PHOTOVOLTAIC SYSTEM PROPOSAL TO REDUCE KOKOMO TRANSMISSION PLANT'S ELECTRICAL DEPENDENCY

by

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LIST OF ABBREVIATIONS

AC - Alternating Current

BAS - Building Automation System

DC - Direct Current

FCA - Fiat Chrysler Automobiles

KTP - Kokomo Transmission Plant

kWh - Kilowatt Hour

NREL - National Renewable Energy Laboratory

PV - Photovoltaic

PCU - Powered Condition Unit

ROI - Return on Investment

SAM - System Advisor Model

UG - Utility Grid

GLOSSARY

Alternating Current - An electric current that reverses its direction many times a second at regular intervals (U.S. Department of Energy, 2019).

Carbon Footprint - The amount of carbon dioxide and other carbon compounds emitted due to the consumption of fossil fuels by a particular person, group, etc. (EPA, 2018).

Direct Current - Electrical current that runs continually in a single direction (Lantero, 2014).

Flat Roof PV System - A photovoltaic system that mounts to the roof of a building (Peek, 2014).

Gigajoule - A measure of energy that equals one billion joules (NREL, 2016).

Greenhouse Gas - Gases that trap heat in the atmosphere (EPA, 2018).

Kilowatt-hour - One thousand watts acting over a period of one hour. The kWh is a unit of energy (U.S. Department of Energy, 2019).

Photovoltaic System - The use of photovoltaic cells to convert sunlight to energy (NREL, 2016).

Power Inverter - A device on a photovoltaic system that converts DC power (direct current) to AC power (alternating current) (Vratislav, 2016).

Powered Condition Unit - Integrated system consisting of a solar charge controller, inverter and a grid charger (Dutton, 2018).

Shading - When an obstruction such as a tree or building is blocking sunlight to a photovoltaic array (Girish, Lakshmi, Rajkiran & Sathyanarayana, 2015).

Soiling - The effect of environmental elements or other debris covering a panel, that hinders optimal performance (UCS, 2015).

ABSTRACT

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Automotive manufacturers are striving to go green, while exceeding the expectations of their stakeholders. The Engineering Technology Capstone Project focused on implementing a photovoltaic (PV) system at the Kokomo Transmission Plant (KTP). The installation of a PV system will reduce KTP's dependency on fossil fuels, while reducing their carbon footprint. The capstone project is to improve KTP's environmental impact while reducing their electrical consumption cost in kilowatt per hour (kWh). The capstone project investigated the type of roof mounted PV system, maintenance, cost, benefits and environmental impact.

CHAPTER 1. INTRODUCTION

1.1 Problem Statement

Kokomo Transmission Plant (KTP) paid Duke Energy over eleven million dollars for electricity in 2017 and the amount increased for 2018 (Rockwell Automation Energy Metrix, 2012). Electrical cost places constraints on the number of projects implemented throughout the facility each year due to the allotted funding. The problem will be measured based off electrical cost consumption (PV Watts Calculator, 2018), PV system performance (Peek, 2014) and environmental impact by greenhouse emission reductions (Barrows, Bird, Ibanez, Margolis & Palmintier, 2014). The problem ties to a grand engineering challenge because installing a PV system at KTP will reduce the facilities carbon footprint (National Academy of Engineering, 2018).

1.2 Problem Impact

Dependency on fossil fuels are excessive at eighty percent consumption throughout the world (The World Bank, 2018). The world is depleting our fossil fuel reserves at a rate faster than new ones are being created (The World Bank, 2018). Fossil fuels are a non-renewable energy source that take millions of years to create. The extensive duration for new fossil fuels to be completed have caused the world to develop new renewable energy sources. Photovoltaic (PV) systems are one of many renewable energy resources that have been capable to combat our dependency on fossil fuels.

Kokomo Transmission Plant (KTP) spent over eleven million dollars alone for electricity from Duke Energy in 2017 (Rockwell Automation, 2012). After the end of the third quarter for 2018, KTP is on pace to exhaust over twenty million dollars before 2019 (Rockwell Automation

2012). The increase in electrical consumption is due to the high demand for the four, six and eight speed transmissions. The other areas that consume electricity are the engine block and nine speed business segments. The KTP facility is 3.1 million square feet and sits on one hundred and ten acres of land (n.a., 2016). A large building with a flat roof the size of KTP presents many opportunities with the installation of a PV system. Department 6200 will be the focus of the proposal for the installation of a PV system. Department 6200 is 132,000 square feet in size. Last year in 2017, department 6200's electrical cost was $572,000.

1.3 Problem Measure

The PV Watts Calculator Version 5.3 and System Advisor Model (SAM) will be the programs to determine the size of the array expanding over department 6200 (NREL, 2018). The National Renewable Energy Laboratory (NREL) is the creator of the PV Watts Calculator and SAM. The PV Watts Calculator determines the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems and allows installers and manufacturers to easily develop estimates of the performance of potential PV installations (NREL, 2018). The System Advisor Model will be the program that will generate simulations and statistical models of data that will support the problem statement. The other tool to create and use is an economic analysis of the PV system. The economic analysis displays all the costs that will be associated with the installation of a PV system. The economic analysis is vital to demonstrate the cost of the array and when Fiat Chrysler Automobile's (FCA) will see a return on their investment (ROI).

1.4 Summary

Chapter one is explaining the problem Fiat Chrysler Automobiles is currently facing with the high electrical cost to operate their manufacturing facility. Kokomo Transmission Plant is a

3.1 million square foot facility that is consuming much electrical energy to meet their aggressive production schedule. The large monetary cost of electrical consumption is not the only problem FCA is facing. The reduction of FCA's carbon footprint is a challenge to be overcome. The decline of FCA's carbon footprint demonstrates to the public that FCA is investing in technology to make them greener as an organization. The earth is dependent on fossil fuels and they are the primary driver that is fueling the world. The implementation of a suitable renewable energy resource such as a photovoltaic array will reduce FCA's dependency on fossil fuels.

Department 6200 is the home of the six-speed transmission assembly. Department 6200 is 132,000 square feet in size. The focus of the capstone research project is to achieve capital funding to install a photovoltaic array on the rooftop above department 6200. The utilization of three tools will provide reasoning for a photovoltaic array that will support the problem statement. The PV Watts Calculator and SAM will allow one to select the exact location and size of the PV array. The monthly monetary reduction in electrical cost will be of a calculation through the PV Watts Calculator and SAM programs. The third tool is an economic analysis to verify the cost savings by year to display when FCA executives will see a return on their investment.

