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ANALYZING COST EFFECTIVENESS OF PHOTOVOLTAIC PAVEMENTS

THESIS

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Abstract

The United States Air Force (USAF) is the largest consumer of energy within the Department of Defense (DoD). As such, the USAF is continually looking for ways to reduce consumption, as well improving network resiliency and assuring supply. One potential method for addressing these items is focusing on applications of renewable energy. A specific application of renewable energy that could greatly benefit the USAF if viable would be photovoltaic (PV) pavements. PV pavements would be able to capitalize upon the large swathes of pavements on Air Force (AF) installations, while not being hampered by other concerns such as clear zones for aircraft.

One way to evaluate viability of a technology is through analyzing cost-effectiveness. While initial efforts were not directly focused on cost-effectiveness, the information gathered helped pave the way for such an analysis. Specifically, previous researchers at the Air Force Institute of Technology (AFIT) designed and implemented an experimental system for collecting performance data on horizontally oriented PV panels. Data was collected from 38 sites worldwide for a time period of up to one year. Five installations were then selected from the 38 original sites to utilize in determining cost-effectiveness. As part of evaluating cost-effectiveness, average power generation values were determined from the data. This information, along with pavement construction costs, helped form the basis of developing a model to evaluate life cycle costs for PV pavements. The model was then applied to each installation a total of 60 times to evaluate individual effectiveness. At the worst-case cost of construction for PV pavements, $460/SM, none of the installations evaluated would be able to consider installation PV pavements a viable alternative to traditional asphalt pavements.

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ANALYZING COST EFFECTIVENESS OF PHOTOVOLTAIC PAVEMENTS

I. INTRODUCTION

Background

Each year, the Department of Defense (DoD) spends approximately $4 billion on installation energy [1]. In addition, energy infrastructure throughout the United States continues to degrade from extensive age and lack of maintenance. These factors have contributed to an ever-growing realization that the United States (U.S.) is susceptible to energy related threats. Numerous Executive Orders (EOs) have been signed in recent years to reduce the risk associated with these items. The most recent, EO 13834, was signed by President Trump in May 2018 [2]. The purpose of the EO, like many energy related EOs, is to drive the federal government to pursue energy use reductions and improve DoD installation resiliency.

The United States Air Force (USAF) is the largest energy user within the DoD, thereby being affected the most by governmental oversight. Most of the energy consumption by the USAir Force is related to aviation fuel. However, almost $1 billion is still spent on energy for facilities each year as can be inferenced from the percentages displayed in Figure 1 [3].

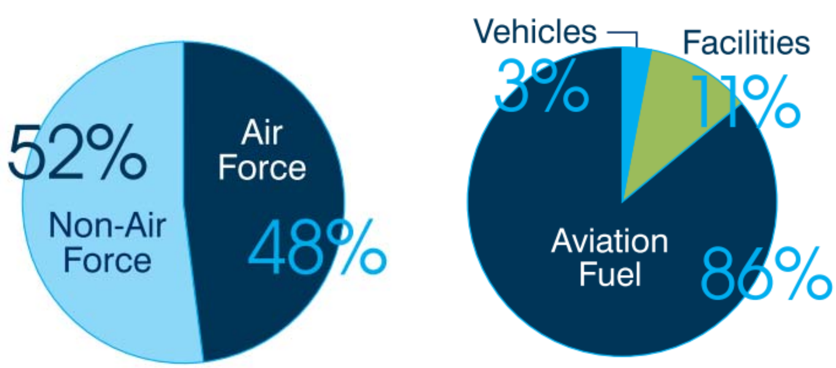


Figure 1. Air Force Energy Consumption [3]

The vast amount spent on energy drove the creation of the USAF Energy Flight Plan, which established three enterprise-wide strategic goals: improve resiliency, optimize demand, and assure supply [3]. The USAF has undergone major changes in pursuit of these goals, but the primary focus has been on renewable energy.

Renewable energy has maintained the spotlight as it helps address all three goals that the Air Force is trying to achieve. The main goal that renewable energy helps achieve is assuring supply. There has been constant media attention directed at fossil fuels and other non-renewable energy sources over the past few years due to the increasing reality that these resources are finite. Even though new reservoirs or technology may slow down depletion rates, the amount of fossil fuels and related resources are still dwindling. There will be a time when those resources have been fully depleted. An alternative technology must rise to help prevent a massive energy deficit, hence where renewable energy comes into play. While fossil fuels take millions of years to create, renewable energy is focused on resources that are naturally occurring or replenish at a rate equal to that of use. Some common renewable energy technologies are photovoltaic (PV) panels, water dams, and wind turbines.

The Air Force has begun to embrace the mindset of utilizing renewable energy, demonstrated by the 340 renewable energy projects either in operation or under construction as of 2017 [4]. Many of the projects lie in the realm of photovoltaic panels due to limitations associated with other methods. For instance, wind turbines are not viable for most Air Force locations due to associated flying missions and clear zones. Further, hydraulic power is not prevalent in the Air Force because few, if any, Air Force installations are located next to a constant flowing water source in which a dam could be placed. As a result, Air Force renewable energy funding and research continues to be focused on photovoltaics.

Photovoltaics can provide several benefits in comparison to traditional power generation methods, but that does not mean they are without limitations. Specifically, photovoltaic panel farms require massive land use. The land usage stems from the traditional tilt method utilized in placing the panels. The tilt method involves rotating the panels on a single or dual axis to follow the sun and provide the greatest radiation absorption. Recently, the idea to orient photovoltaic panels horizontally has come forward for a few reasons, one being a reduced land footprint. For instance, the panels could be placed on flat roofs, which are a common fixture in the Air Force. Further, it is possible that the panels could be used as a paving surface for sidewalks or road structures. The vast number of paved surfaces in the Air Force provided the motivation to evaluate the capabilities of horizontal panels. Data was collected from 37 sites around the world to help analyze performance [5]. The subsequent work conducted in this thesis will focus on whether it is economically viable for photovoltaic panels to be utilized as a pavement option.

Problem Statement

While there is extensive literature regarding the utilization of photovoltaic panels oriented in traditional methods, little exists regarding horizontal applications. This stems from the de facto assumption that tilted panels outperform horizontal panels. However, some unaccounted factors may influence the orientation methods differently and result in instances where horizontal panels provide comparable power generation. Additionally, numerous models exist for predicting power output of photovoltaic panels, but there is a definitive lack of models for panels that have been oriented horizontally. As such, it is difficult to compare the methods to see which may provide a better solution for the Air Force going forward. Further, it is possible that land constraints make horizontal panels a more economical choice for the Air Force.

Research Objectives & Investigative Questions

This research will examine whether utilizing photovoltaic panels oriented horizontally can be economically beneficial for the Air Force, specifically when used in place of a traditional paving surface.

1. Would it be economically viable for Base X to utilize PV pavements versus asphalt pavements over a five, ten, or twenty-year lifecycle?
2. If PV pavements are not viable over a twenty-year lifecycle, what would the cost of electricity need to be to make the technology viable?

Methodology

Previous AFIT researchers conducted studies to determine the capability of photovoltaic panels oriented horizontally. They designed and fielded a system that could gather necessary data. The original system as designed by Nussbaum consisted of two 50W panels connected to a Raspberry Pi located within a Pelican case [6]. The Raspberry Pi, which acts as a central processing unit, was utilized to record the associated power output of each panel, as well as temperature/humidity readings gathered from a probe attached to the case. Additionally, system health could be reported back to researchers through a satellite communication device identified as the RockBlock MK2.

Follow-on efforts by Booker and Applebee revealed that two 50W panels would not be possible for conducting the experiment due to limitations in availability [5], [7]. As such, a 25W mono-crystalline panel and 50W poly-crystalline panel were selected for the finalized system design. After identifying this downfall, a total of 40 systems were constructed and deployed to 37 different locations around the world [5], [7]. The systems gathered the data in 15-minute intervals. Additionally, information related to each location such as latitude was incorporated into the gathered data set.

Data collection continued for one year, at which point all the data was consolidated into a master document. There were 19 sites eliminated from further examination due to lack of data provided, some of which never reported a single month of data. As a result, only 18 of the original 37 sites had data accounting for at least 8 months of the year time period. Fifteen sites were used in the final model determination due to "break-in" issues with the Raspberry Pi at some locations. Looking to build on the data collected from those sites, this research effort focused on creating a model for determining the cost effectiveness of the panels used as a pavement surface. The model incorporated several items such as electricity cost and average power generation. After determining the mathematical model, an Excel spreadsheet was built to serve as a final evaluation tool for the lifecycle analysis.

Organization of Thesis

The traditional thesis organization was utilized in the formatting of this work. Chapter I provided current background regarding issues surrounding energy in the Air Force, as well as identifying relevant research goals. Chapter II will discuss the literature that has been discovered in pursuit of potential data variances and variables for model inclusion. Chapter III depicts the methodology that was utilized in analyzing the provided data set. Chapter IV will then deliver the relevant information discovered during analysis. Chapter V synthesizes the information that has been gathered during the literature review and analysis to provide an opportunity for readers to determine the path forward.

II. LITERATURE REVIEW

Introduction

This chapter focuses on presenting readers with basic knowledge regarding photovoltaics and the proposed research questions. The chapter will begin by presenting a detailed background on how photovoltaics function, their typical construction, standard panel composition, and orientation methods. Additionally, the reader will be supplied information pertaining to non-traditional methods of utilizing photovoltaics including the feasibility and methods for using photovoltaic panels as a pavement surface. The chapter will then conclude with a discussion pertaining to variables that may be more likely to exert significant influence on photovoltaics oriented in such a manner, as well as research from previous Air Force Institute of Technology (AFIT) students.

PV Background

Photovoltaic panels are often portrayed as a relatively new technology in media. However, the basic technology has existed for over 50 years. In fact, Bell Laboratories constructed a photovoltaic module back in 1954 [8]. Unfortunately, the technology did not begin to see any major applications until space exploration became a concern for the United States. Like many technologies before it, utilization of photovoltaics in the space programs led to major innovations and increased efficiencies. Eventually, the technology became defined enough to garner attention as a potential commercial product. The energy crisis in the 1970s led to even greater exposure for photovoltaics, and subsequent pushes for renewable energy have seen the technology gain traction as the way forward for clean and renewable energy.

PV Definition

Photovoltaic is the technical term used to describe the process of converting the energy from the sun into electricity. The term originates from the use of photo, meaning light, and voltaic, meaning electricity [9]. Photovoltaic may be described in layman's terms as solar. Typically, photovoltaic will be heard alongside other terms such as cell, module, panel, or array. These terms mean quite different things but are often used interchangeably by uninformed individuals. The most basic level of any photovoltaic is the cell. The cell receives light produced by the sun and converts the energy received into an electrical output. Cells will always be connected to each other and collectively known as a module. This is also what is described as a solar panel typically. When multiple modules are wired together, an array has been formed [8], [10]. Figure 2 helps provide a visualization to this hierarchy.

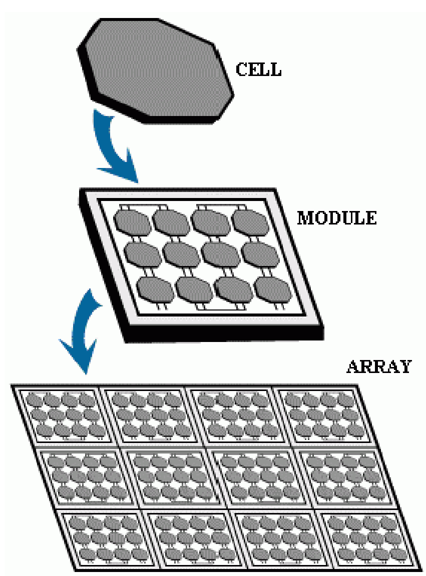


Figure 2. Photovoltaic Terms [8]

Process Explanation

Understanding how semiconductors and electrical fields operate is necessary prior to discussing the process for sunlight conversion. A semiconductor implies that a material possesses electrically conductive traits, with the most common for photovoltaic cells being silicon. In pure form, silicon has an atomic structure that consists of 14 electrons arranged throughout 3 shells [9]. The three-shell base structure forces the electrons to be locked into their associated shells thereby preventing their bonds from being easily broken. Doping, the addition of impurities, must be performed on the silicon to ensure electrons can be readily freed from their bonds. Typically, phosphorous is used in combination with silicon as it has an additional electron that does not have a stabilized bond [9]. The resulting chemical structure is classified as N-type silicon.

