
**Level II Feasibility Report
Energy Evaluation
And
Recommendations**



Waste Management and Research Center

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Executive Summary

Engaging in energy efficiency strategies is a proven method of controlling costs. 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 indicator of overall management quality and corporate performance. Most commercial and institutional buildings use 10 to 30 percent more energy than necessary and have abundant opportunities to save. Cutting a building's energy use by 30 percent yields the same bottom-line benefits as a 5 percent increase in net operating income.

In order to enhance the economy the Illinois Department of Commerce and Economic Opportunity has implemented the Small Business Smart Energy Program for the Commercial Building Sector. The program is funded by the Illinois Department of Commerce and Economic Opportunity. As part of this program, the Smart Energy Design Assistance Center (SEDAC) conducted an energy analysis of the existing State of Illinois Waste Management and Research Center (WMRC) located in Champaign, Illinois. The analysis provides energy savings and life cycle cost estimates for various energy cost reduction measures (ECRMs) with high potential for implementation. This report presents recommendations for energy cost reduction measures resulting from the analysis, along with the methods and assumptions used.

SEDAC has identified over \$57,000 in annual energy cost savings. These savings amount to a 25 percent reduction in WMRC annual energy costs. Implementing the recommended measures will enhance the organization's bottom line, improve building performance, increase the public value of the building, and reduce vulnerability to fuel price fluctuations.

This report considered five ECRMs for application to the building. A package of ECRMs was also considered, which implemented the indicated ECRMs *together*, accounting for any interaction between them. The ECRMs evaluated and their calculated returns on investment are presented in Table E1 below:

Energy Cost Reduction Measure (ECRM) or Package of ECRMs	ID	Internal Rate of Return (IRR)	Net Present Value (NPV)
ECRM1 – Ventilation Heat Recovery	ECRM1	59%	\$186,105
ECRM2 – Super T-8 Lighting Upgrade	ECRM2	8%	(\$3,389)
ECRM3 – Occupancy Sensors	ECRM3	35%	\$5,450
ECRM4 – High Efficiency Hot Water Boilers	ECRM4	9%	(\$9,604)
ECRM5 – System Recommissioning	ECRM5	227%	\$65,526
PKG1 – All ECRMs	PKG1	17%	\$82,706

Table E1 Calculated Life Cycle Costing for ECRMs

Notes to Table E1:

- (1) An entry of “Infinite” under the IRR column is used in a situation where the first cost of the ECRM is lower than the first cost of the Base Building design. If several IRR calculations yield an “Infinite” value, one must consider other financial indicators (e.g. NPV or Monthly Cash Flow) when ranking these alternatives.
- (2) An entry of “n/a” under the IRR column is used in a situation where there is no return on investment, i.e. the annual energy costs associated with the ECRM are higher than the annual energy costs associated with the Base Building design, **or** the initial cost is so high compared to the annual savings that the calculated IRR is less than 1%.
- (3) Discount Rate assumed to be 10% when calculating the NPV, ECRMs with IRR less than 10% will show a negative NPV.
- (4) Results are in today’s dollars on a pre-tax basis.
- (5) When ECRMs are implemented as a package, results vary from application of individual ECRMs.

Table E1 presents the results of the Life Cycle Cost analysis performed on the ECRM recommendations. Projects are typically considered attractive if the Internal Rate of Return (IRR) is greater than the discount rate (here 10%) and the Net Present Value (NPV) is greater than zero.

Table E2 below displays the costs and savings associated with each separate ECRM. Explanations of each ECRM are presented later in the report. The selected ECRMs were modeled because they were the most applicable to the building.