CHAPTER 2. REVIEW OF LITERATURE

The Kokomo Transmission plant consists of multiple departments throughout the 3.1 million square foot facility. Department 6200 will be the focus of the PV system proposal. Department 6200 is the location of the six-speed assembly. The department 6200 machines are between twenty and thirty years old. The machines are not energy efficient and are expensive to operate throughout the KTP facility. A shutdown procedure checklist is in place, which is the only current cost saving opportunity in department 6200. The 2017 energy bill for department 6200 was $571,065.02 (Rockwell Automation, 2012). The installation of a rooftop PV system using the PV Watts calculation will reduce the energy bill up to $175,000 per year (NREL, 2018).

Rogers and Wisland (2014) state:

> Solar power offers the potential to generate electricity with no global warming pollution, no other emissions, no fuel costs, and no risks of fuel price spikes. Solar is, to a great extent, an equal opportunity renewable energy, with sufficient sunshine across the nation to make solar an attractive option in every state. (p. 1)

By 2020, FCA has a target of 32% reduction in carbon dioxide emissions per each vehicle (FCA Sustainability Report, 2017). The 2018 FCA business plan outlines that a 30% reduction in energy consumed per vehicle must be met by 2020 (FCA Sustainability Report, 2018). Fiat Chrysler Automobiles met their 2010 sustainability goal in 2017 of a 33% carbon dioxide reduction per each vehicle (from 0.616 to 0.413 tons CO_2/vehicle) (FCA Sustainability Report, 2018). The 2010 business plan for the energy consumption metric of a 24% decrease was met throughout production (from 7.36 to 5.60 gigajoule (GJ)/vehicle (FCA Sustainability

Report, 2018). The KTP facility can contribute to the 2020 energy business plan by implementing a PV system on the roof. The KTP facility's entire roof is flat and would benefit with the installation of a roof racking PV system. Figure 2.1 is an aerial screenshot of the KTP rooftop.

Figure 2.1: KTP Aerial Rooftop View

The outline of the entire KTP facility is in yellow and department 6200 is in red. The facility has over 3 million square feet of space on the roof to install a PV system for cost saving opportunities.

2.1 Flat Roof PV System

Rooftops provide a large expanse of untapped area for solar energy generation, and onsite distributed generation could potentially reduce the costs and losses associated with the transmission and distribution of electricity (Elmore, Gagnon, Margolis, Melius & Phillips, 2016).

Flat roof photovoltaic systems are solar panels that mount to the roof of a building. The panels absorb the energy from the sun and generate the absorption into electricity. The main components that make up a flat roof PV system are PV modules, solar cables, power inverters and rooftop mounting brackets (Feldman, D., Friedman, B. & Margolis, R., 2013). Flat roof PV systems is an ideal choice for consumers because they do not take up ground space. The flat roof PV system will perform on a roof better than the ground because there are no obstructions that will block sunlight.

Rogers and Wisland (2014) state:

> Rooftop systems also reduce strain on electricity distribution and transmission equipment by allowing homes and businesses to first draw power onsite instead of relying completely on the electricity grid. The benefits are twofold: the use of on-site power avoids the inefficiencies of transporting electricity over long distances, and on-site systems potentially allow the utility to postpone expensive upgrades to its infrastructure. (p. 3)

There are multiple factors to consider to achieve the maximum return on investment of rooftop PV systems (Barrows, Bird, Denholm, Ibanez, Margolis & Palmintier, 2014).

- The slope of the roof.
- Yearly weather conditions.
- The location’s latitude and longitude coordinates.
- Roof quality.
- Shading from other buildings nearby.
- Peak hours of sunlight per day.

Figure 2.2 on page seventeen is a design of a PV cell that is on a PV panel. When sunlight contacts PV panels, electrons release that collect in an electrical circuit. The electrons are the energy that the world consumes to provide electricity. Below are three explanations detailing how a PV array works in Figure 2.2.

Elbaset and Hassan (2017) state:

> The system is mainly composed of a matrix of PV arrays, which converts the sunlight to DC power, and a power conditioning unit (PCU) that converts the direct current (DC) power to an alternating current (AC) power. The generated AC power is injected into the utility grid (UG) and/or utilized by the local loads. (p. 8-9)

Rogers and Wisland (2014) state:

> PV cells are composed of two layers of semiconductor material with opposite charges. Sunlight hitting the surface of a cell knocks electrons loose, which then travel through a circuit from one layer to the other, providing a flow of electricity. (p. 3).

Kiatreungwattana, VanGeet & Stoltenberg (2016) state:

> Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulating electrons (negative charges) in a layer in the cell designed to give up electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load, e.g. light bulb. (p. 8).

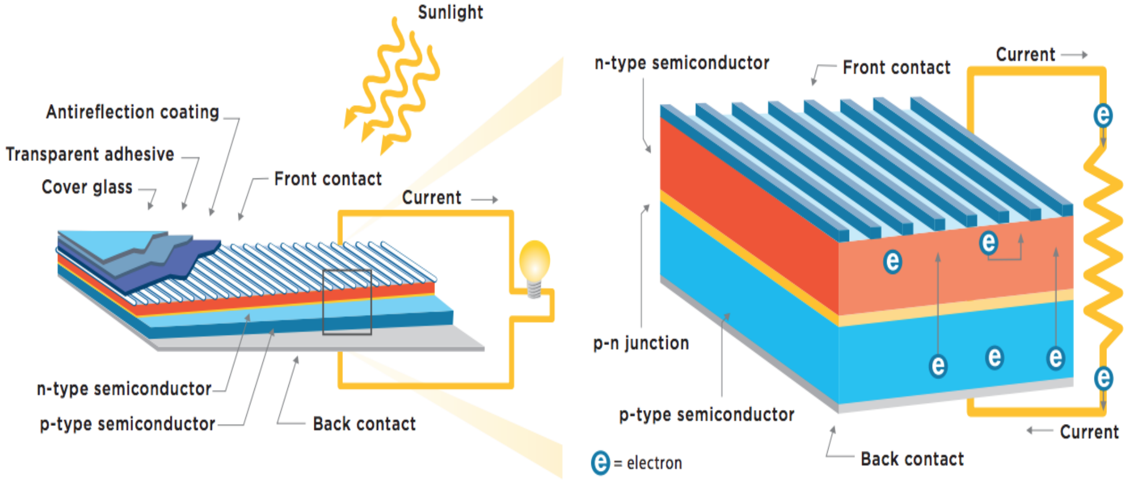

Figure 2.2: PV Cell Make-Up

Figure 2.3 is an example of a ballast rooftop PV system. The KTP facility has a large flat tin metal roof similar to Figure 2.3. The PV panels will be at a thirty-nine-degree tilt in the direction of the sun to attain maximum sunlight exposure as seen in Figure 2.3.