For a photovoltaic cell to properly function, it must ensure that an electrical field exists. An electrical field develops when one portion of the cell has a higher number of electrons in comparison to the opposing side. This can be accomplished by utilizing a P-type silicon on the reverse of N-type silicon. P-type silicon is established by doping silicon with boron, which creates the required absence of electrons [9], [11]. Creating a cell with N-type silicon on one side and P-type silicon on the other drives the non-bonded electrons to look for voids to fill on the opposite side. Eventually, equilibrium is reached between the two sides of the cell, which forms an electron barrier, i.e., electrical field. That barrier ensures that any electrons freed will only be able to flow in one direction. Figure 3 depicts the functioning of such a barrier formed by this combination.

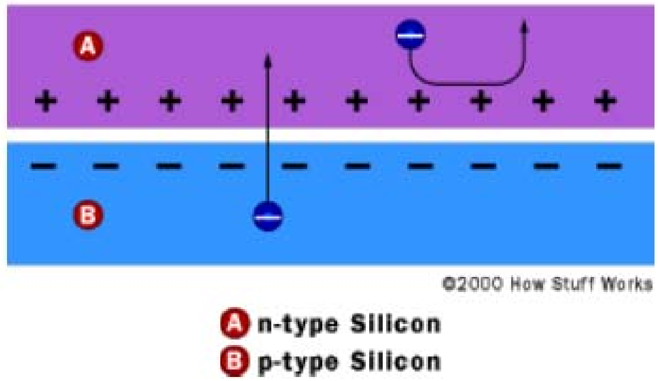


Figure 3. Electrical Field between N-Type & P-type Silicon [9]

The process for converting sunlight in a photovoltaic cell begins at the outer shell, which is constructed from a semiconductor. Once sunlight hits the semiconductor materials, electrons begin to break loose and disrupt the equilibrium that has been established. Specifically, if electrons have broken free on the P-type side and are in proximity to the field, they will be transported across the barrier. These electrons will want to cross back to the opposing side to fill the void created by their departure. The electrons cannot flow across the barrier though and must find an alternative route, which should be provided externally, to return [9]. The flow of the electrons back to the P-type side along the external path creates a current which can be utilized as an electrical source.

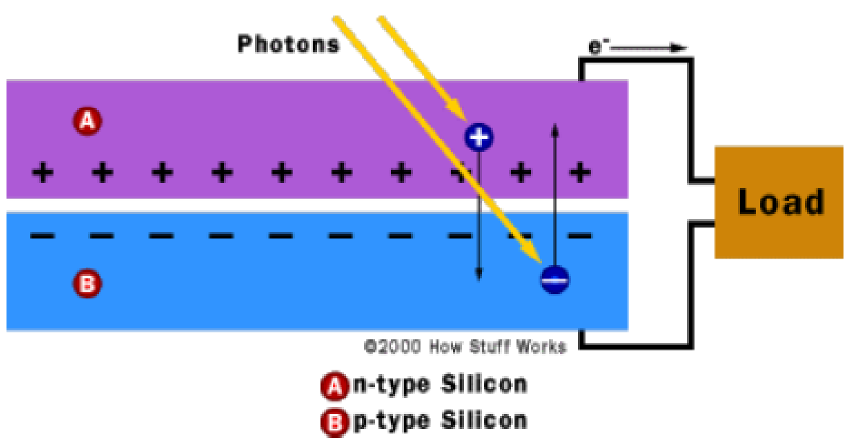


Figure 4. Photovoltaic Cell Function [9]

The process represented in Figure 4 occurs when sunlight hits the photovoltaic cell. However, the amount of energy required for that process to occur is not so simple. Instead, the energy received and utilized to break electrons free in the P-type side is based on band gap energy. The band gap refers to the amount of energy required to break an electron free from a bond [8]–[10]. It differs based on the semiconductor material utilized and impacts how much energy can be absorbed by the cell. Any energy received by the cell below that designated level will be too little to break an electron free. On the reverse, any energy above the band gap energy will free an electron but excess energy will be wasted. The amount of energy directed at the cell is based on the differing wavelengths produced by the sun. The majority of inefficiencies introduced in photovoltaic cells result from being unable to process the energy associated with differing wavelengths [9].

Standard Construction

Photovoltaic cells may be constructed as single or multi-junction. A single junction cell infers that there is only one P-type surface and one N-type surface. As silicon is the most common material utilized, the process for constructing a silicon cell will be examined. The process for developing a single junction cell begins with the casting of silicon into a block which has P-type properties [11]. This block will be cut into cells that are then subjected to a diffusion furnace, producing a N-type surface [11]. Antireflective coating must then be added to the top side of the cell as the base materials cause energy losses due to their reflectivity [9], [11]. Following this, contact grids are imprinted onto the differing sides to serve as the electrical circuit through which electrons will flow. Figure 5 represents the differing components of a single junction cell.

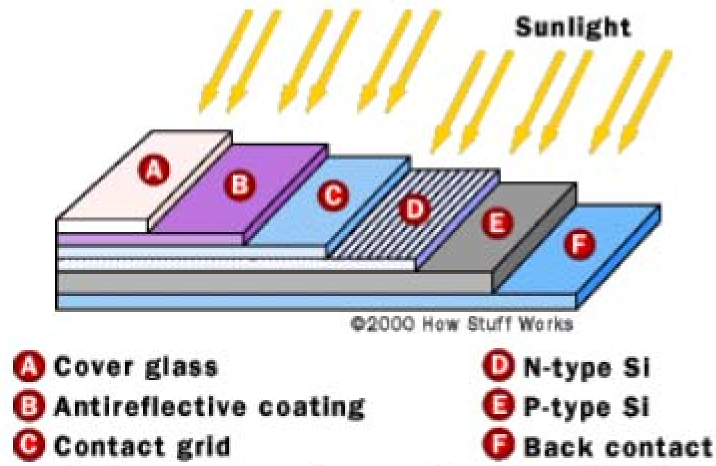


Figure 5. Single Junction Cell [9]

Multi-junction cells are similar in that a cell will feature a P-type surface and a N-type surface. However, multi-junction cells consist of differing cells stacked upon one another. These cells incorporate differing band gap energy levels, thus allowing for the overall cell to more readily convert the energy being received. Figure 6 provides an example of a multi-junction cell.

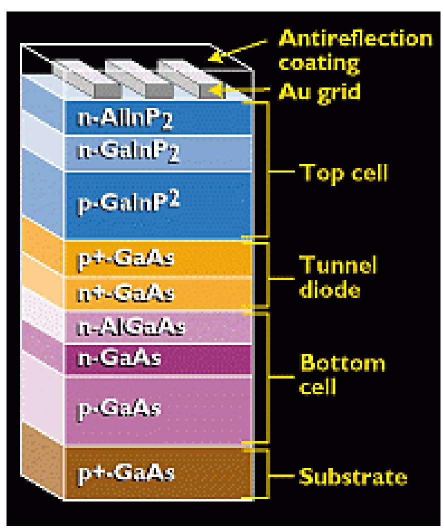


Figure 6. Multi-Junction Cell [8]

Panel Types

While photovoltaics cells may be considered single or multi-junction, those terms pertain to the amount of semiconductor materials. The actual panel type is instead defined by the material source that is used to construct the cell. There are several differing panel types, but only two main categories exist for describing photovoltaic panels. The first category, occasionally referred to as the first generation, consists of silicon based panels [12]. The two panel types that exist within this category are called mono-crystalline and poly-crystalline, which can be seen in Figure 7.

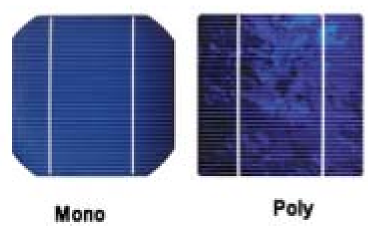


Figure 7. Visual Comparison of Panels

A mono-crystalline panel is defined by its chemical structure, which consists of single crystal silicon. This silicon is produced through the Czochralski process, which creates ingots that can weigh several hundred kilograms [12]. The chemical structure of single crystalline silicon helps these panels to achieve the highest efficiency rates that exist in photovoltaic technology. As it stands, some single junction mono-crystalline panels have achieved an efficiency of 26.7%, with the majority of these panels falling into a range of 15-20% efficiency [13], [14]. Additionally, these panels have demonstrated a better heat resistivity than other panel types. However, these benefits come at a high price point, which led to the development of poly-crystalline panels. These panels instead utilize poly-crystal silicon that is manufactured through the Siemens process [12]. Unfortunately, poly-crystalline panels have reduced efficiencies due to their chemical structure. The highest confirmed efficiency for these panels is 22.3% for a single junction cell, while the majority of panels are only in the 13-16% range [13], [14].

The two panel types described often have high costs, due to silicon usage, which has led researchers to pursue other sources. Their efforts have led to the development of the second generation of panels, which are commonly referred to as thin-film [12]. Several different panels fall into this category, but the most widely recognized ones are amorphous silicon, cadmium telluride, and copper indium gallium [14]. As these panel types are relatively new, the efficiency levels are still lackluster, often only reaching a maximum of 13% [14]. In order to combat this, commercial applications of these panels require significantly more space. The lack of efficiency and need for additional space led previous AFIT researchers to eliminate this panel type from data collection. Instead, a poly-crystalline and mono-crystalline panel were utilized during the experiment.

Panel Typical Orientation

Photovoltaic cells function by converting solar radiation, colloquially known as sunlight, into useable energy. As the amount of direct sunlight increases, so too does the amount of energy output from the cell [15]–[17]. Therefore, the highest amount of sunlight received by a photovoltaic cell is when it is aimed toward the sun. Numerous studies have been conducted to determine the best panel orientation for maximizing solar radiation. The common theme that has arisen is that there are two primary ways to orient panels. One way would be to place the panels at a fixed angle specific to that geographical location to optimize output. A second, more expensive method, would be to install a tracking system along with the panels to continuously follow the sun's movement [15]–[17]. However, there are issues that arise with both orientation methods. The main issue that arises with a fixed angle panel is that it will only achieve near maximum output twice a day. Additionally, significant amounts of space are required to accommodate the tilting of the panel, as well as prevent shading. Panels that utilize a tracking system provide the best possible output but are subject to even greater installation and operating costs [15], [17]. These systems often outweigh the benefits provided by achieving higher output levels. Further, panels oriented in this manner require even more space than regular tilted panels to allow for movement. The weaknesses associated with these methods have led to researchers examining the benefits of orienting panels horizontally. Panels oriented in such a manner are expected to produce less energy than other methods, but circumstances may dictate them as a more viable option. For instance, a significant cost savings can be realized by placing the panels in a fixed horizontal orientation (i.e., no tilt or tracking system necessary). Additionally, no self-induced shading issues are produced by this orientation. Even more, horizontally oriented panels could provide a secondary use such as being a pavement surface.

PV Pavements

As solar panels have continued to increase in popularity, so too have the possible applications. An emerging concept from the past decade is that of utilizing solar panels as a pavement surface. This is still a relatively novel idea as there has yet to be extensive research regarding the capability of such road surfaces. Research is lacking for numerous reasons, but a primary one is that there is widespread belief that the panels cannot be efficient enough to be cost effective in the long run. The remaining sections will examine if the technology may be viable through examining leading companies, their respective practices, possible lifecycle cost concerns, and variables that could influence the efficiency of the panels.

Pavement Companies

Alongside lacking research, there is only a tiny pool of monetary resources being devoted to photovoltaic pavements. This can be seen through the minute number of companies that are pursuing the technology. However, there are three companies that have drawn headlines for their advancements and potential in the field. The first company happens to be U.S. based and is called Solar Roadways, Inc. (SRI). Founded in 2006 by Scott and Julie Brusaw, it received the first of several Small Business Innovation Research (SBIR) grants from the US Department of Transportation (DOT) in 2009 [18]. The first grant SRI received was to determine whether photovoltaic panels were indeed feasible as a road surface. The prototype that resulted from the grant demonstrated the capability existed and helped pave the way for future grants. Subsequent grants received by SRI focused on physical implementation of the technology. As such, a solar panel parking lot was developed and constructed by SRI, leading to several innovations and improvements. Through the resources acquired by the grants, as well as an Indiegogo fundraiser that raised over $2M, the company has continued development of their original ideas [18]. Currently, the company is on the fourth iteration of their Solar Roadway (SR) which can be seen in Figure 8.