Energy Cost Reduction Measure (ECRM) or Package of ECRMs	ID	Additional First Cost	Annual Savings	Monthly Savings
ECRM1 – Ventilation Heat Recovery	ECRM1	\$66,000	\$28,796	\$2,400
ECRM2 – Super T-8 Lighting Upgrade	ECRM2	\$34,900	\$5,017	\$418
ECRM3 – Occupancy Sensors	ECRM3	\$4,410	\$1,577	\$131
ECRM4 – High Efficiency Hot Water Boilers	ECRM4	\$166,400	\$17,153	\$1,420
ECRM5 – System Recommissioning	ECRM5	\$5,000	\$11,326	\$944
PKG1 – All ECRMs	PKG1	\$276,710	\$57,386	\$4,782

Table E2: Summary of Project ECRMs, First Costs, Savings, and Monthly Cash Flow

Notes to Table E2:

- (1) Each ECRM financed at 10% over 10 years, the assumed terms of the small business loan that would be taken to finance the additional first cost of implementing the ECRM.
- (2) The “ID” number is used to refer to the ECRM throughout this report.
- (3) When ECRMs are implemented as a package, results may vary from individual package results.

We strongly recommend implementation of the PKG1 which consists of ventilation heat recovery, Super T-8 lighting retrofit, lighting system occupancy sensors, high efficiency hot water boilers, and system recommissioning.

1 Introduction

The Waste Management and Research Center (WMRC) is a division of the Illinois Department of Natural Resources. The Center assists Illinois industries, businesses, and citizens to reduce and manage waste. The Center activities include providing laboratory services, information services, research funding, and technical assistance. The Smart Energy Design Assistance Center (SEDAC) has performed an energy-savings and utilities cost analysis for various energy cost reduction measures (ECRMs) applied to the WMRC facility. This report presents the results of the analysis along with the methods and assumptions used.

2 Building Description

2.1 General

The analysis in this report is based in part on results from a computer simulation of the building using the Trane TRACE computer program. The sections which follow describe the building details and important input parameters of the computer model.

2.2 Site Conditions and General Building Details

The existing WMRC building consists of three sections. The two story east wing of the building houses the administrative offices and Center library. The mid section of the building has two stories and includes a conference room and laboratory spaces on the first floor, and a second floor level which houses the majority of the building HVAC equipment. The west wing of the building is a single story with about 20 foot ceiling and houses additional laboratory spaces. The building is steel frame and concrete block wall construction with brick façade. The WMRC building is approximately 20 years old. The total floor area of the building is approximately 48,500 sf.

2.3 Building Envelope

The building entrance faces north. The building walls consist of brick, air space, 2-inches of rigid insulation, and 8-inch concrete block. The building has a low-slope, built-up roof with approximately 6 inches of insulation on a steel deck.

The building has glazing on all elevations, with the majority on the north and east elevations. All of the glazing is double pane. Some sections of the north elevation are 1-inch insulated glass in aluminum frames. Total glazing area is approximately 3,400 sf.

2.4 HVAC System and Controls

The building has two separate HVAC systems. There is a variable air volume (VAV) system with baseboard heat used in the office areas and library. There is a constant

volume, 100 percent outside air system with reheat which serves the laboratory spaces. Based on our discussions with WMRC staff we believe that the design intent is for the VAV system to be at positive pressure relative to the constant volume laboratory system to ensure that contaminants cannot migrate into the office HVAC system. The air handlers, reheat coils, and baseboard heaters are served by two 190 ton capacity centrifugal chillers, and four hot water generators (heat exchangers). The hot water generators are served by two 5.2 Million Btu/hr 15 psig gas-fired steam boilers. Plans for the building indicate a central control system but for this report we did not gather detailed information on the control scheme.

2.5 Lighting, Internal Loads, and Occupancy Schedules

The installed lighting in the interior of the building consists of a mix of T12 linear fluorescent lamps, high bay HID lamps, and compact fluorescent lamps. We conducted a preliminary lighting survey and plan review as part of this analysis. Building plans provided by WMRC included a fixture layout, but not a lighting fixture schedule. Therefore information on specific lighting fixture details was based on site inspection. Based on the fixture layout, site inspection, and building vintage, we estimate that the installed wattage averages about 1.5 W/sf.