Figure 2.3: Rooftop PV System

2.2 PV System Maintenance

The life cycle of a pv array is twenty-five years (NREL, 2018). Flat roof PV systems require annual and bi-annual maintenance (NREL, 2016). The panels are made of tempered glass that withstand the elements such as high winds and hail. Soiling occurs that require an individual to clean the panels with a sponge and warm soapy water. Examples of soiling are pollen, dust, and bird droppings that will reduce the panels operating performance (NREL, 2016). Electrical and structural problems require the consumer to contact the PV installer to diagnose and repair (NREL, 2016). Table 2.1 and table 2.2 below is an electrical and cleaning frequency from the NREL to apply as a best practice (NREL, 2016). The tables explain the different types of cleaning and electrical inspection requirements for a PV array.

Table 2.1: PV Array Cleaning Frequency

Service Name	Service Description	Service Category	O&M Category	Interval	Service Provider
General cleaning	General cleaning/veg mobilization	Cleaning	PV Array	Condition or study dependent	Mower/ Trimmer
Array cleaning	Array cleaning	Cleaning	PV Array	Condition or study dependent	Cleaner
Snow cleaning	Snow removal	Cleaning	PV Module	Condition or study dependent	Cleaner
Dust cleaning	Dust removal: agricultural /industrial	Cleaning	PV Module	Condition or study dependent	Cleaner
Pollen cleaning	Pollen cleaning	Cleaning	PV Module	Condition or study dependent	Cleaner
Vegetation management	Determine if any new objects, such as vegetation growth, are causing shading of the array and move them if possible. Remove any debris from behind collectors and from gutters.	Cleaning	PV Array	As needed	Mower/ Trimmer
Bird cleaning	Bird Cleaning	Cleaning	PV Array	Bi-annual	Cleaner

Table 2.2: PV Array Electrical Maintenance Frequency

Service Name	Service Description	Service Category	O&M Category	Interval	Service Provider	Warranty Type	Applicable Unit
Contractor response	Contractor available by email and phone 24x7x365	Emergency Response	PV Array	Ongoing	Administrator	N/A	System
Corrosion inspection	Inspect electrical boxes for corrosion or intrusion of water or insects. Seal boxes if required.	Inspection	AC Wiring	Annual	Inspector	N/A	Combiner Box
AC disconnect switch inspection	Check position of disconnect switches and breakers.	Inspection	AC Wiring	Annual	Inspector	N/A	Disconnect Box
Protection device inspection	Exercise operation of all protection devices.	Inspection	AC Wiring	Annual	Journeyman Electrician	N/A	
AC disconnect box inspection	AC disconnect box inspection	Inspection	Electrical	Annual	Electrician	N/A	Disconnect Box
Grounding inspection	Test system grounding with "megger"	Inspection	DC Wiring	Annual	Master Electrician	N/A	Strings
Cable inspection	Inspect cabling for signs of cracks, defects, pulling out of connections; overheating, arcing, short or open circuits, and ground faults.	Inspection	DC Wiring	Annual	Inspector	N/A	Strings
DC disconnect switch inspection	Check proper position of DC disconnect switches.	Inspection	DC Wiring	Annual	Inspector	N/A	
Combiner box inspection	Open each combiner box and check that no fuses have blown and that all electrical connections are tight. Check for water incursion and corrosion damage. Use an infrared	Inspection	DC Wiring	Annual	Journeyman Electrician	N/A	Combiner Box

2.3 Environmental Impact of a Roof Mount PV System

Photovoltaic arrays have become a customary choice for organizations around the world as a renewable energy resource. Solar power provides health, environmental and climate benefits by reducing emissions of carbon dioxide and criteria air pollutants, which include sulfur dioxide, nitrogen oxides, and fine particulate matter (Apt, Azevedo, Evans & Morgan, 2013).

Photovoltaic generation will produce the following environmental benefits:

- No contribution of greenhouse gases that increase global warming (UCS, 2015).
- Produces no harmful emissions associated with coal power (UCS, 2015).
- Creates none of the long-lasting problems associated with nuclear power (UCS, 2015).
- No harmful effects that can contribute to contamination of waterways (UCS, 2015).

2.4 Summary

Chapter two explained FCA's sustainability report from their 2010 business plan and how the organization met their energy targets. The 2018 business plan outlined even more improvements to be met in order to reduce FCA's electrical consumption. The flat roof at KTP is a prime candidate for a roof mount PV array. There are no obstructions on the roof that will cause the PV arrays to not be able to absorb the energy from the sun. After installation of the PV array, they require minimal maintenance and cleaning to prevent soiling. Chapter two went into detail of what components are in a PV array and how a PV array works. Following the PV arrays functionality, also mentioned is the environmental benefits of an installed PV array.

CHAPTER 3. RESEARCH METHODOLOGY

The purpose of the research is to demonstrate the yearly electrical cost and carbon dioxide reduction with the installation of a flat roof PV system. Renewable energies exhibit very low specific greenhouse gas emissions (Blechinger, Breyer & Koskinen, 2015). A flat roof PV system not only will save FCA money, but the organization will see a reduction in greenhouse emissions. The problem tied in with an engineering grand challenge because installing a PV system will lower KTP's emissions while the world creates new methods to sequester carbon dioxide (National Academy of Engineering, 2019).

3.1 Research Instruments

The EnergyMetrix report by Rockwell Automation is a database that allows a person to view all electrical consumption at KTP. The KTP facility's electricity is from Duke Energy. The researcher can view each monthly billing cycle before and after the installation of a roof PV system shown in Appendix A. EnergyMetrix provides the data to show the improvement of the reduction in KTP's electrical spending.

