Electricity Consumption Assessment at JLG Industries Headquarters: Lighting System Optimization and Recommendations for Energy Consumption Reduction

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Executive Summary

JLG Industries Headquarters, located in Mcconnelsburg Pennsylvania, is the largest facility in the company and also brings in the most revenue to the firm. Properly illuminating such a large production area translates into high annual costs of electricity. The company has also signed an agreement to lower its energy consumption by 25% in less than 10 years. Decreasing the annual electricity consumption due to lighting requirements and positioning itself closer to the energy reduction goal may be accomplished by switching from older lighting technologies like Compact Fluorescent and Metal Halide Bulbs to Light Emitting Diodes (LEDs). For this reason, the department of Environmental Engineers at JLG have asked for PennTAP's assistance in conjunction with Energy Engineering senior students from the College of Earth and Mineral Sciences. The task is to conduct a Lighting Energy Audit to determine the lighting energy consumption, energy reduction possibilities and the costs and payback period of the solution.

Business Background

JLG Industries was founded in 1969 by John L. Grove (JLG). JLG industries is now the world's leading designer and manufacturer of access equipment; more specifically, their main manufactured products are telehandlers and aerial work platforms. JLG headquarters features a facility with a production area of 430,620 ft^2, and an office area of 82,190 ft^2. The hours of operation of the production facility are 24 hours per day, 5 days per week and 52 weeks per year for a total of 6,240 hours of annual operation. The office space runs for 8 hours per day, 5 days per week for 52 weeks per year. This amounts for a total of 2,080 hours. A total of 1,756 employees labor in this company.[1] The following satellite picture of the facility was obtained via google for a site overview.

Figure 1. JLG Industries HQ Aerial view

JLG Industries' total yearly consumption of electricity is 24 million kWh for an annual cost of \$1,700,000.[1] This amounts for an average consumption of 46 kWh / ft^2 / year. JLG has three sources of energy. The company's suppliers are Allegheny Power and West Penn Power for electricity. Central Penn Gas for Natural Gas and Suburban Propane supplies their propane. Their energy requirements are best visualized and compared in the following graph.

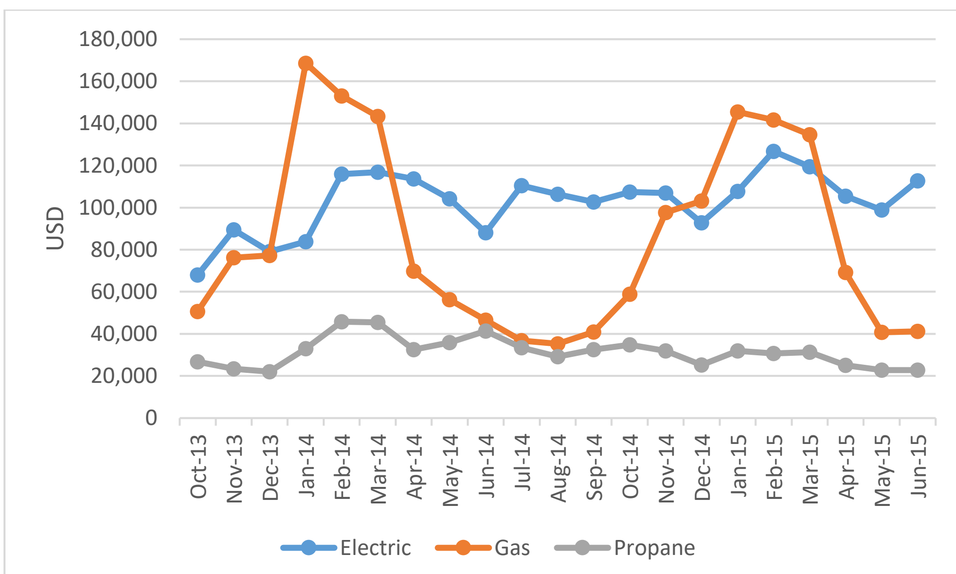


Figure 2. Electric, Gas, Propane Energy cost monthly comparison

This graph portrays the significance of the annual electricity consumption. Among the other energy sources, Natural Gas is responsible for \$1,100,000 annually while propane amounts to \$300,000 per year. Therefore, electricity is the highest source of energy costs. More specifically, electricity is calculated to represent 54% of the total energy costs for JLG headquarters. This relationship depicts that a lighting system retrofit would significantly aid in reducing overall energy consumption to achieve the desired 25% reduction goal.