Figure 8. Fourth Iteration SR Panels

Another leading company in the field of photovoltaic pavements is the Colas Group. The company was founded in 1929 and specializes in the transportation construction and maintenance sector [19]. It is predominantly based out of France but features ventures throughout the world to include the US. Due to its scale, the company has the capability to continue research without funding from additional sources. However, the company did partner with the INES, French National Institute for Solar Energy, to create their proprietary technology called Wattway [19]. Whereas SRI has focused efforts on developing an actual pavement, Wattway involves placing photovoltaic cells on top of existing road surfaces [19]. Figure 9 provides an example of Wattway's concept and panel.

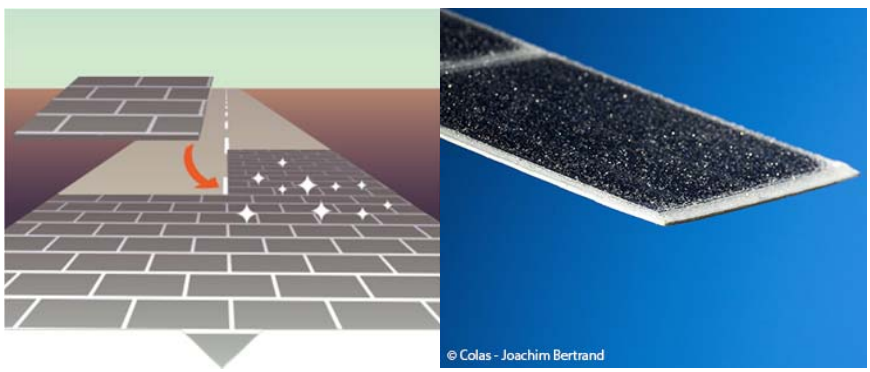


Figure 9. Wattway Concept & Panel [19]

The last company that has been making advances in photovoltaic pavements is called Pavenergy. The company is based out of Portugal but is an industry leader in China, where it recently partnered with the state owned construction company Qilu to construct a solar road in the Shandong province [20], [21]. Much like SRI, the company is focused on utilizing panels as an actual pavement surface rather than something to be adhered to existing infrastructure. Figure 10 provides an example of Pavenergy's panel.

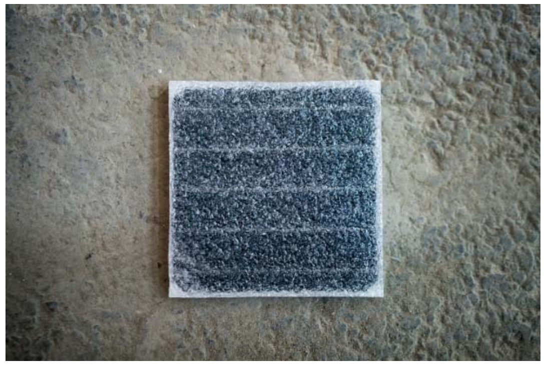


Figure 10. Pavenergy Solar Road Panel [20]

Pavement Integrity & Cost Concerns

Regardless of application, photovoltaic panels face questions regarding structural integrity due to their relatively frail nature. The goal of any photovoltaic panel is to produce the highest efficiency with the lowest cost. One way to accomplish this is by utilizing a panel covering that enables passage of sunlight while providing the bare minimum protection to the cells and electrical components. Some manufactured panels can even survive hail, but oftentimes impacts like that compromise the integrity of the cover and destroy the panel. Thus, it is easy to discern that a significant challenge companies face is manufacturing a panel that can survive not only adverse weather effects but support heavily loaded vehicles such as semi-trucks. Fortunately, at least one of these companies, SRI, has performed testing related to these concerns.

As mentioned previously, SRI has received several grants from the DOT regarding the feasibility of the technology and developing prototypes to perform more advanced testing. Specifically, the Phase II grant focused on concerns such as load testing. After several iterations, SRI was able to manufacture a tempered glass that can withstand loading of up to 250,000 lbs, much higher than a traditional semi-truck loaded at 80,000 lbs [18]. Further, the testing revealed that traction measures could be met by the panels, including the minimum required stopping distance for a vehicle travelling at 80 mph [18]. Unfortunately, in providing a panel that could withstand this loading and traction, some sacrifices had to be made in the form of panel efficiency. The overall output of the panels utilizing this tempered glass decreased by 11% [18]. Additional testing regarding structural integrity was performed during Phase IIB. This testing focused on areas such as freeze/thaw cycles, moisture condition, shear testing, and advanced loading. Currently, the results of that grant have not been published.

While ensuring that these pavements are structurally sound is one of the biggest challenges faced, the goal for these companies to provide a profitable product. Therefore, ensuring consumer attraction to these panels, from a cost standpoint, is another major factor in the design process. Unfortunately, SRI has not published any cost information for their panels but does claim that the panels have a lifecycle of 20 years, with the possibility of performance up to 30 years [18]. Colas and Pavenergy are similar in that there is no cost information readily available for their products, but news outlets have reported that their end goal would be to manufacture a product that would cost approximately $310 per square meter [20]. While not on a cost equivalent basis with regular road construction, this cost would make the panels competitive, even more so depending on the construction setting. For instance, a rural setting sees an average cost of $180 per square meter of new road, while urban road construction tends to be around $255 per square meter [22], [23].

PV Output Variables

Numerous factors affect the amount of power produced by photovoltaic panels. Even further, traditional variables that are associated with tilted panels may undergo amplified or reduced effects based on switching to a horizontal orientation. These factors range in scale but nonetheless may still significantly affect any model that is developed for predicting power output. As such, it is pertinent to discuss factors that may influence the model being developed as well as how those factors differ from use in a traditional orientation.

A variable that has been utilized throughout several models in the prediction of power output is the amount of cloud cover [24]–[26]. In fact, in one model researchers were able to utilize only two variables, one of which was cloud variation, to predict the power output at an hourly interval [24]. The relationship that exists between cloud cover and irradiance received is inverse, such that as the amount of cover increases the amount of power generated decreases. There should not be a distinguishable difference in the effect that cloud cover has on the panels due to a difference in orientation.

Another pertinent variable to predicting performance for these cells is the ambient temperature. It stands to reason that as ambient temperature increases (typically associated with increased sunlight), power generation values increase. However, this is not always the case. Instead, ambient temperature is typically measured due to association with the internal cell structure temperature. As the internal cell temperature rises, the efficiency of the system will decrease. While the temperature relationship is not directly linear, a 1 degrees Celsius increase in ambient temperature often results in an efficiency loss of 0.5% [27], [28].

The two previously discussed factors do not depend upon orientation. However, there are a few variables that can have an increased negative effect when panels are placed horizontally. Typically, tilted solar panels arrays are in areas with ample clear space to ensure shading factors are reduced. There may still be some shading present from the other panels in the array, but environmental shading should not be present. When panels are placed in a horizontal orientation, especially when used as a pavement, it may not be possible to avoid shading from environmental factors such as trees. Soiling is another variable that will tend to see increased negative effects for panels oriented horizontally. The reasoning behind this is simple in that dust or other debris items undergo gravitational settling and therefore are more likely to be deposited on a horizontal surface [29], [30]. This presents an area of concern for horizontal panels as some areas with daily-cleaned specimens reported up to 6% output losses, while those going over six months without cleaning have demonstrated up to a 50% loss in power [28], [29]. Therefore, areas exhibiting higher density dust, which tends to reduce output even further, may not be suited to hosting horizontal panels [27], [28].

There are several remaining factors that are specific to horizontal panels being utilized as a paving surface. These factors are rubber deposition (similar to soiling effects), road maintenance time, and vehicular shading. Unfortunately, due to the lack of research into this idea, there are not large quantities of information regarding the effect of these variables. Regarding rubber deposition, it can be assumed that output losses would be slightly less than that of other soiling effects because rubber would typically be deposited among intersections where vehicles are starting/stopping repeatedly, whereas dust and other debris would likely settle among the entire surface area of a horizontal panel. The second factor stated is road maintenance times. SRI states that their product would require less maintenance time due to the simplicity in replacing panels, but again there is no measurable output or way to measure the validity regarding this statement [18]. The last variable, vehicular shading, should only account for approximately a 10% reduction in output except in major cities where large scale traffic backups occur regularly [19]. This reduction, in addition to tree shading, may severely hamper power generation efforts.

Standard Pavements

Roads are classified as either rigid or flexible depending on the pavement type used in construction. These pavement types are determined based on how surface loading is subsequently distributed. In rigid pavements, the load is primarily distributed throughout the pavement surface. The pavement may have some small deflection and loading transferred to the base course below, but the design relies on the slab utilized. Typical construction for a rigid pavement consists of a concrete slab. Flexible pavements focus on distributing the load to the underlying layers below, ensuring that no layer receives excessive stress values [31]. These pavements commonly use hot-mix asphalt as the surface layer. While Air Force installations may use some rigid pavements, typically for runways and taxiways, the primary construction method for roads on an installation consists of flexible pavement.

Regardless of pavement type, a singular system is used in conducting pavement evaluations, which is known as the Pavement Condition Index (PCI). It was originally developed by the U.S. Army Corps of Engineers, but then further expanded upon and defined by the American Society of Testing and Materials [32]. It has since been adopted DoD wide, with the Air Force implementation being defined in AFI 32-1041. The system consists of dividing pavement into respective branches and sections which are then evaluated individually. The evaluation provides a measure of present condition based on distresses that can be observed on the surface [32]. The condition is then scored on a scale ranging from 0 to 100. To expand upon the system, the Air Force developed descriptions for each of the seven PCI rating categories.

PCI Index	PCI Rating		Descriptions
86 - 100	Green	Good	Pavement has minor or no distresses and will require only routine maintenance.
71 - 85	Bright Green	Satisfactory	Pavement has scattered low-severity distresses that should require routine maintenance.
56 - 70	Yellow	Fair	Pavement has a combination of generally low- and medium-severity distresses. Near term M&R needs may range routine to major.
41 - 55	Rose	Poor	Pavement has low-, medium-, and high-severity distresses that probably cause some operational problems. Near term M&R needs should range from routine to reconstruction.
26 - 40	Red	Very Poor	Pavement has predominantly medium- and high-severity distresses causing considerable maintenance and operational problems. Near-term M&R needs will be intensive.
11 - 25	Dark Red	Serious	Pavement has mainly high-severity distresses that cause operational restrictions. Repair needs are immediate.
0 - 10	Light Gray	Failed	Pavement deterioration has progressed to the point that safe aircraft operations are no longer possible. Complete reconstruction is required.

Figure 11. PCI Descriptions [33]

These descriptions provide an idea as to the intensity of repairs needed, which applies to both airfield pavements and roadways. As seen in Figure 11, there are two items that stick out, the first being maintenance and repairs. Maintenance and repair needs can range in scope, beginning with something as small as filling a pothole. However, these items can progress to repairs such as mill and overlay, which removes the existing surface and places a new surface layer down (also known as resurfacing). Reconstruction, or replacement, on the other hand involves demolishing the subsurface layers in addition to the surface layer. This allows for either recompacting or placing new subsurface material that is adequate for the pavement surface to be laid upon it. While requisite repairs have been outlined, an Air Force wide timeline for when repairs should occur has not been established. Instead, based on prior working experience, as well as local government publications, a standard timeline for mill and overlay focused projects is approximately at the ten-year period [34], [35]. Costs associated with similarly focused repair projects tend to be valued at $120/SM, which while expensive is still significantly cheaper than new construction [20], [22], [23].

Conclusion

Photovoltaic pavements face several drawbacks in the form of poorly defined variables. Specifically, there are variables such as rubber deposition, maintenance time, and vehicular shading that will reduce the performance of the cells but do not have large amounts of test data associated with their ramifications. Opposing, photovoltaic pavements may benefit from some unknown variables like humidity concentration. The biggest boon for photovoltaic pavements though is being able to implement renewable energy technology that may otherwise not be viable due to cost or a variety of reasons. This effort seeks to demonstrate that photovoltaic pavements are a viable cost-effective measure that can be implemented at Air Force installations. This will be accomplished by analyzing photovoltaic performance data respective to location and power generation in combination with electricity prices over a 20-year time period.