The PV Watts Calculator Version 5.3 provides estimations of the cost savings with the installation of a roof PV system (NREL, 2018). The program utilized Google Maps to select any location in the world where the user can highlight the size of an area for a specific PV system. The PV Watts Calculator displays by month the performance estimation of a PV system. The information from PV Watts created a baseline to understand the effectiveness of a PV system at KTP.

Working at FCA, executives expect to see statistical cost saving models if they plan to invest money on the PV system project. The System Advisor Model (SAM) is a performance and financial model designed to facilitate decision making for people involved in the renewable energy industry (NREL, 2018). The SAM makes performance predictions and cost of energy estimates for grid-connected power projects based on installation and operating costs and system design parameters that you specify as inputs to the model (NREL, 2018).

3.2 Procedures for Data Gathering

The data collection came from a computer and by an interview. All data will list in detail the procedures to follow to access the specific energy and monetary savings for each research instrument.

3.1.1.1 PV Watts Calculator Version 5.3

- Open the PV Watts Calculator online.
- Enter the PV system locations address.
- Wait for the system to analyze and generate the weather report from the location entry.
- Click on the tab "system info" and began entering the size of the PV system.
- If unsure of the system dimensions, one can draw the size of the PV system of the location through Google Maps. This will generate the PV system specification from the size drawn.
- Click on the results page and an estimate of the energy savings by month for a year that the PV system can provide.

3.1.1.2 System Advisor Model (SAM)

- Open the System Advisor Model online.
- Enter the address of the PV system installation.
- Enter the PV system specifications.

- Click simulate to generate the graphs of the energy and dollar savings.

3.3 Presentation of Data

Table 3.1 is the monetary saving estimates for department 6200 six-speed transmission by the PV Watts Calculator. The PV Watts Calculator determined the appropriate positioning of the PV arrays according to the specific street address. Table 3.1 on page twenty-five displayed a yearly estimate of the AC and DC output, the solar radiation absorption and the cost savings according to operating performance. The importance of the table below on page twenty-four is in the "AC System Output" and "Value" columns. The first-year return on the PV array is over $175,000. The addition of the standard discount rate of three percent for the first-year savings calculate to $184,000. The monetary savings are important because being unable to achieve an economic payback before year eight will not gain approval at FCA. Environmental projects at FCA must require an economic payback between five to nine years. All non-environmental projects cannot exceed four years for a ROI. The extension for environmental projects is due to FCA wanting to contribute to reducing pollution globally. The AC system of the PV array generated an annual estimate of 2,068,115 kWh of output. The figure is important because having the PV array will cut FCA's reliance on electricity by 2,068,115 kWh a year. Fiat Chrysler Automobiles will save money, but also greatly reduce their carbon footprint each year with a two million kWh savings. The elimination of over two million kWh is a saving of over 1,600 metric tons of carbon dioxide annually.

Chameides (2007) states:

> Picture a football field, and then imagine a round balloon with one end lined up on the goal line and the other on the 10 yards line – that is, a balloon with a diameter of 10

yards. If that balloon were filled with CO_2, it would weigh about 1 ton; it would be a 1-ton CO_2 balloon.

Picture the football field, but now with 1,400 massive balloons of carbon dioxide reduction per year by FCA.

Lindsey (2018) states:

Carbon dioxide levels today are higher than at any point in at least the past 800,000 years Carbon dioxide concentrations are rising mostly because of the fossil fuels that people are burning for energy. Fossil fuels like coal and oil contain carbon that plants pulled out of the atmosphere through photosynthesis over the span of many millions of years; we are returning that carbon to the atmosphere in just a few hundred years.

Table 3.1: PV Watts KTP Energy Savings

PVWatts: Monthly PV Performance					
Requested Location:	2401 south reed road kokomo, in				
Lat (deg N):	39.73				
Long (deg W):	86.28				
DC System Size (kW):	1551.1				
Array Type:	Fixed (roof mount)				
Array Tilt (deg):	39				
Array Azimuth (deg):	180				
System Losses:	14				
Invert Efficiency:	96				
DC to AC Size Ratio:	1.1				
Average Cost of Electricity($/kWh):	0.08				
Capacity Factor (%)	15.2				
Month	AC System Output(kWh)	Solar Radiation (kWh/m^2/day)	Plane of Array Irradiance (W/m^2)	DC array Output (kWh)	Value ($)
1	132237.375	3.12830162	96.97734833	138604.4063	11,213.73
2	153158.8281	4.09143686	114.5602264	160294.7344	12,987.87
3	175808.3125	4.43560839	137.5038605	184074.7031	14,908.54
4	190732.6094	5.16450644	154.9351959	199606.0781	16,174.13
5	214009.0313	5.75442982	178.3873291	223973.8906	18,147.97
6	203850.9219	5.87404442	176.2213287	213390.375	17,286.56
7	210865.1719	5.94905806	184.4208069	220638.2656	17,881.37
8	205158.125	5.69164705	176.4410553	214562.9375	17,397.41
9	184126.0156	5.19990206	155.9970551	192596.7031	15,613.89
10	179587.4375	4.68942928	145.3723145	187726.8438	15,229.01
11	119037.6641	3.06003809	91.80113983	125047.6172	10,094.39
12	99543.88281	2.35582519	73.03057861	104819.9375	8,441.32
Total	2068115.375	55.39422728	1685.648239	2165336.492	175376.19

The SAM bar graph below in Figure 3.2 correlated with the potential savings of both the PV Watts Calculator and my economic analysis. The energy savings in kWh equated to $105,000 the first year and increased each year after in electrical savings. Adding up all twenty-five years is over three million dollars in electrical savings, which correlated with the economic analysis.

