion of the cost of the improvements. A summary of the economic analysis for all ECRMs is shown in Table 20 below.

Energy Cost Reduction Measure (ECRM)	**Annual Cost Savings ($/yr)**	**Initial Investment**	**Internal Rate of Return (IRR)**	**Net Present Value (NPV)**
ECRM 1 – Gym Lighting Upgrade - NO Incentives	$3,256	$27,360	1.4%	(-$4,013)
ECRM 2 – Gym Lighting Upgrade plus Daylighting and Controls - NO Incentives	$4,702	$53,760	3%	(-$6,870)
ECRM 3 – T12 to T8 Lighting Upgrades - NO Incentives	$2,638	$8,718	27%	$9,555
ECRM 4 – Occupancy Sensors - NO Incentives	$1,801	$10,200	10%	$2,477
ECRM 5 – Replace West Gym HVAC w/ Ground Source Heat Pump - FULL Cost – NO Incentives	$13,460	$385,380	(-4%)	(-$212,111)
ECRM 6 – Vending Controls - NO Incentives	$1,630	$2,000	81%	$9,129
ECRM 7 – Site and Parking Lot Lighting - NO Incentives	$1,488	$9,505	7%	$1,020
Package 1: ECRM's 2, 3, 4, 6, 7 – NO Incentives	$12,259	$84,183	11%	$35,398
Package 2: ECRM's 2, 3, 4, 5, 6, 7 – WITH Incentives and using INCREMENTAL cost for ECRM 5	**$25,719**	**$226,624**	**7%**	**$26,627**

Table 20: Summary of ECRM Savings

Notes to Table 20:

(1) NO incentives are included in the summary above except for Package 2 as noted. Package 1 includes some ECRMs which have a negative NPV with NO Incentives but which as a package has a positive NPV even without incentives. See Table 17 for a summary including the individual ECRM savings WITH incentives.

(2) Discount Rate is assumed to be 5%; ECRMs with IRR less than 5% will show a negative NPV.

(3) This analysis does not include a likely increase in energy prices. Results are in today's dollars on a pre-tax basis based on $0.08 per kWh and $1.16 per therm.

(4) When multiple ECRMs are implemented together, results vary from application of individual ECRMs

A summary of the energy savings for all ECRMs is shown in Table 21 below.

Energy Cost Reduction Measure (ECRM)	Annual Energy Savings			
	kWh	kW	Therms	% Facility Energy Use (kBtu)
ECRM 1 – Gym Lighting Upgrade	42,552	17	(-232)	1.5%
ECRM 2 – Gym Lighting Upgrade plus Daylighting and Controls	61,929	56	(-338)	2.2%
ECRM 3 – T12 to T8 Lighting Upgrades	33,424	18	(-157)	1.2%
ECRM 4 – Occupancy Sensors	22,249	14	(-162)	0.7%
ECRM 5 – Replace West Gym HVAC w/ Ground Source Heat Pump	166,274	227	-	6.9%
ECRM 6 – Vending Controls	16,576	-	-	0.7%
ECRM 7 – Site and Parking Lot Lighting	14,366	-	-	0.6%
Package 1: ECRM's 2, 3, 4, 6, 7	148,545	88	(-657)	5.4%
Package 2: ECRM's 2, 3, 4, 5, 6, 7	314,819	315	(-657)	12%

Table 21: Economic Analysis for the Energy Cost Reduction Measures

Notes to Table 21:
(1) When multiple ECRMs are implemented together, results vary from application of individual ECRMs

SEDAC recommends implementing Package 2 if incentives are obtained and the west gym equipment is planned to be replaced (incremental cost difference used for return on investment calculations). If upgrades are not planned for the west gym equipment then our recommendation is to implement Package 1. We also recommend considering the additional energy savings measures outlined in Section 5 of this report.

Appendices

Appendix A – Abbreviations

AC – Air conditioning

ACH – Air changes per hour

AFF – Above finished floor

AFUE – Annual fuel utilization efficiency

ASHRAE – American Society of Heating, Refrigeration and Air-Conditioning Engineers

Btu – British thermal unit

CFM – Cubic feet per minute

CLG – Cooling

COP – Coefficient of performance

CRI – Color rendering index

DCEO – Illinois Department of Commerce and Economic Opportunity

DSIRE – Database of State Incentives for Renewables and Efficiency

DX – Direct expansion

DWH – Domestic water heater

ECRM – Energy cost reduction measure

EEPS – Energy Efficient Portfolio Standard

EER – Energy efficiency ratio

Effic – Efficiency

ERV – Energy recovery ventilator

F – Fahrenheit

ft – Foot or feet

fc – foot candle

GSHP – Ground source heat pump

HP – Horsepower

HRV – Heat recovery ventilator

HSPF – Heating seasonal performance factor

Htg – Heating

HVAC – Heating, ventilating and air conditioning

HW – Hot water

HX – Heat exchanger

IM – Injection molding

IRR – Internal rate of return

kW – kilowatt, one thousand watts

kWh – kilowatt-hours, one thousand watt-hours

LCCA – Life cycle cost analysis

lm/W – lumens per watt

LPD – Lighting power density

MH – Metal halide

NPW – Net present worth

OA – Outside air

OSB – Oriented strand boards

PKG – Package

PSIG – Pounds per square inch, gauge

RTU – Roof top unit

R-Value – A measure of the resistance of building materials to heat transfer

SC – Shading coefficient

SEER – Seasonal energy efficiency ratio

SF or sf – Square feet

SHGC – Solar heat gain coefficient

Svgs – Savings

T5 – A tubular fluorescent lamp 5/8 in. diameter

T8 – A tubular fluorescent lamp one in. diameter

Therm – A unit of measure for natural gas equal to 100,000 Btus or 100 Cubic Feet.

U-Value – A factor expressing the ability of a material to transfer heat.

V– volts

VFD – Variable frequency drive

yr – Year(s)

Appendix B – Envelope Recommendations

The Climate Zone 4 Recommendation Table below is taken from the ASHRAE Advanced Energy Design Guide for K12 Schools. The table provides a list of recommended specifications for building envelope, lighting, HVAC, and service hot water systems. Chapter 5 of the guide "How to Implement Recommendations" contains the how-to-tips referenced in the table.

Climate Zone 4 Recommendations for K-12 Schools

	Item	Component	Recommendation	How-To Tip	✓
Envelope	Roofs	Insulation entirely above deck	R-25 c.i.	EN1–2	
		Attic and other	R-38	EN3, EN15–16, EN18	
		Metal building	R-13 + R-19	EN3–4, EN15, EN18	
		SRI	Comply with Standard 90.1*	EN1	
	Walls	Mass (HC > 7 Btu/ft^2·°F)	R-9.5 c.i.	EN5, EN15, EN18	
		Steel framed	R-13 + R-7.5 c.i.	EN6, EN15, EN18	
		Wood framed and other	R-13	EN7, EN15, EN18	
		Metal building	R-19	EN7, EN15, EN18	
		Below-grade walls	Comply with Standard 90.1*	EN8, EN15, EN18	
	Floors	Mass	R-8.3 c.i.	EN9, EN15, EN18	
		Steel framed	R-30	EN10, EN15, EN18	
		Wood framed and other	R-30	EN10, EN15, EN18	
	Slabs	Unheated	Comply with Standard 90.1*	EN11, EN17–18	
		Heated	R-15 for 24 in.	EN12, EN17–18	
	Doors	Swinging	U-0.70	EN13, EN18	
		Nonswinging	U-0.50	EN14, EN18	
	Vertical Fenestration	Total fenestration to gross wall area ratio	35% max	EN20	
		Thermal transmittance—all types and orientations	U-0.42	EN19, EN24, EN28	
		SHGC—all types and orientations	SHGC—0.40	EN19, EN24, EN28	
		Exterior sun control (S, E, W only)	Projection factor > 0.5	EN21, EN23, EN26	
Lighting	Interior Finishes	Interior room surface average reflectance	70%+ on ceilings and walls above 7 ft 50%+ on walls below 7 ft	DL14, EL1	
	Interior Lighting—Daylighted Option	Classroom daylighting (daylighting fenestration to floor area ratio)	Toplighted—South-facing roof monitors: 8%–11%; North-facing roof monitors: 12%–15%	DL1–19, DL28–35	
			Sidelighted—South-facing: 8%–11% North-facing: 15%–20%	DL1–19, DL20–27	
			Combined toplighted and sidelighted— South-facing sidelighted: 6%–8% Toplighted: 2%–3% North-facing sidelighted: 9%–13% Toplighted: 3%–5%	DL1–19, DL20–35	
		Gym toplighting (daylighting fenestration to floor area ratio)	South-facing roof monitors: 5%–8% North-facing roof monitors: 7%–10% Only skylights—3%–4%	DL1–19, DL36–37	
		LPD	1.2 W/ft^2 maximum	EL9–16	
		Light source system efficacy (linear fluorescent)	75 mean lm/W minimum	EL2–3, EL5	
		Light source system efficacy (all other sources)	50 mean lm/W minimum	EL4–5	
		Occupancy controls	Manual on, auto off all zones	EL6, EL8, DL16	
		Dimming controls daylight harvesting	Dim all fixtures in classrooms and gym, and other fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	DL16	
	Interior Lighting—Nondaylighted Option	LPD	0.9 W/ft^2	EL9–16	
		Light source system efficacy (linear fluorescent)	85 mean lm/W minimum	EL2–3, EL5	
		Light source system efficacy (all other sources)	50 mean lm/W minimum	EL4–5	
		Occupancy controls—general	Manual on, auto off all zones	EL6, EL8, DL16	
		Dimming controls daylight harvesting	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	DL16	
HVAC	Packaged DX Rooftops (or DX Split Systems)	Air conditioner (<65 kBtu/h)	13.0 SEER	HV1, HV7–8, HV10	
		Air conditioner (≥65 and <135 kBtu/h)	11.3 EER		
		Air conditioner (≥135 and <240 kBtu/h)	11.0 EER		
		Air conditioner (≥240 kBtu/h)	10.6 EER and 11.2 IPLV		
		Heat pump (<65 kBtu/h)	13.0 SEER/7.7 HPSF		

