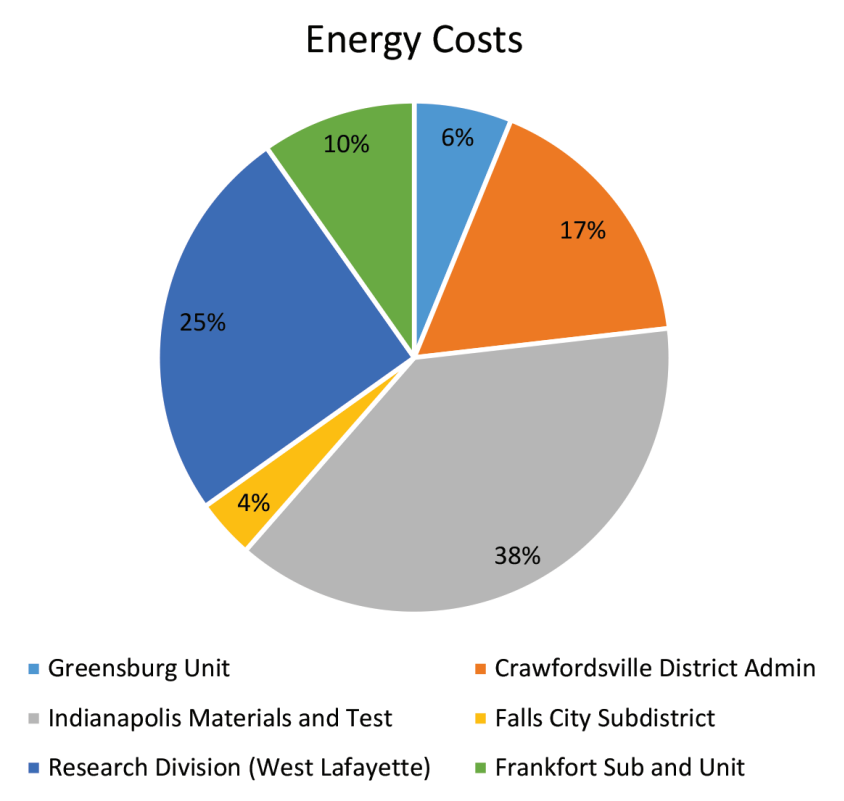
JOINT TRANSPORTATION RESEARCH PROGRAM
INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY

Improving Energy Efficiency of Facilities



Kelly Weger, Jim Handy

SPR-3946 • Report Number: FHWA/IN/JTRP-2016/29 • DOI: 10.5703/1288284316356

RECOMMENDED CITATION

Weger, K., & Handy, J. (2016). *Improving energy efficiency of facilities* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2016/29). West Lafayette, IN: Purdue University. http://dx.doi.org/10.5703/1288284316356

AUTHORS

Kelly Weger
Lead Service Manager, Sustainability
Technical Assistance Program
Purdue University

Jim Handy
Senior Industry Advisor
Technical Assistance Program
Purdue University
(317) 275-6813
jhandy@purdue.edu
Corresponding Author

JOINT TRANSPORTATION RESEARCH PROGRAM

The Joint Transportation Research Program serves as a vehicle for INDOT collaboration with higher education institutions and industry in Indiana to facilitate innovation that results in continuous improvement in the planning, design, construction, operation, management and economic efficiency of the Indiana transportation infrastructure. https://engineering.purdue.edu/JTRP/index_html

Published reports of the Joint Transportation Research Program are available at http://docs.lib.purdue.edu/jtrp/.

NOTICE

COPYRIGHT

Print ISBN: 978-1-62260-449-4
ePUB ISBN: 978-1-62260-450-0

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/IN/JTRP-2016/29		

4. Title and Subtitle	5. Report Date
Improving Energy Efficiency of Facilities	October 2016
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Kelly Weger, Jim Handy	FHWA/IN/JTRP-2016/29

9. Performing Organization Name and Address	10. Work Unit No.
Joint Transportation Research Program Purdue University 550 Stadium Mall Drive West Lafayette, IN 47907-2051	
	11. Contract or Grant No. SPR-3946

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes
Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration.

16. Abstract

The Indiana Department of Transportation (INDOT) has entered into an agreement with the Purdue University Manufacturing Extension Partnership (MEP) to perform energy assessments on six sites. The six sites were selected to represent a variety of types of buildings typical for INDOT's portfolio. These include the Research and Development Building in West Lafayette, the Crawfordsville Administration Building, the Falls City Sub-District, the Greensburg Unit, the Frankfort Sub-District Building, and the Central Materials and Testing in Indianapolis.

This energy assessment report identifies, evaluates, and prioritizes energy-saving projects. Purdue MEP provided a comprehensive energy assessment of each site, and many energy efficiency measures (EEMs) were identified, with the potential to save in annual energy costs. We also researched available incentives from local utilities and calculated the payback period for each EEM.
As a result of the assessments, six reports have been generated in order to:

- Provide a benchmarking analysis to show energy performance relative to similar buildings
- Provide insight into the historical energy usage patterns of the facility
- Present recommended energy efficiency measures (EEM) for consideration
- Provide analysis to determine first order approximate costs and savings for each EEM
- Discover opportunities for incentives that may be available to help fund energy improvements

In collaboration with the energy assessments, Purdue MEP worked with INDOT to provide instruction and facilitation in the Energy Star Portfolio Manager tool.

17. Key Words	18. Distribution Statement
energy, assessment, efficiency, lighting, controls, water	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	47	

Form DOT F 1700.7 (8-69)

EXECUTIVE SUMMARY

IMPROVING ENERGY EFFICIENCY OF FACILITIES

Introduction

The Indiana Department of Transportation (INDOT) has entered into an agreement with the Purdue University Manufacturing Extension Partnership (MEP) to perform energy assessments on six sites. These sites—the Research and Development building in West Lafayette, the Crawfordsville administration building, the Falls City Sub-District building, the Greensburg Unit building, the Frankfort Sub-District building, and Central Materials and Testing building in Indianapolis—were selected to represent the variety of building types typical for INDOT's portfolio.

This energy assessment report identifies, evaluates, and prioritizes energy-saving projects. Purdue MEP provided a comprehensive energy assessment of each site, and many energy efficiency measures (EEMs) were identified that could reduce annual energy costs. We also researched available incentives from local utilities and calculated the payback period for each EEM.

As a result of the assessments, six reports have been generated to:

- Provide a benchmarking analysis to show energy performance relative to similar buildings
- Provide insight into the historical energy usage patterns of the facility
- Present recommended EEMs for consideration
- Provide analysis to determine first order approximate costs and savings for each EEM
- Discover opportunities for incentives that may be available to help fund energy improvements

Findings

If all recommended EEMs for all six locations are implemented, this would yield an *average annual cost savings of over 30%* off the current utility costs. Of the six selected sites, Central Materials and Testing is the largest portion of the cost.

Each of the six sites has unique EEM recommendations detailed in the individual reports. Some common themes that are consistent throughout the sites include:

- Switching lighting from T12 or higher wattage T8 to lower wattage T8 or LED
- Replacing exterior HID lights with LED
- Installing automatic sensors for lighting in certain areas with low occupancy
- Updating older mechanical equipment with high-efficiency replacements
- Installing better controls to manage HVAC equipment, which may include setbacks, programmable thermostats, BAS, or outside air resets

See Appendix A to this report for lighting options spec sheets for all sites. See Appendix B to this report for specific HVAC equipment options spec sheets for sites.

Implementation

Prior to the on-site assessment, INDOT provided 12–24 months of utility data to the assessment team. The consumption data was analyzed and compared to cooling degree days (CDD) and heating degree days (HDD) for weather normalization. Any observed anomalies were flagged for further questioning and a preliminary utility analysis was generated for discussion purposes.

On the day of the on-site assessment, the facility personnel at each site provided background information on the facility's primary energy systems as well as previous and planned renovations and projects. The assessment team then did a walk-through of the various types of spaces, including meeting rooms, lab spaces, offices, break areas, common areas, and so forth. The assessment team investigated the mechanical rooms to observe the HVAC equipment.

Data collected on site was used to perform detailed energy calculations. Potential alternatives were investigated and a cost analysis performed to determine which solutions were feasible and cost-effective. Recommendations were made, including proposed energy reduction, cost savings, applicable incentives, and simple payback periods. This information was presented to INDOT in the form of an energy assessment report for each of the six individual sites.

Next steps for implementation and verification include:

- Evaluating all recommended measures collectively
- Identifying EEMs to pursue first
- Obtaining cost estimates from outside contractors
- Performing energy efficiency updates at selected sites
- Tracking energy costs and comparing to weather normalized historical data
- Determining best practices for implementing across the state

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The Indiana Department of Transportation (INDOT) has entered into an agreement with the Purdue University Manufacturing Extension Partnership (MEP) to perform energy assessments on six sites. The six sites were selected to represent a variety of types of buildings typical for INDOT's portfolio. These include the Research and Development building in Lafayette, the Crawfordsville administration building, the Fall City Sub-District building, the Greensburg Unit building, the Frankfort Sub-District building, and the Central Materials and Testing building in Indianapolis.

This energy assessment report identifies, evaluates, and prioritizes energy-saving projects. Purdue MEP provided a comprehensive energy assessment of each site, and many energy efficiency measures (EEMs) were identified, with the potential to save in annual energy costs. We also researched available incentives from local utilities and calculated the payback period for each EEM.

As a result of the assessments, six reports have been generated in order to:

- Provide a benchmarking analysis to show energy performance relative to similar buildings
- Provide insight into the historical energy usage patterns of the facility
- Present recommended energy efficiency measures (EEM) for consideration
- Provide analysis to determine first order approximate costs and savings for each EEM
- Discover opportunities for incentives that may be available to help fund energy improvements

In collaboration with the energy assessments, Purdue MEP worked with INDOT to provide instruction and facilitation in the Energy Star Portfolio Manager tool. Making energy improvements requires understanding your baseline, and setting clear targets for reductions in energy use. The Portfolio Manager Tool allows online tracking, sharing, and reporting on energy use in multiple buildings, making it a good option for users with numerous facilities. Working with INDOT, utility consumption information was entered into an online, shareable platform, which allows INDOT to track, review, and compare ongoing progress for every site in their portfolio. This free tool will be explored for possible future expansion to all sites.

2. ENERGY ASSESSMENTS

2.1 Research and Development Building (Figure 2.1 and Table 2.1)

The Research and Development building site is a compound that includes lab spaces, high bay garage spaces, and office spaces.

Purdue MEP provided a comprehensive energy assessment of the Research and Development building on October 28, 2015, and 69 energy efficiency measures (EEMs) were identified, with the potential to save an estimated **$38,000** in annual energy costs, which would pay for themselves in a little over 3 years through the annual energy savings. After lighting incentives from Duke Energy and Vectren, the **payback period drops to 2.3 years**. The reoccurring cost savings opportunities in this assessment represent a 46% reduction in the site's annual utility costs.

See Appendix C for spec sheets for the major equipment recommended and Appendix D for the calculations for determining the boiler sizing at the Research site.

2.2 Crawfordsville Administration Building (Figure 2.2 and Table 2.2)

The Crawfordsville District administration building is located in Crawfordsville, Indiana, and houses such functions as Planning, Permits, Highway Management and Human Resources among others.

Purdue MEP provided a comprehensive energy assessment of the administration building on November 18, 2015, and 45 energy efficiency measures (EEMs) were identified, with the potential to save an estimated **$21,000** in annual energy costs, which would pay for themselves in 1.3 years through the annual energy savings. After incentives from Tipmont REMC and Vectren, the **payback period drops to 1 year**. The reoccurring cost savings opportunities in this assessment represent a 35% reduction in the site's annual utility costs.

2.3 Frankfort Sub-District Building (Figure 2.3 and Table 2.3)

The Frankfort Sub and Unit buildings are located in Frankfort, Indiana, and are primarily used as a hub of operations for vehicle maintenance, vehicle washing, snow plowing, salting and sanding operations. The Indiana Department of Transportation (INDOT) has entered into an agreement with the Purdue University Manufacturing Extension Partnership (MEP) to perform audits on six sites. The six sites were selected to represent a variety of types of buildings typical for INDOT's portfolio.

This energy assessment report identifies, evaluates, and prioritizes energy-saving projects.

Purdue MEP provided a comprehensive energy assessment of the Frankfort site on November 18, 2015, and 42 energy efficiency measures (EEMs) were identified, with the potential to save an estimated **$13,000** in annual energy costs, which would pay for themselves in 1.5 years through the annual energy savings. After incentives from Vectren, the **payback period drops to 1.4 years**. The reoccurring cost savings opportunities in this assessment represent a 33% reduction in the site's annual utility costs.