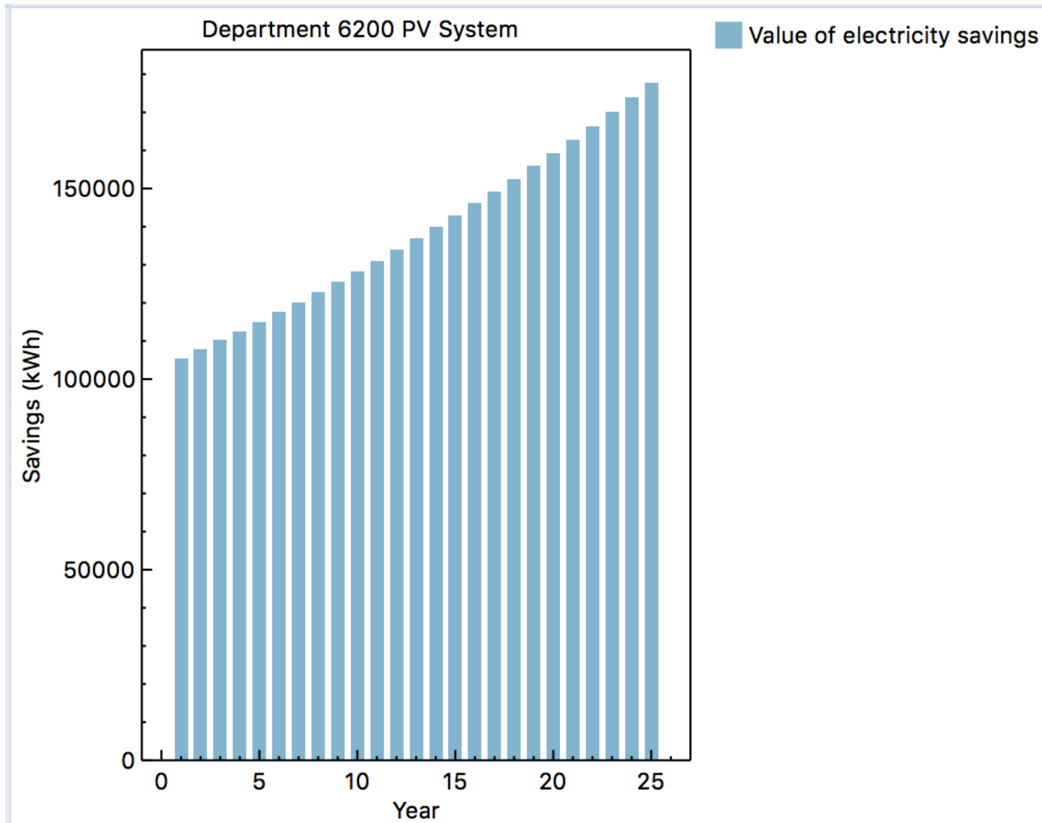

Figure 3.2: Department 6200 Six-Speed Transmission Electrical Savings

3.4 Return on Investment

Table 3.2 is the economic analysis of a PV roof system covering 132,000 square feet over department 6200. The economic analysis spreadsheet is a creation by Professor Bill Hutzel of Purdue University's Polytechnic Institute (Hutzel, 2018). The original installation price is $1,638,000, but with Indiana's renewable energy thirty percent tax credit, the price became

$1,260,000 (State of Indiana, 2019). The life cycle of PV system panels is twenty-five years (NREL, 2019). The annual maintenance cost calculated to $32,500. The maintenance cost is found by dividing an electrician salary of $65,000 by two. The thirty percent tax credit will save FCA $378,000. The economic analysis showed a positive net present value at year eight.

Table 3.2: Economic Analysis of PV System

life cycle investment (years)	25
installation cost ($)	-1,260,000
first year energy savings ($)	175,376
annual maintenance/repair costs ($)	-32500
annual personnel costs ($)	0
# of employees	0
salary escalation rate (%)	0
energy escalation rate (%)	5
repair/maintenance escalation rate (%)	2
discount rate (%)	3%
change in worker productivity (%)	0.00

compound interest			
		1	yearly
n	12	12	monthly
		52	weekly
		365	daily

Cash Flow in Year of Occurrence

year	install cost $	energy savings $	repair & maintenance $	change in worker productivity	total annual cash flow $	present value total annual $	cumulative value	year	daily	weekly	monthly	yearly
0	-1,260,000	0	0	0	-1,260,000	-1,260,000	-1,260,000	0	-1,260,000	-1,260,000	-1,260,000	-1,260,000
1	0	184,145	-33,150	0	150,995	146,538	-1,113,462	1	146,532	146,533	146,538	146,597
2	0	193,352	-33,813	0	159,539	150,259	-963,203	2	150,249	150,251	150,259	150,381
3	0	203,020	-34,489	0	168,530	154,042	-809,160	3	154,026	154,029	154,042	154,229
4	0	213,171	-35,179	0	177,992	157,888	-651,272	4	157,865	157,870	157,888	158,143
5	0	223,829	-35,883	0	187,947	161,797	-489,475	5	161,768	161,774	161,797	162,124
6	0	235,021	-36,600	0	198,420	165,772	-323,703	6	165,736	165,743	165,772	166,174
7	0	246,772	-37,332	0	209,439	169,813	-153,890	7	169,770	169,779	169,813	170,293
8	0	259,110	-38,079	0	221,031	173,921	20,031	8	173,871	173,881	173,921	174,484
9	0	272,066	-38,841	0	233,225	178,099	198,130	9	178,041	178,053	178,099	178,748
10	0	285,669	-39,617	0	246,052	182,348	380,478	10	182,282	182,295	182,348	183,086
11	0	299,952	-40,410	0	259,543	186,668	567,147	11	186,594	186,609	186,668	187,499
12	0	314,950	-41,218	0	273,732	191,062	758,209	12	190,979	190,996	191,062	191,990
13	0	330,698	-42,042	0	288,655	195,531	953,740	13	195,439	195,458	195,531	196,560
14	0	347,232	-42,883	0	304,349	200,077	1,153,817	14	199,975	199,996	200,077	201,211
15	0	364,594	-43,741	0	320,853	204,700	1,358,517	15	204,589	204,612	204,700	205,944
16	0	382,824	-44,616	0	338,208	209,403	1,567,920	16	209,282	209,307	209,403	210,760
17	0	401,965	-45,508	0	356,457	214,187	1,782,107	17	214,055	214,082	214,187	215,662
18	0	422,063	-46,418	0	375,645	219,054	2,001,161	18	218,911	218,941	219,054	220,652
19	0	443,166	-47,346	0	395,820	224,006	2,225,167	19	223,852	223,883	224,006	225,731
20	0	465,325	-48,293	0	417,031	229,043	2,454,210	20	228,877	228,911	229,043	230,900
21	0	488,591	-49,259	0	439,332	234,169	2,688,379	21	233,991	234,027	234,169	236,163
22	0	513,021	-50,244	0	462,776	239,384	2,927,762	22	239,193	239,232	239,384	241,519
23	0	538,672	-51,249	0	487,422	244,690	3,172,452	23	244,486	244,528	244,690	246,973
24	0	565,605	-52,274	0	513,331	250,090	3,422,542	24	249,872	249,917	250,090	252,525
25	0	593,885	-53,320	0	540,566	255,584	3,678,126	25	255,353	255,400	255,584	258,177
		net present value of life-cyce cash flows:				3,678,126	3,678,126		3,675,589	3,676,109	3,678,126	3,706,526