* **Note:** If the table contains "Comply with Standard 90.1" for a component, the user must meet the more stringent of either the most current version of ASHRAE Standard 90.1 or the local code requirements.

Climate Zone 4 Recommendations for K-12 Schools

	Item	Component	Recommendation	How-To Tip	✓
	Packaged DX Rooftops (or DX Split Systems)	Heat pump (≥65 and <135 kBtu/h)	10.6 EER/3.2 COP	HV1, HV7–8, HV10	
		Heat pump (≥135 kBtu/h)	10.1 EER and 11.0 IPLV/3.1 COP		
		Gas furnace (<225 kBtu/h)	80% AFUE or E_t		
		Gas furnace (≥225 kBtu/h)	80% E_c		
		Economizer	>54 kBtu/h	HV13	
		Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14	
		Fans	Constant volume: 1 hp/1000 cfm Variable volume: 1.3 hp/1000 cfm	HV19	
	WSHP System	Water-source heat pump (<65 kBtu/h)	Cooling: 12.0 EER at 86°F Heating: 4.5 COP at 68°F	HV2, HV7–8, HV10	
		Water-source heat pump (≥65 kBtu/h)	Cooling: 12.0 EER at 86°F Heating: 4.2 COP at 68°F		
		GSHP (<65 kBtu/h)	Cooling: 14.1 EER at 77°F and 17.0 EER at 59°F Heating: 3.5 COP at 32°F and 4.0 COP at 50°F	HV2, HV7–8, V10, AS4	
		GSHP (≥65 kBtu/h)	Cooling: 13.0 EER at 77°F and 16.0 EER at 59°F Heating: 3.1 COP at 32°F and 3.5 COP at 50°F		
		Gas boiler	85% E_c	HV2, HV7, HV10	
		Economizer	Comply with Standard 90.1*	HV13	
		Ventilation	DOAS with either energy recovery or demand control	HV9, HV11–12, HV14	
		WSHP duct pressure drop	Total ESP < 0.2 in. H_2O	HV19	
	Unit Ventilator and Chiller System	Air-cooled chiller efficiency	10.0 EER and 11.5 IPLV	HV3, HV7–8, V10, HV25	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV7–8, HV10, HV25	
		Gas boiler	85% E_c	HV3, HV7, HV10, HV26	
		Economizer	>54 kBtu/h	HV13	
		Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14	
		Pressure drop	Total ESP < 0.2 in. H_2O	HV19	
	Fan Coil and Chiller System	Air-cooled chiller efficiency	10.0 EER and 11.5 IPLV	HV4, HV7–8, HV10, HV25	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV4, HV7–8, HV10, HV25	
		Gas boiler	85% E_c	HV4, HV7, HV10, HV26	
		Economizer	Comply with Standard 90.1*	HV13	
		Ventilation	DOAS with either energy recovery or demand control	HV9, HV11–12, HV14	
		Pressure drop	Total ESP < 0.2 in. H_2O	HV19	
	Packaged Rooftop VAV System	Rooftop air conditioner (≥240 kBtu/h)	10.6 EER and 11.2 IPLV	HV5, HV7–8, HV10	
		Gas furnace (≥225 kBtu/h)	80% E_c		
		Gas boiler	85% E_c	HV5, HV7, HV10, HV26	
		Economizer	>54 kBtu/h	HV13	
		Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14	
		Fans	1.3 hp/1000 cfm	HV19	
	VAV and Chiller System	Air-cooled chiller efficiency	10.0 EER and 11.5 IPLV	HV6, HV7–8, HV10, HV25	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV6, HV7–8, HV10, HV25	
		Gas boiler	85% E_c	HV6, HV7, HV10, HV26	
		Economizer	>54 kBtu/h	HV13	
		Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14	
		Fans	1.3 hp/1000 cfm	HV19	
	Ducts and Dampers	Outdoor air damper	Motorized	HV11, HV13	
		Friction rate	0.08 in. w.c./100 ft	HV16	
		Sealing	Seal Class B	HV18	
		Location	Interior only	HV16	
		Insulation level	R-6	HV17	
SWH	SWH	Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
		Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
		Electric (storage or instantaneous)	EF > 0.99 – 0.0012 × volume	WH1–5	
		Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

* **Note:** If the table contains “Comply with Standard 90.1” for a component, the user must meet the more stringent of either the most current version of ASHRAE Standard 90.1 or the local code requirements.

Appendix C – Retrofits for High-Bay Lighting Applications

The following is taken from the Lighting Controls Association web site at http://www.aboutlightingcontrols.org/education/papers/high-low-bay.shtml

Fluorescent Retrofits for High/Low-Bay Applications

By Craig DiLouie, Lighting Controls Association

Originally published November 2004; revised May 2009

Indoor spaces with high ceilings, such as factories, warehouses, big box retail stores, gymnasiums and all-purpose rooms are often lighted by probe-start metal halide lighting systems. At higher ceiling heights, 350W and 400W units are common.

Probe-start metal halide lamps are compact, rugged, powerful light sources, well suited for illuminating large spaces with a crisp, white light. These systems are able to operate reliably in a wide range of ambient temperatures, with numerous fixtures specially designed to operate in demanding environments such as hazardous locations.

Probe-start metal halide lighting presents a number of disadvantages, however. These systems are not easily dimmable, experience color shift over time, and require four minutes to start and about 10 minutes for re-strike after shutoff. Most significantly, service life, light output and efficacy severely degrade over time. These systems are often deployed in basic-grade spun-aluminum dome fixtures, which present a typical 75% efficiency—meaning 25% of the light produced remains trapped in the light fixture. As a result of its lumen maintenance and typical fixture efficiencies, this standard metal halide system appears low-cost but in fact is not very economical relative to the best alternatives, as either more fixtures, or higher-wattage fixtures, are required to provide desired maintained light levels.

The inefficiency of these fixtures, in fact, led to a prohibition on manufacturing probe-start fixtures that do not meet a certain ballast efficacy standard, as mandated by the Energy Independence and Security Act of 2007, virtually eliminating probe-start magnetic-ballasted fixtures starting in 2009.

Advancements in lamp and ballast technology have resulted in two alternatives to this basic system that can significantly reduce energy consumption while providing other benefits. The first alternative is fluorescent T8 or T5HO hi-bay fixtures, which can replace probe-start metal halide fixtures in retrofit or new construction for energy savings up to about 50%. The second alternative is pulse-start metal halide lamp-ballast systems, which can provide up to 25% energy cost savings in existing applications and up to 30% in capital and operating costs in new construction.

Galt High School upgraded its metal halide fixtures with T5HO linear fixtures, reducing energy consumption by nearly 50%. Photo courtesy of Sacramento Municipal Utility District.

Hi-Bay Lighting

In the lighting industry, one may hear the terms "high-bay" (also "hi-bay") and "low-bay" (also "lo-bay") lighting.

In the construction of some types of industrial facilities, a skeletal framework is used, which forms an interior subspace called a "bay," which in turn marks the space as "high bay" or "low bay."

An older definition designated hi-bay to mean >25 ft. off the floor, medium-bay to mean 15-25 ft., and lo-bay to mean <15 ft.