2.4 Falls City Sub-District Building (Figure 2.4 and Table 2.4)

The Falls City Sub building and the Sellersburg Unit building are located in Clarksville, Indiana, and house such functions as vehicle maintenance, road salting/plowing and emergency roadside assistance. There are

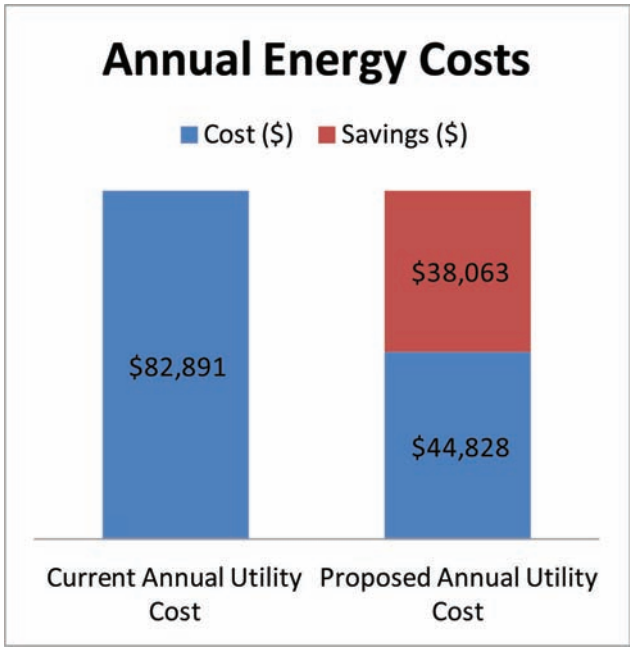


Figure 2.1 Annual energy costs: Research and Development building.

TABLE 2.1
Energy Efficiency Snapshot: Research and Development Building

Item #	Category	Description	Implementation Cost			Annual Savings	Simple Payback Before Incentive (Years)	Simple Payback AFTER Incentive (Years)
			Initial Cost	Utility Incentive	Cost After Incentive			
1	Lighting	Retrofit T12s & T8s with LED Replace high bay lights Install occupancy sensors Rezone select lighting circuits	$60,769	$19,609	$41,160	**$13,528**	4.5	3.0
2	Controls	Outside air resets on VAV AHU set points Equipment shutdowns at night Unoccupied space temperature resets Programmable thermostats in garages Rebalance fume hoods	$23,200	$7,684	$15,516	**$14,201**	1.6	1.1
3	Mech.	Install high-efficiency condensing boilers Repair and cover VRF refrigerant piping	$30,000	$3,000	$27,000	**$7,417**	4.0	3.6
4	Façade	Replace vestibule glass Insulate block walls Replace overhead doors in Superpave garage Install skylights for daylighting garages	TBD	$0	TBD	**$1,984**	TBD	TBD
5	Water	Replace power flush toilets with low flush models Replace tank style toilets with low flush models Replace sink aerators	$2,260	$0	$2,260	**$931**	2.4	2.4
6	Other	Evaluate electric rate change Stormwater credits	TBD	TBD	TBD	**TBD**	TBD	TBD
		Total recommended	**$116,229**	**$30,292**	**$85,937**	**$38,063**	**3.1**	**2.3**

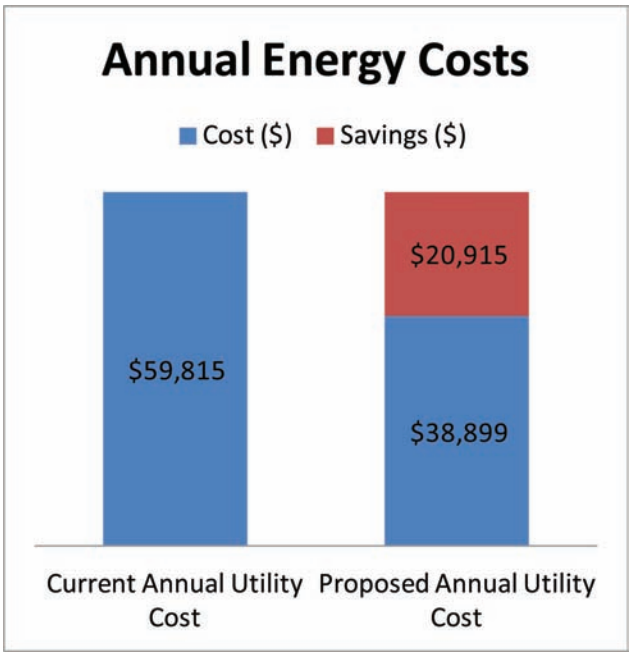


Figure 2.2 Annual energy costs: Crawfordsville administration building.

TABLE 2.2
Energy Efficiency Snapshot: Crawfordsville Administration Building

Item #	Category	Description	Implementation Cost			Annual Savings	Simple Payback Before Incentive (Years)	Simple Payback AFTER Incentive (Years)
			Initial Cost	Utility Incentive	Cost After Incentive			
1	Lighting	Install 28W T8 fluorescent tubes Install occupancy sensors	$3,362	$426	$2,936	$932	3.6	3.1
2	Controls	Outside air resets on VAV AHU set points Equipment shutdowns at night Unoccupied space temperature resets Replace thermostats and implement night setbacks	$23,900	$7,207	$16,693	$19,007	1.3	0.9
3	Mech.	Replace obsolete VAV boxes	TBD	$0	TBD	TBD	TBD	TBD
4	Façade	Replace lobby and side doors	TBD	$0	TBD	$434	TBD	TBD
5	Water	None	$0	$0	$0	$0		
6	Other	Install timer and tank blanket on domestic hot water	$300	$0	$300	$542	0.6	0.6
		Total recommended	**$27,562**	**$7,633**	**$19,929**	**$20,915**	**1.3**	**1.0**

also salt storage buildings and a hot-start system serving 25 highway vehicles.

Purdue MEP provided a comprehensive energy assessment of the Sub, Unit building and the Hot Start System on January 19, 2016, and 36 energy efficiency measures (EEMs) were identified, with the potential to save nearly **$12,000** in annual energy costs, which would pay for themselves in 3.3 years through the annual energy savings. After incentives from Duke Energy and Vectren, the **payback period drops to 2.6 years**. The reoccurring cost savings opportunities in this assessment represent a 37% reduction in the site's annual utility costs.

2.5 Greensburg Unit Building (Figure 2.5 and Table 2.5)

The Greensburg Unit building is located in Clarksville, Indiana, and houses such functions as vehicle maintenance and road salting/plowing.

Purdue MEP provided a comprehensive energy assessment of the Greensburg Unit building on February 17, 2016, and five energy efficiency measures (EEMs) were

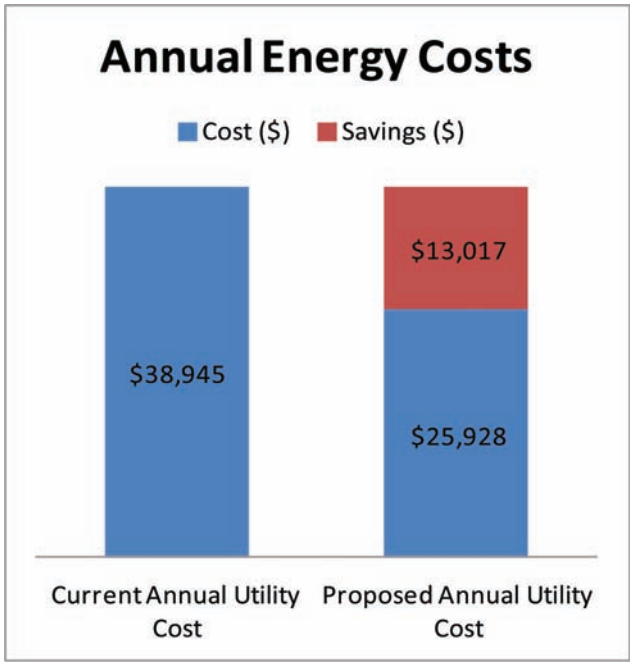


Figure 2.3 Annual energy costs: Frankfort Sub-District building.

TABLE 2.3
Energy Efficiency Snapshot: Frankfort Sub-District Building

Item #	Category	Description	Implementation Cost			Annual Savings	Simple Payback Before Incentive (Years)	Simple Payback AFTER Incentive (Years)
			Initial Cost	Utility Incentive	Cost After Incentive			
1	Lighting	Replace T8 32W tubes with 28W Replace high bay lights Install occupancy sensors	**$5,595**	$0	$5,595	**$1,035**	5.4	5.4
2	Controls	Unoccupied space temperature resets Programmable thermostats in garages	**$3,800**	**$1,880**	$1,920	**$4,368**	0.9	0.4
3	Mechan.	None	**$0**	$0	$0	**$0**	0.0	0.0
4	Façade	None	$0	$0	$0	**$0**	0.0	0.0
5	Water	None	$0	$0	$0	**$0**	0.0	0.0
6	Other	Water meter replacements Gas meter replacement Find and repair compressed air leaks Install timers on shop equipment	$10,100	$0	$10,100	**$7,615**	1.3	1.3

identified, with the potential to save over **$2,600** in annual energy costs, which would pay for themselves in 1.2 years through the annual energy savings. After incentives from Vectren, the **payback period drops to 1.0 years**. The reoccurring cost savings opportunities in this assessment represent a 9% reduction in the site's annual utility costs.

For example, in Greensburg, the 175W MH exterior lighting is recommended to be replaced with LED lighting for $1,190. There are seven fixtures and the per fixture cost is $170 ($120 for the PCT lamp and $50 to install). This is a lamp replacement only. The lamp just screws into the existing fixtures. See Appendix A for additional information on sample lighting products.

2.6 Central Materials and Testing Building (Figure 2.6 and Table 2.6)

Central Material Testing is located in Indianapolis, Indiana, and houses labs to test chemicals, concrete, cement, aggregate, steel and rubber samples from construction projects.

Purdue MEP provided a comprehensive energy assessment of Central Material Testing on March 22 and 23, 2016, and many energy efficiency measures (EEMs) were identified, with the potential to save more than **$42,000** in annual energy costs, which would pay for themselves in 5.3 years through the annual energy savings. After

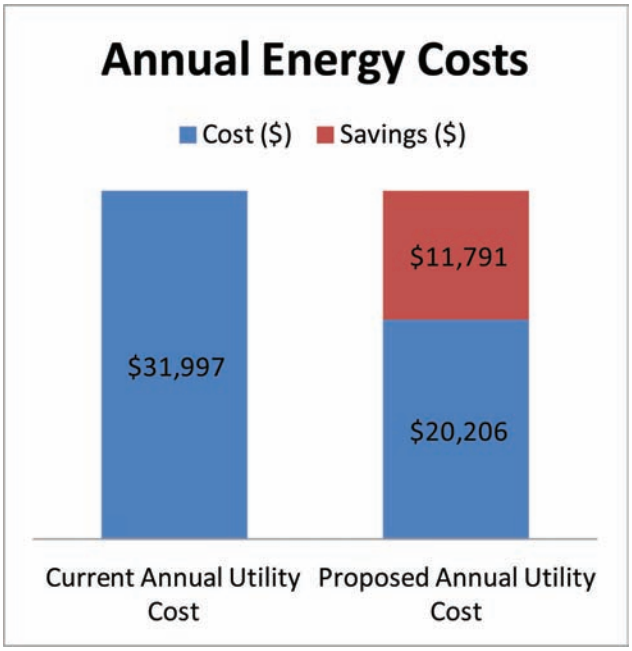


Figure 2.4 Annual energy costs: Falls City Sub-District building.

TABLE 2.4
Energy Efficiency Snapshot: Falls City Sub-District Building

Item #	Category	Description	Implementation Cost			Annual Savings	Simple Payback Before Incentive (Years)	Simple Payback AFTER Incentive (Years)
			Initial Cost	Utility Incentive	Cost After Incentive			
1	Lighting	Replace T12 40W tubes with LED Replace high bay lights Install occupancy sensors	$14,858	$5,351	$9,507	**$3,105**	4.8	3.1
2	Controls	Install programmable thermostats and implement unoccupied space temperature resets Install timers on sub building exhaust fans	$7,600	$490	$7,110	**$2,838**	2.7	2.5
3	Mech.	Install waste oil burning heater in the unit heater	$10,000	$2,189	$7,811	**$3,680**	2.7	2.1
4	Façade	Reseal overhead doors	$600	$0	$600	**$678**	0.9	0.9
5	Water	None	$0	$0	$0	**$0**	0.0	0.0
6	Other	Install smart controls on hot start system Find and repair compressed air leaks Install timer on air compressor	$5,700	$0	$5,700	**$1,490**	3.8	3.8
		Total recommended	**$38,758**	**$8,030**	**$30,728**	**$11,791**	**3.3**	**2.6**

incentives from IPL and Citizens Energy, the **payback period drops to 4.5 years**. The reoccurring cost savings opportunities in this assessment represent a 29% reduction in the site's annual utility costs.

NOTE: The facility's future is currently not clear and nearly all of the opportunities identified have simple paybacks of four years or more. What's more, the roof was not included in the measures recommended based on payback, but is a critical repair which must be done if this building is going to be continue to be occupied. Also, the ventilation at this site was noted to be less than the current standards, both in the office area and the lab areas. This means that a new facility would use considerably more energy. This assessment needs to be reviewed keeping these other considerations in mind.