According to Diane Tischler the head of finance at KTP (2018):

> The corporate standard in regards to return on investment for environmental projects over one million dollars is five to nine years. If this was not an environmental project then the economic payback must not exceed four years.

3.5 Greenhouse Gas Reduction

The installation of a PV array on the roof above department 6200 not only will reduce electrical cost, but improve the environment. Figure 3.3 on page twenty-nine is a display of the reduction in greenhouse gas emissions with a solar array DC capacity of 1551.1 kw. The calculation is from the Environmental Protection Agency website. The calculator allows a person to breakdown the potential electrical savings. The operator can then convert the reduction in metric tons of greenhouse emissions from the electrical savings (EPA, 2018). The figure allows people to better comprehend the reduction amount of greenhouse gas emissions and carbon dioxide. The data on page twenty-nine details the environmental improvement from a PV array installation on the roof of KTP.

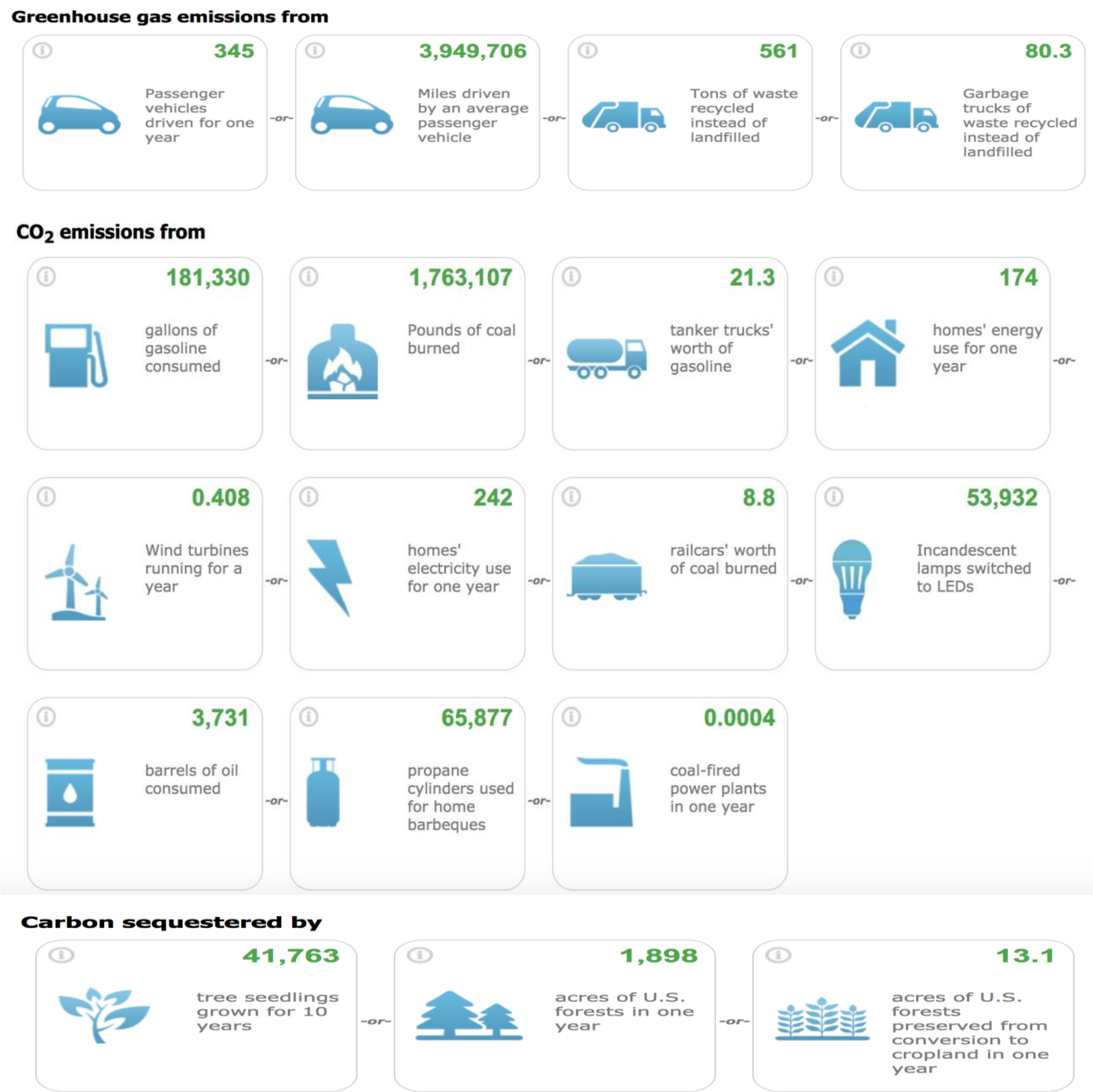

Figure 3.3: Greenhouse Gas Emission Reduction

3.6 Limitations

- One-year period of time to get approval from the corporate office.
- The energy and savings are dependent on the sun. Indiana has 4.5 hours of peak sunlight on average (NREL, 2016).
- PV cells efficiency are low, but slowly improving.
- Once the panels are on the roof, they cannot move if the company changed locations.

3.7 Assumptions

- Thunderstorms and hail will damage the PV system.
- The PV systems prices are not cost effective in comparison to other renewable energy resources.
- The United States government will guarantee all renewable energy tax credits for a PV system.
- Preventative maintenance will have to be weekly to ensure optimal performance.