Some manufacturers define hi-bay as being over 15 ft. or 20 ft. off the floor.

IESNA categorizes spaces as either hi-bay (>25 ft.) or lo-bay (<25 ft.).

The terms hi-bay and lo-bay also refer to fixtures designed for these applications, although it is not uncommon to see hi-bay fixtures in lo-bay applications, and vice versa.

Typical hi-bay applications. Photos courtesy of Lithonia Lighting.

Fluorescent Fixtures

Fluorescent fixtures for high-ceiling applications offer single- or multi-point pendant mounting for retrofit or construction alternative to HID fixtures such as probe-start metal halide. Manufacturers include Lithonia, Holophane, Columbia Lighting, Cooper Lighting, Day-Brite, HE Williams, MetalOptics, Amerillum, Orion, Simkar, Intrepid, 1st Source Lighting, Ruud Lighting, Stonco, Guth Lighting, Hubbell and others.

- These fixtures may house 4, 6 or other number of lamps.
- The lamps are typically T8 or T5HO, although compact fluorescent models are available.
- Optics are available with narrow and wide distributions. Wide distributions are best for lower mounting heights and general lighting areas, while narrow distributions are best for aisle and similar applications. Some fixtures offer a degree of uplight as well as direct downlight.
- Some models are available that can operate in demanding environments.
- Models are available that offer emergency ballasting options.

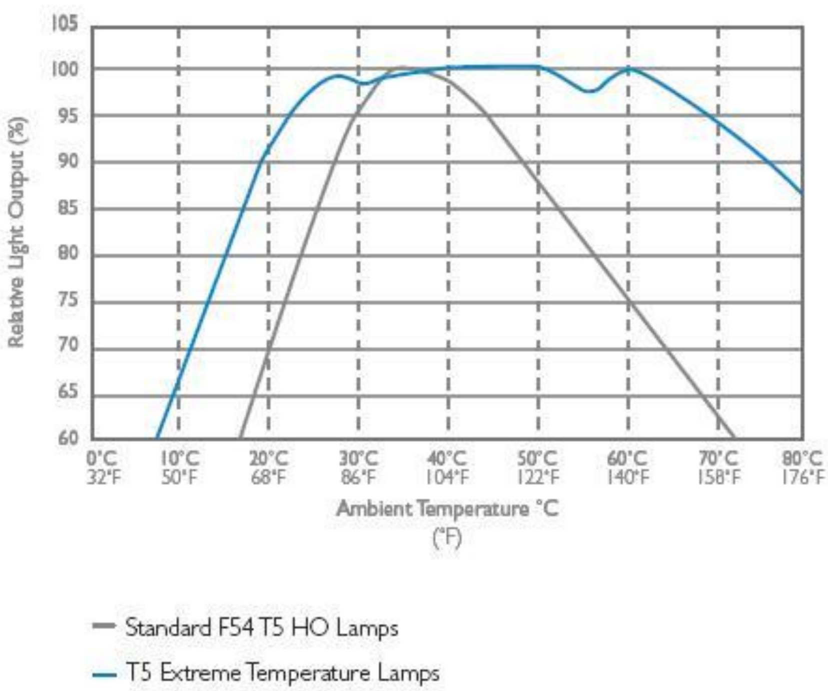
T5HO Systems

T5HO lamps are about 5/8 in. in diameter, about 40% of the size of T12 lamps, and therefore enable better photo-optic control of the light produced by the fixture, increasing efficiency and providing uniform distribution of light output. T5HO lamps used for hi-ceiling lighting applications are typically 4-ft. 54W lamps. Because T5HO lamps are built to metric dimensions, a 4-ft. lamp is actually 45.8 in. long, a little shorter than T8 and T12 lamps.

Initial rated light output is based on peak output at an ambient temperature of 35°C (95°F), whereas T8 and T12 lamps are based on 25°C (77°F). Amalgam lamps extend reliability of light output across a wider temperature range between cold and hot. T5HO lamps operate on programmed-start or instant-start electronic ballasts; universal-voltage (120-277V and 347-480V) ballast, dimming ballasts and four-lamp ballasts are available. T5HO lamps are not interchangeable with T8, T12 and T5 lamps.

Photo courtesy of OSRAM SYLVANIA.

There are two recent developments of interest. First, 49-51W T5HO lamps are now available that can replace 54W lamps for energy savings and a boost in efficacy with no loss of light output. Second, amalgam T5 VHO lamps are now available. These lamps produce 7,200 lumens of initial light output, reaching 80% of light output about three minutes after startup. Using amalgam technology, light output is above 90% from 65°F to 170°F. Dimming, however, may not be recommended.



Using amalgam technology, light output is above 90% from 65°F to 170°F for this T5 VHO lamp. Graphic courtesy of Philips Lighting.

T8 Systems

Fluorescent fixtures for high-ceiling lighting applications often include "Super T8" lighting systems. Super T8 lamps are 32W lamps that provide 3,100+ initial lumens instead of the 2,850 offered by standard 32W T8 lamps, and 95% lumen maintenance at 40% of rated service life. Examples include Philips Advantage, Sylvania Xtreme XPS and GE's

High Lumen Eco. Super T8 lamps can be operated on programmed-start or instant-start ballasts. For hi-bay lighting, they are often paired with high-ballast-factor ballasts (1.15-1.18 BF) to maximize system light output. For example, a system consisting of six 3,100-lumen T8 lamps operating on 1.18 BF ballasts produces nearly 22,000 lumens, still about a third less than a 6-lamp T5HO system but somewhat more than a 4-lamp T5HO system.

Note that amalgam T8 VHO lamps are now available that produce light output above 90% from 50°F to 160°F (10°C to 70°C). This lamp produces the same light output as the T5 VHO, but offers lower wattage, higher efficacy, shorter rated life, and ability to dim down to 20%. See the below table for a comparison.

	T5 VHO amalgam	T8 VHO amalgam
Watts	95	84
Initial lumens	7,200	7,200
Mean lumens	6,480	6480 (3500K and 4100K); 6,550 (5000K)
Efficacy	76	86
CRI	85	85 (3500K/4100K); 82 (5000K)
CCT	3500K, 4100K	3500K, 4100K
Life @ 12 hrs/st on PS ballast	35,000	25,000
Light output <90%	65°-170°F	50°-160°F

T5HO Versus T8

You may hear recommendations to use T8 fixtures for a better quality of light and less glare at fixture heights <20 ft., T5HO fixtures for quality light output and higher fixture efficiency at >20 ft., and either between 18 and 25 ft. However, while T5HO may produce "glare bombs" at lower mounting heights, both T8 and T5HO fixtures can be used in both hi- and lo-bay applications, depending on the application, and if correctly applied.

Otherwise, a T5HO system is not as efficacious as T8 lamps, but produces more light output for the same number of lamps. With more light produced from a smaller diameter lamp, T5HO lamps are much brighter than T8 lamps, which can become a lighting quality factor.

T5HO lamp operation is optimized at a higher ambient temperature than T8s; another thing to watch out for with T8s is high-BF ballasts, which produce more heat. This may make T5HO systems more desirable in industrial spaces with higher ambient temperatures at the fixture mounting height. Note that ambient temperature is less a function of heat around the fixture as it is heat within the fixture's lamp compartment; for best results, specify fixtures with a good temperature design.

A final consideration is maintenance. To get the highest amount of light output from a T8 fixture, Super T8 lamps should be specified, but the owner must continue to order this lamp type to maintain lighting performance. The maintenance department should not be permitted to substitute cheaper and lower-lumen 32W T8 lamps, particularly if these standard T8 lamps are used in a connected office. Conversely, if Super T8 lamps are used in a connected office, then this can be seen as a maintenance advantage for using them in a hi-ceiling application in the same building or campus.

In this school gymnasium, 400W metal halide fixtures (left) were changed over to F32T8 hi-bay fixtures (right) on a one-for-one replacement basis, increasing light levels from 30 to 50 fc and CRI from 65 to 85 while reducing wattage per fixture from 450W to 224W. Photos courtesy of Acuity Brands Lighting.

Lumen Maintenance

A 400W probe-start metal halide fixture, with a ballast factor of 1.0, produces 36,000 initial lumens. A 6-lamp Super T8 fluorescent fixture, with a ballast factor of 1.18, produces about 21,950 initial lumens. How can this fluorescent fixture replace the metal halide fixture to generate 52% energy savings and still produce comparable light levels?

The answer is lumen maintenance. In review, lumen maintenance is an expression of the fraction of initial light output that is produced by a light source over time—typically at 40% of lamp life, which provides mean lumens. This determines the design light level.