Site Visit & Team Data Analysis Methodology

Due to the magnitude of the facility, group 1 of the members of EGEE 494 were fragmented into two equal halves with one PennTAP advisor per division. One group took on buildings 7, 8, 9, 11, 12, 19, 24, 25, Building Boom Assembly and office, and Outside areas. The other group assessed buildings 1, 2, 3, 10, 13, 14, 15, 18, 20, 26. Both groups searched the facility for evaluating the type and quantity of lighting devices through visual inspections. The number of fixtures, bulbs per fixtures and rows and columns of fixtures was then recorded. To determine the consumption of the types of lighting used, both groups went to the maintenance department to confirm visual inspections deductions and check on the consumption of the bulbs installed in the facility.

The three main types of lighting encountered were Metal Halides, varying from in power at 250W, 400W and 1000W; Compact Fluorescent bulbs: T12(4ft) -34, T12(8ft) – 95W, T8 – 32 W, and T5 – 54W and some sporadic Light Emitting Diodes (LEDs)- 223 W. The amount of bulbs for each type was recorded by dividing the teams into partners which searched for specific types of bulbs per building. Because of the distinct locations where each bulb type was located within the same room, it was easier to assign partners to focus on finding and quantifying the Metal Halides, while the other partner did the same for the compact fluorescent bulbs. The power consumption was calculated based on the time it was used.

Theory

New technologies of Light Emitting Diodes are replacing older technologies of Metal Halides and Compact Fluorescent bulbs in the market mainly because of their illumination efficiency. This parameter is calculated by the lumens provided by a bulb over the wattage consumed. This relationship is depicted in equation **(1)**. [2]

$$\text{Efficiency} = \text{Lumens} / \text{Watts} \qquad \textbf{(1)}$$

An important aspect to note about Metal Halides is that their CRI index is the highest of the three technologies. The color-rendering index measures how realistic the light that the bulb produces is. For example, the CRI of natural sunlight and a candle are both 100. Incandescent and Halogen bulbs vary from 95-100; LEDs, however, vary form 90-100.[3]

Even though the feasibility of these alternatives was not evaluated during the site visit, some strategies to reduce electric lighting dependency are also worth mentioning. These include, daylight harvesting, occupancy sensors and timers, De-Lamping or over-lighting control, and adjusting lighting for specific tasks where needed.

For calculating the conservation of potential lighting replacements, the following relationships are used:

- Equation **(2)** states the Energy Conservation (EC).

$$\mathbf{EC = (E_{EL} * H_{EL}) - (E_{RL} * H_{RL})} \qquad \mathbf{(2)}$$

Where:
$_{EL}$ = Existing lighting
$_{RL}$ = Replaced lighting
H = Hours of usage
E = Energy

- Equation **(3)** states the Costs (C) in $ / kWh

$$\mathbf{C = (E*P*H\ /1000)} \qquad \mathbf{(3)}$$

Where:
E = Energy consumed (W)
P = Price
H = Hours used

- Equation **(4)** states the Annual Savings (S) in $

$$\mathbf{S = C_{OL} - C_{NL}} \qquad \mathbf{(4)}$$

Where:
C_{OL} = Costs of original lighting
C_{NL} = Costs of New Lighting

- Equation **(5)** states the Payback Period (PP) in years

$$\mathbf{PP = I_{Cost} / S} \qquad \mathbf{(5)}$$

Where:
I_{Cost} = Installment cost
S = Annual Savings

These equations show the relationships that will be used to analyze the data and evaluate the feasibility of the lighting replacement project at JLG Industries' Headquarters.

Results

During the lighting audit, our team found that the illumination technology being used at the facility was 250W, 400W and 1000W Metal Halides bulbs; 4ft and 8ft T12 and T8 bulbs; T5 bulbs and sporadic LED fixtures inside the buildings. A detailed spreadsheet of the quantity of bulbs and fixtures may be found in Appendix A. In addition, this sheet takes into consideration the hours of operation of each group of equipment by dividing them into Full Time shifts: which amount to 7488 hours per year, and Part Time shifts: which amount to 4004 hours per year. The results of the calculations under these parameters are the following expressed on table 1.