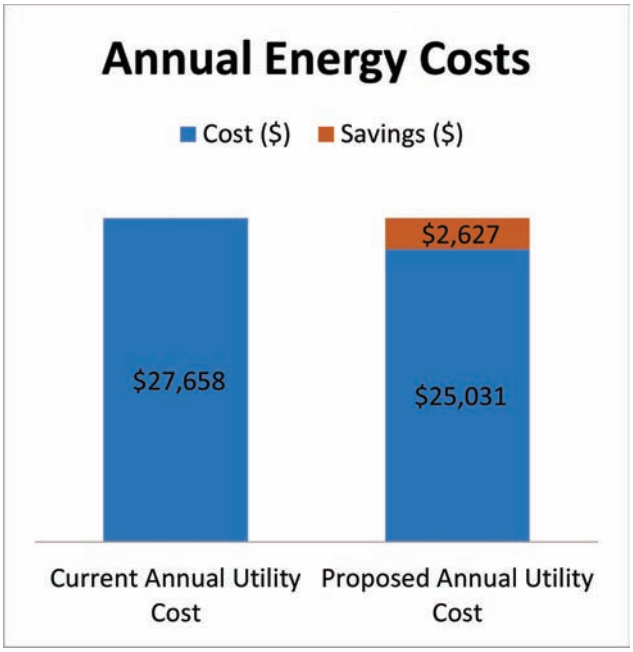


Figure 2.5 Annual energy costs: Greensburg Unit building.

TABLE 2.5
Energy Efficiency Snapshot: Greensburg Unit Building

Item #	Category	Description	Implementation Cost			Annual Savings	Simple Payback Before Incentive (Years)	Simple Payback AFTER Incentive (Years)
			Initial Cost	Utility Incentive	Cost After Incentive			
1	Lighting	Replace high bay lights	$1,190	$0	$1,190	**$288**	4.1	4.1
2	Controls	Install programmable thermostats and implement unoccupied space temperature resets	$1,600	$592	$1,008	**$2,037**	0.8	0.5
3	Mech.	None	$0	$0	$0	**$0**	0.0	0.0
4	Façade	Adjust overhead doors	$300	$0	$300	**$303**	1.0	1.0
5	Water	None	$0	$0	$0	**$0**	0.0	0.0
6	Other	Investigate alternate water rate or meter size	$0	$0	$0	**$0**	0.0	0.0
		(All measures analyzed)	*$5,042*	*$ 592*	*$4,450*	*$2,883*	*1.7*	1.5
		Total recommended	**$3,090**	**$592**	**$2,498**	**$2,627**	**1.2**	**1.0**

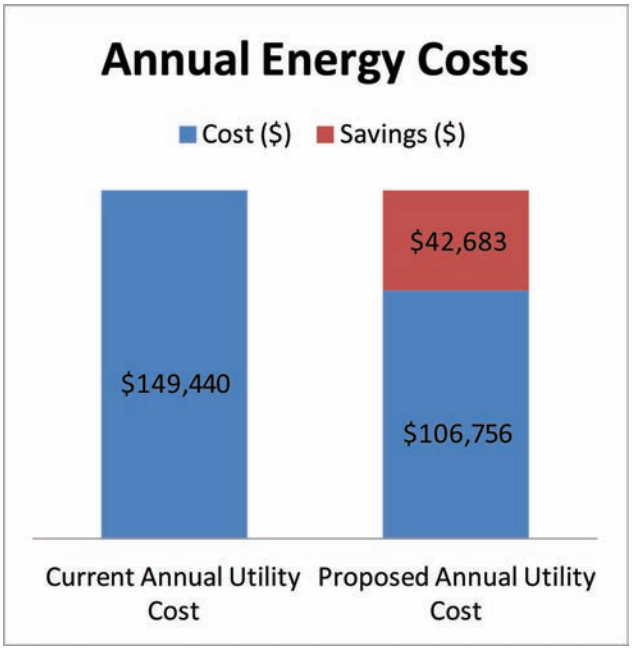


Figure 2.6 Annual energy costs: Central Materials and Testing building.

TABLE 2.6
Energy Efficiency Snapshot: Central Materials and Testing Building

Item #	Category	Description	Implementation Cost: Initial Cost	Implementation Cost: Utility Incentive	Implementation Cost: Cost After Incentive	Annual Savings	Simple Payback Before Incentive (Years)	Simple Payback AFTER Incentive (Years)
1	Lighting	Retrofit T12s & T8s with LED Replace exterior lights with LED Install occupancy sensors	$78,700	$27,455	$51,245	**$23,793**	3.3	2.2
2	Controls	Outside air resets on VAV AHU set points Equipment shutdowns at night Unoccupied space temperature resets Rebalance fume hoods Replace timers on exhaust systems	$105,500	$5,040	$100,460	**$10,634**	9.9	9.4
3	Mech.	Install high-efficiency condensing boilers Find and repair hot water/cold water tie-in	$26,000	$1,750	$24,250	**$4,356**	6.0	5.6
4	Façade	Replace roof Replace single pane windows and install insulated panels in areas where dropped ceilings have been installed	$0	$0	$0	**$0**	0.0	0.0
5	Water	None	$0	$0	$0	**$0**	0.0	0.0
6	Other	Move transformers to outside pad Explore natural gas test oven options Combine transformer account with general use electric accounts	$17,000	$0	$17,000	**$3,900**	4.4	4.4
		(All measures analyzed)	*$ 1,577,200*	*$ 34,245*	*$1,542,955*	*$ 49,641*	*31.8*	31.1
		Total recommended	**$227,200**	**$34,245**	**$192,955**	**$42,683**	**5.3**	**4.5**

3. ENERGY TRACKING

In collaboration with the energy assessments, Purdue MEP worked with INDOT to provide instruction and facilitation in the Energy Star Portfolio Manager tool. This is a no-cost, online platform that allows electronic data sharing between departments and other connected contacts on Portfolio Manager.

Making energy improvements requires understanding your baseline, and setting clear targets for reductions in energy use. The Portfolio Manager Tool allows online tracking, sharing, and reporting on energy use in multiple buildings, making it a good option for users with numerous facilities.

Working with INDOT staff, Purdue MEP provided two days of training best practices for utilizing the Portfolio Manager tool. During and after the on-site training, profiles for each of the six locations were created, including basic information on square footage, number of occupants, types of use, hours of operation, etc. Actual energy and water consumption data was then entered into an online, shareable platform, which allows INDOT to track, review, and compare ongoing progress for every site in their portfolio. This free tool will be explored for possible future expansion to all sites.

3.1 Portfolio Manager Website

Figures 3.1, 3.2, and 3.3 are examples of what the Portfolio Manager tool looks like when you log in to access the information on your facilities. These partial screenshots demonstrate a clean, user-friendly layout with understandable navigation and structure.

3.2 Reporting Capabilities

The Portfolio Manager tool comes with several options for automatic report generation. In addition to these preloaded reports that you can select from, you can also create your own custom template to meet needs specific to

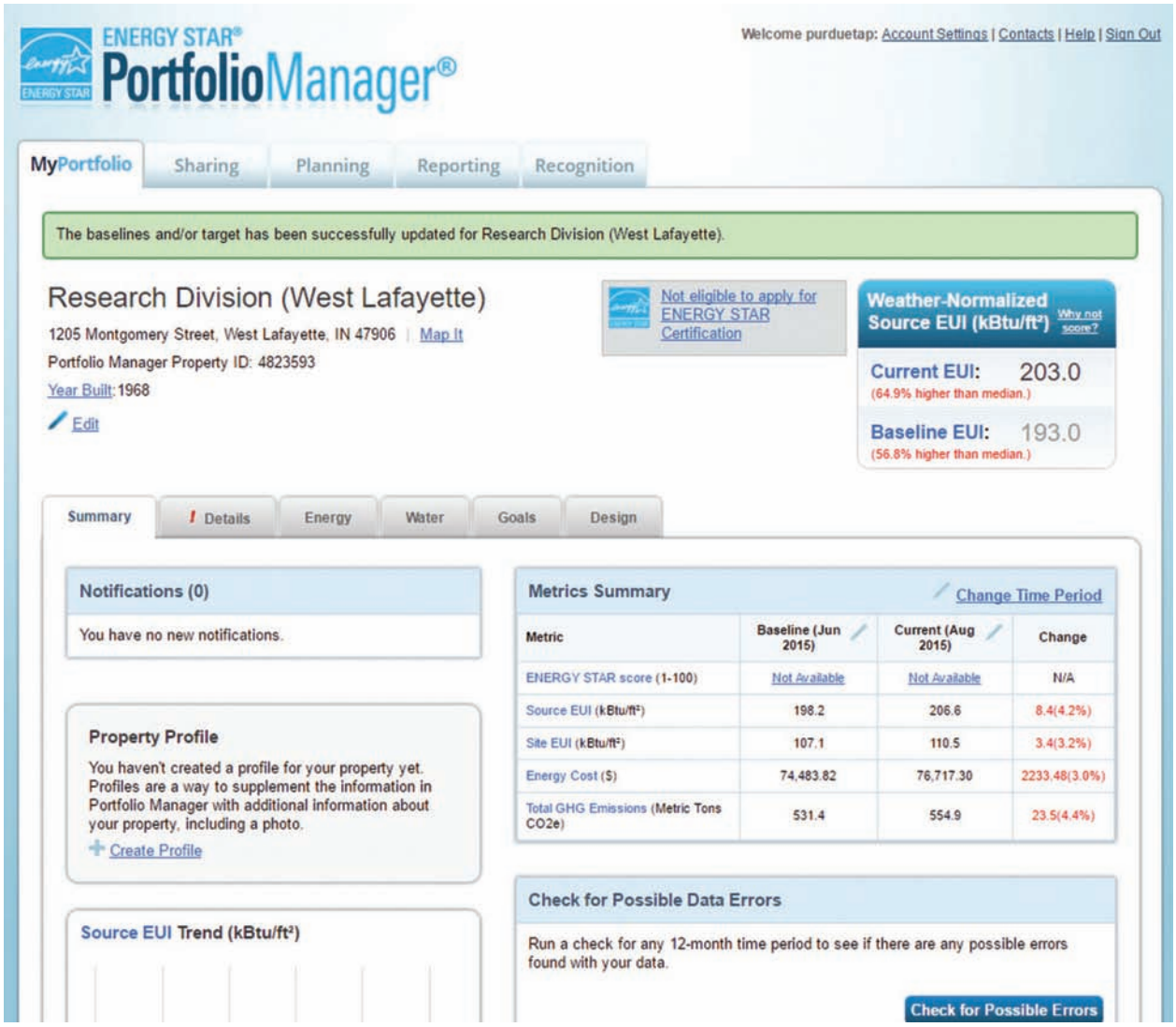


Figure 3.1 Portfolio Manager: summary tab.

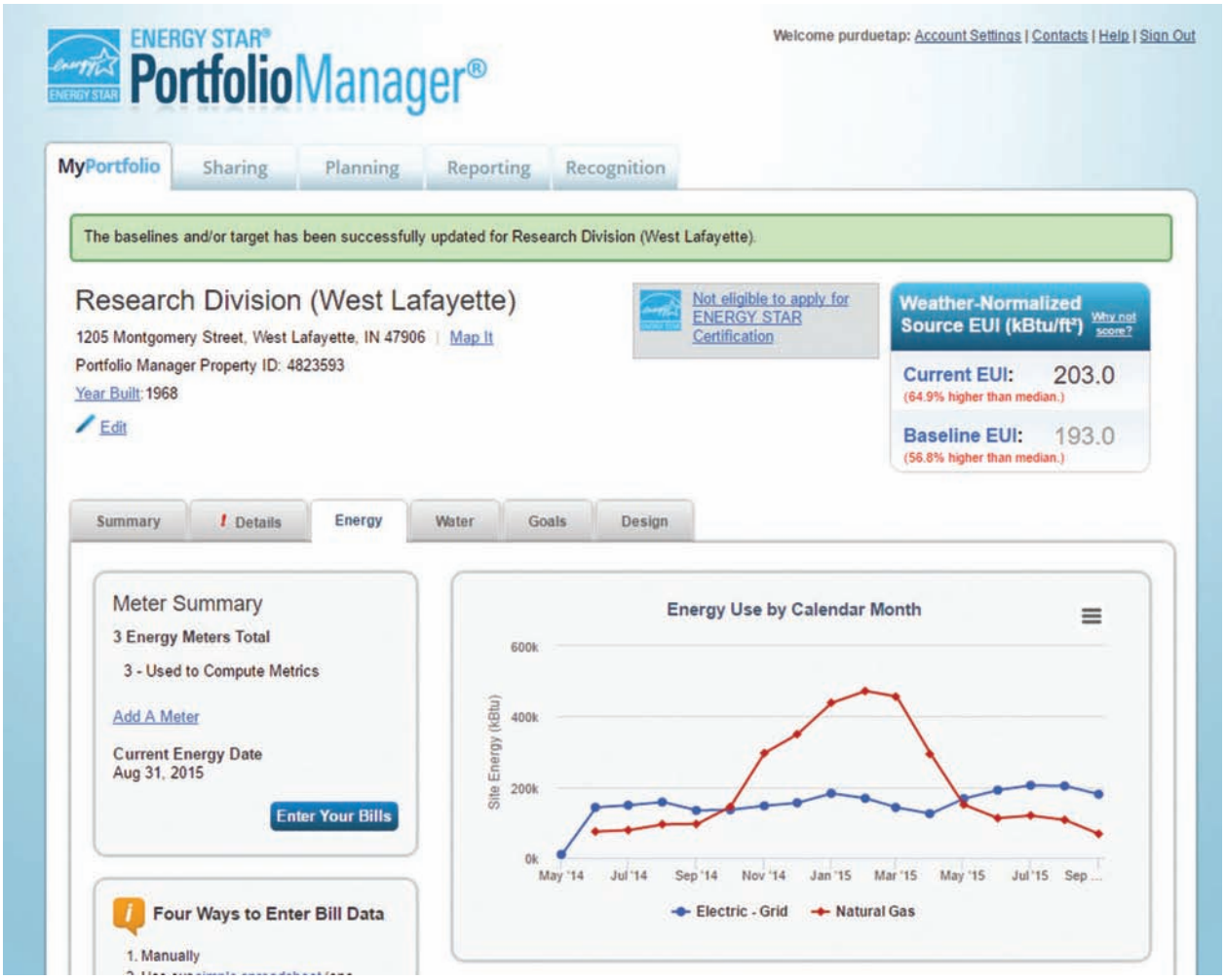


Figure 3.2 Portfolio Manager: energy tab.

your organization. Reports can be graphics based, or also downloaded in excel spreadsheets for further analysis and manipulation. Figures 3.4, 3.5, 3.6, and 3.7 are examples of the pre-loaded reporting capabilities, demonstrating the current information for all INDOT buildings already entered into Portfolio Manager.