Probe-start metal halide lamps experience a higher level of lumen depreciation than T5HO and T8 lamps. For example, a 400W metal halide lamp can lose 35% of its light output at 40% of life, while a T5HO or T8 lamp will lose only 5-6%. As a result, a 6-lamp Super T8 lamp-ballast system produces 11% fewer mean lumens for 52% less energy.

System	Initial Lumens*	Mean Lumens @ 40% Lamp Life**	Relative Mean Lumen Output
400W Probe-Start Metal Halide	36,000	23,500	100%
400W Pulse-Start Metal Halide	42,000	32,800 (magnetic ballast); 36,000 (electronic ballast)	140%; 153%
4-Lamp T5HO Fluorescent	20,000	19,000	81%
6-Lamp T5HO Fluorescent	30,000	28,500	121%
6-Lamp Super T8 Fluorescent	21,948	20,851	89%

**Fluorescent lamp lumens are based on optical temperatures; adjust as needed.

**Note that pulse-start system light output declines at a significantly sharper rate than fluorescent after 40% of lamp life. To further the comparison, consider researching and comparing these numbers at end of lamp life rather than at the mean. Data source: Advance.

Wattages

This article focuses on comparing a standard probe-start metal halide lamp-ballast system with relevant T5HO and Super T8 lighting systems. Note that when comparing wattages to do so based on system wattage (lamp/ballast) rather than solely on lamp wattage. A “400W metal halide” system, accounting for ballast losses, draws 458W, not 400W. Similarly, a 6-lamp T5HO system draws 324W based solely on lamp wattage but 351W when these lamps operate on necessary ballasts. Comparing system wattages can be important when determining cost savings resulting from a lighting retrofit, but in new construction, efficacy, covered on the next page, is often considered more important.

System	Total Lamp Watts	Total System Watts	Relative System Wattage
400W Probe-Start Metal Halide	400W	458W	100%
400W Pulse-Start Metal Halide	400W	452W (magnetic ballast); 425W (electronic ballast)	99%; 93%
4-Lamp T5HO Fluorescent	216W	234W	51%
6-Lamp T5HO Fluorescent	324W	351W	77%
6-Lamp Super T8 Fluorescent	192W	222W	48%

Data source: Advance.

Efficacy

Efficacy, in review, is an expression of relative lamp efficiency. Expressed in lumens of light output per watt of electrical input, this useful metric is similar to “miles per gallon.” As lumen output decreases over time, efficacy decreases because wattage says the same.

400W probe-start metal halide has an initial lamp-ballast system efficacy of 79 lumens/W. Although well below the efficacy of Super T8 with its efficacy of 99 lumens/W, it is only 7% less efficacious than T5HO with its efficacy of 85 lumens/W. However, initial efficacy is virtually meaningless because efficacy changes during operation. At 40% of lamp life, considered the design average, the efficacy of a 400W probe-start lamp-ballast system drops 40% to 51 lumens/W, while T5HO and Super T8 efficacies drop 5% to 81 lumens/W and 94 lumens/W respectively.

System	Initial Efficacy (lumens/W)	Mean Efficacy @ 40% Lamp Life	Relative Mean Efficacy
400W Probe-Start Metal Halide	79	51	100%
400W Pulse-Start Metal Halide	93 (magnetic ballast); 99 (electronic ballast)	73; 85	143%; 167%
4-Lamp T5HO Fluorescent	85	81	159%
6-Lamp T5HO Fluorescent	85	81	159%
6-Lamp Super T8 Fluorescent	99	94	184%

Data source: Advance.

Fixture-Based Efficacy

Fluorescent and metal halide lighting systems operate as the light-producing component within a light fixture. The light output and efficacy numbers previously discussed, therefore, must account for the impact of the fixture.

Many probe-start metal halide light fixtures found in the field offer low efficiencies of about 75%, while the best T5HO and T8 (and HID) hi-bay fixtures offer efficiencies as high as 91-92%. (For best results when choosing fluorescent, select fixtures with optics that are specifically designed for the specific lamp type, whether it be T5HO or T8.)

When one considers the impact of fixture optics, the basic-grade 400W probe-start metal halide fixture produces the lowest amount of maintained light output of all the options, and has a maintained efficacy of less than half the Super T8 option.

System	Fixture Efficiency	Fixture Mean Lumens @ 40% Lamp Life	Relative Mean Lumen Output	Fixture Mean Efficacy (lumens/W)	Relative Fixture Efficacy
400W Probe-Start Metal Halide, basic-grade dome	75%	17,625	100%	39	100%
400W Probe-Start Metal Halide, high-performance dome	92%	21,620	123%	47	121%
400W Pulse-Start Metal Halide, high-performance dome	92%	30,176 (magnetic ballast); 33,120 (electronic ballast)	171%; 188%	67; 78	172%; 200%
4-Lamp T5HO Fluorescent, high-performance reflector	92%	17,480	99%	75	192%
6-Lamp T5HO Fluorescent, high-performance reflector	92%	26,220	149%	75	192%
6-Lamp Super T8 Fluorescent, high-performance reflector	91%	18,974	108%	85	218%

Source of fixture efficiency numbers: Lighting Wizards, Inc.

Controls Flexibility

Probe-start metal halide lamps take 4 minutes to start and 10 minutes to restart after being turned off and then shortly after turned on again. Pulse-start lamps take 2 minutes to achieve full brightness on a magnetic ballast and less than 1 minute on an electronic ballast, while taking 4 minutes to hot re-strike. Because of safety concerns, HID systems are not compatible with switching controls such as occupancy sensors.

Hi-bay occupancy sensor. Photo courtesy of Leviton.

Fluorescent systems, however, start almost instantly, opening up significant controls possibilities. Line-voltage occupancy sensors have significantly reduced their installed cost, making it economical to install one sensor per fixture for intermittently occupied spaces. (This type of strategy, for example, can be used to satisfy the Commercial Buildings Deduction's bi-level switching requirement.) Fluorescent systems are also relatively easy and inexpensive to dim, enabling daylight harvesting with skylights or flexible light level selection in all-purpose spaces. These opportunities further extend the potential for energy cost savings.

Lamp Life

In review, the rated service life of gaseous discharge lamps is an average. At rated life, half of a large population of lamps is expected to fail, distributed according to the lamp's mortality curve. Lamp life is particularly important in hi-bay applications because the fixtures can be difficult to reach for maintenance.

At first glance, probe-start metal halide appears to offer very good service life compared to fluorescents. However, service life is rated based on the anticipated switching cycle, or "hours/start," as the frequency of switching lamps on and off significantly impacts service life. Fluorescent lamps are typically rated based on 3 hours/start, while metal halide lamps are typically rated based on 10 hours/start. Fluorescent service life improves on an apples-to-apples basis of 10-hour switching cycles. At 10 hours/start, Super T8 leads the pack with a 28,000-hour service life compared to 24,000 hours for T5HO and 20,000 hours for probe-start.

Note, however, that fluorescent lighting enables the introduction of occupancy sensors, which may switch the lamps more frequently and thereby reduce lamp life. For these applications, programmed-start ballasts can be specified to optimize lamp life.

System	Rated Service Life @ 10 Hours/Start (hours)	Relative Service Life
250W Probe-Start Metal Halide	15,000	75%
250W Pulse-Start Metal Halide	20,000	100%
400W Probe-Start Metal Halide	20,000*	100%
400W Pulse-Start Metal Halide	20,000	100%
4-Lamp T5HO Fluorescent (Programmed Start Ballast)	24,000**	120%
6-Lamp T5HO Fluorescent (Programmed Start Ballast)	24,000**	120%
6-Lamp Super T8 Fluorescent (Instant Start Ballast)	28,000	140%

* OSRAM SYLVANIA has introduced a 250W pulse-start metal halide lamp rated to 20,000 hours.

** Philips Lighting has re-rated its T5HO lamps with programmed-start ballasts to 25,000 hours at 3/hours/start, which would increase for 10 hours/start.

Data source: Advance, with notations by Lighting Wizards.

Color Temperature

In review, color temperature indicates the color appearance of a light source and the light it emits. For general lighting in many industrial spaces and warehouses, 4000K is considered suitable. In big box retail stores, color temperature is typically on the warmer side of neutral-white (3000-3500K), but can vary based on preference.

Typical probe-start metal halide lamps provide a 3000-4000K color temperature. As metal halide lamps age, however, chemical changes occur in the lamp which can cause a shift in color temperature of 200-600K over time. If group relamping (replacement of all lamps in a system at periodic intervals) does not occur, replacement lamps mingling with older lamps can result in noticeable poor lamp-to-lamp color consistency over time; some lamps may appear white while others may appear bluish, pink or purple. Additionally, when metal halide lamps are dimmed, they may shift to a higher color temperature, from white to blue-green; when a clear lamp is dimmed to 50% of rated power, color temperature can increase by 1500K, according to the Lighting Research Center.