III. METHODOLOGY

This chapter outlines the materials and methods utilized in creating a model to analyze the cost effectiveness of photovoltaic pavements. Due to the significant influence exerted from prior research, the chapter will begin by discussing the previous efforts that have culminated in the topic at hand. Specifically, the chapter will begin by providing information related to the experimental system's design and implementation of the system for data gathering. Following, data compilation and analysis techniques preceding the current topic will be discussed. The chapter will then conclude with discussing further data refinement, as well as detailing development of the model and tool for the final analysis.

Test System Design

Unfortunately, little data exists regarding the performance of horizontally oriented PV panels. Recognizing this shortfall, efforts were undertaken by AFIT researchers to develop a test system that could collect performance metrics for such panels. These efforts were led by Capt. Nussbaum, in association with the Electrical Engineering Department, to design an initial test system, while subsequent efforts oversaw construction of the system [6]. The design incorporated two panel types: mono-crystalline and poly-crystalline. These panel types are the predominant panels used in residential and commercial applications, thereby increasing availability and experimental replication. However, even with widespread use, issues were discovered during panel procurement. Therefore, the final manufactured system incorporated a 25W ALEKO mono-crystalline panel and a 50W Renogy poly-crystalline panel [36].

Alongside the panels, a Raspberry Pi served as the central processing unit (CPU) for the system. The CPU is considered the brain of the operations, establishing control of the associated collection systems and compiling the information into a singular source. Further, it provided external connection capability, i.e., HDMI and USB, enabling diagnostic capabilities related to system issues. An example layout of the CPU is provided in Figure 12. The intent was for this capability to work in hand with the RockBlock MK2, a satellite communication system responsible for relaying system health messages. Unfortunately, complications arose with the RockBlock and the health messages were disregarded [7]. Both the RockBlock and Raspberry Pi were housed within a Pelican case, which served as the hub for the entire system. The Pelican case provided a protected environment for the electronics to continue to function even in the most austere locations.

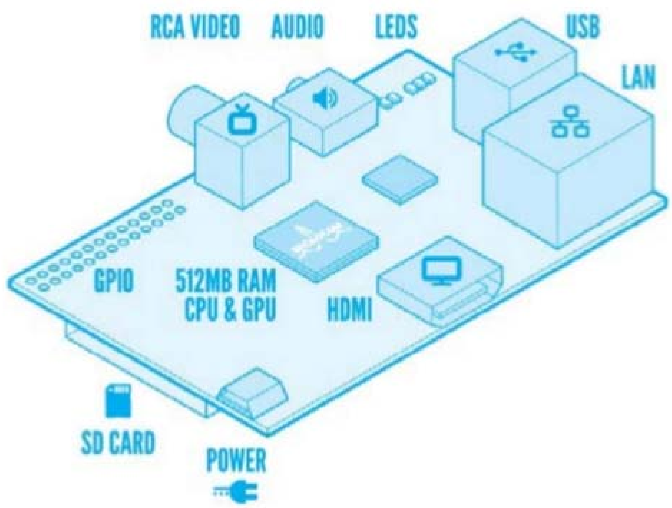


Figure 12. CPU Components (Raspberry Pi) [37]

The remaining components of the system were the measurement probe and the power source. The measurement probe was located on the exterior of the Pelican case and was responsible for collecting ambient air temperature and humidity readings. The probe relayed the readings to the CPU, which stored the information, as well as voltage output of the panels, in 15-minute intervals. A constant power source was necessary for the system to ensure continual

CPU operation without downtime. Power was provided at each site either through connection to the existing electrical infrastructure (US standards) or through a standalone battery. In total, five locations required the standalone battery due to site constraints [5]. Upon facing shipping restrictions, only battery model information was provided to the respective sites that could not provide standard power, leaving the sites to procure their own batteries. These locations were provided an additional 30W panel that could keep the battery charged, as can be seen in Figure 13.

Figure 13. Battery Powered System [5]

Experimental Implementation

Alongside system design, site selection was critical to ensure data was representative for the geographical area and not redundant. Therefore, previous researchers utilized a variety of statistical methods to select installations out of the 1,763 deemed available (based on unique real property site identifier codes) [6]. The selection process began through conducting an analysis of variance on both latitude and longitude, which led to five distinct bins for each variable. Subsequently, an overlaid histogram of the latitudinal and longitudinal bins was created, which produced 25 regions containing all 1,763 locations. Looking at Figure 14, only twenty regions contained sites, which eliminated five sites from consideration as a system host [36].

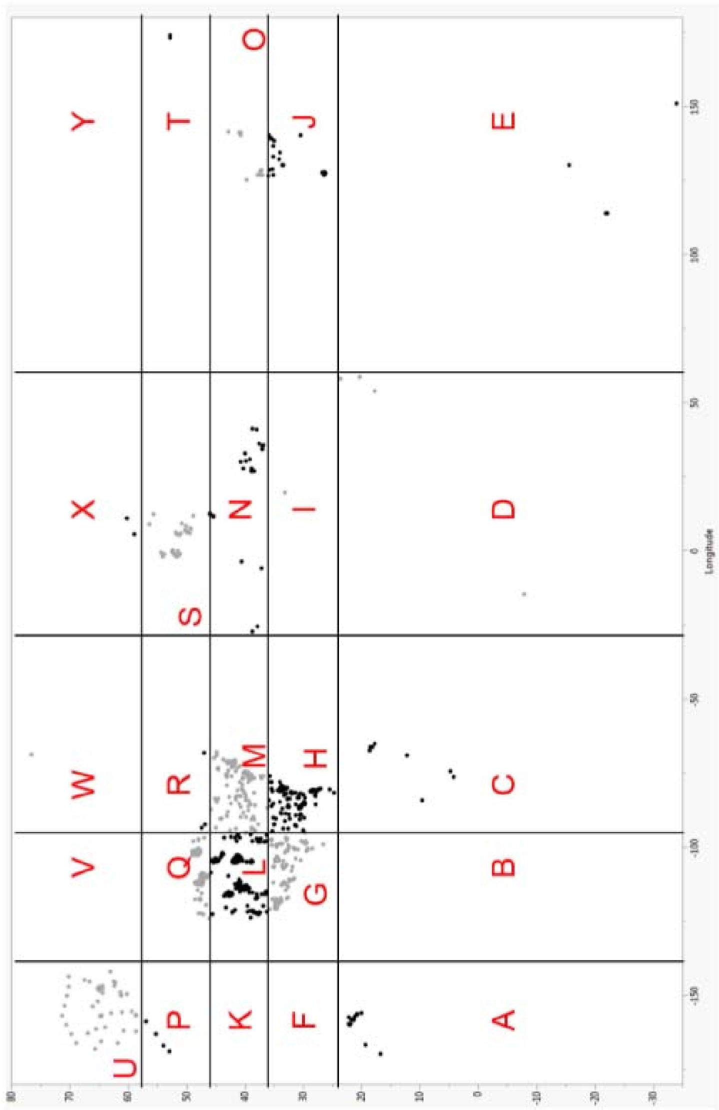


Figure 14. 25 Regions Based on Latitude & Longitude [6]

Summary statistic calculations were performed on the remaining twenty locations to determine mean latitude and longitude. Researchers assumed that any location near those values would be considered an accurate representative for the region. Unfortunately, some of the installations closest to the mean values were unavailable due to a variety of reasons. In such cases, the researchers gave preference to matching latitude [6]. The coordinates for each of the final sites selected based on region are summarized in Table 1.

Region	Desired Lat	Desired Long	Selected Site Lat	Selected Site Long	Lat Delta	Long Delta
A	21.01796316	-158.8819526	20.8817	-156.4675	0.136263	2.414453
B	0	0	N/A	N/A	0	0
C	14.03258	-70.07715	12.1833	-69	1.84928	1.07715
D	13.80936667	42.30361667	11.5172	43.0644	2.292167	0.760783
E	-23.401475	127.46385	-22.19	114.103	1.211475	13.36085
F	0	0	N/A	N/A	0	0
G	33.10169884	-106.1646988	32.9186	-106.134	0.183099	0.030699
H	31.293064	-83.62521143	31.1671	-92.62	0.125964	8.994789
I	33.1833	19.7167	29.346964	47.521819	3.836336	27.805119
J	31.63523824	132.2586029	33.5667	130.4333	1.931462	1.825303
K	0	0	N/A	N/A	0	0
L	40.96126303	-108.2169311	40.9428	-113.412	0.018463	5.195069
M	41.01970582	-79.92033386	40.6703	-86.1469	0.349406	6.226566
N	39.26723409	9.109268182	38.7808	-27.1453	0.486434	36.25457
O	38.396	130.6304375	39.65	125.3333	1.254	5.297138
P	54.787125	-164.28625	55.2629	-162.807	0.475775	1.47925
Q	47.79719507	-107.3443075	47.7949	-101.298	0.002295	6.046308
R	46.9237875	-89.2779125	46.9344	-67.913	0.010612	21.36491
S	50.04802442	5.847924419	50.0263	6.799	0.021724	0.951076
T	52.77605	173.6425	52.7195	174.106	0.05655	0.4635
U	64.02361129	-152.6679081	64.2905	-149.187	0.266889	3.480908
V	0	0	N/A	N/A	0	0
W	76.5311	-68.7031	76.5311	-68.7031	0	0
X	59.37473333	7.517366667	58.9633	5.7331	0.411433	1.784267
Y	0	0	N/A	N/A		

Table 1. Region Based Site Selection [6]

While requirements were satisfied for 20 locations, the experiment had been designed to provide test systems to a total of 37 locations. As such, a Pareto analysis was performed on the 25 regions to determine which areas housed the most installations. However, the researchers also wanted to incorporate climate classifications, based on the Koppen-Geiger system, to ensure experimental diversity. Through multiple Pareto analyses, researchers selected the remaining 17 sites with priority given to larger installations within a populous region and in climate types that were deemed significant for further analysis [6]. Figure 15 provides a summary picture for placement of all test systems.