3.3 Recommendations

The work performed as part of the report is a critical starting point. Establishing the baseline energy usage for multiple buildings allows INDOT to make informed decisions about which recommended EEMs will be pursued. Sustaining energy cost savings is more difficult, and requires ongoing tracking and reporting on energy consumption at each site. It is recommended that INDOT continue to work with the available reporting tools and enter updated energy consumption data quarterly in order to monitor ongoing improvements in energy use. Learning which features are valuable from the free Portfolio Manager tool will enable INDOT to further determine what needs are moving forward, with either this tool or a subscription tracking tool. As energy improvement projects are completed, understanding and tracking the energy usage data with comparison to the baseline will be a key component to validating the energy savings and simple payback for various EEMs. Once this tracking is completed for the six buildings included in this study, extrapolation will be much easier, to expand the most effective measures to sites throughout the state.

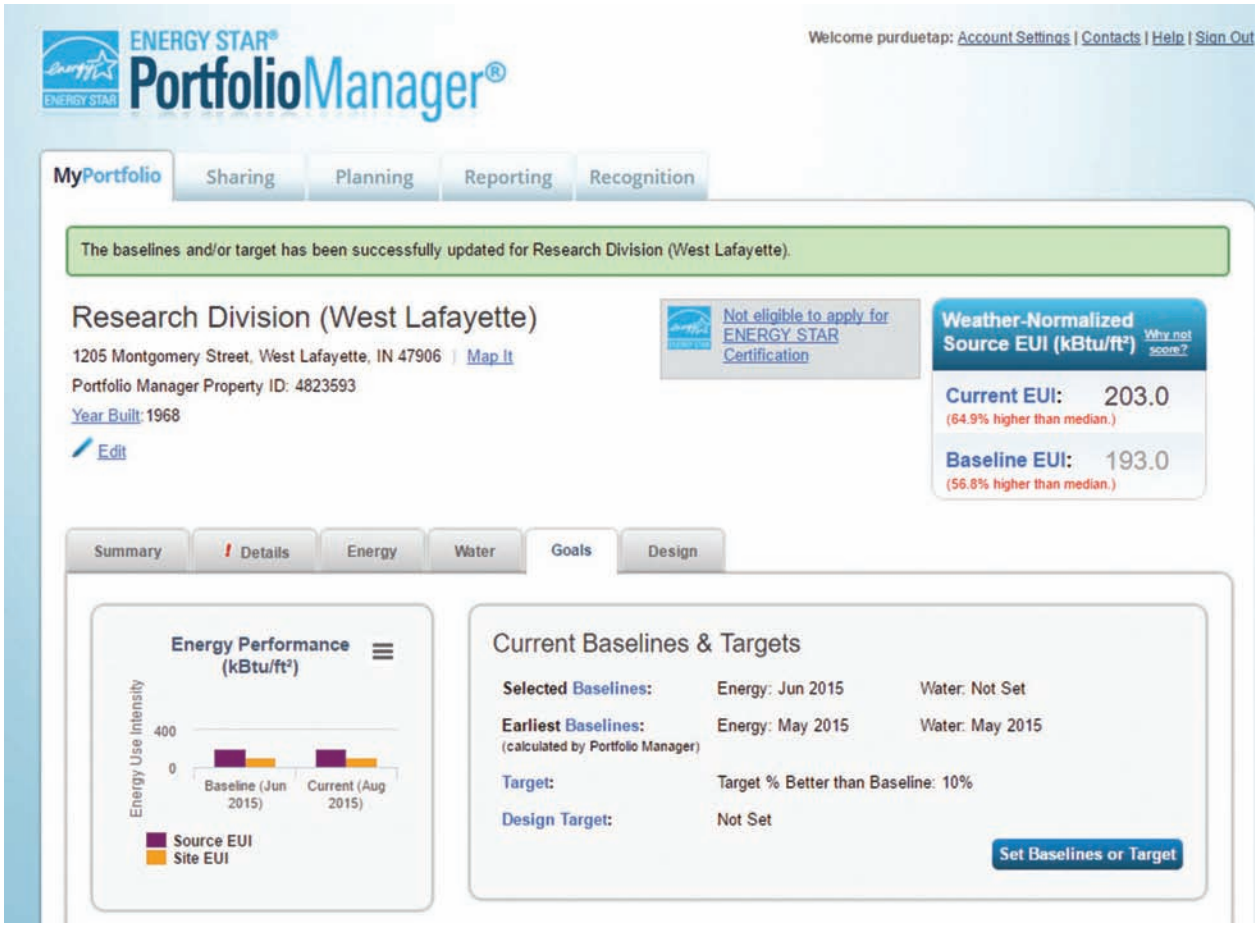


Figure 3.3 Portfolio Manager: goals tab.

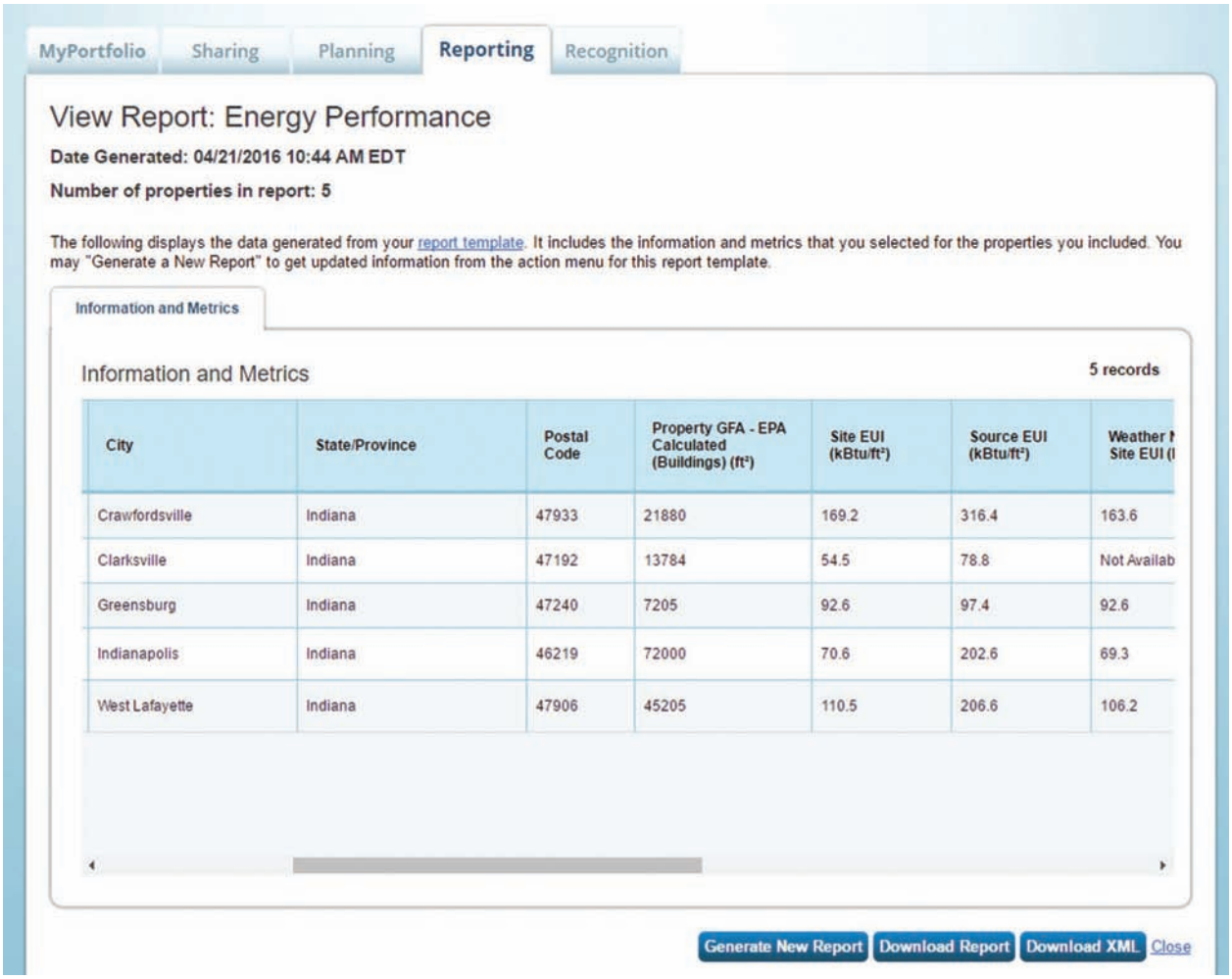


Figure 3.4 Reporting: energy performance data.

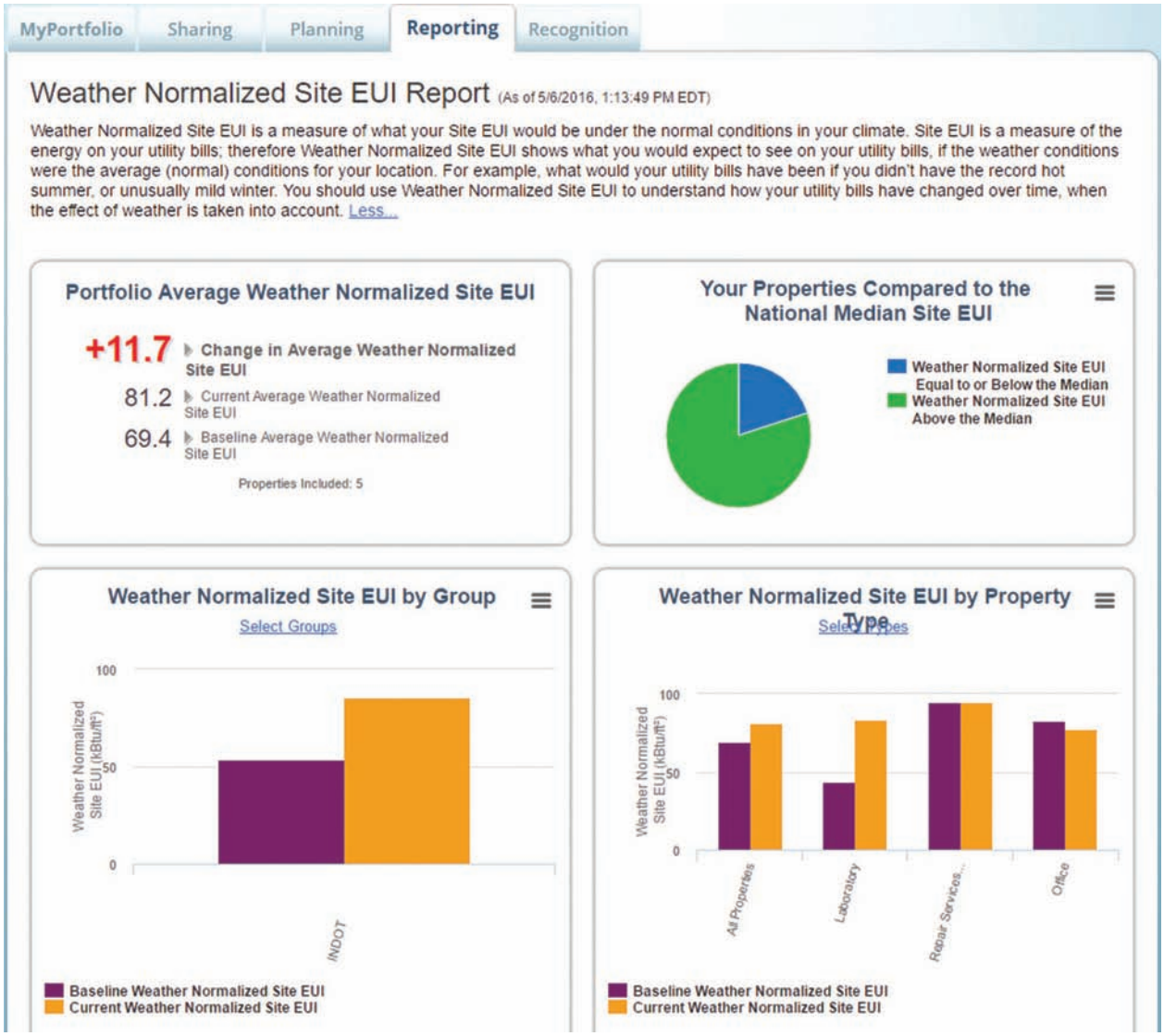


Figure 3.5 Reporting: weather normalized site EUI.