HID lamps can experience a color shift during dimming and also a reduction in color rendering ability. Metal halide lamps are most susceptible to changes in lamp color characteristics.

T8 and T5HO experience negligible color shift during operation (although dimming may make the lamps appear uniformly cooler) and therefore maintain consistent color lamp to lamp. These lamps also offer a broader color temperature range from a neutral-white range up to a very cool 5000K.

Probe-Start Metal Halide	3000-4000K
Pulse-Start Metal Halide	3600-4000K
Ceramic Pulse-Start Metal Halide	3000-4200K
T5HO Fluorescent	3000-5000K
Super T8 Fluorescent	3000-5000K

Data source: Advance.

Color Rendering

In review, color rendering, expressed on the Color Rendering Index (CRI), is the ability of a light source to make colors in the space appear “natural.” According to IESNA, in a manufacturing space, an >80 CRI rating may be suitable, although a CRI >90 may be desirable for tasks where matching or distinguishing colors is critical. In a warehouse, a CRI of at least 60 is suitable, with a CRI of at least 80 desirable where color is important. In big box retail stores and supermarkets, light sources should have a >80 CRI.

T5HO and T8 lamps provide 82-85 CRI compared to 65 for probe-start metal halide lamps. (Note that metal halide lamps may suffer a reduction in CRI when dimming; for example, when a clear metal halide lamp is dimmed to 50% of rated power, the CRI value may decline from 65 to 45.) To achieve a 90+ CRI, some fluorescent models are available but the higher color rendering is achieved at the expense of light output, disqualifying these lamps for many hi-bay applications. Other choices include daylight, ceramic metal halide and incandescent, although incandescent is generally undesirable due to its short service life and very low efficacy.

Probe-Start Metal Halide	65 CRI
Pulse-Start Metal Halide	65 CRI (clear); 70 CRI (coated)
Ceramic Pulse-Start Metal Halide	80-90+ CRI
T5HO Fluorescent	82-85 CRI
Super T8 Fluorescent	85 CRI

Data source: Advance.

Lighting Quality and Aesthetics

Lighting quality and aesthetic issues that are important to consider include color, glare, shadows, uplight, uniformity, vertical distribution and fixture appearance.

Metal halide lamps are point sources, while fluorescent lamps are linear sources. As a result, fluorescent fixtures are less likely to present “glare bombs” than metal halide fixtures, while increasing vertical light levels and providing softer light distribution, which minimizes shadows. However, whether metal halide or fluorescent is used, these aspects are highly dependent on good fixture design. On the other hand, metal halide hi-bay fixtures with clear prismatic domes are often seen in big box retail stores, selected partly for their aesthetic appearance and ability to provide dramatic highlights and a uniform uplight pattern on the ceiling. Wherever metal halide is selected, pulse-start metal halide should be considered.

Hi-bay fixtures with linear sources can improve vertical footcandles, important in applications such as big box retail, warehouses and some sports facilities.

Photo courtesy of Lithonia Lighting.

Maintenance

Fluorescent hi-bays often present 4-6 times more lamps to maintain, with the primary cost-adder being labor. As lamps fail, fixtures exhibit lamp outages, which can affect space appearance, not to mention produce less light. Typically, a lift or similar mechanism will be required, as pole changers do not work with linear fluorescent lamps.

On the other hand, if a metal halide lamp fails, a significant space will not have a sufficient light level. With fluorescent fixtures, when a lamp fails, the space will still receive light from the remaining lamps. Similarly, fixtures usually contain more than one ballast, so if one ballast fails, the other may continue operating. Lamp life with fluorescent systems can be maximized with programmed-start ballasts, especially important if occupancy sensors are present which can result in frequent switching. If maintenance is an extremely critical issue, consider induction lamps, which can provide up to a 100,000-hour rated lamp life and retained performance in extremely cold conditions, albeit for a much higher installed cost.

In this gym, if one lamp fails in a fixture, other lamps in the same fixture will continue to produce light. Photo courtesy of Sacramento Municipal Utility District.

Another maintenance issue is lamp replacement when Super T8 lamps are used. It is critical for maintenance personnel to replace Super T8 lamps with Super T8 lamps and not standard 32W T8 lamps because this will result in a reduction in light levels.

Disadvantages of Fluorescent

Fluorescent fixtures are not for all hi-ceiling lighting applications:

- Extreme mounting heights, which may lend themselves better to 1000W metal halide lamps.
- Unconditioned spaces with wide temperature ranges.
- Severe environments such as hazardous locations, corrosive environments, etc. for which a suitable fluorescent fixture is not available.
- Environments where the aesthetic of a dome-shaped fixture is desired; for these spaces, one can still consider domes fitted with compact fluorescent lamps.

- Spaces where a retrofit or upgrade alternative is not economical. In a retrofit, this will depend on product purchasing, installation labor and local energy costs. In a new construction project, note that a good fluorescent hi-bay fixture costs more to install than a basic-grade hi-bay metal halide fixture, but these initial cost savings are wiped out within months due to higher operating costs.

As always in lighting, the choice of the best system will often depend not just on the economics of initial and operating cost, but also on environmental considerations and what level of performance the owner is looking for from their lighting system.

Lighting Controls

Hi-bay fluorescent lighting enables owners to take advantage of all the control systems already enjoyed in office settings—scheduling, daylight harvesting, bi-level switching, occupancy sensors and dimming.

Utility Con Edison's Astoria, NY 320,000-sq.ft. distribution warehouse. Con Ed wanted to streamline the lighting system in its Astoria, NY 320,000-sq.ft. distribution warehouse, improve efficiency and lighting quality, and integrate a sensor to control vacant areas and aisles, thereby adding to operating cost savings. Con Edison replaced the entire lighting system (left) with T5HO fixtures operating on programmed-start electronic ballasts and controlled by occupancy sensors (right). Photos courtesy of OSRAM SYLVANIA.

Automatic Shutoff

Fluorescent lighting starts almost instantly and therefore is highly compatible with automatic switching strategies such as automatic shutoff using occupancy sensors or control panels with time clocks.

U.S. Marine Corps Base Joseph H. Pendleton—home to the 1st Marine Expeditionary Force and 1st Marine Division, responding to an Executive Order signed in 1999 by President Clinton mandating higher efficiency in Federal facilities—instituted a lighting upgrade in scores of buildings. The upgrade involved conversion from HID fixtures to T5HO hi-bay fixtures from Amerillum and light harvesting fixtures from Daylight Technology, controlled by Square D's Powerlink lighting control system. The panel-based Powerlink system provides automatic lighting shutoff with modules providing daylight harvesting control capabilities. Energy savings is estimated at 57%, a cost savings of more than $230,000. Photos courtesy of Energy & Power Management Magazine.

Occupancy Sensors

Besides scheduling, occupancy sensors represent a major controls opportunity that can be used to maximize energy savings during a fluorescent upgrade, particularly in warehouses and similar spaces that are often under-occupied.

Line-voltage occupancy sensors have slashed the cost of occupancy-sensing by about two-thirds, according to Platts/McGraw-Hill, making it economical to consider installing a sensor for each fixture in intermittently, infrequently occupied areas. The sensor is installed directly onto the fluorescent fixture or electrical junction boxes. Occupancy sensors are available with lenses specifically designed for hi-bay applications, providing reliable coverage from a range of mounting heights, and some are available with narrow-view lenses for warehouse aisles. When using occupancy sensors, which can result in frequent switching, consider programmed-start ballasts to maximize lamp life.

Menlo Worldwide Logistics replaced 240 400W metal halide fixtures in its Fremont, CA 120,000 sq.ft. distribution center with 6-lamp Super T8 fixtures equipped with occupancy sensors. The upgrade resulted in 44% energy savings. Photo courtesy of Watt Stopper/Legrand

Dimming

Fluorescent dimming can be accomplished in two ways. First, fixtures can be wired with multiple circuits to vary light levels, enabling bi-level or multi-level switching. Unlike hi-lo HID ballasts, energy savings proportional to light output reduction. Second, the fixtures can be equipped with dimming ballasts for continuous dimming. Unlike HID dimming, the lamps can be dimmed to 10-20%. Both bi-level switching and continuous dimming can be instituted to generate energy savings resulting from occupancy-sensing (with occupancy sensors), scheduled demand reduction (with a scheduling device such as a control panel with a time clock), and/or daylight harvesting (with a photosensor). Bi-level switching and continuous dimming also enable flexibility to adjust light levels for multiple uses of a space.