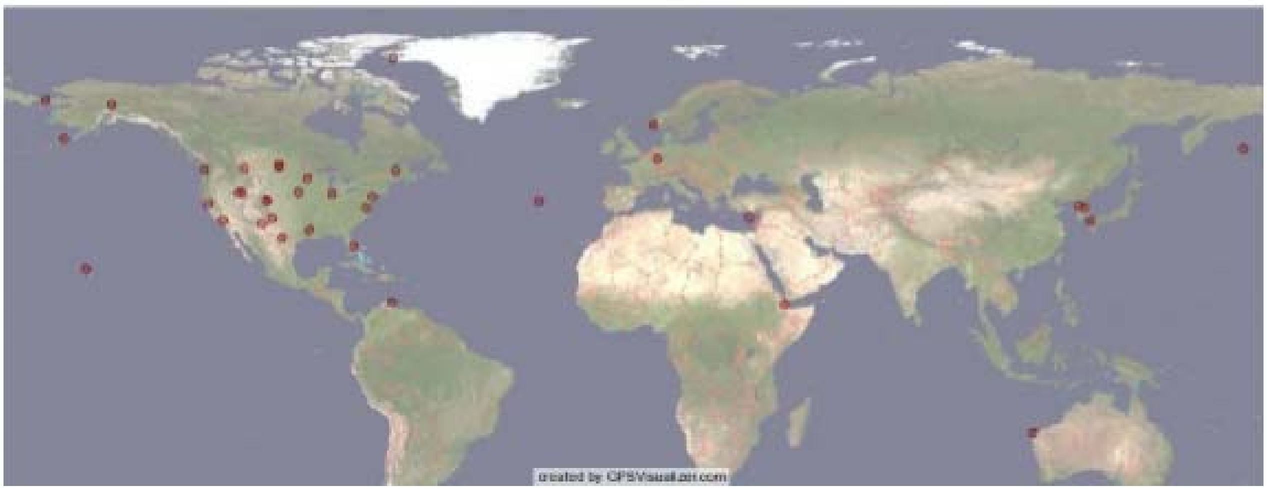
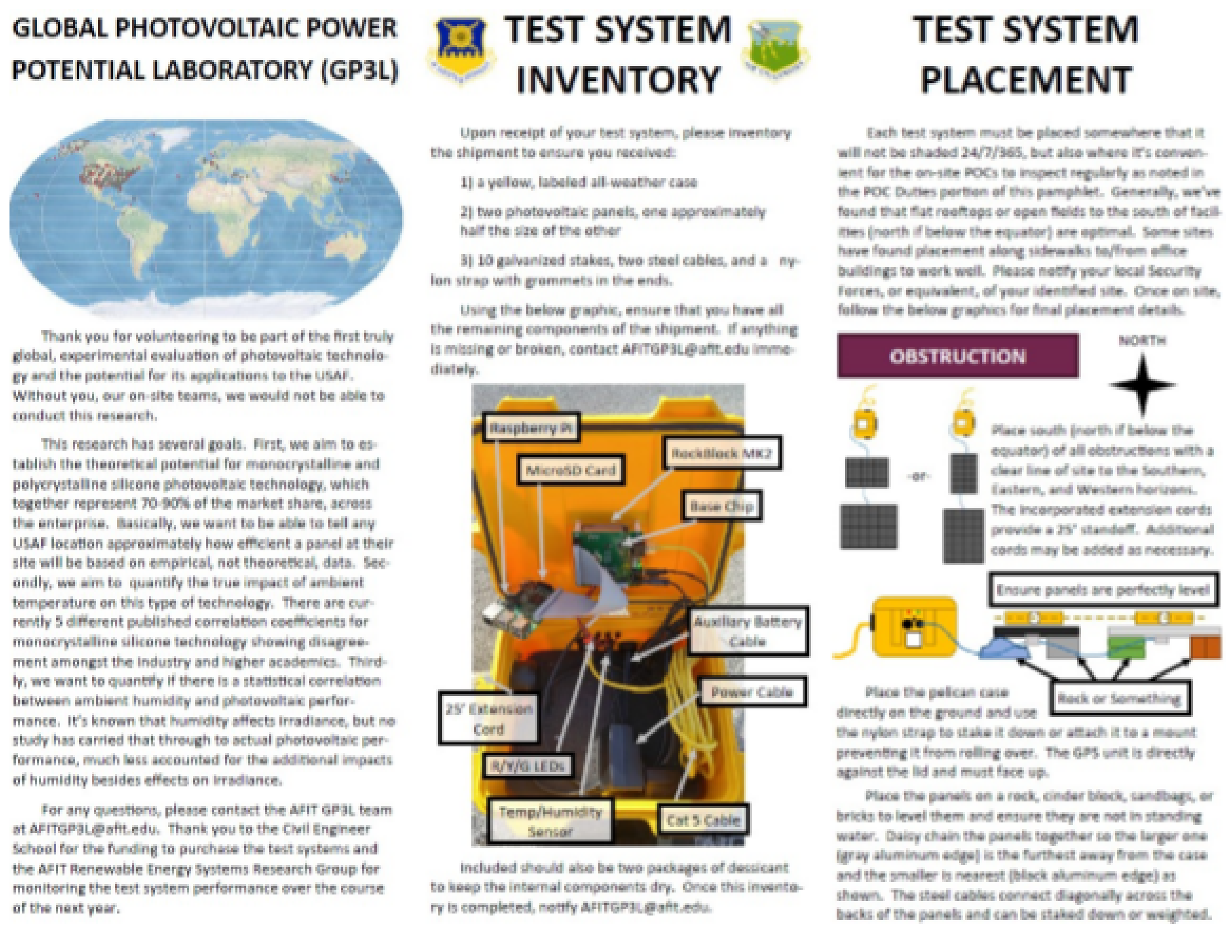


Figure 15. Test System Location Placement [7]

Point of contacts (POCs) were required to help aid in system setup and monitoring. It was decided that the energy office for each location would serve as the primary POC. In cases that the energy office could not participate, a command designated POC was instead chosen [7]. After establishing POCs and completing assembly for the systems, the systems were finally shipped in early 2017 to the sites, with data collection beginning for many sites in June 2017. Instructions for system setup were included to try to ensure conformity and preserve experimental methodology, as demonstrated in Figure 16.



GLOBAL PHOTOVOLTAIC POWER POTENTIAL LABORATORY (GP3L)

Thank you for volunteering to be part of the first truly global, experimental evaluation of photovoltaic technology and the potential for its applications to the USAF. Without you, our on-site teams, we would not be able to conduct this research.

This research has several goals. First, we aim to establish the theoretical potential for monocrystalline and polycrystalline silicone photovoltaic technology, which together represent 70-90% of the market share, across the enterprise. Basically, we want to be able to tell any USAF location approximately how efficient a panel at their site will be based on empirical, not theoretical, data. Secondly, we aim to quantify the true impact of ambient temperature on this type of technology. There are currently 5 different published correlation coefficients for monocrystalline silicone technology showing disagreement amongst the industry and higher academics. Thirdly, we want to quantify if there is a statistical correlation between ambient humidity and photovoltaic performance. It's known that humidity affects irradiance, but no study has carried that through to actual photovoltaic performance, much less accounted for the additional impacts of humidity besides effects on irradiance.

For any questions, please contact the AFIT GP3L team at AFITGP3L@afit.edu. Thank you to the Civil Engineer School for the funding to purchase the test systems and the AFIT Renewable Energy Systems Research Group for monitoring the test system performance over the course of the next year.

TEST SYSTEM INVENTORY

Upon receipt of your test system, please inventory the shipment to ensure you received:

1) a yellow, labeled all-weather case

2) two photovoltaic panels, one approximately half the size of the other

3) 10 galvanized stakes, two steel cables, and a nylon strap with grommets in the ends.

Using the below graphic, ensure that you have all the remaining components of the shipment. If anything is missing or broken, contact AFITGP3L@afit.edu immediately.

Included should also be two packages of dessicant to keep the internal components dry. Once this inventory is completed, notify AFITGP3L@afit.edu.

TEST SYSTEM PLACEMENT

Each test system must be placed somewhere that it will not be shaded 24/7/365, but also where it's convenient for the on-site POCs to inspect regularly as noted in the POC Duties portion of this pamphlet. Generally, we've found that flat rooftops or open fields to the south of facilities (north if below the equator) are optimal. Some sites have found placement along sidewalks to/from office buildings to work well. Please notify your local Security Forces, or equivalent, of your identified site. Once on site, follow the below graphics for final placement details.

Place south (north if below the equator) of all obstructions with a clear line of site to the Southern, Eastern, and Western horizons. The incorporated extension cords provide a 25' standoff. Additional cords may be added as necessary.

Place the pelican case directly on the ground and use the nylon strap to stake it down or attach it to a mount preventing it from rolling over. The GPS unit is directly against the lid and must face up.

Place the panels on a rock, cinder block, sandbags, or bricks to level them and ensure they are not in standing water. Daisy chain the panels together so the larger one (gray aluminum edge) is the furthest away from the case and the smaller is nearest (black aluminum edge) as shown. The steel cables connect diagonally across the backs of the panels and can be staked down or weighted.

Figure 16. POC Provided Instructions for System Setup [7]

Data Collection & Compilation

The experimental systems were responsible for collecting a myriad of variables. These were ambient air temperature, internal system temperature, panel temperature, humidity, voltage, current, time, and date. Measurements were collected in 15-minute intervals, except for voltage and current. Voltage and current were instead measured 64 times throughout the 15-minute interval, with each measurement then being converted to a power output (watts). The highest power output per interval was recorded as the actual output [36]. Data recording was performed by the CPU and stored onto a SD card within the CPU. Each month, the respective site POC was responsible for removing the SD card and uploading the data to the researchers.

The experiment collection period lasted from June 2017 to October 2018. Unfortunately, several sites never provided any data after initial system setup. Additionally, numerous sites failed to provide consistent data over the timeframe, often missing months at a time. As such, it was determined that upon final completion of the data collection period that only locations with at least eight months of data would be included in the compiled dataset. This resulted in 18 of the original 37 sites being included in the final compiled dataset.

Data Cleaning

Prior to performing any specialized data refinement, several data cleaning steps had already been undertaken by previous researchers. One of the first steps taken in cleaning the data was converting time readings to the respective local time for each test site location. This was necessary as all initial readings were recorded in Zulu time [36]. However, the time conversion did not account for daylight savings as it was not considered during the recording period. Additionally, some of the regions where systems were located do not account for daylight savings.

While the test system gathered data for both mono-crystalline and poly-crystalline panels, it became readily apparent during data examination that the mono-crystalline data was invalid as can be seen in Figure 17. It was noted by one researcher that the 25W panel recorded an output of 400W for one location, while some frequently sunny locations had no outputs over 10W for the entire collection period [38]. Therefore, all data points related to the mono-crystalline panels were expunged from the dataset.

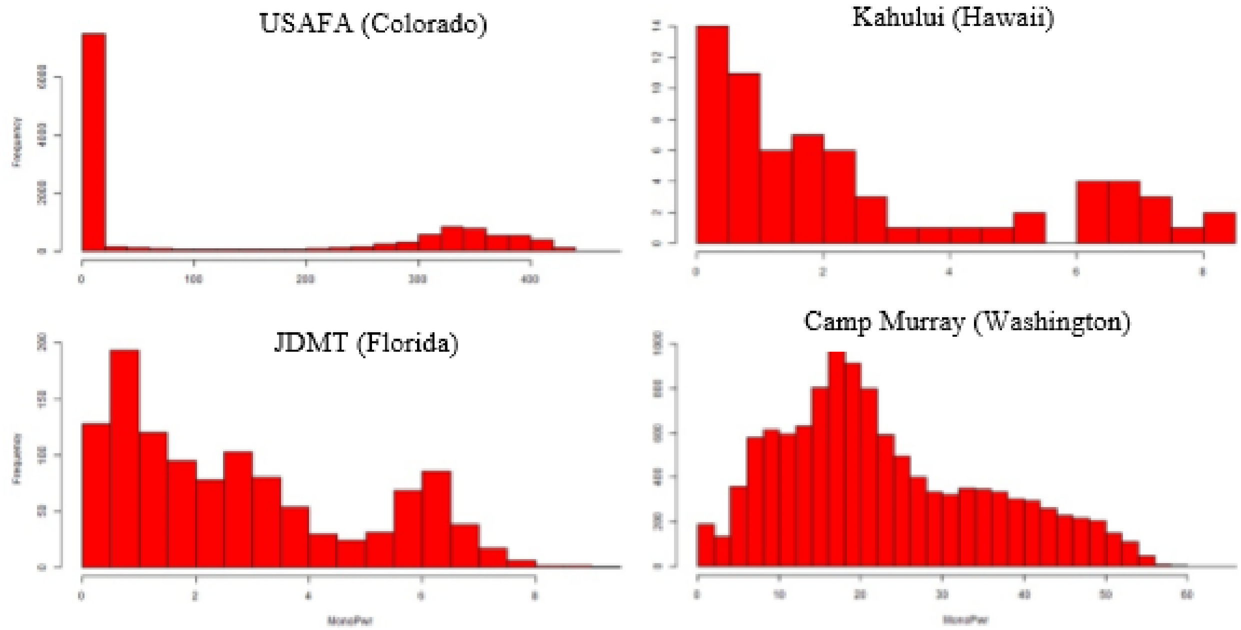


Figure 17. Monocrystalline Power Output Examples [38]

Several sites also demonstrated what was colloquially termed a "break-in" period during the collection of data. The sites recorded numerous readings for the polycrystalline panel above the panel rating of 50W. Upon further examination, it was seen that these values were only recorded during the first few months of initial operation and the sites later recorded expected values [36]. The likely cause for the high values was due to a calibration error with the Raspberry Pi unit, hence the subsequent correction. Due to the likelihood of the readings being false, the affected months were removed from the dataset.

All readings taken at Learmonth Solar Observatory were removed. This was the only location within the Southern Hemisphere and thus presented concerns that modelling errors would arise due to its inclusion in the dataset. Specifically, additional analysis performed by previous researchers included seasonal effects, which could have been obscured if the site was considered [36]. Lastly, data points associated with temperature values below -39.3 degrees Celsius were removed. Some locations recording these temperature values could not possibly reach these, e.g. areas such as Florida [36]. Even more, temperature values below that value recorded humidity and power primarily as zero, making it almost impossible to decipher if the readings were legitimate [38].