Figure 3.6 Reporting: energy cost intensity.

Figure 3.7 Reporting: greenhouse gas emissions.

RESOURCE

Deru, M., Kelsey, J., Pearson, D., et al. (2011). *ASHRAE procedures for commercial energy audits* (2nd ed.). Atlanta, GA: ASHRAE.

APPENDICES

The appendices that follow are also available for download at http://dx.doi.org/10.5703/1288284316356.

Appendix A: Spec Sheets for Lighting
Appendix B: Spec Sheets for HVAC
Appendix C: Spec Sheets for Major Equipment Recommended
Appendix D: Calculations for Determining Boiler Sizing at Research Site

APPENDIX A

LITHONIA LIGHTING®

Catalog Number	
Notes	
Type	

FEATURES & SPECIFICATIONS

INTENDED USE
Provides years of maintenance-free general illumination for residential and commercial outdoor applications such as yards, driveways, patios, loading areas and warehouses. Motion activation deters intruders.

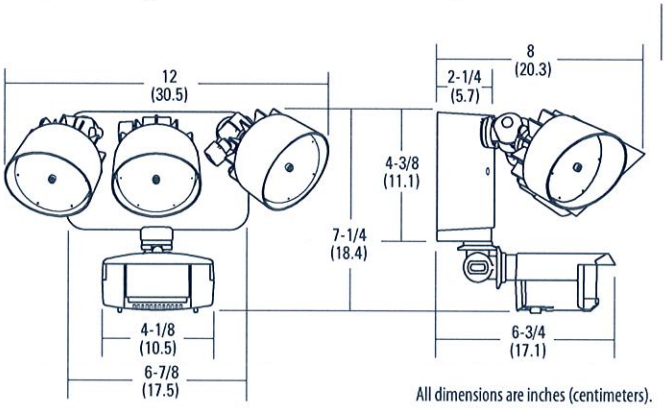
CONSTRUCTION
Three tool-free adjustable heads allow for easy aiming up/down or side to side.
Rugged cast aluminum, corrosion-resistant housing in bronze or white.
Clear acrylic lenses are fully gasketed to keep out moisture, dirt and bugs.
120V driver operates at 60Hz.
Rated for outdoor installations, -40°C minimum ambient.

OPTICS
High-performance 5000K CCT LEDs produce 2063 lumens and maintain 70% of light output at 50,000 hours of service. (Nominal correlated color temperature per ANSI C78-377-2008; LED lifespan based on IESNA LM-80-08 results and calculated per IESNA TM-21-11 methodology.)
Dual array motion sensor provides 180° detection with up to 70 feet forward range, and additional downward perimeter protection for added security.
Sensitivity and on-time adjustable knobs provide precision control, and the sensor has a manual override option.
An integrated photocell prevents activation during daylight.

INSTALLATION
Mounts easily to existing junction box on wall or under building eave.
Adjustable heads allow precise illumination.
Not recommended to wire multiple fixtures in parallel.

LISTINGS
UL/C-UL Certified to US and Canadian safety standards. Wet location listed for mounting higher than 4' off the ground.

WARRANTY
Five-year limited warranty. Full warranty terms located at
www.acuitybrands.com/CustomerResources/Terms_and_conditions.aspx.
NOTE: Specifications are subject to change without notice.
Actual performance may differ as a result of end-user environment and application.

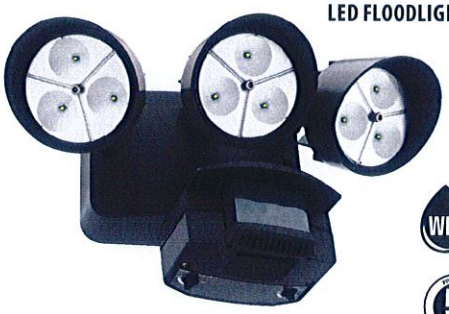


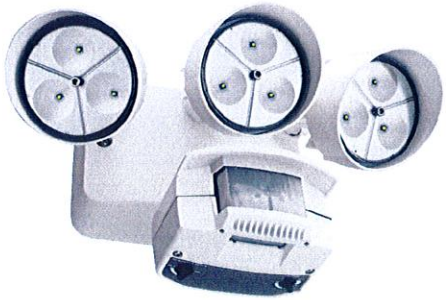
All dimensions are inches (centimeters).

Outdoor General Purpose

OFLR 9 MO

LED FLOODLIGHT WITH MOTION SENSOR
3 ADJUSTABLE HEADS
High Performance LED





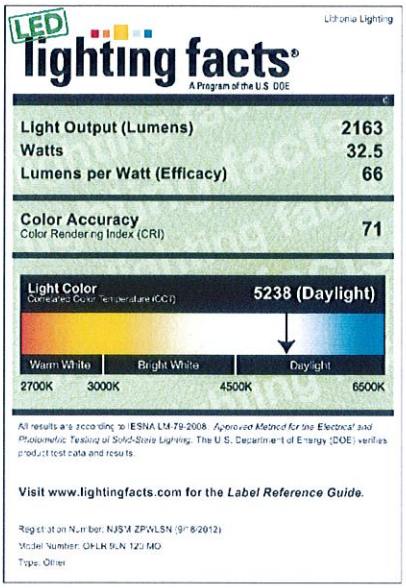
ORDERING INFORMATION All configurations of this product are considered "standard" and have short lead times. **Example:** OFLR 9LN 120 MO BZ

OFLR	9LN	120	MO	
Series	**Number of LEDs**	**Voltage**	**Features**	**Finish**
OFLR LED floodlight	**9LN** 9 LEDs, 3 heads	**120** 120 volts	**MO** Motion sensor	**BZ** Bronze **WH** White

3-Head LED Floodlight with Motion Sensor

PHOTOMETRICS

Full photometric data report available within 2 weeks from request. Consult factory.



DECORATIVE & RESIDENTIAL: One Lithonia Way Conyers, GA 30012 Phone: 800.748.5070 Fax: 770.860.3903 www.lithonia.com

PLT

lighting facts Program of the U.S. DOE

Intertek

LED Corn Bulb Lamp Series

Warranty 5 Years

5 Years Warranty

Samsung LM561B

Rubycon

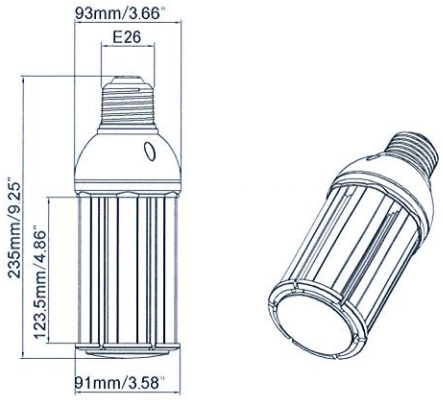
E26

JAE Connector

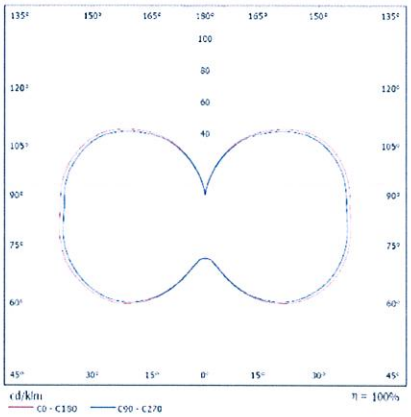
Specifications

Model	PLT-5104
Rate Power	37W
Input Voltage	AC100-277V 50-60Hz
CCT	6000K
Power Factor	⩾0.9
CRI	>80
Lumen	4378lm
Chips	Samsung
LED Quantity	108LEDs 0.3W
LED LM80	Yes

Dimension



Luminous emittance



Long Life 10 years OK

Long Lifespan of 10years

Reliability ON OFF x 1,000,000 OK

Reliability Test

Auto Safety OK

Safety Protection Circuit

Hg · UV OK

No Mercury
No UVLight

Electricity Fee $857 $428 OK

Big Saving(87%)
on Electricity Costs

Enclosed OK

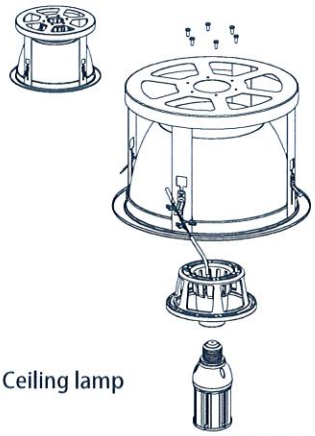
Usable in Enclosed
Luminaires

Omni OK

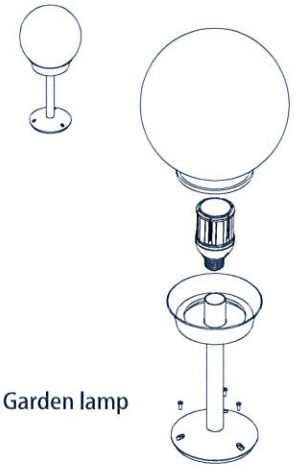
Omni Wide Angle

Installation

High bay lamp



Ceiling lamp



Garden lamp

Absolute Maximum Rating

Parameter	Rating	Units
Aluminum Heat Sink Temperature	61.8	°C
Operating Temperature	-20~+65	°C
Storage Temperature	-40~+80	°C
Equilibrium Temperature	25	°C

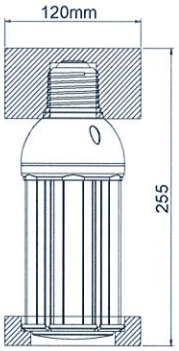
Label

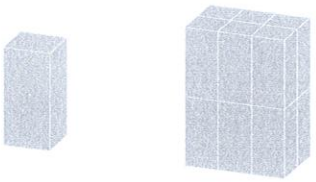
LED Corn Bulb lamp
Model:PLT-5104
AC100-277V
50-60Hz Power:36W
CCT:6000K

LED Corn Bulb lamp
Model:PLT-5104
AC100-277V
50-60Hz Power:36W
CCT:6000K

Product Packing Specification

Packing Details	
Pack Quantity	12pcs
Net Weight	1.6lbs/816g
Gross Weight Per CTN	24lbs/12.1kg
Box Size	126*126*267mm
CTN Size	395*266*554mm





⚠ CAUTIONS

- Make sure remove the traditional ballast before replace the LED corn light.
- Don't take apart the product or replace mechanical and electronic components.
- Don't stare at the strong light for a long time as it may cause injury to eyes.