Gyms, which are typically multi-use spaces, are suitable applications for fluorescent dimming. Photo courtesy of MetalOptics.

Appendix D – White Paper on Outdoor Lighting Issues

White Paper on Outdoor Lighting Issues

Quality Lighting Applications

Prepared by the

Outdoor Lighting Task Force
Luminaire Section
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209

NEMA
Setting Standards for Excellence

Outdoor Lighting Issues

Introduction:

Providing quality outdoor lighting is a challenge to state and local policymakers. The need to balance safety and security while maintaining natural habitats are legitimate issues. This white paper is intended to educate and provide information related to outdoor lighting issues and quality lighting. This paper will identify specific lighting issues, explain the interaction of these lighting issues, define correct lighting terminology and provide straightforward technical guidance.

The NEMA Outdoor Lighting Task Force is a specific working group of the NEMA Luminaire Section. The Section is comprised of thirteen manufacturers representing some 90 percent of the lighting market, both in indoor and outdoor.

The National Electrical Manufacturers Association (NEMA) is the leading trade association in the United States representing the interests of electroindustry manufacturers. Founded in 1926 and headquartered near Washington, D.C., our 400 member companies manufacture products used in the generation, transmission and distribution, control, and end-use of electricity. Domestic shipments of electrical products within the NEMA scope exceed $100 billion.

What Is Happening Around the States on Outdoor Lighting Issues?

Recommendations made by the NEMA Outdoor Lighting Task Force have been adopted by California in a rulemaking on outdoor lighting, as well as in Virginia and Rhode Island law. Many states and municipalities have, or are in the process of, developing outdoor lighting standards. When carefully constructed, these standards can help to reduce sky glow, light trespass onto adjacent properties, glare and energy consumption. However, myriad remedies including among others: full cutoff luminaire recommendations for specific lumen output; use of specific lamp source types or wattages; and, pole height limitations have been proposed. These well-intentioned remedies are not clearly defined and actually work to make outdoor lighting a greater problem. Poorly written codes can increase in energy usage resulting in greater air and light pollution; some requirements also make it very difficult to ensure a safe and secure environment.

What are the Fundamental Principles that Require Consideration?

Effective lighting design incorporates careful consideration of many variables including overall visibility, safety and security, energy efficiency, light trespass, and environmental concerns such as sky glow or impact on local wildlife. It is important to understand the interrelationship of the various factors that affect quality lighting before outdoor lighting codes are written. Moreover, outdoor lighting codes often try solutions that result in unintended consequences. These include, among others:

- Mandating the use of full cutoff luminaires will reduce light emitted directly from the luminaire into the night sky, but can increase sky glow from light reflected off ground surfaces. It may also require the use of more lighting equipment resulting in increased overall cost and energy consumption.

- Pole height limitations often result in poor lighting uniformity, increased costs, greater sky glow, and higher energy consumption. Pole height mandates typically increase the required number of poles and luminaires leading to increased costs and energy consumption. Excessively dark areas may compromise safety and security while excessively bright areas will increase sky glow due to light reflected from ground surfaces into the night sky.

- The use of Low Pressure Sodium lighting is often required in areas surrounding observatories because it can be easily filtered by observatory instrumentation. However, the characteristics of this source will result in a reduction in the ability to distinguish specific colors and contrast and as such, should be carefully considered for appropriate uses. Low Pressure Sodium lamps concentrate their output in the yellow portion of the visual spectrum. These types of lamps may cause color identification problems and may impact nighttime visibility.

- It is important to evaluate the effectiveness of scheduled outdoor lighting operation time frames. Reducing late-night light levels may be effective in some areas to reduce energy consumption and sky glow. However these schedules must be flexible and sensitive to safety and security issues.

What are the Most Effective Design Techniques?

Effective design techniques for outdoor lighting include:

- Defining lighting criteria based on the demographics for the area. There are distinct differences in the lighting requirements between urban and rural areas. Many codes and guidelines reference these areas as "environmental zones" or "lighting zones." It is important to ensure that sufficient light levels accommodate the safety and security needs for the area. Retail or other areas with higher safety and security requirements may need to be addressed separately.

- The use of technically feasible and recommended lighting component devices that minimize unwanted light. These components include: using pole heights and spacing appropriate to the application; utilizing a shield that minimizes the component of light above horizontal and glare when luminaires need to be tilted or aimed (but avoiding tilting cutoff luminaires); control systems to reduce light levels during inactive periods or at predetermined times.

- IESNA recommended target illuminance guidelines for Security Lighting for People, Property and Public Spaces will provide adequate illuminance recommendations to ensure visibility for increased safety and security. Excessive illuminance levels may increase the likelihood of sky glow, light trespass and glare. Adaptation difficulties may exist when leaving a brightly lit area to the darker roadway. Use of excessive lamp wattage and/or illuminance wastes energy and contributes to glare and sky glow.

What Does the NEMA Outdoor Lighting Task Force Propose?

The Outdoor Lighting Task Force recommends legislative language that achieves effective light distribution while addressing energy consumption, sky glow, safety, security, operating costs and concerns. However, NEMA recommends language that does not mandate the use of full cut-off lighting. Such applications will restrict design flexibility, increase energy consumption, and may increase sky glow.

The Outdoor Lighting Task Force promotes technological solutions. Lighting professionals need a full range of options at their disposal to effectively address outdoor lighting concerns. The broad restriction of general product types will limit the use of new or emerging product technologies. Qualified lighting professionals recommend lighting that provides a minimum acceptable illuminance for a designated purpose (based on nationally recognized standards). Code requirements may also limit products to two percent (2%) uplight above the horizontal plane of the luminaire for general area lighting such as parking lots or outdoor sales lots.

Finally, any language should allow exemptions for (among others): significant safety or security concerns; historic or residential areas that require special product aesthetics or vertical illuminance criteria (this exemption may be designed to limit the lamp lumens or wattage to control glare and light trespass); temporary lighting used for emergency or nighttime work; lighting used solely to enhance the beauty of an object; and special public events.

What are Further Sources of Recognized Information?

Input should be gathered from recognized lighting professionals or equipment manufacturers. These entities, and other industry organizations that can also provide useful information include:

- Illuminating Engineering Society of North America (IESNA)
- International Association of Lighting Designers (IALD)
- National Council on Qualifications for the Lighting Professions (NCQLP)
- National Electrical Manufacturers Association (NEMA)

These organizations can help to identify the specific issues for your lighting needs, and understand the interrelationship of product and design criteria. In addition, the International Dark-Sky Association can provide information regarding outdoor lighting near or around observatories, or areas concerned with sky glow.

For further information regarding this white paper, please contact the National Electrical Manufacturers Association (NEMA) at 703-841-3200 or via our website at www.nema.org.

OUTDOOR LIGHTING ISSUES:

	What Is It?	What Causes It?	How Is Do I Minimize It?	Typical Code Issues
Sky Glow **- or-** ***"Light Pollution"***	Sky glow is the haze or "glow" of light that surrounds highly populated areas and reduces the ability to view the night time sky. Sky glow is of particular concern in areas near observatories. Light emitted or reflected into the sky interferes with the ability of the observatory and the public to view the sky in an unobstructed manner.	The sky glow phenomenon is a result of light reflected from atmospheric particles such as fog, dust, or smog. It results from light entering the sky from outdoor lighting in these two ways: • Light emitted from a luminaire in a direction above the plane of the horizon. • Light emitted from a luminaire in a direction below the plane of the horizon but reflected from the surrounding surface, including the ground, towards the sky. The effect this has depends on the amount of light aimed to the reflective surface, the reflectivity of that surface and the angle of the light leaving the surface.	To minimize sky glow effects, appropriate lighting equipment and layout design should be utilized: • Turn off non-critical lighting late at night; but roadway luminaires should remain lit at night. • Limit the use of non-cutoff luminaires. • Select luminaires emitting little to no light above the plane of the horizon. • Utilize internal or external shielding that minimizes the component of light above horizontal when luminaires need to be tilted or aimed. • Design to appropriate light levels and space poles such that illuminance on the ground is uniform. Excessive illuminance will increase the reflected component of light into the sky and affect visual adaptation especially when driving from one area to another.	Outdoor codes often mandate full cutoff luminaires. Such devices restrict design flexibility and can cause greater sky glow. Requirements for IESNA cutoff luminaires, when properly applied, can reduce uplight, but a better requirement to limit sky glow may be to limit uplight. Restrictions on pole heights often create more application problems, such as reduced uniformity or increased sky glow due to light reflected off ground surfaces. Curfews for lighting can create enforcement and regulatory burdens. When properly implemented for sensitive areas or specific applications such as sportslighting, curfews can reduce nuisance lighting and reduce energy consumption. Regulating lamps lumen per watt (high and low pressure sodium issues) can cause color identification issues and hinder lighting quality and visual acuity.
Light Trespass	Light trespass occurs when neighbors of an illuminated space are affected by the lighting system's inability to contain its light within the intended area. The most common form of light trespass is spill light, illuminating objects beyond the property boundaries. Light trespass has become an increasing concern as residences and commercial developments are constructed closer to each other. Light trespass may be more obvious during late night hours.	Light trespass occurs when a luminaire emits too much light at high angles or projects light too far from where it is intended. A common cause of light trespass is the inappropriate selection, tilting or aiming of outdoor luminaires for the particular lighting task. Even luminaires that are designed to control their light output can be light trespass offenders when improperly applied within a lighting design. It is important to remember that all types of outdoor luminaires will emit some amount of light to an unwanted area.	Light trespass can be minimized through the: • Careful selection of lamp wattage, luminaire type, and placement. • Appropriate reflector selection; aiming and shielding of the luminaires is critical to keep the projection of the light within property boundaries. When using floodlights or wallpacks in areas close to adjacent properties, select products that utilize advanced optical techniques to minimize light trespass. Noncutoff luminaires will not have a significant impact on light trespass if the light does not project far from the luminaire location.	Codes will often require the following that don't fully solve the problem or introduce unintended results: • Optical cutoff luminaires; flat lenses are a requirement in some codes; • Product mandates that eliminate lighting choices thus limiting application flexibility • Maximum allowed lumens or "lumen caps" • Pole height limits • Civil and/or criminal penalties; clogs system • Trespass limits that are not technologically feasible