Table 1. JLG Headquarters' Annual Energy Consumption from lighting

Annual Energy (kWh)	$ 2,414,341.64
Total Cost / Year	$ 169,003.92

Recommendations & Conclusion

Research in the market shows that new technologies exist which consume less energy and could therefore signify lower electricity costs. However, the replacement of current lighting technologies for LEDs may incur in a higher capital investment because the cost of the new technology is higher. Nonetheless, it should be noted that Metal Halides bulbs have an average lifespan of 10,000 hours and their luminance efficacy decreases steadily over time. Alternatively, LEDs have an average lifespan of 50,000 hours at a consistent level of performance.[4] JLG industries should consider that even though the price of older technologies may be lower, in average, they are replaced at least 4 times for every time an LED bulb has to be replaced. However, it is important to note that this assumption has not been included in the calculations because the facility already owns a significant quantity of old technology lighting replacements.

Below, Table 2 shows the existing lighting and its energy present energy consumption. The proposed LEDs substitutions are located to the right. These products were chosen as the least expensive alternative to the existing lighting technologies at retail price. In addition, the new technologies were selected as direct replacements to the bulb level rather than the fixtures. As a consequence, fixtures will be compatible with both the new and old equipment; eliminating the need of replacing the fixtures as well. This convenience will dramatically lower the total capital costs required, while still being able to achieve the benefits of transitioning to more efficient bulbs. Finally, the detailed expected energy consumption is stated which allows to see the specific energy conservation achieved by each alternative.

Table 2. Replacement Recommendations and Expected Energy Consumption Calculation

Replacement Recommendations							
Existing Lighting	**Energy (KWh/yr)**	**LED equivalent**	**Power (kW)**	**Investment**	**Expected Energy Consumption (kWh)**		
MH 250W	78,533.00	Corn LED Bulb	0.054	$ 89.00	16,963.13	(kWh)	
MH 400W	509,496.00	OEO EZ LED	0.152	$ 144.00	193,608.48	(kWh)	
MH 1000W	140,140.00	Corn LED Bulb	0.25	$ 185.00	35,035.00	(kWh)	
T12	101,253.57	ELED Lights Tube T12	0.04	$ 25.00	78,158.08	(kWh)	
T8	588,368.46	ELED Lights Tube T8	0.015	$ 20.00	273,872.04	(kWh)	
T5	986,618.88	Green LED T5	0.025	$ 13.00	456,768.00	(kWh)	

Table 3, located below, shows the actual energy consumption of lighting which can be replaced. The costs related to these were calculated at a price of $0.07 per kWh. On the right side of the table, the expected annual energy consumption was calculated after replacements. The annual costs were also calculated at a price of $0.07 per kWh. The annual costs with the present technology is $168,208.69. After switching to the proposed alternative, the expected energy cost is $73,808.33.

Table 3. Existing vs. New Lighting Annual Demands & Costs

Existing Lighting Power Demand	2,404,409.90	**kWh**	**New Lighting Power Demand**	1,054,404.73	**kWh**
Costs ($0.07 / kWh)	$168,308.69		**Costs (0.07 / kWh)**	$73,808.33	

Because purchasing LEDs is more expensive than the existing technologies, the total capital costs required to implement this project were calculated. Table 4 shows this relationship as well as the payback period. Replacing all the bulbs for the proposed alternatives amounts to a required capital cost of $ 133,787. Taking into consideration the projected annual savings of $ 94,500.36, the expected payback period for the execution of this project is 16 months and 21 days.

Table 4. Quantity of bulbs required, cost per bulb, total capital required, payback period

Capital Investments						
Type	**Corn LED**	**OEO EZ LED**	**LED Corn**	**ELED T12**	**ELED T8**	**Green LED T5**
# Bulbs	48	205	35	488	2480	2440
Cost per Bulb	$ 89.00	$ 144.00	$ 185.00	$ 25.00	$ 20.00	$ 13.00
Replacement Costs	$ 4,272.00	$ 29,520.00	$ 6,475.00	$ 12,200.00	$ 49,600.00	$ 31,720.00
Total Capital Required	$ 133,787.00					
Payback Period (Years)	1.42					

Table 5, located below, shows a quick summary of the most important parameters obtained from this evaluation. If the proposed alternative is executed, the expected energy conservation will be about 1,350,000 kWh per year. This amounts to a 56% decrease in the total electricity consumption due to lighting in JLG Headquarters. In terms of dollars, this project would represent a $94,500 decrease in the annual electricity costs. For purchasing all the equipment required, a total of $133,787 must be invested. However, the payback period is relatively quick at 1.42 years because only the bulbs are being replaced. It is important to note that if some fixtures need replacement as well, this cost would rise significantly as other technology would be required.