Location Specific Collection – Current Efforts

Before gathering additional data for all locations, it became apparent that steps should be taken to ensure the analysis would be more manageable. The simplest way to accomplish this was through reducing the number of bases to undergo examination; therefore, five bases were selected to focus efforts on: Malmstrom AFB, Offutt Air AFB, Travis AFB, Peterson AFB, and the United States Air Force Academy (USAFA). These locations were selected as representatives due to previous research results, which demonstrated that these bases had consistent data throughout the approximate year of observation. During subsequent analyses, it was established that not all locations were as optimal as thought, due to issues with the power generation data, which led to further refinement efforts in order to facilitate model accuracy and tool usage.

There were multiple datasets not contained within the initial experiment that had to be gathered to facilitate the development of the cost effectiveness analysis tool. The first dataset collected was focused on providing the number of available pavement surfaces at the locations specified above. Initially, performing hand calculations based on information provided by Google Maps was considered to gather the data. Obviously, this method would have been extremely time intensive, as well as susceptible to measuring errors. This led to consideration toward contacting the real property officer at each installation to see if a consolidated pavement list could be provided for that location. However, through some additional connections, it was determined that the Air Force Civil Engineer Center (AFCEC) Geospatial Integration Office could provide the information that was required for the analysis. After reaching out, the members of the office graciously provided this information. The data was provided in an Excel spreadsheet containing a total of ten sheets, with each base being represented by two sheets within the document. The first sheet represented roadways located on that installation, while the second sheet contained roadways and other potential pavement features. Each sheet also provided information on a total of 46 metrics. Therefore, while the information simplified data collection efforts, an enhanced need for refinement was realized.

The other dataset deemed necessary for the final cost analysis was the energy consumption at each location. Again, initial thoughts were to reach out to the Energy Manager at each installation to request assistance in gathering monthly consumption values. However, having leveraged the resources provided by AFCEC for the pavement values, it was considered that this could be another opportunity for assistance. After an impromptu inquiry, it was determined that AFCEC/CNA could provide the information necessary. The office provided several reports for the bases requested, focusing on monthly energy consumption values for a multitude of commodities (i.e., natural gas, electric, etc.) throughout the FY17 and FY18 reporting periods.

Data Refinement

The data for pavement at each location was robust; however, it included numerous objects that were not paved roadways and thus required astute cleaning to ensure accuracy. As mentioned, there were two sheets for each respective base, one of which was focused only on installation roadways. The cleaning process for sheets in that category began with the removal of unnecessary metrics, displayed as columns, throughout the document. These were variables that provided no content for the desired end goal, which was being able to accurately calculate the total pavement surface at an installation. Some sample category descriptors that were removed during this initial process were latitude, longitude, installation ID, site ID, etc. Table 2 provides an example of the spreadsheet layout.

OBJECT	ROADAREAID	SDSID	SDSFEATURE	SDSFEATU_	SDSMETAD	AREASIZ	AREASIZE	PERIMETE	PERIMETE	LATITUD	LONGITU	MGRSCENTR	CATCO	FA
66436	TDKA_TDKA0000082	{7D2B656B-BF1F-4768-9D03-44C8A11F0A61}	Selfridge St	ROAD	2	1.20167991	squareFoot	11.99148508	foot	4297729.688	526250.5649	13SEC2625197730	851147	8511
66437	TDKA_TDKA0000099	{A90D6900-FD52-4C72-9B07-CBCAB13BEA21}	Kirtland Ln	ROAD	2	5771.162675	squareFoot	830.028757	foot	4297471.572	526254.1338	13SEC2625497471	851147	8511
66438	TDKA_TDKA0000100	{606886A9-D3E6-4A86-8F8A-AEABD2E1541A}	McChord St	ROAD	2	0.22042544	squareFoot	6.60651232	foot	4297515.043	526287.9888	13SEC2628897515	851147	8511
66439	TDKA_TDKA0000101	{8609328E-5812-49E8-BB30-E80AE3BFB624}	Youngstown St	ROAD	2	0.42424137	squareFoot	8.39693232	foot	4297553.892	526093.4311	13SEC2609397554	851147	8511
66440	TDKA_TDKA0000102	{A3FCB953-5F41-45EE-A774-8BC723636DEB}	Youngstown St	ROAD	2	1.38995232	squareFoot	12.15698174	foot	4297566.591	526088.043	13SEC2608897567	851147	8511
66441	TDKA_TDKA0000098	{F2ADE27F-7DFA-4870-BD62-012B779D44C2}	McChord St	ROAD	2	0.35767313	squareFoot	7.70118967	foot	4297505.844	526297.6574	13SEC2629897506	851147	8511
66442	TDKA_TDKA0000152	{807A4F87-CE6A-4937-B540-293ABB36AE20}	Dirt Road	ROAD UNSURF	1	9389.349039	squareFoot	1589.65267	foot	4296492.047	526652.8779	13SEC2665196503	851201	99999
66461	TDKA_TDKA0000104	{7959203D-4885-489C-A723-DBA788DBDF5F}	Kirtland Ln	ROAD	2	28570.19842	squareFoot	2471.832948	foot	4297533.451	526151.0572	13SEC2612197522	851147	8511
66462	TDKA_TDKA0000105	{6A2F2C6B-1D6A-40F0-B456-139781D410B1}	Larson Ln	ROAD	2	6350.240666	squareFoot	799.9816036	foot	4297491.608	526399.4465	13SEC2639997493	851147	8511

Table 2. Partial Road Area Sheet

In total, 38 of the original 46 metrics were removed from each sheet pertaining to road area. The remaining eight columns were used to determine whether the entry was a valid roadway, installation location, and the total area of the roadway. This information was consolidated for the five installations to allow for ease of access and further decisions regarding inclusion. After having extracted the columns, judgement calls regarding what would be considered useable roadways had to be made. Specifically, as the model is focused on evaluating photovoltaic panels as a road pavement, the intent was to remove extraneous items that were not considered to be useable roadways. This led to the removal of 441 different entries within the sheet, consisting of items related to unpaved roads, driveways, parking lots, and roads not belonging to the base. Additionally, a bit of a reality check had to be conducted regarding size values contained in the sheet. Specifically, there were several entries under a total area of 100 square feet, which would lend credence to an entry not being an actual road surface. As such, 22 records were removed from the dataset in relation to this assumption. There were 15 additional records removed for having a blank area size, as well as 1 record removed for being unreasonably high, i.e. single roadway over 5 million square feet.

The process for extracting the relevant information from the secondary sheet in relation to road surface was much the same as previously described, with Table 3 providing a partial view of the beginning product. Again, each sheet began with 46 variables, which was quickly reduced to 10.

OBJECT	pavementBranchIDPK	sdsID	sdsFeatureNam	sdsFeatureDescription	sdsMetadataID	areaSize	areaSizeU(	perimeterS	perime
1	TDKA-TDKA0001-PM-PBA-1	{515487BA-C91D-4BD4-A2E4-B13917FC1DC4}	TBD	Static Display Foundation	TBD	197.5902415	squareFoot	54.23688074	foot
2	TDKA-TDKA0001-PM-PBA-2	{9046CB4B-DC85-4F0B-B667-A015AA0CE2E3}	TBD	Porch	TBD	27.75433979	squareFoot	21.07324147	foot
3	TDKA-TDKA0001-PM-PBA-3	{EACBB2EA-9700-45C5-89FF-51277161B22E}	TBD	Manhole Vault - Storm Sewer Utility	TBD	45.92853247	squareFoot	28.46110105	foot
4	TDKA-TDKA0001-PM-PBA-4	{A7E0E76C-D90B-4384-8239-6D5330CA87A4}	TBD	Manhole Vault - Storm Sewer Utility	TBD	40.10787583	squareFoot	27.41265134	foot
5	TDKA-TDKA0001-PM-PBA-5	{55D1B88D-67BB-4F85-BC73-0848152E3656}	Equipment Pad	PAD EQUIP	132133	46.81738606	squareFoot	61.09339839	foot
6	TDKA-TDKA0001-PM-PBA-6	{D3461EE8-4261-401A-BBD6-8B999D531C53}	TBD	Possible Sidewalk	TBD	138.3214653	squareFoot	60.48712887	foot
7	TDKA-TDKA0001-PM-PBA-7	{2C0295E3-09E8-46AB-B77F-21952F01F178}	TBD	Mechanical Courtyard #2025	TBD	5941.788144	squareFoot	644.2726043	foot
8	TDKA-TDKA0001-PM-PBA-8	{10F96CC3-41C8-4321-B2F4-3DD908964097}	TBD	Mechanical Courtyard #2025	TBD	4339.882581	squareFoot	598.4613173	foot
9	TDKA-TDKA0001-PM-PBA-9	{AE50ECBB-6D09-4018-AF0A-E3527888CD5C}	TBD	Static Display Foundation	TBD	11707.75866	squareFoot	454.2972758	foot
10	TDKA-TDKA0001-PM-PBA-10	{84E99619-DCED-4ECB-95E9-A06712671D7C}	TBD	Possible Equipment Pad	TBD	137.6717035	squareFoot	50.75980288	foot

Table 3. Partial Pavement Area Sheet

The remaining categories contained information related to validity, installation location, and area. The information for each sheet was then consolidated into a final document and ready for further refinement. Unfortunately, many entries within the pavement area sheet were not relevant for further analysis, i.e. curbs and gutters. This led to the removal of over 25,000 entries from the sheet. Approximately another 1,000 records were removed due to lack of information that could help differentiate whether the entries were valid or just an extraneous feature.

Like mentioned prior, energy consumptions values for the bases selected were provided by AFCEC in order to facilitate the final model. Each installation had at least one fiscal year (FY) of data, with some bases having multiple. For instance, the USAFA had information back to FY16, while others such as Offutt AFB only had data for FY18. Due to this discrepancy, it was decided to examine whether each of the five bases were able to provide a one-year window where the collection period was the same. As it happened, each of the locations provided had energy consumption values for FY18. Therefore, consumption values not attributed to FY18 were removed from the respective spreadsheets.

Additionally, it was decided that the end focus for the model would purely be on electrical consumption. As such, all other energy consumption sources (such as natural gas, etc.) were removed from the documents. The remaining information for each base was then consolidated to help identify any trends, as well as any missing data that required correcting. The consolidation effort revealed a total of three entries that lacked energy consumption values. Specifically, the December reporting period for Malmstrom AFB, as well as the February and June reporting periods for Offutt AFB were missing. In order to replace these missing data values, both the preceding and following months were examined to determine which month had the highest consumption. The month with the highest consumption was then selected to serve as the value for the missing data. This was done to ensure that the replaced values were a worst-case scenario when conducting the final analysis.

Finally, the energy consumption values that had been provided were measured in Million British Thermal Units (MBTUs). As the photovoltaic data collected by previous researchers was measured in Watts, it was determined that converting the MBTUs to kilowatt hours would be the best path forward. This was accomplished through using the conversion factor demonstrated in Equation 1, which was provided by the AFCEC

$$1\ kWh = .003412\ MBTU$$

Equation 1. MBTU Conversion Factor

Following conversion, the only data set that required cleaning was the previously provided generation values. However, prior to cleaning, it had to be decided what frame of reference would be used in the final analysis. Specifically, each experimental system had gathered power measurements in 15-minute intervals all day long, regardless of daylight and nighttime hours. This resulted in the inclusion of numerous data points which ultimately provide no real value as the power being produced was approximately zero. These values would highly skew any average output values that would be calculated later during the analysis. As such, the measurement window that was analyzed throughout this research was from 0700 to 1945 at night, providing a total of 13 hours. While some locations may not have received daylight at each specific hour in relation to the selected window, the designated times provided the most reliable reference for measurement without negatively skewing power generation averages.

After having established the representative time frame, the dataset was ready to undergo additional scrutiny regarding completeness. In just a few moments, it became apparent that there were a significant amount of data points missing for this reduced timeframe. For instance, while some days had no missing intervals, there were multiple cases of several hours being absent. To identify the missing data, as well as the respective dates, an equation was created in Excel that counted the number of recordings based on the day. A small snapshot of some initial results is demonstrated in Table 4, where the highlighted value represents a complete day of data.