3.8 Summary

Chapter three presented data of the benefits of installing a PV array on the roof at the KTP facility. The PV Watts Calculator displayed the first-year energy savings of a PV array, while detailing the systematic process to access the program. The SAM program is the second research instrument that provided a statistical analysis of findings for a twenty-five-year span, which is the operational life of a PV array. A step by step process is in detail how to utilize the SAM program that offers more information than the PV Watts Calculator. Each program is user friendly and both figures show a correlation in the cost saving estimates. Obtaining a cost saving estimation allows oneself to create an economic analysis where the savings will explain in detail when FCA will see their ROI. The EPA greenhouse gas calculator is another instrument that detailed the environmental benefits of a PV array installation at KTP.

CHAPTER 4. RESULTS

The data in chapter three was a collective analysis from the PV Watts Calculator, SAM, greenhouse gas emissions calculator and an economic analysis. Each tool was to verify the results throughout the data collection process to verify their correlation and accuracy. The goal was to run a simulation of a 1,551.1kw solar array expanding 130,000 square feet on the PV Watts Calculator. After reviewing the PV Watts data, the data was inputted as a systematic data sample on SAM that produced similar cost savings between both programs. Understanding that the data produced similar electrical cost savings, one is then able to calculate the total kWh of energy savings for one year. The data in kWh was calculated as total greenhouse gas and carbon dioxide emissions offset in metric tons from the annual electrical savings. Even though the cost savings and environmental impact are significant over a twenty-five-year span, FCA requires an economic analysis to understand their ROI. The savings are high, but can drop significantly during purchasing, installation and maintenance of the PV array.

4.1 PV Watts Calculator and SAM

The data collection from the PV Watts Calculator and SAM for KTP in Kokomo, Indiana is on a monthly basis. Monthly data allowed oneself and FCA to monitor the performance of the PV array each month in correlation to the weather throughout the year. The summer months produce more daylight each day that creates stronger returns in electrical savings. During the winter, the days are shorter and this will reduce cost savings due to the lack of sunlight. The data in Table 3.1 on page twenty-five for the months of April to October are the highest return in electrical savings. The cost savings ranged from $15,000-$18,000 each month. During the winter and spring, the savings declined between the months of November to March. The cost savings lowest return was at $8,000 and the highest was at $14,000. The PV array is still collecting the sun's energy even when it is cloudy or snow has covered the solar panels.

Gay (2017) states:

> Research has shown that solar can still successfully generate electricity in snowy areas and other harsh environments. Light snow has little impact on solar panels because it easily slides off. Heavy snow can limit the amount of energy produced by solar panels, but light is still able to move through the snow and forward scattering brings more light to the solar cells than one might expect. Even when solar panels are completely covered by snow, they can still generate electricity.

The data type is a calculation by the amount of sunlight radiating on each solar panel that translates into kWh. When the PV array begins absorbing the sun's radiation, the energy will be stored in the power inverter. The power inverter communicates the energy amount to FCA's building automation system (BAS). The Metasys building automation system by Johnson Controls at FCA will allow facility engineers to monitor the PV arrays performance in real time (Johnson Controls, 2019). Having the ability to monitor the PV arrays performance through a BAS allows engineers and maintenance to react immediately to any problems that arise. One example of a BAS translating important information is during the winter months. Due to the decrease in sunlight, returns will be more advantageous if PV array panels are at a thirty-nine to a fifty-degree angle. The additional tilt will expose the panels to the sun longer due to the sun setting faster during the winter months. The data from the solar array will be in the Metasys BAS server. Presentations detailing the electrical energy savings can be from a transposition from Metasys into a Microsoft Excel spreadsheet.

4.2 Economic Analysis

The economic analysis is a Microsoft Excel spreadsheet that details the solar array's monetary performance from year zero to year twenty-five. The economic analysis data detailed the kWh savings from the PV Watts and SAM simulations. There will be an annual presentation of the forecasted savings that also applies the compound interest. The compound interest is in a format to describe the cost savings at a daily, weekly, monthly and yearly frequency. The federal tax credit for renewable energy is thirty percent that applies to the purchasing cost of a PV array. The tax credit decreased the PV array cost from $1,638,000 to $1,260,000. First year energy savings were $175,000 with an annual maintenance cost of $32,500. The maintenance cost is half the salary of an electrician at FCA. Each year the energy savings increased at an additional $10,000-$18,000 from the previous year. The ROI is at year eight when the cumulative value reached $20,031 from the original debt of $1,260,000 at year zero. During the twenty-five-year life of the PV array, the estimated net profit calculated to $3,678,126.

4.3 Environmental Impact

The data necessary to understand the environmental impact is to calculate the kWh annual savings from the PV Watts Calculator and SAM. Annually, the PV array generated 2,165,336 kWh of energy savings. Utilizing the emissions calculator from the EPA, a person can convert the energy savings as an offset of greenhouse gas and carbon dioxide emissions in metric tons. Overall, the annual reduction is 1,611 metric tons. Figure 3.3 on page twenty-nine demonstrated how much 1,611 metric tons is and the beneficial impact made to the world. There will be an annual presentation of the data to demonstrate to the FCA environmental department that the PV array continues to have an impact on the environment. The data will be on a Microsoft Excel spreadsheet for tracking purposes.

4.4 Summary

Chapter four delved into detail about the data from each instrument to analyze the performance of the PV array. The PV Watts Calculator and SAM were successful because both simulations had a correlation between their data of the PV array's monetary return. The data from the PV array is in a BAS and a Microsoft Excel spreadsheet. The information from PV Watts Calculator, SAM, economic analysis and the EPA calculator are all on a monthly and annual frequency. The results are a success with a PV array because FCA will see an estimated net profit over $3,000,000 throughout a twenty-five-year period. Fiat Chrysler Automobiles will achieve their economic payback at year eight, which is compliant with the company's financial requirements for capital projects. During the twenty-five-year period, FCA will reduce their carbon footprint by 1,600 metric tons annually.