	What Is It?	What Causes It?	How Do I Minimize It?	Typical Code Issues
Glare	Glare occurs when a bright source causes the eye to be continually drawn toward the bright image or source thus preventing and adequately viewed target; may create a loss of contrast or an afterimage on the retina of the eye reducing overall visibility. Two classifications of glare: • ***Discomfort glare***: does not necessarily keep the viewer from seeing an object but does cause a constant adaptation of the eye to the contrast of light levels that in turn may cause a sensation of discomfort. • ***Disability glare:*** occurs when the bright source causes stray light to scatter in the eye which causes the primary image on the retina to be obscured. It may prevent the viewer from seeing things of importance.	There are two distinct situations when glare occurs: 1. When a spot in the field of view is significantly brighter in contrast to the rest of the field of view. An example is when a bright direct or reflected lamp image is visible. 2. When a significant difference in light levels exists between adjacent areas. An example is when a person leaves a brightly lit gas station and re-enters the roadway; it may take minutes for the eyes to adapt to the lower lighting levels.	Full cutoff and cutoff luminaires can help prevent the direct image of a bright source and lower the intensity of the light at high angles. Luminaires may be equipped with louvers and/or exterior visors to prevent viewing a bright source at lower angles. Use of quality prismatic or opaque lens materials can spread the bright image over a larger area and reduce the brightness of the source. Maximum mounting heights are required for proper aiming of floodlight luminaires to reduce glare in an adjacent, unintended, field of view. It is important to conform to ambient light levels based on the environment of proposed installation. Even lighting designs intended to comply with local codes or master store specifications may need to be adjusted to accommodate the specific surrounding environment.	Codes will often require the following that don't fully solve the problem or introduce unintended results: • Full cutoff luminaires; flat lenses are a requirement in some codes; • Product mandates that eliminate lighting choices thus limiting application • Maximum allowed lumens or "lumen caps" • Pole height limits • Civil and/or criminal penalties; clogs system • Glare limits that are not technologically feasible Codes designed to limit glare can specify various levels of optical cutoff for specific zones or specific limits on high angle brightness.
Energy Use	Outdoor lighting products use electrical energy to light a given area. Are there efficiencies that can be captured to gain greater energy cost savings?	Higher energy costs are associated with the excessive use of nonessential devices; these devices provide too much light or operate at the wrong hours, among other issues.	Energy costs can be reduced by ensuring that the proper design has been chosen for the given application, and that the lighting devices are operating at the right times. Moreover, the favorable use of lighting controls and reasonable, flexible curfews can be structured to achieve greater energy cost savings.	Code language that implements design mandates can use more energy. The arbitrary and inflexible use of a full cutoff luminaire in every lighting application combined with a lumen mandate may lead to more fixtures and greater energy and maintenance costs. Every use is unique: code language must allow for comprehensive quality lighting designs that factor lighting power densities, lamp types and control devices according to design/application criteria.
Manage Safety and Security	Outdoor lighting is often installed to discourage crime and vandalism and to promote a perception of safety. Public facilities utilize lighting to manage their liability responsibilities.	Inappropriate lighting (too much or too little) creates an imbalance. Specifically, too little light can cause poor uniformity and shadows leading to potential criminal activity. Too much light can result in glare reducing the ability to identify potential hazards or criminal activities.	Lighting professionals have established criteria for these and other issues in the IESNA G-1-03 document. This document specifies higher illuminance for safety concerns. Moreover, the IESNA guidelines provide for adequate vertical lighting and uniformity ratios.	Codes affect liability, safety and security and pedestrian safety; codes must allow for comprehensive quality lighting designs that account for design/application criteria to protect community movement, property, and safety and security concerns (e.g. anti-terror efforts to 24 hour public safety). IESNA safety and security guidelines or others established for crime prevention must be considered.

	What Is It?	What Causes It?	How Do I Minimize It?	Typical Code Issues
Natural Habitat	Natural habitat such as sea turtles and birds utilize the moon and stars to guide them. Interference with the natural environment may cause detrimental impacts on hatching and migration patterns.	Excessive electrical light, especially light that contributes to glare, light trespass and sky glow can improperly direct young sea turtles away from the water. Excessive light can also misdirect bird migration due to negative impact on the bird's ability to see the stars.	In areas where natural habitat concerns exist, the lighting design should utilize lighting products that minimize glare, light trespass and sky glow. The spectral content of certain types of lamps may also minimize the impact on wildlife.	Outdoor codes often mandate full cutoff luminaires. Such devices restrict design flexibility and can cause greater sky glow. Codes should include requirements to protect natural habitat by defining those areas where there is a need to minimize the impact. Careful evaluation of the local conditions and identifying specific, enforceable criterion is necessary for a successful code. In many cases, using certain types of light sources such as high pressure sodium, restricting high angle brightness or enforcing curfews can result in the most effective results.
Lighting Quality	Lighting quality can mean various things to different stakeholders. Typically, this term is used to describe lighting that provides the right amount of light, to the right place at the right time. Lighting quality may also consider the materials used to manufacture a product or characteristics that relate to the maintenance of the system.	Superior lighting installations are achieved by careful evaluation of the requirements of the site (visibility, environmental issues, security, maintenance, etc.). Designs will often require a tradeoff among various these requirements. Quality lighting products generally include premium materials and precisely designed optical systems (reflectors, refractors, lenses).	Quality lighting applications can be compromised even when superior products are used. The lighting products and proper design techniques integrate together to achieve preferred results.	Codes often state objectives to maximize quality lighting. The tradeoffs required to address multiple lighting objectives generally cannot maximize a single criterion. To achieve quality lighting, specific requirements should to be defined and measurements for compliance should be identified. Vague statements about quality typically reduce the effectiveness of a code.
Visibility	Visibility for outdoor applications is depends on a several factors including the: amount of light; uniformity of light; spectral qualities of the light source; age of people conducting activities in that area; contrast of surfaces within the area; and importance and speed required to perform tasks within the area.	Visibility in a nighttime environment uses different photoreceptors in the human eye than for daytime visibility; they respond to light with more blue spectral content, but are less effective providing good visibility in the direct field of focus. Some research suggests that nighttime electrical lighting will make photoreceptors operable. Good visibility is generally created lighting designs provide uniform lighting, minimizes excessive high angle brightness (glare) and uses light sources with blue content in their spectral distribution.	Higher pole heights or lower wattage sources on lower poles can often reduce the brightness within the field of view. Visibility can be compromised when the lighting is not uniform or if there is excessive glare and improve visibility. Visibility can also be compromised when there is insufficient light in the blue-green portion of the spectrum, which also reduces the ability of a person to identify colors. The site layout can also affect visibility, especially when landscape or other structures interfere with the proper distribution of light from the electrical lighting system.	Codes often set objectives to maximize visibility. However, many codes include requirements or mandates that can have a negative impact on visibility such as: pole height limitations and lamp type or wattage mandates, among others. Addressing visibility in a code is typically best addressed with requirements for specific performance criteria such as illuminance levels, uniformity or glare.