Date	Malmstrom	Offutt	Peterson	Travis	USAFA
20171001	0	47	50	49	49
20171002	0	47	49	49	44
20171003	0	46	50	50	0
20171004	0	45	51	51	0
20171005	0	47	49	50	0
20171006	0	44	49	52	0

Table 4. Missing PV Recordings Based on Date

As this information was the backbone data for the final analysis, a path forward for correcting the missing information had to be developed. While numerous techniques exist for dealing with missing data, such as replacement by randomly generated values, it was decided that examining the previous/post 15-minute intervals and replicating the smallest value would be the optimal solution. The smallest power value helps ensure that the final analysis provides a worst-case scenario, thus providing a more realistic comparison for decision makers. In cases where sequential values were missing the technique of examining the previous/post interval was still applied. However, the technique is more susceptible to validity issues when readings have a vast differentiation in time. This concern becomes even more apparent for two installations in which an entire month of data was missing, therefore leading to that month being completely replaced.

The process began by identifying time frames in which a measurement gap larger than the prescribed 15-minutes existed. A formula was implemented that displayed a text response for each cell that did not meet the 15-minute interval, thereby allowing for distinction in subsequent steps. After identifying these zones, Excel can select cells based on special criteria such as zeros, or in this case based on text [39]. This allowed for blank rows to be inserted into the region where data was missing. The replicated data was then incorporated into the dataset through selecting all blank rows, again based on special cell criteria, and using keyboard shortcuts that copied previous cell information [40]. As mentioned though, the power values were not simply copied, but instead selected from previous/post measurements based on the lowest value. Several iterations of the process were required to accommodate instances in which more than one 15-minute recording was missing. Once all values were sufficiently replicated, final data counts were performed to ensure that each day had the correct number of data points.

Tool Development

The initial step in developing an adequate tool for measuring cost effectiveness of PV panels as a road surface began with determining which software would best facilitate the analysis. While data preparation for the variables identified could be considered intensive, the overall analysis being conducted is not mathematically complex. Therefore, it was decided that Microsoft Excel would be utilized for the analysis as it provides a basic computation tool that has expansive capabilities. Following selection of the analysis tool, the information to be included required compilation into the final document. This was accomplished to facilitate computation, as well as allowing for easier access for any follow-on research. The data placed into the background sheet consisted of several variables that were discussed throughout previous sections. The first variable, hourly power generation, was selected to help provide measurement regarding energy consumption being offset, as well as overall energy savings. It is measured in Watts, with each independent location having an average consolidated at the monthly level. This average was determined through creating pivot tables from the revised dataset of power generation discussed during refinement and is summarized in Table 5.

Watts per Hour Average					
	Malmstrom	*Offutt*	*Peterson*	*Travis*	*USAFA*
Jan	1.118	1.999	2.592	1.822	2.026
Feb	1.863	2.797	3.838	5.549	2.161
Mar	4.215	4.53	6.943	6.102	2.026
Apr	6.373	6.831	7.734	9.17	8.315
May	7.927	9.034	9.194	11.612	9.09
Jun	8.99	9.921	9.286	13.003	8.971
Jul	10.669	11.153	8.627	11.199	8.694
Aug	7.692	9.496	7.511	8.891	7.561
Sep	4.482	5.217	7.214	6.305	5.806
Oct	0.673	4.511	4.883	6.769	2.026
Nov	0.673	1.303	3.274	2.902	2.026
Dec	0.54	1.303	2.565	2.684	2.026

Table 5. Power Generation Averages (Per Panel)

The next variable included into the background data sheet was the monthly electrical consumption for each installation. Electrical consumption was provided to help determine whether it was possible to produce enough power from the panels to offset the consumption of the base. As discussed earlier, the values had been converted into kWh measurements to facilitate the comparison between generation and consumption, which can be seen in Table 6.

Base	*Reporting Period*	*Revised kWh*
Malmstrom	2017 - 10 October	9018010
Malmstrom	2017 - 11 November	5984177
Malmstrom	2017 - 12 December	5984177
Malmstrom	2018 - 01 January	4144650
Malmstrom	2018 - 02 February	4086159
Malmstrom	2018 - 03 March	3585022
Malmstrom	2018 - 04 April	3174285
Malmstrom	2018 - 05 May	3496842
Malmstrom	2018 - 06 June	3608637
Malmstrom	2018 - 07 July	3851808
Malmstrom	2018 - 08 August	4269735
Malmstrom	2018 - 09 September	3657069

Table 6. Malmstrom Electrical Consumption

The last two variables input into the background data sheet were the total pavement area and cost of potential paving sources. The amount of pavement area was measured in square feet, although converted to square meters during the analysis as researched costs were measured on a square meter basis. The combined square footage for an installation serves as an evaluation measure of the amount of pavement to be resurfaced or totally replaced. As for cost of paving sources, there were five different methods provided for tool development which are seen in Table 7. The traditional method, which is considered the cheapest, would be asphalt resurfacing. Rural construction refers to the entirely new construction of a road, to include sub-base and base, that would be subjected to relatively low volume traffic. On the opposing hand, urban construction would be for new road construction subject to high volume traffic loading. The cost values for PV roadways utilize suggested values found during market research, with one being a best-case scenario and the other a worst-case scenario.

Pavement Costs ($/SM)		
$	120	Ashaplt Resurface
$	180	Rural Construction (NEW)
$	255	Urban Construction (NEW)
$	310	PV Construction (Best Case)
$	460	PV Construction (Worst Case)

Table 7. Pavement Cost Values

After all requisite information was loaded into the document, the respective calculations Excel needed to perform for the analysis were created. The first calculation required was determining the amount of pavement area that would be resurfaced and/or replaced. This was accomplished by establishing a user input area for selecting percentage values to replace. Based on that user input, the percentage values are compared to total installation pavement to identify the respective square footage value. The square footage value is then converted into a square meter measurement, using the conversion factor provided in Equation 2.

$$1\ Square\ Foot = 0.092903\ Square\ Meters$$

Equation 2. Square Meter Conversion Factor

Once pavement values were determined, the equivalent number of panels to fully replace that surface area was calculated. The photovoltaic panel dimensions were based off evaluating a current Renogy product, similar to the one used in the test system, with the results being 0.372 square meters. The calculation took the total pavement area divided by this value to find an approximate panel count. Real-life application would incur some discrepancies with this value, but for research purposes it provides an accurate example of the required panel count.

As there were pre-determined cost values, calculations for determining initial costs for the pavement methods were simple. The calculation was a result of multiplying the pavement measurement by the cost per square meter for the respective method. However, in order to provide the best representation, a traffic load input is also required by the user. The traffic load input does not affect resurface cost, but it does influence which value is selected from background calculations for the replacement cost.

Lastly, the tool was meant to provide a way to effectively analyze lifecycle cost effectiveness for photovoltaic pavements. Therefore, measuring construction costs against a 5, 10, 15, and 20-year life cycle was necessary for the tool. While initial costs took into consideration differing values for resurfacing and replacement, it was assumed that the same roads would only undergo resurfacing at the 10-year mark. There was no additional maintenance considered for those roads, as well as no maintenance considered for the PV roadways. However, due to the 10-year resurfacing, as well as potential energy savings, the time value of money had to be considered. This was accomplished by utilizing pre-determined formulas in Excel that converted all values into present value and is discussed in detail below. Energy savings, measured in dollars, was based on a variety of previous outputs and entered information. Particularly, the hourly average watts produced was converted into a kWh equivalent. This value had been determined based on the number of panels that would be used to replace the pre-existing roadways. Further, a dollar cost could be assigned to these values based on the average rate the installation pays for electric. Table 8 represents how the energy cost savings were represented during the analysis. Electric costs were determined by comparing monthly electric bills with consumptions values at each installation. For installations lacking cost data, electric costs were determined based on federally provided information.

Energy Cost Equivalent of kWh (Generated)					
	Malmstrom	Offutt	Peterson	Travis	USAFA
Jan	$ 5,146.35	$ 9,201.76	$ 11,931.44	$ 8,386.99	$ 9,326.04
Feb	$ 8,575.72	$ 12,875.09	$ 17,667.00	$ 25,543.04	$ 9,947.47
Mar	$ 19,402.40	$ 20,852.40	$ 31,959.88	$ 28,088.60	$ 9,326.04
Apr	$ 29,336.06	$ 31,444.32	$ 35,600.99	$ 42,211.16	$ 38,275.44
May	$ 36,489.41	$ 41,585.13	$ 42,321.63	$ 53,452.12	$ 41,842.90
Jun	$ 41,382.59	$ 45,668.15	$ 42,745.13	$ 59,855.15	$ 41,295.13
Jul	$ 49,111.32	$ 51,339.26	$ 39,711.63	$ 51,551.01	$ 40,020.04
Aug	$ 35,407.66	$ 43,711.79	$ 34,574.48	$ 40,926.87	$ 34,804.64
Sep	$ 20,631.45	$ 24,014.79	$ 33,207.34	$ 29,023.05	$ 26,726.06
Oct	$ 3,097.94	$ 20,764.94	$ 22,477.33	$ 31,158.92	$ 9,326.04
Nov	$ 3,097.94	$ 5,997.94	$ 15,070.81	$ 13,358.43	$ 9,326.04
Dec	$ 2,485.72	$ 5,997.94	$ 11,807.16	$ 12,354.93	$ 9,326.04
SUM	$ 254,164.57	$ 313,453.52	$ 339,074.82	$ 395,910.28	$ 279,541.90

Table 8. Monthly Energy Cost Equivalence Values

Mathematical Model

While the previously described tool allows for ease of analysis, it does not provide a model for determining cost effectiveness of the PV pavements. Instead, it provides a summary output for the 20-year lifecycle which is based upon the results of the mathematical model developed for this research. The goal for the model developed during this research was to provide a way to analyze the cost effectiveness of PV pavements. Looking to accomplish this, several background data values described previously were included as variables for the model. For instance, power generation values were gathered based upon previous research efforts. These values were then utilized to calculate the cost savings provided by the PV pavements. Additionally, engineering economy was applied to the model to account for the changing value of money over a 20-year lifecycle. This principle, along with the associated variables included, are represented in the equations provided in the two subsections following.

Photovoltaic Equations

Each of the following equations pertain to calculating the life cycle cost of PV pavements. The first equation, noted as Equation 3, is responsible for determining the initial construction cost for PV pavements. Equation 4 is used to evaluate the cost savings that would be generated by the panels on a yearly basis. Lastly, Equation 5 brings both elements together to evaluate performance from a net present value (NPV) perspective.

$$PIC_{k,m,l,j} = \Big(\big((rpr_k + new_m) * tpa_l\big) * cp_j\Big) * lf_l$$

Equation 3. Photovoltaic Initial Cost

$$A_{k,m,l} = \left[\frac{\big((rpr_k + new_m) * tpa_l\big)}{pd} * g_l * ce_l\right]$$

Equation 4. Photovoltaic Cost Savings

$$NPV_{k,m,l,j,i,N} = PIC_{k,m,l,j} - \left(\left(\frac{P}{A_{k,m,l}}, i_N, N\right) * A_{k,m,l}\right)$$

$$i_N = \begin{cases} 1.3, & N = 5 \\ 1.4, & N = 10 \\ 1.45, & N = 15 \\ 1.5, & N = 20 \end{cases}$$

Equation 5. Photovoltaic Net Present Value

$rpr_k = Resurface\ percentage\ (based\ on\ index)$
$new_m = Replacement\ percentage\ (based\ on\ index)$
$tpa_l = Total\ pavement\ area\ at\ installation$
$cp_j = Cost\ of\ pavement$
$pd = Panel\ dimension$
$g_l = Average\ panel\ generation\ value\ (based\ on\ location\ index)$
$ce_l = Cost\ of\ electricity$
$lf_l = Location\ factor$
$l = Location\ index, varies\ from\ \{1,2,3,4,5\}$
$j = Pavement\ cost\ index, varies\ from\ \{1,2\}$
$k = Resurface\ index\ value, varies\ from\ \{0.01, 0.02, \dots, 0.1\}$

$m = Reconstruction\ index\ value, varies\ from\ \{0, 0.01, 0.02\}$
$N = Time\ Horizon$
$i_N = Interest\ rate\ dependent\ upon\ time\ horizon$