PLT

lighting facts Program of the U.S. DOE

Intertek

LED Corn Bulb Lamp Series

Warranty 5 Years

5 Years Warranty

Samsung LM561B

Rubycon

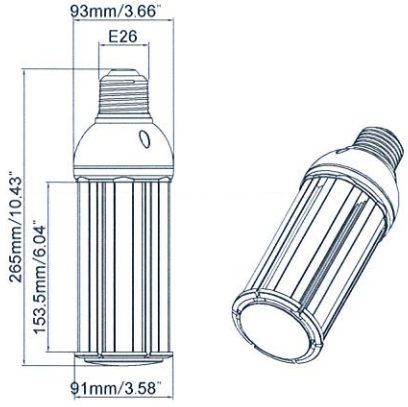
E26

JAE Connector

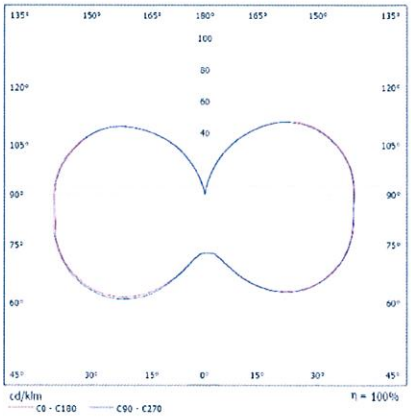
Specifications

Model	PLT-6103
Rate Power	45W
Input Voltage	AC100-277V 50-60Hz
CCT	5000K
Power Factor	⩾0.9
CRI	>80
Lumen	5786lm
Chips	Samsung
LED Quantity	135LEDs 0.3W
LED LM80	Yes

Dimension



Luminous emittance



Long Life 10 years OK

Long Lifespan of 10years

Reliability ON OFF x 1,000,000 OK

Reliability Test

Auto Safety OK

Safety Protection Circuit

Hg · UV OK

No Mercury
No UVLight

Electricity Fee $857 $428 OK

Big Saving(87%)
on Electricity Costs

Enclosed OK

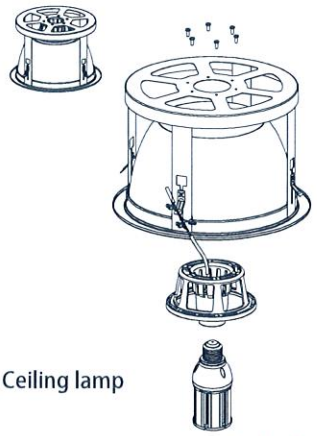
Usable in Enclosed
Luminaires

Omni OK

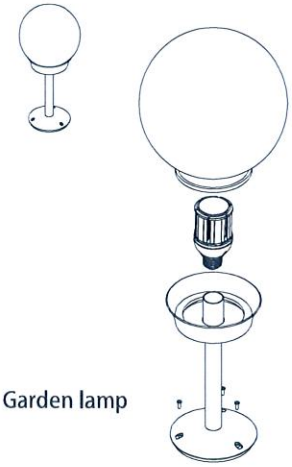
Omni Wide Angle

Installation

High bay lamp



Ceiling lamp



Garden lamp

Absolute Maximum Rating

Parameter	Rating	Units
Aluminum Heat Sink Temperature	64.9	°C
Operating Temperature	-20~+65	°C
Storage Temperature	-40~+80	°C
Equilibrium Temperature	25	°C

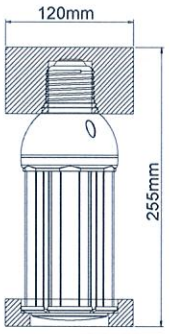
Label

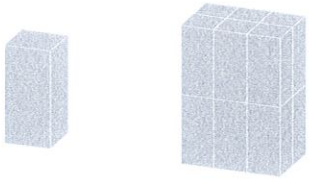
LED Corn Bulb lamp
Model:PLT-6103
AC100-277V 50-60Hz
Power:45W CCT:5000K

LED Corn Bulb lamp
Model:PLT-6103
AC100-277V 50-60Hz
Power:45W CCT:5000K

Product Packing Specification

Packing Details	
Pack Quantity	12pcs
Net Weight	2lbs/933g
Gross Weight Per CTN	30.2lbs/13.7kg
Box Size	126*126*296mm
CTN Size	395*266*612mm





⚠ CAUTIONS

- Make sure remove the traditional ballast before replace the LED corn light.
- Don't take apart the product or replace mechanical and electronic components.
- Don't stare at the strong light for a long time as it may cause injury to eyes.

LUNERA SUSAN LAMP

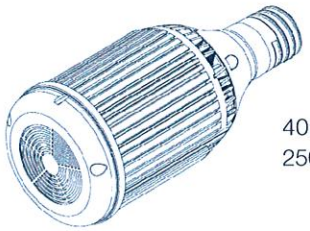
LED Replacement for Metal Halide Lamp

[400W / 320W] or [250W / 175W] E39 Mogul Base, Horizontal Mount

LUNERA

Description

The Susan Lamp 400W/320W or 250W/175W are plug-and-play replacements for Metal Halide (MH) lamps with an E39 mogul base. With a significantly lower energy consumption than conventional MH lamps, this LED lamp replaces 400W, 320W, 250W or 175W MH lamps.

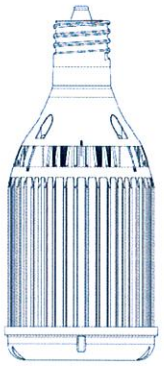


400W/320W
250W/175W

Lunera's BallastLED technology making the lamp truly plug-and-play by allowing it to operate directly off of existing ballasts. Simply replace the existing MH lamp with the Susan Lamp without making any modifications to the fixture.

The Susan Lamp has a rated life of 50,000 hours – 5 times longer than that of MH lamps. That eliminates replacement cycles and reduces maintenance costs.

The Susan Lamp is available in a range of color temperatures including 3500K, 4000K and 5000K. It delivers consistent light levels across its long life, which results in a high quality lighting experience.



400W/320W
250W/175W

Features

- Replaces 400W, 320W, 250W or 175W Metal Halide (MH) lamps
- Plug and Play installation, with existing installed magnetic ballasts
- Ultra-low energy draw, extends existing magnetic ballast life
- Up to 13,100 lumens, fixture delivered light output
- 72W to 145W lamp power, yields 60%-80% energy savings
- >80 CRI
- CCT 3500K, 4000K and 5000K
- Thermal IQ™ to support ambient temperatures up to 150°F
- 50,000 hours to L70 lifespan

Ordering Information

Example: SN-H-E39-400W-320W-4000-G2

Series	Version	Socket Type	Lamp Wattage Replaced	CCT	Generation
SN: Susan Lamp	**H:** Horizontal	**E39:** Fits in mogul (E39) base MH socket	**400W-320W:** 400W (M57) / 320W (M132) **250W-175W:** 250W (M58) / 175W (M57)	**3500:** 3500K **4000:** 4000K **5000:** 5000K	**G2:** 2nd Generation

PROJECT	CONTACT	MODEL NO.
REFERENCE NO.	QUANTITY	DATE

LUNERA SUSAN LAMP

Product Specifications - Horizontal Mount Lamp - 400W / 320W Version

	Driven by 400W (M59) Ballast	Driven by 320W (M132) Ballast
Illumination		
Color Temperatures	3500K, 4000K, 5000K	3500K, 4000K, 5000K
Lumens	3500K: 12,000 lm 4000K: 12,300 lm 5000K: 13,100 lm	3500K: 10,750 lm 4000K: 11,000 lm 5000K: 11,700 lm
Color Consistency	Lunera TruColor™ proprietary process	Lunera TruColor™ proprietary process
Lumen Maintenance (L70)	50,000+ hours life	50,000+ hours life
Electrical System		
Input Voltage	Driven by magnetic MH ballast	Driven by magnetic MH ballast
Power Consumption	145W	120W
Lamp Wattage Replaced	400W	320W
Physical		
Dimensions (H x W)	9.4" x 8.3"	9.4" x 8.3"
Weight	2.5 lbs	2.5 lbs
Housing and Finish	Painted	Painted
Environment		
Ambient Temperature	-40°F to 150°F*	-40°F to 150°F*
Humidity Rating	Damp OK, no direct water spray	Damp OK, no direct water spray
Fixture Type	Open or enclosed	Open or enclosed
Installation		
Socket Type	Fits horizontal mount mogul base (E39/EX39) MH socket	Fits horizontal mount mogul base (E39/EX39) MH socket
Certifications & Qualifications		
UL	Recognized, US & CAN	Recognized, US & CAN
RoHS Compliant	Contains no lead or mercury	Contains no lead or mercury
LM79, LM80, IES Files	Complete	Complete
Warranty		
Warranty	5 years	5 years

* Thermal IQ™ is a proprietary Lunera technology which enables the Susan Lamp to operate reliably up to 150°F ambient by dimming itself at extreme temperatures based upon thermal characteristics of the fixture in which it has been installed.

* Lamp dimming profiles subject to fixture type and environmental conditions. Contact Lunera for more detailed information.

LUNERA®

LUNERA SUSAN LAMP

Product Specifications - Horizontal Mount Lamp - 250W / 175W Version

	Driven by 250W (M58) Ballast	Driven by 175W (M57) Ballast
Illumination		
Color Temperatures	3500K, 4000K, 5000K	3500K, 4000K, 5000K
Lumens	3500K: 7,500 lm 4000K: 7,600 lm 5000K: 8,100 lm	3500K: 6,500 lm 4000K: 6,600 lm 5000K: 7,000 lm
Color Consistency	Lunera TruColor™ proprietary process	Lunera TruColor™ proprietary process
Lumen Maintenance (L70)	50,000+ hours life	50,000+ hours life
Electrical System		
Input Voltage	Driven by magnetic MH ballast	Driven by magnetic MH ballast
Power Consumption	94W	72W
Lamp Wattage Replaced	250W	175W
Physical		
Dimensions (H x W)	9.4" x 8.3"	9.4" x 8.3"
Weight	2.5 lbs	2.5 lbs
Housing and Finish	Painted	Painted
Environment		
Ambient Temperature	-40°F to 150°F*	-40°F to 150°F*
Humidity Rating	Damp OK, no direct water spray	Damp OK, no direct water spray
Fixture Type	Open or enclosed	Open or enclosed
Installation		
Socket Type	Fits horizontal mount mogul base (E39/EX39) MH socket	Fits horizontal mount mogul base (E39/EX39) MH socket
Certifications & Qualifications		
UL	Recognized, US & CAN	Recognized, US & CAN
RoHS Compliant	Contains no lead or mercury	Contains no lead or mercury
LM79, LM80, IES Files	Complete	Complete
Warranty		
Warranty	5 years	5 years

* Thermal IQ™ is a proprietary Lunera technology which enables the Susan Lamp to operate reliably up to 150°F ambient by dimming itself at extreme temperatures based upon thermal characteristics of the fixture in which it has been installed.

* Lamp dimming profiles subject to fixture type and environmental conditions. Contact Lunera for more detailed information.

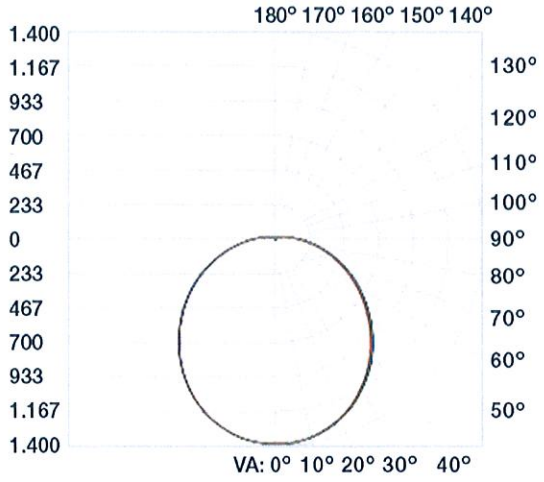
LUNERA®

LUNERA SUSAN LAMP

Photometry

Vertical lamp photometrics for the Susan Lamp E39 400W/320W or 250W/175W versions.
LM-79 REPORT NO. 101930332LAX-021

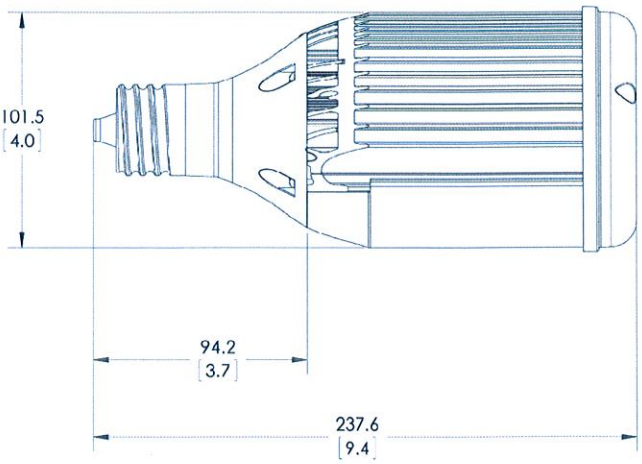
Polar Candela Distribution



Product Dimensions

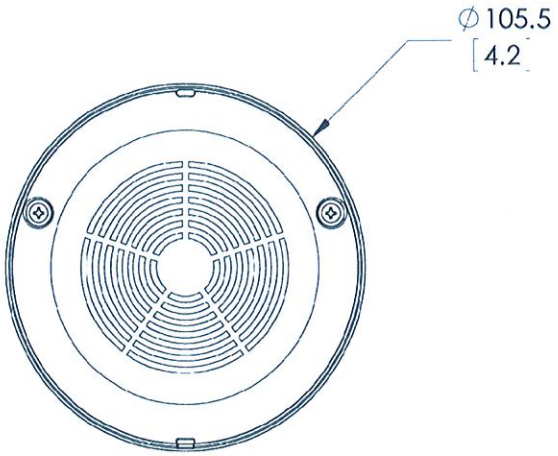
Measurements are rounded up. Dimensions are shown in millimeters. Please contact your Lunera representative for exact dimensions.

[400 / 320W] or [250W / 175W]



CAUTION

- These lamps are NOT approved for use with line voltage.