Domestic hot water and laboratory process hot water is provided by one of the hot water generators. We could not accurately estimate hot water usage because of the possibility of reheat in the summer months. That is, the gas consumption minimum which occurs in the summer is likely a combination of domestic hot water usage and reheat.

There are significant intermittent internal loads from laboratory equipment and experimental apparatus. We estimated the internal loads to average about 1 W/sf on a schedule which follows building occupancy.

Building hours of operation are from 7:00 a.m. to 5:00 p.m. daily, 5 days per week, with occasional usage of the building on Saturdays and Sundays to support the research mission.

3 Energy Consumption Analysis

3.1 Benchmarking

Based on the last twelve months of the bills provided by WMRC, the total energy usage (gas and electric) is about 320 kBtu per square foot per year. We obtained total energy benchmark data for six laboratories in the Midwest climate region from <http://www.labs21century.gov/toolkit/benchmarking.htm>. Total energy usage for these six laboratories ranged from 576 to 247 kBtu/sf/yr with an average of 372 kBtu/sf/yr. This suggests that WMRC energy usage is about average for facilities of this type. Total annual energy costs are about \$218,200 per year, which is about \$4.50 per square foot

per year. At the present time the energy costs are about evenly divided between electricity and natural gas.

3.2 Actual and Model Energy Consumption Profiles

Figure 3.1 and 3.2 below illustrate the energy consumption profiles predicted by the TRACE model compared to actual monthly kWh and therm consumption taken from site utility bills.

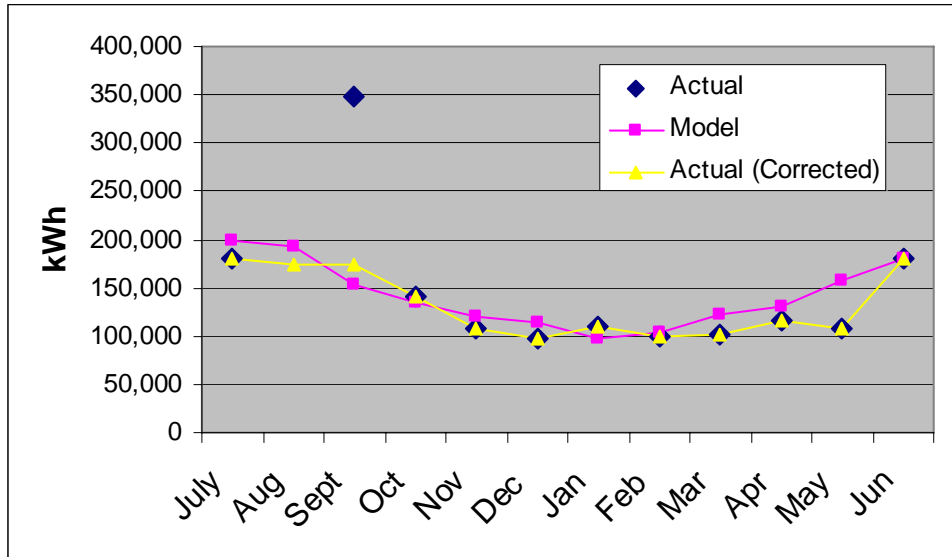


Figure 3.1 Comparison of Actual and Model Electricity Consumption

The results in Figure 3.1 indicate a good match between the model and the corrected actual electric consumption. The uncorrected data was missing a value for August, and the September value was an outlier. We surmised that the September bill actually included both August and September usage, so we merely divided by two to correct the data set. Actual kWh consumption based on the bills available was 1,586,700 kWh. This compares with the model kWh consumption of 1,702,151 kWh a difference of about 7 percent.

The match between the model and actual natural gas consumption is shown in the figure below.