CHAPTER 5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary

The results achieved in chapter four correlated with one another because the SAM and PV Watts calculator detailed similar cost saving benefits for KTP. The savings after the first year resulted in six figure savings from both simulations ran. Year after year, the savings increased. The economic analysis showed FCA seeing a return on their investment at year eight and continued to return $175,000-$255,000 up to year twenty-five. The environmental influence displayed a significant impact with the installation of a PV array at KTP. The goal of every company is to be profitable, but having the ability to protect the environment is an additional desire company's want established. Being compliant with safety and environmental regulations will prevent companies from facing costly fines from the government. A noteworthy finding according to the economic analysis is even as the PV array ages, the energy savings continued to increase the following year. The second important finding is that the 30% energy tax credit provided by the government is only good until December 31, 2019. Any installation of a PV array following this date will receive a 26% energy tax credit up until January 1, 2021 (U.S. Department of Energy, 2019). The Kokomo Transmission Plant will see decreased savings on their PV array install if installed in 2020.

5.2 Conclusions

Alternative energy methods are vital for the future of our planet. Fossil fuels are being depleted faster than they are being restored. Installing a PV array on the rooftop of KTP will reduce the facility's dependency on fossil fuels based off the research that has been conducted for this proposal. Flat rooftops offer tremendous potential for a PV array and KTP has all of the features that would make them an ideal candidate for a PV array expanding 130,000 square feet. The findings discovered correlated with the review of literature. When the two simulations were designed, the following variables were incorporated into the tests:

- KTP's flat roof
- Size of the array
- Cost per kWh in Kokomo, IN
- The tilt in degrees of the solar panels
- Weather conditions in Kokomo, IN
- Efficiency of the solar panels

The outcomes of both simulations supported the findings throughout the review of literature.

During the capstone directed research project limitations were encountered during the conducted research. The most concerning limitation was not having the ability to view the results of a PV array in real time to gain a better understanding of what the returns would have been of an investment of this type. Being able to visit an installed PV array and study how it operated, while viewing the financial returns would have been beneficial for the research conducted. The SAM and PV Watts Calculator are tools that give users an understanding of what potential returns are. Multiple scenarios can be designed to reflect weather patterns, different size of PV arrays and amount of sunlight. Having the opportunity to study a real PV array connected to a building automated system throughout the area would have provided a better understanding of all variables companies can encounter each day. The second limitation is the long process required to attain capital funding for large scale projects at FCA. Large scale expenditures for a project of this size will have many channels of management that it will go through to attain approval. Projects seeking to attain approval of this size takes up to one year at a minimum to receive funding. During the start of this project learning that it would take a year for approval was very discouraging. Waiting a year will put the project in the year 2020, which will cost even more to fund because KTP will only be eligible for a 26% energy credit from the government. The next limitation and an important one is the amount of sunlight. Indiana has 4.5 hours of peak sunlight on average. The project will have a financial loss if one year has many bad days of weather with no sunlight. The last limitation is once the solar array is mounted on the roof, it can be moved, but for a large price. Kokomo Transmission may decide to relocate someday, but they will have to leave their large investment of the PV array behind unless they are willing to pay a large amount of money to remove and re-install the panels.

Based off the results of the economic analysis, KTP has much to gain with the installation of a PV array on their rooftop. The returns alone after year eight will be able to fund almost one-third of the electrical bill in department 6200. Kokomo Transmission Plant could also decide to utilize the electricity at other locations throughout the plant. The KTP facility uses many powered industrial vehicles such as fork trucks and other carts to haul parts throughout the facility. A project could be implemented into a kaizen where the electricity from the PV array is supplied to the charging stations for each of the powered industrial vehicles. Directing the power to charge vehicles is another cost cutting technique that can be implemented to achieve further business metrics laid out by the corporate office. Having alternatives of this type will allow all parties involved to allocate the proper resources to fund the PV array installation at KTP.

5.3 Recommendations

A PV array is recommended to be installed at KTP. While the cost is high to install, the returns are greater at over three million dollars throughout the life of the project. The KTP facility will be creating their own electricity and at the same time reducing their need for fossil fuels. Carbon greenhouse emissions will be reduced by KTP, which will place the facility in an even more advantageous position to continue meeting their corporate business plans from an environmental and financial aspect. Having the opportunity to become compliant in these two metrics will allow KTP to place their focus on other metrics that are more difficult to accomplish. When the PV array begins to show signs of solid returns, this will allow the appropriate individuals to propose further expansions of the PV array on the 3 million square foot roof at KTP. The ultimate goal of the project is to provide the understanding and need of a PV array and to eliminate KTP's dependency on fossil fuels.

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APPENDIX A. ENERGY METRIX REPORT

BILLING - DEPT 6200 - 62TE ASSEMBLY

1/1/2017 12:00 AM to 12/31/2017 11:59 PM

Time Zone: (UTC-05:00) Eastern Time (US & Canada)

Rate Schedule: Duke Energy Rate HLF test (rev 10-11-17)

Total Charge: $572,326.25

Description	Quantity		Rate	Charge
Connection Charge (prorated)	3.0		75	$2,699.99
Demand Charge (prorated)	1,375.0	kW	12.05	$198,824.64
Energy Charge	6,369,977.3	kWh	0.016065	$102,333.69
KVAR Charge (prorated)	214.1	kVAR	0.24	$616.52
Rider 60 - Fuel Adjustment	6,369,977.3	kWh	0.010608	$67,572.72
Rider 61 - IGCC Rider (prorated)	1,375.0	kW	6.704615	$110,625.95
Rider 62 - Pollution Cntl. Adj. (prorated)	1,375.0	kW	1.539774	$25,406.22
Rider 63 - Emission Allowance	6,369,977.3	kWh	-0.0001	($637.00)
Rider 66-A - Energy Efficiency Adj.	6,369,977.3	kWh	0.000332	$2,114.83
Rider 67 - Merger Amortization Credit	6,369,977.3	kWh	-0.000337	($2,146.68)
Rider 68 - Midwest ISO Adjustment	6,369,977.3	kWh	0.002201	$14,020.32
Rider 70 - Summer Reliability Adjustment	6,369,977.3	kWh	0.00063	$4,013.09
Rider 71 - Clean Coal Adjustment (prorated)	1,375.0	kW	2.769365	$45,694.44
Rider 72 - Federally Mandated Cost Rate Adjustment	1,375.0	kW	0.071971	$1,187.52
			Subtotal:	**$572,326.25**

Cost allocation rate

Description	Quantity		Rate	Charge
Blended cost per kWh	572,326.2	$	0.0898	$0.00
			Subtotal:	**$0.00**