LUNERA®

Philips | Model # 456590 | Internet # 206402867

4 ft. T8 17-Watt Cool White Linear LED Light Bulb (10-Pack)

★★★★☆ (15) | **Write a Review** | **Questions & Answers (17)**

Was ~~$89.97~~

$62.97 **/case** (limit 35 per order)

Save $27.00 (30%) through 07/06/2016

Red White Blue Savings

- Life: 32.9 years (based on 3 hours/day)
- 2100 lumens
- Energy used: 17-Watt

PRODUCT NOT SOLD IN STORES

Open Expanded View | Click Image to Zoom

PRODUCT OVERVIEW Model # 456590 | Internet # 206402867

Experience hassle-free energy savings simply by replacing your currently liner fluorescent tube with the Philips InstantFit 17-Watt 4 ft. T8 linear LED light bulb. It is the easiest way to replace a linear fluorescent light bulb with an LED solution. Philips InstantFit is a true plug 'n play solution that allows you to leave your existing ballast in your system, while upgrading to the energy savings of LED technology. This product is compatible with most instant start ballasts and requires no modifications to your existing fixture, which means no rewiring is necessary with this InstantFit design. They are ideal for use in general lighting applications where fluorescent lighting is used, and are perfect for applications with frequent "on/off" switching cycles. In residential settings, this light bulb is perfect for laundry rooms, kitchens, garages and basements and in commercial settings in retail offices, parking garages or industrial spaces. Unlike fluorescent bulbs, Philips InstantFit linear T8 LED light bulbs contain no mercury, offering a safe and sustainable, solution, while operating well in cold temperatures.

- Brightness: 2100 Lumens
- Estimated yearly energy cost: $2.05 (based on 3 hours/day, 11 cents/kWh, costs depend on rates and use)
- Life: 32.9 years (based on 3 hours/day)
- Light appearance: 4000K (cool white)
- Energy used: 17-Watt (equivalent to a 32-Watt linear fluorescent light bulb)
- Lumens per watt: 123.5 Lumens
- Uses 55% less energy compared to a linear fluorescent light bulb

- Ideal for use in general lighting applications where fluorescent lighting is used like laundry rooms, kitchens, garages as well as commercial use in offices and hospitals
- Instant fit design means that no modifications are needed to the current fixture housing instant start ballast, nor rewiring, simply plug it in and use
- Contains mercury: no

SPECIFICATIONS

DIMENSIONS

Bulb Diameter (In.)	1.00	Product Height (in.)	1.46
Product Depth (in.)	48.03	Product Width (in.)	1.46

DETAILS

Actual Color Temperature (K)	4000	Light Bulb Shape Code	T8
Average Life (hours)	36000	Light Color	Cool White
Bulb Shape	Linear	Light Output (lumens)	2100
Bulb Type	Linear Fluorescent	Lighting Technology	LED
Color Rendering Index	82	Number in Package	10
Indoor/Outdoor	Indoor	Returnable	90-Day
Light Bulb Base Code	Bi-Pin	Watt Equivalence	32
Light Bulb Base Type	Bi-Pin	Wattage (watts)	17
Light Bulb Features	Energy Saving		

Feedback

WARRANTY / CERTIFICATIONS

ENERGY STAR Certified	No	Manufacturer Warranty	There is a warranty for this item. Please see the package for details.

MORE PRODUCTS WITH THESE FEATURES

Light Bulb Shape Code: **T8** | Bulb Shape: **Linear** | Watt Equivalence: **30 - 45** | Light Color: **Cool White**

Brand: **Philips** | Bulb Type: **Linear Fluorescent** | Light Bulb Base Code: **Bi-Pin**

SEARCH

APPENDIX B

Lanair Waste Oil-Fired Thermostat-Controlled Heater Package — 150,000 BTU, 3500 Sq. Ft. Capacity, Through-Wall Chimney, Model# MX-150B Package B

Item# 46545 New — Write a Review | 1 Answered Question

Only $5499.00

- MX-150 heater
- Pump, filter, fuel piping kit, fuel lines, fittings, and burner
- Rust-resistant galvanized cabinet
- Adjustable locking louvers
- Axial fan

See more details
Factory Shipped —
Estimated Delivery: 7 - 9 Business Days
Not Available in Stores

[+] What do you think of our product images?

Product Summary

With this Lanair Waste Oil-Fired Heater Package, you can take control of rising energy costs. Waste oil not only eliminates the cost to haul used oil off-site, but it can reduce your heating bills too. In addition, burning waste oil to get "free" heat deals with a major pollution problem in an environmentally friendly way. Complete package is designed for commercial use. Advanced atomization technology with monthly maintenance eliminates the tedious daily cleaning required by old vaporization technology. Heat output varies with fuel type, building design, placement and heat loss. U.S.A.

This item is not for sale in the state of California. Customers are responsible for checking local codes and regulations prior to purchase.

What's Included

(1) Heater (1) 80-gal. oil tank (1) Chimney kit

Features + Benefits

- MX-150 heater
- Pump, filter, fuel piping kit, fuel lines, fittings, and burner
- Rust-resistant galvanized cabinet
- Adjustable locking louvers
- Axial fan
- Chimney pipe: Class A kit for 16ft. eave — through-wall
- Chimney location: Top/left side
- AC power: 120V 60Hz.
- Compressed air **(customer supplied)**: 2 CFM, 15 PSI
- Combustion chamber: 12 GA CRS
- Hanging weight (lbs.): 413
- UL listed

Key Specs

Item#	46545
Manufacturer's Warranty	12 months limited parts / No labor
Ship Weight	767.0 lbs
BTU Output	150,000
Heating Capability (sq. ft.)	3,500
Volts	120
Amps	19.5
Blower (CFM)	2,600

Fuel Capacity (gal.)	80
Fuel Type	Waste oil
Fuel Consumption (gal./hr.)	1.07
Thermostat Included	Yes
Chimney Pipe Size (in.)	6
Chimney Type	Through-wall
Dimensions L x W x H (in.)	48 x 40 1/4 x 24

[+] How can we improve these key specs?

Q + A Terms and Conditions
Print Questions + Answers for Lanair Waste Oil-Fired Thermostat-Controlled Heater Package — 150,000 BTU, 3500 Sq. Ft. Capacity, Through-Wall Chimney, Model# MX-150B Package B

[+] How can we improve this page?

Lux | Model # WIN100-005 | Internet # 204356315 | Store SKU # 1000050898

5-2-Day Outlet Programmable Thermostat

★★★★★ (32) | **Write a Review** | **Questions & Answers (10)**

Open Expanded View | Click Image to Zoom


$36.85 /each

- Turn space heaters/window AC into programmable and more efficient
- Programmable outlet thermostat -flexible to comfort & schedules
- Easy plug-in thermostat for weekday and weekend comfort & savings

NEARBY STORES MAY HAVE THIS ITEM

Check Nearby Stores

PRODUCT OVERVIEW

Model # WIN100-005 | Internet # 204356315 | Store SKU # 1000050898

The WIN100 is a programmable 5-2-day heating and cooling outlet thermostat to be used with window air conditioners or electric space heaters. The WIN100 allows users to easily customize heating or cooling temperatures to meet their comfort levels and schedules. The WIN100 is simple to use, extremely accurate and very reliable for year around home comfort and energy savings.

- Weekdays and weekends can be programmed differently
- Armchair programmable
- For use with window air conditioners and electric space heaters 120-Volt
- Digital temperature control with easy to use touch keys
- Display shows the preset and current temperature for easy reference

SPECIFICATIONS

DIMENSIONS

Display height (in.)	.625 in	Product Height (in.)	5.25
Display width (in.)	1.375 in	Product Width (in.)	2.75
Product Depth (in.)	1.75		

DETAILS

Batteries Included	No	Returnable	90-Day
Battery Power Type	Alkaline	Shape	Rectangle
Battery Size	13	System Compatible	Heating Only
Color Family	Whites	Thermostat Features	No Additional Features
Number of HVAC Zones	1	Thermostat Type	Heating and Cooling
Periods per Programmable Day	4	Voltage (volts)	120

WARRANTY / CERTIFICATIONS

Certifications and Listings	4-UL Certified,ETL Listed	Manufacturer Warranty	Three Year Limited Warranty
ENERGY STAR Certified	No		

MORE PRODUCTS WITH THESE FEATURES

Thermostat Features: **No Additional Features** | Color Family: **Whites** | Price: **$30 - $40** | Brand: **Lux**

Review Rating: **4 & Up**

SEARCH

TECHNICAL BULLETIN

PROTECTIVE COATING

K-Flex® 374 Protective Coating is a white vinyl / acrylic water based coating product. It is designed to provide years of protection for flexible elastomeric insulation from the deteriorating effects of the ultraviolet rays (UV) of the sun. K-Flex® 374 Protective Coating should not be confused with waterproof mastic coatings.

K-Flex® 374 has excellent adhesion characteristics to elastomeric insulation products. It is recommended that the coating not be tinted. The minimum storage temperature for 374 is 50°F. K-Flex® 374 can be subjected to temperatures below 50°F as long as the temperature does not fall below freezing. The shelf life is 6 months from the date of shipment from K-Flex USA for unopened containers.

K-Flex® 374 can be applied by brush, roller, or spray. The coating must be applied to a clean surface, free of dirt, grease, oil, etc., to ensure good adhesion. If the surface requires cleaning, wipe with denatured alcohol, which is fast drying and does not leave a residue. The minimum application temperature for K-Flex® 374 Protective Coating is 50°F. Do not dilute K-Flex® 374 Protective Coating. Two (2) coats are recommended for best appearance and optimum performance. Four (4) hours should be allowed for drying between coats. The coating should be allowed to dry for 24 hours before being subjected to rain or temperatures below freezing. K-Flex® 374 applied below 50° F may have the initial appearance of being acceptable, only to crack or flake off at a later date. If the temperature on the day of the installation is below 50° F, the following options are recommended:

- Return to the job and apply the protective coating after it has warmed up. Applying the coating at a later date, provided the insulation remains clean, is better than applying it in unacceptable conditions. If the time period prior to coating application is more than 60 days, the job should be covered, particularly if it is a roof top application.
- The job can be covered / tented and heat applied to the application during the time of coating and drying.
- Maintain a minimum temperature of 50° F for a minimum of 4 hours after application.

K-Flex® 374 Protective Coating may crack over time, especially if the insulation is flexed. The coating is not as flexible or elastic as the elastomeric insulation. The insulation will expand and contract with variations in the ambient and / or operating temperature. This expansion and contraction may cause the coating to form small cracks. Despite these cracks, the coating will not flake off and will continue to protect the insulation from UV exposure. The coating may yellow slightly from its original white color or become less flexible with age, but this will not inhibit its ability to protect the insulation from UV degradation. The product is not recommended for applications where the insulation will be subjected to standing or ponded water, or for burial applications. Like all water-based paints, K-Flex® 374 Protective Coating will require periodic maintenance. Re-application every 3 years will maintain performance.

UV sterilization equipment is sometimes used in air handling systems. These systems give off UV light that is intended to kill mold spores and bacteria. They may be located within duct work or air handling units. Flexible, closed-cell elastomeric insulation materials are subject to surface degradations due to long term or intense UV exposure. When UV sterilization systems are used in air handling systems insulated with elastomeric insulation materials, it is necessary to provide a protective coating to protect the insulation from this UV exposure. Coatings used in air handling systems must be registered with the EPA. K-Flex® 374 Protective Coating is suitable for this application.

Other Coating/Jacketing recommendations:

Factory-applied Cladding

K-Flex USA offers a full line of elastomeric insulation products with factory-applied cladding.

K-FLEX CLAD® AL, available in tube and sheet/roll form, is ideal for outdoor applications. The K-FLEX CLAD® AL jacket consists of a polymeric film with an aluminum finish and PET weathering surface. K-FLEX

CLAD® AL elbows and tees are also available. K-FLEX CLAD® AL can also be used indoors where an ASTM E84 25 / 450 flame spread and smoke developed rating is acceptable. K-FLEX CLAD® AL is highly weather, damage and dent resistant.

K-FLEX CLAD® WT, available in tube and sheet/roll form, is ideal for indoor and outdoor applications. The K-FLEX CLAD® WT jacket consists of a UV stabilized PVC with a white finish and PET weathering surface. K-FLEX CLAD® WT elbows and tees are also available. K-FLEX CLAD® WT is ASTM E84 25 / 50 rated, making it acceptable for use both indoors and outdoors. K-FLEX CLAD® WT is highly weather, mechanical damage and dent resistant. K-FLEX CLAD® WT is NSF certified and is ideal for applications requiring wash-down.

K-FLEX CLAD® IN consists of an extremely durable and chemical resistant (hypalon) elastomeric cladding which can be applied to elastomeric pipe and sheet / roll insulation. This product was developed to withstand the rigors of chemical processing plants, off-shore oil rigs and refineries under the most severe weather conditions. It is ideal for applications with extreme temperature cycling or acidic environments.

Factory-applied cladding systems simplify installation and provide a high performance insulation system while cutting installation time and reducing installation cost and long term maintenance requirements.

Coating Recommendations
The following three (3) coatings have been identified as having excellent adhesion to flexible insulation products. All of these are solvent-based mastics and will provide weather protection when applied per the manufacturer's installation instructions.

Approved Coatings for Outdoor Applications:

- Childers Products Company; CP-30 Low Odor Chil-Perm®
- Foster Products Corporation; 30-35 Foster Tite-Fit™ Coating
- Mon-Eco Industries; 55-10 Eco-Vapor Cote Coating

Approved "Peel and Stick" Covering for Outdoor and Heavy Abuse Applications:

- Polyguard Products, Inc.[(800) 541-4994]; ALUMAGUARD 60™

Additional Approved Coatings (water based) for Light Traffic Areas

- Childers Products Company; CP-10/CP-11 (Brush/Spray)

Surface Preparation
The surface of the insulation must be clean and free of any dust, dirt, scale, moisture, oil and grease. Always follow coating manufacturer's instructions for proper surface preparation.