DEFINITIONS:

Many existing codes utilize improper or inconsistent use of lighting terminology. The following definitions accurately describe lighting terminology often used in outdoor lighting codes. Where appropriate, a paraphrased definition is provided in plain English to supplement the technical definition.

Term	Paraphrased Definition	Technical Definition Based on IESNA
Candela (cd)	Unit describing the intensity of a light source in a specified direction. Sometimes incorrectly referred to as a "light ray".	The SI unit of luminous intensity, equal to one lumen per steradian (lm/sr).
Cutoff Full Cutoff	A light distribution where no light is permitted at or above a horizontal plane located at the bottom of a luminaire. There will be little to no light at the angles that are usually associated with glare. *See Figure 1.*	A luminaire light distribution where zero candela intensity occurs at an angle of 90 degrees above nadir, and at all greater angles from nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10 percent) at a vertical angle of 80 degrees above nadir.
Cutoff	A light distribution where a negligible amount of light is permitted at a horizontal plane located at the bottom of a luminaire. Light above the horizontal plane at the bottom of the luminaire is not limited, but cutoff luminaires usually have very little light above the luminaire. *See Figure 2.*	A luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 25 (2.5 percent) at an angle of 90 degrees above nadir, and 100 (10 percent) at a vertical angle of 80 degrees above nadir.
Cutoff Semicutoff	A light distribution where slightly more light is permitted at a horizontal plane located at the bottom of a luminaire than the cutoff distribution. Like cutoff, light above the horizontal plane at the bottom of the luminaire is not limited, but the . amount of light above the luminaire is relatively small. *See Figure 3.*	A luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 50 (5 percent) at an angle of 90 degrees above nadir, and 200 (20 percent) at a vertical angle of 80 degrees above nadir.
Cutoff Noncutoff	A light distribution that can produce considerable light above the horizontal plane located at the bottom of a luminaire. *See Figure 4.*	A luminaire light distribution where there is no candela limitation in the zone above maximum candela.
Disability glare	Glare that is significant enough to keep a person from seeing adequately.	The effect of stray light in the eye whereby visibility and visual performance are reduced. A direct glare source that produces discomfort may also produce disability glare by introducing a measurable amount of stray light in the eye.
Discomfort glare	Glare that is bothersome to an individual.	Glare that produces discomfort. It does not necessarily interfere with visual performance or visibility.
Efficacy *(Luminous Efficacy)*	A measurement used to compare light output to power consumed. Efficacy is a ratio of lumens to watts and can be defined for bare lamps or for luminaires.	The quotient of total luminous flux emitted by the total power input.
Efficiency	A ratio of the light emitted from a luminaire to the light produced by the bare lamps.	The ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the lamp or lamps used therein.
Glare *(see also disability glare or discomfort glare)*	Light that hinders or bothers the human eye.	The sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort, or loss in visual performance and visibility. Note: the magnitude of the sensation of glare depends upon such factors as the size, position, luminance of the source, number of sources and the luminance to which the eyes are adapted.
High Intensity Discharge (HID)	A family of electric-discharge light sources including Metal Halide, High Pressure Sodium, and Mercury Vapor lamps.	An electric-discharge lamp in which the light-producing arc is stabilized by wall temperature, and the arc tube has a bulb wall loading in excess of 3 W/cm^2. HID lamps include groups of lamps known as mercury, metal halide and high-pressure sodium.
High Pressure Sodium (HPS)	A HID light source that typically provides high efficacy, but poor color. Color rendering is better with HPS than LPS, but the source is still considered to be yellow by most people.	A high-intensity discharge (HID) lamp in which light is produced by radiation from sodium vapor operating at a partial pressure of about 1.33×10^4 Pa (100 Torr).
Illuminance (footcandle or lux)	A term that quantifies light striking a surface or plane at a point. It is expressed either in lumens per square foot (footcandles/the English unit) or lumens per square meter (lux/the metric unit). 1 footcandle = 10.76 lux	The areal density of the luminous flux incident at a point on a surface.
Lamp	A light bulb.	A generic term for a source created to produce optical radiation. By extension, the term is also used to denote sources that radiate in regions of the spectrum adjacent to the visible.
Low Pressure Sodium (LPS)	Considered a single-color light source (appears to be yellow in color and causes most other colors to be seen as gray or brown).	A discharge lamp in which light is produced by radiation from sodium vapor operating at a partial pressure of 0.1-1.5 Pa (approximately $10^{-3} – 10^{-2}$ Torr)
Luminaire *(Light Fixture)*	A complete lighting unit, often referred to as a "light fixture". A luminaire consists of the light source, optical reflector and housing, and electrical components for safely starting and operating the source.	A complete lighting unit consisting of a lamp or lamps and ballasting (when applicable) together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.

Lumen	The unit representing the quantity of light being produced by a lamp or emitted from a luminaire.	The luminous flux emitted within a unit solid angle (1 sr) by a point source having a uniform luminous intensity of 1 cd.
Luminance	A term that quantifies directional brightness of a light source or of a surface that is illuminated and reflects light. It is expressed as footlamberts (English units) or candelas/meters squared (Metric units). (*Note: footlambert is no longer a recognized unit by the IESNA.*)	The quotient of the luminous flux at an element of the surface surrounding the point, and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of the surface on a plan perpendicular to the given direction.
Mercury *(Mercury Vapor)*	A HID light source that typically provides long lamp life, but poor color and low efficacy compared to other HID sources.	A high-intensity discharge (HID) lamp in which the major portion of the light is produced by a radiation from mercury operating at a partial pressure in excess of 10^5 Pa (approximately 1 atm).
Metal Halide	A HID light source that typically provides good color and high efficacy.	A high-intensity discharge (HID) lamp in which the major portion of light is produced by radiation of metal halides and their products of dissociation – possibly in combination with metallic vapors such as mercury.
Nadir	The point directly below the luminaire when the luminaire is pointed down (0-degree angle).	None.
Photo Control	The device that turns the luminaire on at dusk and off at dawn. Also called photo eye, photocell, and or control. Photo controls may contain a timer to turn luminaires off part way through the night.	None
Shielded, Partially Shielded or Fully Shielded	Sometimes used in reference to a luminaire that is provided with internal or external louvers, shields or visors to limit glare. Also used to refer to luminaires that are designed to control glare without the use of additional shields. "Shielded" and "Fully Shielded" are sometimes used in place of either "Cutoff" or "Full Cutoff". "Partially Shielded" is sometimes used in place of "Semicutoff". The cutoff classifications are the industry-accepted terminology.	None

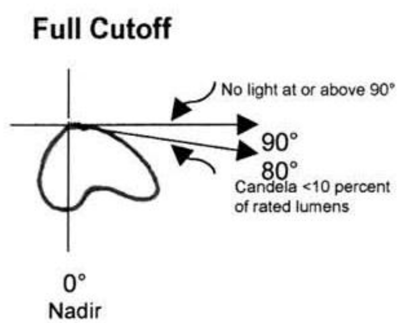


FIGURE 1

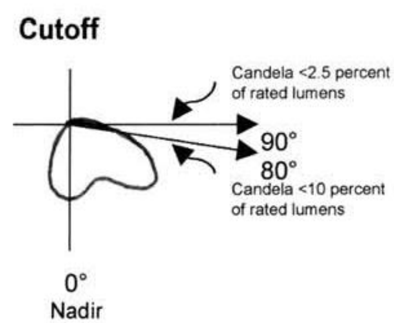


FIGURE 2

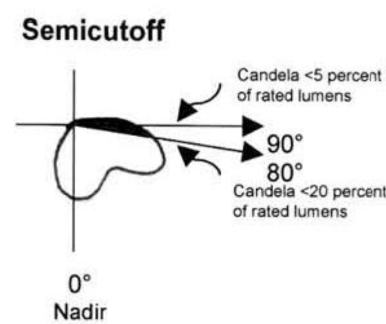


FIGURE 3

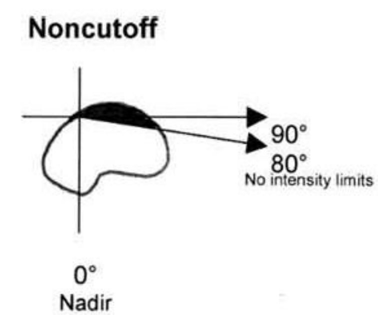


FIGURE 4

References:

Rea, Mark S (editor), *IESNA Handbook*, Ninth Edition, New York: Illuminating Engineering Society of North America (IESNA), 1999.

IESNA Outdoor Environment Lighting Committee, "Lighting for Exterior Environments", RP-33-99, New York: IESNA, 1999.

IESNA G-1-03, "Guideline for Security Lighting for People, Property, and Public Spaces"