Table 5. Proposed Solution Conclusion

Energy Conservation (kWh)	1,350,005.18
Percentage Decrease	56%
Annual Savings ($)	$ 94,500.36
Capital Investment	$ 133,787.00
Payback Period (years)	1.42

JLG industries had expressed interest in achieving a 25% decrease in their energy consumption in the near future. Electricity consumption represents a 60.71% of their total energy demands. After conducting this audit and evaluating the data gathered, it can be calculated that switching to LEDs would decrease Annual Energy Consumption from lighting by 56%. Knowing from this evaluation that lighting represents 10% of the facility's electricity consumption, it can be calculated that transitioning to LEDs would decrease the total energy demand by 3.4%. This is a relatively simple first step towards their objective.

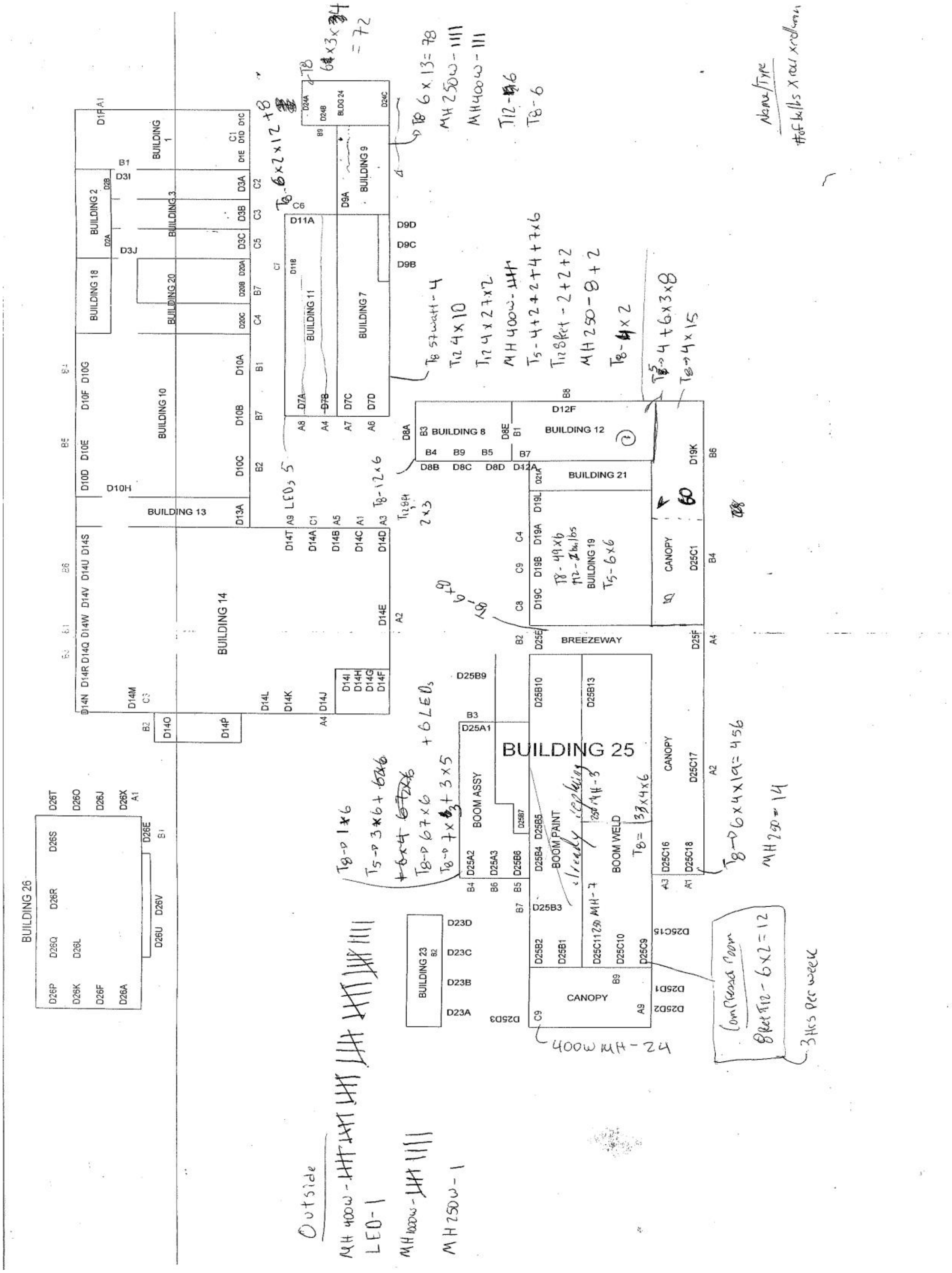
To further reduce lighting consumption, rules should be implemented to increase the facility's energy efficiency. Our guide during the site visit revealed that lighting may be left on during hours where there was no operation. As this report shows, every second of lighting operation is dollars of electricity costs. Therefore, lighting controls could be implemented in which supervisors overview lighting and takes responsibility for using lighting only where and when it is required. Other than this, JLG should also inquire about daylight harvesting solutions that could help into further reducing lighting electricity demands. Most of the buildings allowed little to no outside light in, depending solely on electricity.