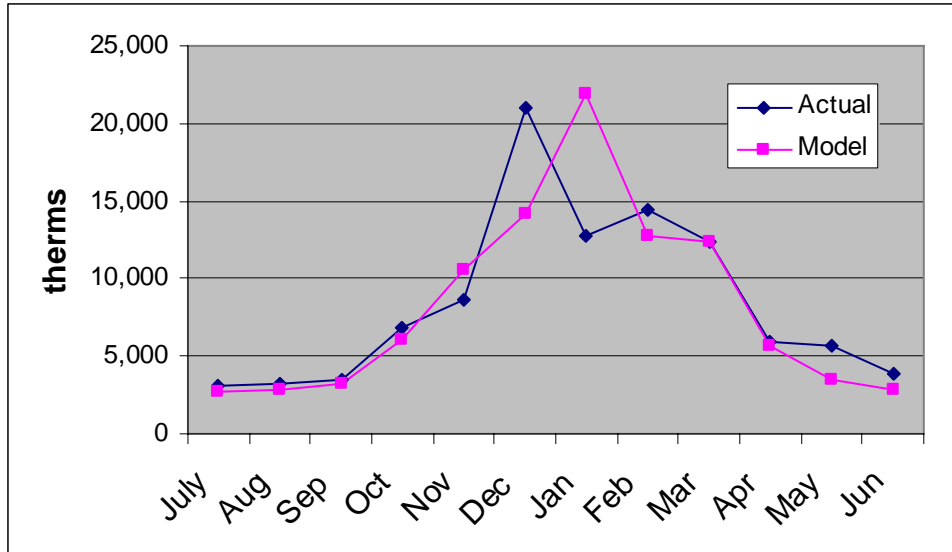


Figure 3.2 Comparison of Model and Actual Therms

The model prediction and actual therm consumption match fairly well. The model's annual therm consumption is 98,508 and the actual is 101,370; a difference of about 3 percent. The differences between the model gas and electric consumption and the actual gas and electric consumption are both less than ten percent, which is adequate for the purposes of this analysis.

4 Analysis Approach

4.1 General

The basic analysis approach involves three steps.

First, the baseline energy model is constructed in TRACE 700, a software product developed by the Trane Company. TRACE 700 is a computer program that performs an hourly building energy simulation, which calculates the amount of energy (and the resulting utility cost of that energy) that the building is expected to use over an entire typical weather year. Model inputs include building geometry and orientation, wall & roof details, window area and type, type of heating/cooling system, type of lighting, local weather information, and schedules regarding lighting usage, internal equipment usage, and occupancy. This "baseline" computer model shows the building's estimated annual energy consumption and utility cost. This simulation provides expected energy consumption, but is no guarantee; similar to the EPA-rated MPG on new autos, a building's actual energy consumption has a strong dependence on the exact way it is constructed, operated, and maintained over its life. In cases where utility billing records are available we use this information to fine tune the TRACE model for improved accuracy.

Second, the SEDAC team performs computer analysis of energy cost reduction measures (ECRMs). These alternatives are generated by SEDAC personnel after

reviewing and discussing the baseline building plans or inspection report. SEDAC personnel look at the baseline building and determine which ECRMs should be investigated. The baseline computer model is changed to reflect the implementation of these ECRMs, and the computer model generates the resultant energy consumption and expected utility costs. Some ECRMs such as the recommissioning were evaluated external to the model since the model does not cover all instances.

Finally, the estimated savings and the additional costs of implementing all analyzed ECRMs are evaluated in a life cycle cost analysis.

4.2 Utility Rates

WMRC provided us with a historical record of natural gas and electricity monthly consumption and costs. Based on that information we determined that for the last 12 months the electricity cost averaged about \$0.0720 per kWh and the natural gas cost averaged about \$1.05 per therm. Both costs have increased significantly during the period for which the data were collected. Initial electricity costs were on the order of \$0.02 per kWh and natural gas costs were on the order of \$0.25 per therm.