Application Technique
Always follow coating manufacturer's application instructions and guidelines. Mastic products typically require two coats and may require reinforcing mesh. All coatings will require periodic inspection and maintenance.

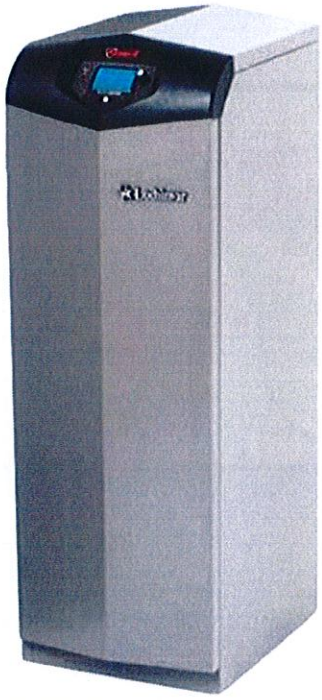
Notes:

1. A slight bleed through of the ink used to identify the insulation product could occur on a single coating application. This will not affect the physical properties of the coating.
2. After long term outdoor exposure, the above coatings may weather to a light tan or yellow color. This surface appearance will not affect any other physical properties of the coating.

Other Jacket Recommendations
At the installer's option, metal or plastic (PVC) jacketing can be utilized to provide the necessary outdoor protection of insulation products. Always follow jacketing manufacturer's application instructions and guidelines.

APPENDIX C

Lochinvar Knight XL KBN400 324000 BTU High Efficiency Natural Gas Boiler



SKU: 102761

$7,888.09/ea CARGO SHIPPING ONLY

Save 29% • Retail: $11,071.00

⚠ Available to Ship in 2-3 weeks

About the Lochinvar KBN400

Lochinvar Knight XL KBN400 324000 BTU High Efficiency Natural Gas Boiler. The Lochinvar Knight XL Series Boilers are the smartest choice for a condensing performance boilers. Engineered with Lochinvar's exclusive SMART SYSTEM Control (LCD Display Screen, and the ability to control up to three temperature set-points) and a vast variety of other innovative features. Knight Boilers promise to deliver ease of installation and maintenance. With up to 94. 6% efficiency, low emissions and a fully modulating burner, these are the best Green Choice for today's conscious market. All boilers are equipped for direct-vent installation with air intake and exhaust runs up to 100 feet. This range of choices is ideal for residential or light-duty applications such as small hotels, schools and office buildings. Included with Lochinvar's Knight XL Boiler Series, is a 399,000-800,000 BTU/hr, and a fully modulating burner with 5:1 turndown. You can find optional equipment kits for your Knight Boilers also.

Product Details

Product:	Boiler
Manufacturer:	Lochinvar
Type:	Pump Relay
Fuel Type:	Natural Gas
Other Info:	Password Securable
Mpn #	KBN400
Dimensions	27 " X 16 " X 43 "
Weight	285 lbs.

Product Features

- Modulating Burner With 5:1 Turndown
- Low Gas Pressure Operation
- Zero Clearances to Combustibles
- Easy Access Terminal Strip
- Natural to LP Conversion Kit
- Inlet & Outlet Temperature Sensors
- Low Water Flow Indication
- Domestic Hot Water Prioritization
- Adjustable Leveling Legs

- Sidewall Vent Terminals
- On/Off Switch
- ASME Stainless Steel Heat Exchanger
- Contact On Any Failure
- SMART SYSTEM Digital Operating Control
- 2 line, 16 Character LCD Display
- Password Security
- Built In Cascading Sequencer
- Building Management System Control
- 0-10 VDC Input Control
- Outdoor Reset
- Night Setback
- Three Pump Control (System, Boiler & DHW)
- Direct-Vent Sealed Combustion
- Pump Relay With Freeze Protection
- Product Service Indicator
- Field Connection Versatility
- Optional PC Or Pocket PC Software
- Floor Standing
- Gallon Capacity: 3.4
- Heating Surface (Sq.Ft.): 41.8
- Water Connections: 1-1/2"
- Drain: 3/4"
- Max Working Pressure: 160 psi
- 50 psi Relief Valve
- Number of Relief Valves: 1
- Relief Valve Size: 3/4"
- Relief Valve Pressure Rating: 50 psi
- Gas Inlet Connection: 1"
- BTU/Hr Input: 399,000
- BTU/Hr Output (High Fire): 372,267
- BTU/Hr Output (Low Fire): 74,453
- Voltage/Heater: 120 V
- Voltage/Control: 24 V
- Total Amps: 1.5 A
- Adjustable High Limit With Manual Reset
- Number of Electrical Connections: 1

- Dimensions (H x W x D): 42-1/2" x 15-1/2" x 27"
- Vent Size: 4"
- Vent Category: IV
- Vent Material: PVC
- Shipping Weight: 285 lb
- Flow Switch
- Temperature & Pressure Gauge
- Direct-Spark Ignition
- Low NOx Operation

Reviews

★★★★★

Be the first to review this product

APPENDIX D

Heating Eff Upgrades

Assumptions

Lafayette TMY3 Data

	Input
Total Heating Bill - MMBTUs	2699
Summer Bill - June/July/Aug	60
Summer Usage (Y/N)	Y
Heating Break Even Temp	55
Peak Winter Load - MBTU*	450
Low Bin Temp	-12.5
Summer Reheat Based Load - MBTU	81
Exiting Fuel (Gas/Oil = 1, Electric = 2)	1
Existing Burner Eff.	79%
Existing Skin Loss at Design Capacity	2%
Existing Losses From Cycling % at Min Load	30%
Existing Losses From Cycling % at Max Load	5%
Proposed Fuel (Gas/Oil = 1, Electric = 2)	1
Proposed Burner Eff. (at 180F if Condensing)	88%
Proposed Burner Eff. (at 120F if Condensing)	92%
Proposed Skin Loss at Design Capacity	1%
Proposed Losses From Cycling % at Min Load	3%
Proposed Losses From Cycling % at Max Load	1%

6am to 6pm		Heating	Existing Eff.				Proposed Eff.				MMBTU Hourly Usage		MMBTU Usage		
Bin Temp	Hours	Load	Burner	Skin	Cycle	System Eff.	Burner	Skin	Cycle	System Eff.	Before	After	Before	After	Savings
102.5	0	-	0%	0%	0%	0%	0%	0%	0%	0%	-	-	-	-	-
97.5	4	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	1	0	0
92.5	24	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	5	2	2.5
87.5	124	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	25	12	13.0
82.5	166	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	33	16	17.4
77.5	321	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	64	30	33.7
72.5	353	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	70	33	37.0
67.5	366	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	73	34	38.4
62.5	412	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	82	39	43.2
57.5	330	81	79%	8%	30%	41%	92%	3%	3%	86%	0.20	0.09	66	31	34.6
52.5	350	94	79%	7%	29%	43%	92%	2%	3%	87%	0.22	0.11	77	38	39.0
47.5	310	122	79%	6%	27%	46%	92%	2%	3%	87%	0.26	0.14	82	43	38.2
42.5	289	149	79%	5%	25%	49%	91%	2%	3%	87%	0.30	0.17	88	49	38.3
37.5	164	176	79%	4%	24%	52%	91%	1%	2%	87%	0.34	0.20	56	33	22.8
32.5	253	204	79%	3%	22%	54%	91%	1%	2%	87%	0.38	0.23	95	59	36.3
27.5	228	231	79%	3%	20%	56%	90%	1%	2%	87%	0.41	0.27	94	60	33.2
22.5	189	258	79%	3%	18%	58%	90%	1%	2%	87%	0.44	0.30	84	56	27.6
17.5	193	286	79%	2%	16%	61%	90%	1%	2%	87%	0.47	0.33	91	63	27.8
12.5	117	313	79%	2%	14%	63%	89%	1%	2%	87%	0.50	0.36	59	42	16.4
7.5	75	341	79%	2%	12%	65%	89%	1%	2%	87%	0.53	0.39	40	29	10.2
2.5	56	368	79%	2%	11%	67%	89%	1%	1%	87%	0.55	0.42	31	24	7.2
-2.5	33	395	79%	2%	9%	69%	89%	1%	1%	87%	0.58	0.46	19	15	4.0
-7.5	18	423	79%	2%	7%	71%	88%	1%	1%	87%	0.60	0.49	11	9	2.0
-12.5	5	450	79%	2%	5%	73%	88%	1%	1%	87%	0.62	0.52	3	3	0.5
		4,536											1,245	721	524

6pm to 6am		Heating	Existing Eff.				Proposed Eff.				MMBTU Hourly Usage		MMBTU Usage		
Bin Temp	Hours	Load	Burner	Skin	Cycle	System Eff.	Burner	Skin	Cycle	System Eff.	Before	After	Before	After	Savings
92.5	0	-	0%	0%	0%	0%	0%	0%	0%	0%	-	-	-	-	-
87.5	28	81	79%	8%	30%	41%	92%	3%	3%	86%	0.2	0.1	6	3	3
82.5	60	81	79%	8%	30%	41%	92%	3%	3%	86%	0.2	0.1	12	6	6
77.5	147	81	79%	8%	30%	41%	92%	3%	3%	86%	0.2	0.1	29	14	15
72.5	315	81	79%	8%	30%	41%	92%	3%	3%	86%	0.2	0.1	63	29	33
67.5	457	81	79%	8%	30%	41%	92%	3%	3%	86%	0.2	0.1	91	43	48
62.5	530	81	79%	8%	30%	41%	92%	3%	3%	86%	0.2	0.1	105	50	56
57.5	381	81	79%	8%	30%	41%	92%	3%	3%	86%	0.2	0.1	76	36	40
52.5	460	94	79%	7%	29%	43%	92%	2%	3%	87%	0.2	0.1	101	50	51
47.5	354	122	79%	6%	27%	46%	92%	2%	3%	87%	0.3	0.1	93	50	44
42.5	404	149	79%	5%	25%	49%	91%	2%	3%	87%	0.3	0.2	123	69	54
37.5	248	176	79%	4%	24%	52%	91%	1%	2%	87%	0.3	0.2	85	50	35
32.5	271	204	79%	3%	22%	54%	91%	1%	2%	87%	0.4	0.2	102	63	39
27.5	270	231	79%	3%	20%	56%	90%	1%	2%	87%	0.4	0.3	111	72	39
22.5	244	258	79%	3%	18%	58%	90%	1%	2%	87%	0.4	0.3	108	72	36
17.5	192	286	79%	2%	16%	61%	90%	1%	2%	87%	0.5	0.3	91	63	28
12.5	130	313	79%	2%	14%	63%	89%	1%	2%	87%	0.5	0.4	65	47	18
7.5	93	341	79%	2%	12%	65%	89%	1%	2%	87%	0.5	0.4	49	36	13
2.5	81	368	79%	2%	11%	67%	89%	1%	1%	87%	0.6	0.4	45	34	10
-2.5	53	395	79%	2%	9%	69%	89%	1%	1%	87%	0.6	0.5	31	24	6
-7.5	21	423	79%	2%	7%	71%	88%	1%	1%	87%	0.6	0.5	13	10	2
-12.5	4	450	79%	2%	5%	73%	88%	1%	1%	87%	0.6	0.5	2	2	0
		4,375											1,399	823	576

	Before	After	Savings
Total MMBTU Usage	2,644	1,544	1,100
% of Bill	98%	57%	41%

Formulas:

Heating Load = if Hrs = 0, 0 if OA > Breakeven Temp, If Summer Usage, Summer Reheat Load, 0, (Summer RH Load + (Peak Load - Summer Reheat Load) x (Breakeven Temp - OA Temp) / (Breakeven Temp - Low Bin Temp)

Burn Eff. = If Load = 0, 0, Avg. Burner Eff.

Skin Loss = If Load = 0, 0, Skin Loss x Peak Load / Building Load

Cycle Loss = If Load = 0, 0, if OA > Breakeven Temp, Cycle Loss at Min Load, Cycle Loss at Min Load - (Cycle Loss at Min Load - Cycle Loss at Peak Load) x (Breakeven Temp - OA Temp) / (Breakeven Temp - Low Bin Temp)

System Eff. = Burner Eff. - Skin Losses - Cycle Losses

MMBTU Usage = if Load = 0, 0, Heating Load x Hrs / System Eff.

MMBTU Hourly Usage = if Load = 0, 0, MMBTU Usage / Hrs

Monthly KW = MMBTU Peak Load x 1,000,000 / 3413

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,500 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

Further information about JTRP and its current research program is available at: http://www.purdue.edu/jtrp

About This Report

An open access version of this publication is available online. This can be most easily located using the Digital Object Identifier (doi) listed below. Pre-2011 publications that include color illustrations are available online in color but are printed only in grayscale.

The recommended citation for this publication is:

Weger, K., & Handy, J. (2016). *Improving energy efficiency of facilities* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2016/29). West Lafayette, IN: Purdue University. http://dx.doi.org/10.5703/1288284316356