As for error, it should be noted that several sources are possible within this report. The most prominent is the data recollection method used. Because the teams were divided into sub-teams and we had no previous experience working together, there was complete confidence in the second team being accurate in evaluating the types of bulbs encountered. In addition, the cost of electricity was assumed to be $0.07 at all times, as stated at the Pre-site evaluation form. This neglects peak hour demands and price shifts that result.

References

1. *Pre-site Assessment Information*, as found on ANGEL, JLG Folder. July, 2015
2. *Lighting Reading Materials: Modules 1-4*, as found on ANGEL, PennTAP Required Readings.
3. Shapiro, I. M. (2016). Overview. In *Energy Audits and Improvements for Commercial Buildings* . Hoboken, NJ, USA: John Wiley & Sons, Inc.
4. *Lighting and Compressed Air. Dir.* PENN TAP. Leadership in Building Energy Efficiency, 2015. Slide program.

Appendix A: Audit Sheet Map for Sub-team 1



Appendix B: Audit Spreadsheet for Sub-team 2

Bldg 10 - ignore halogen (safety - backup)

LAMP INVENTORY BY LOCATION

Company/Site: JLG Mcconnellsburg   Date: 9/27/16   Group: 1 - (1 site)

Candidate for (type) of control (see note #2)	Location	Lamp Description Include: Bulb Type (see Note #1) For Fluorescents Include: "T#" (e.g., T12; T8; T5) Length (e.g., 2ft; 4ft; 8ft)	Watts/Bulb	# Bulbs/Fixture	# Fixtures/ room/area	# Rooms (usually 1)	Total # Bulbs	Time Lamps are "On" per year: Hrs/day Basis: Hrs/day	Days/Week	Weeks/Yr	% of "x" Basis: % of "x"	"x" = max hrs/yr
	Bldg 1 - ~~Section C1~~	T5 - 4ft	54	6	~~30~~	1		24	6			
	Bldg 3 - Bay 1 D3A	T5 - 4ft	54	6	140 20	1						
	Bldg 3 - Bay 2 D3B	T5 - 4ft	54	6	21	1						
	Bldg 3 - Bay 3 D3C	T5 - 4ft	54	6	20	1						
	Bldg 20 - A&B	T5 - 4ft	54	6	18	1						
	Bldg 20 - C	T5 - 4ft	54	6	21	1						
	Bldg 20 - Hallway	T5 - 4ft	54	6	5	1						
	Bldg 2											
	Bldg 18											
	Bldg 10	T5 - 4ft	54	6	86							
	Bldg 10 - office (including upstairs)	T8 - 4ft	32	4	12							
	Bldg 10 - office hallway	T8 - 4ft	32	2	2							
	Bldg 10 - workstation	T8 - 4ft	32	2	1							
	Bldg 10 - Metal Halide	400 - MH	400	1	1							
	Bldg 13 - Hallway	T12 - 8ft	95	2	2							
	Bldg 13											
	Bldg 14 - 800s	T5 - 4ft	54	6	52							
	Bldg 14 - 1100 - 1500	T5 - 4ft	54	6	52							
	Bldg 14 - 642 - 1043	T5 - 4ft	54	6	54							
	Bldg 14 - 1055/1255	T5 - 4ft	54	6	31							
	Bldg 14 - side (wallshared w/ Bldg 13)	T8 - 4ft	32	2	12							
	Bldg 14 - corner room	T12 - 4ft	95	2	2							

Note #1: Bulb Type Includes:
FL = Fluorescent, INC = Incandescent
MH = Metal Halide, CFL = Compact Fluorescent
MV = Mercury Vapor, HPS = High Pressure Sodium