5 Capital Improvement Energy Cost Reduction Measures

5.1 ECRM1 – Ventilation Heat Recovery

The WMRC uses a 100 percent outside air constant volume system with reheat to supply space conditioning and ventilation for its laboratory spaces. This system is very well suited for ventilation heat recovery. The USEPA *Laboratories for the 21st Century: Best Practices – Energy Recovery for Ventilation Air in Laboratories* (attached) indicates heating energy savings in the range of 40 percent for heat pipe or run-around-loop heat recovery technology.

This ECRM considers application of heat pipe or runaround loop heat recovery equipment for the constant volume system. These technologies are selected to avoid any possibility of cross contamination of air streams. Using TRACE we estimated that installation of a heat pipe heat recovery system would result in natural gas energy savings of 29,734 therms; about 30 percent of annual consumption. There is a slight increase in electrical energy consumption due to increased pressure drop in the air handling system.

Energy cost savings for this ECRM were estimated to be \$28,796 annually. Using a twenty year life cycle, the IRR is 59% and the net present value is \$186,105. This ECRM has favorable economics and should be considered for implementation.

5.2 ECRM2 - High Efficiency Lighting Retrofits

The WMRC utilizes T-12 lighting technology throughout the building. There also are high bay HID fixtures and CFL lamps in recessed fixtures. Based on review of plans provided by WMRC and a site inspection, we estimated an overall lighting power density of 1.5 W/sf. Presently, Super T-8 systems using electronic ballasts are routinely designed to result in lighting power densities of 1 W/sf or less.

This ECRM consists of upgrading all existing T-12 fixtures with magnetic ballasts to Super T-8 fixtures with electronic ballasts. We assumed a conversion of 4-lamp T-12 fixture with two ballasts to three lamp Super T-8 fixtures with one ballast. We assumed existing two lamp fixtures are relamped with Super T-8 lamps and their ballasts replaced with electronic ballasts.

We estimated the cost for the retrofit based on 259 3-lamp fixtures at a cost of \$100/fixture and re-lamping and re-ballasting 180 2-lamp fixtures at a cost of \$50 per fixture. This results in a total estimated cost of \$34,900 for the retrofit.

Annual energy cost savings for this ECRM were estimated to be \$5,017. Using a ten year life cycle, the IRR is 8% and the net present value is negative \$3,389. This ECRM has marginal economics. It may be worthwhile for WMRC to solicit price quotes for the retrofit. If the prices are less than \$34,900, the ECRM may become attractive.

5.3 ECRM3 – Lighting Occupancy Sensors

This ECRM consists of application of occupancy sensors to switch off a portion of the lighting system when the space is unoccupied. In the case of laboratory spaces, we assumed that one 4-lamp fixture in each lab would remain under manual on/off control for emergency/safety purposes.

To estimate costs for the ECRM we assumed an average of 7 fixtures per occupancy sensor, which would require about 63 sensors for the entire building. We assumed an installed cost per sensor of \$72, for a total cost of \$4,410.

Annual energy cost savings for this ECRM were estimated to be \$1,577. Using a ten year life cycle, the IRR is 35% and the net present value is \$5,450. This ECRM has favorable economics and should be considered for implementation.

5.4 ECRM4 – High Efficiency Hot Water Boilers

This ECRM examines the energy savings due to replacing the existing gas-fired steam boilers with modular, high efficiency (90+ percent) hot water boilers. The existing boilers and heat exchanger system while well maintained probably is operating at a seasonal efficiency of about 75 percent. This is due to limitations in the boilers ability to operate efficiently at part loads, and losses in the heat transfer process.

Transitioning to a high efficiency modular boiler system will result in much improved baseline and seasonal efficiencies. The modular system will allow much better performance in meeting part loads such as occur in the shoulder seasons.

We estimate annual savings from this ECRM to be about \$17,153. Costs for the boiler retrofit were estimated to be \$166,400. Based on a twenty year life cycle we estimated the IRR to be 9%. The net present value is negative \$9,604. This ECRM has marginal economics. It may not be attractive to replace the steam boilers at this time, but at the end of their service life the conversion to a modular hot water boiler system should be considered.

5.5 ECRM5 – System Recommissioning

Building recommissioning is a comprehensive review of the building systems operation which includes adjustments to control systems, assessment of equipment operating strategies, and overall maintenance status. There are several aspects of the WMRC HVAC systems which either by intent, or inadvertently, can result in simultaneous heating and cooling. This offers significant opportunity for recommissioning energy savings.

We would recommend a careful examination of air flow balancing in the constant volume supply to the building laboratories to reduce the use of terminal reheat. We would also recommend a review of control system or time clock set-points for ventilation air to determine if ventilation rates can be reduced during certain periods.

We estimate that a focused recommissioning effort for the WMRC building would cost approximately \$0.10 per sf, for an overall cost of about \$5,000.

The EPA ENERGY STAR Building Upgrade Manual – Recommissioning Section indicates that building recommissioning can produce overall energy savings which range from 5 to 15 percent. We used a value of 5 percent to estimate savings of \$11,326 for this ECRM. This results in an IRR of 227% and a net present value of \$65,526. This ECRM has very favorable economics and should be strongly considered for implementation.

5.6 PKG1 – ECRMs 1, 2, 3, 4 and 5

This package combines the heat recovery, T-8 lighting, occupancy sensors, high efficiency hot water boilers, and system recommissioning ECRMs. The package combines high return projects with lower return projects for maximum energy savings, and overall acceptable rates of return. Total cost for the package is the sum of the costs of the individual ECRMs; equal to \$276,710.

Annual savings were estimated to be \$57,386. The IRR based on a ten year life cycle is 17%, and the net present value is \$82,706. This package has favorable economics and should be considered for implementation.

5.7 Summary of Energy Modeling Results and Analysis

The following table presents the results of the computer modeling and energy savings analysis.

Energy Cost Reduction Measure (ECRM) or Package of ECRMs	Electricity					Natural Gas		Total Annual Energy Cost
	Annual kWh	kWh Cost	Annual Peak kW	kW Cost	Total Electricity Cost	Annual Therms	Therm Cost	
Base Building	1,702,151	\$122,721	411	n/a	\$122,721	98,508	\$103,794	\$226,515
ECRM1 – Ventilation Heat Recovery	1,735,756	\$125,146	401	n/a	\$125,146	68,774	\$72,573	\$197,719
ECRM2 – High Efficiency Lighting Retrofits	1,611,775	\$116,206	374	n/a	\$116,206	99,936	\$105,292	\$221,498
ECRM3 – Laboratory Lighting Occupancy Sensors.	1,676,889	\$120,900	401	n/a	\$120,900	98,741	\$104,038	\$224,938
ECRM4 – High Efficiency Hot Water Boilers	1,702,151	\$122,721	411	n/a	\$122,721	82,172	\$86,640	\$209,362
ECRM6 – System Recommissioning	1,617,043	\$116,585	390	n/a	\$116,585	93,583	\$98,604	\$215,189
PKG1 – All ECRMs	1,550,416	\$111,784	340	n/a	\$111,784	54,288	\$57,345	\$169,129

Table 5.1 Summary of Energy Modeling Results

Note that overall \$/kWh and \$/therm costs will vary among the ECRMs even when the same electric and gas rates are applied. ECRMs with lower kWh and therm consumption may appear to have greater \$/kWh and \$/therm costs due to the greater impact of demand charges (where applicable) and customer charges, i.e., these charges are spread over fewer kWh and therms.