Note #2: Type of Control Includes:
OCC = Occupancy Sensor, DIM = Dimmer
PHO = Light Sensor, on/off, TIM = Timer
3LS = 3 Level light switch

LAMP INVENTORY BY LOCATION

Company/Site: JLG - McC **Date:** 9-27-16 **Group:** 1-1

Candidate for (type) of control (see note #2)	Location	Lamp Description (Include: Bulb Type (see Note #1); For Fluorescents Include: "T#" (e.g., T12; T8; T5), Length (e.g., 2ft; 4ft; 8ft))	Watts/Bulb	# Bulbs/Fixture	# Fixtures/ room/area	# Rooms (usually 1)	Total # Bulbs	Time Lamps are "On" per year: Hrs/day Basis: Hrs/day	Days/Week	Weeks/Yr	% of "x" Basis: % of "x"	"x" = max hrs/yr
	Bldg 14 - Axel buildup	T5-4ft	54	4	14			24	6			
	Bldg 14 - Receiving Dock	Metal Halide - 400	400	1	12							
	Bldg 14 - Center Office	T5-4ft	54	4	18							
	Bldg 26 - Metal Halide	MH	400	1	77							
	Bldg 26 - LED (2ft) small	LED - 2ft		4	4							
	Bldg 26 - T12	T12-8ft	95	2	8							
	Bldg 26 - T5	T5-4ft	54	6	8							
	Bldg 26 - LED large	LED - 4ft		4	4							
	Bldg 26 - Washing bay 1	T5-4ft	54	6	8							
	Bldg 26 - Washing bay 1	T12-8ft	95	2	1							
	Bldg 26 - washing bay 1	MH	400	1	6							
	Bldg 26 - washing bay 2	MH	400	1	14							
	Bldg 26 - washing bay 2	T12-8ft	95	2	1							
	Bldg 26 - Perimeter (LED)	LED		4	1							
	Bldg 26 - Perimeter (MH)	MH - 1000	1000	1	10							
	Bldg 26 - Perimeter (HID)	HID	250	1	2							
	Bldg 26 - Perimeter (MH small)	MH	400	1	3							
	Bldg 15 - Cab Assembly	T5-4ft	54	4	24							
	Bldg 15 - Perimeter	MH	400	1	8							
	Bldg 10 - Exterior - B5	MH	400	1	4							
	~~Bldg 14 - B1 side (exterior)~~	~~MH~~			4							
	~~Bldg 14 - B2 A9~~	~~MH~~			2							

- open wall to outside on 24/7

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Note #2 Type of Control Includes:
OCC = Occupancy Sensor; DIM = Dimmer
PHO = Light Sensor on/off; TIM = Timer
3LS = 3 Level light switch

Assuming 6 days/wk - Not always on but on average approximately 6 days/wk

LAMP INVENTORY BY LOCATION

Company/Site: JLG McC **Date:** 9-27-16 **Group:** 1-1

Candidate for (type) of control (see note #2)	Location	Lamp Description Include: Bulb Type (see Note #1) For Fluorescents Include: "T#" (e.g., T12; T8; T5) Length (e.g., 2ft; 4ft; 8ft)	Watts/Bulb	# Bulbs/Fixture	# Fixtures/ room/area	# Rooms (usually 1)	Total # Bulbs	Time Lamps are "On" per year: Hrs/day Basis: Hrs/day	Days/Week	Weeks/Yr	% of "x" Basis: % of "x"	"x" = max hrs/yr
	Bldg 14 - Bumpout perim	MH	400		1			24	6			
	Bldg 14 - Bumpout perim	LED		1	1							
	Bldg 14 - Perimeter (Total)	MH	1000		15							
	Bldg 14 - Courtyard	MH	400	1	8							
	Bldg 10/20/3/1 - - (South Wall) - outside	MH	400	1	10							
	Bldg 1 - outside (East)	MH	400	1	5							
	Bldg 1 - outside (East)	MH	250	1	2							
	Bldg 10 - outside (North)	MH	250	1	4							
	Bldg 2 - Maintenance shop	T5-4ft	54	6	14							
	Bldg 2 - Maintenance shop (upper)	T12-8ft	95	2	10							
	Bldg 2 - Maintenance shop (lower)	LED		1	20							
	Bldg 2 - Maintenance shop (upper)	T8-4ft	32	3	4							
	Bldg 2 - Maintenance (upper)	T12-4ft	34	2	3							

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