5.8 Other Efficiency Measures

PC Energy Management

ENERGY STAR estimates annual savings of up to \$45 per computer by using power management. Energy saving settings control the display monitor and computer box (cpu, hard drive, etc) separately. Monitor power management places inactive display monitors in a low-power sleep mode. It does not affect the computer processor, and can be implemented without affecting the system. Screen savers are not energy saving and may actually increase energy consumption during sleep mode. Computer box power management places inactive systems into low-power sleep mode, such as hibernate or stand-by. Sleeping computers may interfere with older applications and certain peripherals in network settings. ENERGY STAR has excellent resources for power management and compatibility with older applications:

http://www.energystar.gov/index.cfm?c=power_mgt.pr_power_management

LED Exit Signs

LED exit signs use about one eighth of the energy of standard incandescent fixtures and should be employed throughout the facility. Since exit signs are lit 24 hours a day, efficient equipment choices yield significant returns. A useful website pertaining to LED exit signs is: (<http://www.theexitstore.com/Chicago-Approved-Edge-Lit-LED.htm>)

Temperature Set-Back

Use of temperature set-back and set-up should be considered for spaces where constant temperature control is not critical. Set-up of cooling season temperature for the constant volume system will require careful evaluation of the reheat coil control operation. Heating season set-back should be straightforward for both the constant volume and variable air volume systems.

Shut-Down Unused Fume Hoods

Plans for the building indicate that the fume hoods are served by adjustable speed fans whose speed is controlled by the sash position sensor. The minimum ventilation rate for the hoods when the sash is closed is not zero, so if hoods are unused energy can be saved by turning the hood off.

Turn Off Unit Heaters in Summer

There are several locations in the building where ceiling mounted hot-water unit heaters provide supplemental heating. A typical heater is shown in the figure below. In normal operation the heater fan operates when the thermostat calls for heat. However, even when the fan is not operating the unit can heat the space through convection if hot water is flowing through the heat exchanger. If this occurs during the cooling season it can waste both cooling and heating system energy. During the cooling season the system operation should be checked to insure that hot water supply to these heaters is turned off.



Figure 5.1 Ceiling Mounted Unit Heater

Turn Off Cooling Tower Sump Heater

Since the cooling tower is not operated during the winter, there is no need for operation of the sump heater. The control of this heater should be reviewed to insure that it does not operate in the summer (when it would add unnecessary load to the cooling tower) or the winter.

6 Recommendations

The results of this study indicate that several of the energy cost reduction measures either alone or in combination offer the potential for significant energy cost savings. The package which maximizes energy cost savings is PKG1 which combines all of the ECRMs.

We recommend PKG1 for implementation. The energy cost reduction measures included in this package result in favorable economics and offer the potential for annual savings of \$57,386; equivalent to about 25 percent of the total annual utility bill for the base case. It should also be noted that since this is a state-owned building, the discount factor of 10 percent used in our analysis is very conservative. A more appropriate discount factor may be in the 4 percent range, improving the economics of all the options. Additionally, in the coming year, money will be available from the electric utility to partially fund energy improvements of buildings connected to their systems.

This recommendation produces solid financial benefits, along with a number of qualitative improvements to building comfort, aesthetics, and environmental impact. The recommendations reduce the lifetime costs of building ownership and the monthly utility cost savings improve the organization's bottom line.

7 Appendices

7.1 Appendix A – Abbreviations

A/C – 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

CMU – Concrete Masonry Unit

COP - Coefficient of Performance

CRI – Color Rendering Index

DX - Direct Expansion

DWH – Domestic Water Heater

ECRMs - Energy Cost Reduction Measures

EER - Energy Efficiency Ratio

EPACT – Energy Policy Act

ERV - Energy Recovery Ventilator

F - Fahrenheit

ft - Foot, or Feet

GSHP - Ground Source Heat Pump

HP – Horsepower

HRV – Heat recovery ventilator

HX - Heat Exchanger

hr - Hour

HVAC - Heating, Ventilating, and Air Conditioning

IRR - Internal Rate of Return

kW - kilowatt, one thousand watts

kWh - kilowatt-hours, one thousand watt-hours

LCCA - Life Cycle Cost Analysis

NPW – Net Present Worth

OA - Outside Air

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

SF or sf – Square Feet

SHGC – Solar Heat Gain Coefficient

SEER – Seasonal energy efficiency ratio

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

T8 – A tubular fluorescent lamp one-inch 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

wph – Whopper sandwiches per hour

yr - Year(s)