Asphalt Equations

The equations throughout this section are quite similar to the PV pavements. The first equation, noted as Equation 6, provides the initial cost of construction for an asphalt pavement. Equation 7 then provides the cost for performing future repairs, i.e., resurfacing at the 10-year mark. Finally, Equation 8 provides the overall calculation for evaluating the life cycle cost of asphalt based upon NPV.

$$AIC_{k,m,l,r} = [\left(rpr_k * tpa_l * \frac{\$120}{SM}\right) + (new_m * tpa_l * cp_r)] * lf_l$$

Equation 6. Asphalt Initial Cost

$$F_{k,m,l} = [\left((rpr_k + new_m) * tpa_l\right) * \frac{\$120}{SM}] * lf_l$$

Equation 7. Asphalt Future Cost

$$NPV_{k,m,l,r,N} = AIC_{k,m,l,r} + \left(\left(\frac{P}{F_{k,m,l}}, 1.5, 10\right) * F_{k,m,l}\right)$$

Equation 8. Asphalt Net Present Value

$rpr_k = Resurface\ percentage\ (based\ on\ index)$
$new_m = Replacement\ percentage\ (based\ on\ index)$
$tpa_l = Total\ pavement\ area\ at\ installation$
$cp_r = Cost\ of\ pavement$
$pd = Panel\ dimension$
$g_l = Average\ panel\ generation\ value\ (based\ on\ location\ index)$
$ce_l = Cost\ of\ electricity$
$lf_l = Location\ factor$
$l = Location\ index, varies\ from\ \{1,2,3,4,5\}$
$r = Pavement\ cost\ index, varies\ from\ \{1,2\}$
$k = Resurface\ index\ value, varies\ from\ \{0.01, 0.02, \ldots, 0.1\}$
$m = Reconstruction\ index\ value, varies\ from\ \{0, 0.01, 0.02\}$
$N = Time\ Horizon$

Tool Use

To facilitate end-user performance and alleviate any potential miscommunications, a small guide for operating the tool has been provided. When first opening the spreadsheet, two tabs will be available. The tab names correspond with their usage, one named "Required Inputs" and the other "Costs & Savings." Those intending to replicate any results or use this spreadsheet for further analysis should begin with the "Required Inputs" tab. The tab provides a default view like that represented in Figure 18.

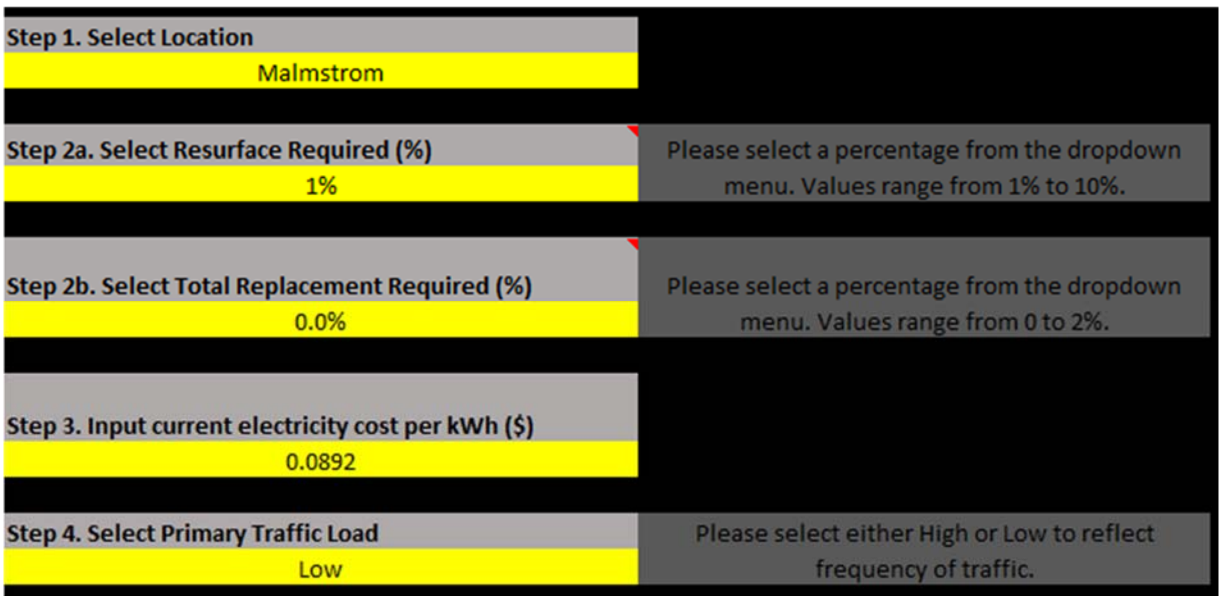


Figure 18. Required Inputs Tab

After arriving at the tab, the first step is to determine a location to be analyzed. There are five locations that have been provided for use. Selections for the menu should be associated with a location that best matches the climate type of the target location, as pictured in Figure 19.

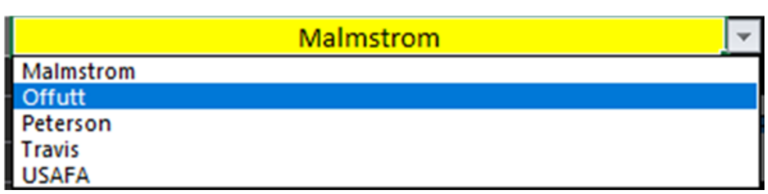


Figure 19. Drop-down Demonstration

Once a selection is made, the next step is to input the amount of pavement being considered for construction efforts. There are two drop-down menus that help to differentiate the different needs of an installation. The first selection, resurface required, is pertaining to the amount of pavement that requires mill and overlay, or a resurfacing technique that is close to cost equivalent. Values for this may range anywhere from 1% to 10%, as expectations are that a base would not exceed 10% of their total roads to undergo resurfacing at once. The second selection, total replacement required, has a two-fold definition. This term can be applied to roads that require total reconstruction, or the amount of area that would require new road construction. This menu has been limited to values ranging from 0 to 2%. Regardless of input method selected, the total amount of asphalt input into the tool will be evaluated as undergoing an additional resurfacing project at the 10-year period.

The next required input is the cost the installation pays for electricity. This cost is measured in $ per kWh, so a user may need to find an equivalent cost depending on their respective electric provider. Following, the user needs to input expected traffic loading in the next drop-down menu. Traffic loading refers to the volume of traffic expected, not necessarily weight limits. Therefore, erring on the side of High for the selection would not be a bad choice if in doubt. Once this choice has been completed, the user is ready to look at the final evaluation results on the "Costs & Savings" tab.

There are several different results provided to help anyone determining whether PV pavements would be viable at their installation. Beginning on the upper left, a user can view the initial cost to compare asphalt with the PV pavement as pictured in Figure 20.

Initial Construction Cost (Asphalt)	
$	3,527,314.35

Initial Construction Cost (PV Best Case)	
$	9,112,228.73

Initial Construction Cost (PV Worst Case)	
$	13,521,371.67

Figure 20. Initial Construction Costs

When viewing these costs, it will become readily apparent that there are two costs for PV pavements. These differing numbers are based on ranges provided for the relative cost to utilize PV pavements. The PV Best Case simply refers to the cheapest value possible, whereas PV Worst Case would be the most expensive value. In addition to these initial costs however, the amount of savings realized by not utilizing as much electricity have been incorporated into a figure to the right side of the tab, which is represented by Figure 21.

PV Savings Produced		
5 Years	$	637,181.18
10 Years	$	1,173,670.63
15 Years	$	1,625,380.36
20 Years	$	2,005,707.83

Figure 21. Savings Produced

For users looking to see the whole picture at once, a summary lifecycle cost table has been provided. The table incorporates both products described above to allow direct comparison over the identified time periods. As identified in the product itself, these values have all been measured in present value. Therefore, decisions can be made on a relative playing field when evaluating which path forward is best, or whether this technology is viable. An example output has been provided in Figure 22.

LIFECYCLE COSTS			
Installation	**Resurface %**	**Replacement %**	**Traffic**
Malmstrom	5%	1%	Low
	Asphalt	**PV Best Case**	**PV Worst Case**
Initial	$ 22,927,543.26	$ 57,407,041.01	$ 85,184,641.50
5 Year	$ 21,551,890.67	$ 50,115,443.64	$ 76,226,388.10
10 Year	$ 38,863,750.17	$ 46,548,401.80	$ 72,659,346.27
15 Year	$ 38,863,750.17	$ 43,251,313.97	$ 69,362,258.43
20 Year	$ 38,863,750.17	$ 40,232,835.44	$ 66,343,779.90

Figure 22. Tool Output - Example

Assuming singular electric costs for each installation, there are a total of 300 iterations that can be evaluated. These iterations are delineated by items such as location, resurface percentage, replacement percentage, and type of traffic loading. In total, there are 30 results for both high and low traffic load types with consideration to the inputs. The resulting 60 iterations for each specific installation encompass values ranging from 1% resurface and 0% replacement all the way up to 10% resurfacing and 2% replacement.

Conclusion

Previous efforts paved the way forward for the research at hand. The original experiment maintained a focus on evaluating photovoltaic pavements and began that thought process with designing an experimental system to collect data on horizontal photovoltaics. These systems were then subsequently constructed and implemented, providing up to a year's worth of data for some locations. Building upon previous data cleaning efforts, this effort focused on developing a mathematical model and corresponding tool that could evaluate cost effectiveness of photovoltaic pavements. Future chapters will look to discuss whether these efforts were fruitful.

IV. ANALYSIS AND RESULTS

This chapter provides the reader with information pertaining to the analysis performed, as well as results for each location as identified throughout previous chapters. The chapter begins by providing a quick introduction to the analysis performed, whereas in-depth knowledge regarding model and tool development are included in the Methodology. Following, results for each individual location are provided to generate an understanding of how factors such as weather and generation affect cost effectiveness. Finally, the chapter concludes with a discussion pertaining to overall data trends.

Cost Evaluation

Evaluating the cost effectiveness of photovoltaic pavements is the overarching goal for the research at hand. In striving to accomplish said goal, it was determined that performing a lifecycle cost comparison would be required. This is because it provides a direct cost comparison of similar technologies over a specified time period (i.e., 20 years). The values supplied for the lifecycle cost comparison were calculated by employing the tool developed in usage with the mathematical model. The tool incorporated parameters consisting of the anticipated resurface and replacement percentages, traffic loading, and electricity cost. Additionally, power generation averages and total pavement area were established for each location. Each location then had 60 distinct scenarios calculated based on said parameters, for a total of 300 iterations. Example iterations are provided throughout this chapter to help the reader visualize the results. In these iterations, cells highlighted green represent PV outperforming asphalt at the specified time period. Through the analyses performed, it became readily apparent that some locations could more effectively employ PV pavements.

Malmstrom AFB

The first location analyzed by the model was Malmstrom AFB, with an electricity cost of \$0.0892/kWh. Beginning with the traffic loading designated as low, it became evident that it would be difficult for PV pavements to compete with asphalt. From the thirty results produced for low traffic loading, only one scenario resulted in PV pavements outperforming asphalt at the 15-year time period, with the stipulation that the cost for PV pavements was best-case (i.e., lowest PV cost - \$310/SM). Additionally, the scenario specified a low amount of resurfacing and a relatively high level of replacement at 2%, the results of which can be seen in Figure 23. A further five scenarios demonstrated viability at the 20-year time period, but again with the stipulation that the cost utilized for PV was the best-case scenario. These results may be viewed in Appendix B.

Malmstrom	1%	2%	Low
	Asphalt	**PV Best Case**	**PV Worst Case**
Initial	\$ 14,109,257.39	\$ 28,703,520.51	\$ 42,592,320.75
5 Year	\$ 13,262,701.95	\$ 25,057,721.82	\$ 38,113,194.05
10 Year	\$ 21,918,631.70	\$ 23,274,200.90	\$ 36,329,673.13
15 Year	\$ 21,918,631.70	\$ 21,625,656.98	\$ 34,681,129.21
20 Year	\$ 21,918,631.70	\$ 20,116,417.72	\$ 33,171,889.95

Figure 23. Malmstrom AFB - Best of Low Traffic Loading (1% Resurface, 2% New)

Looking at high traffic loading, there were a few instances in which PV pavements could provide a comparable capability at the 10-year time period. There were three cases in which PV pavements outperformed asphalt at the 10-year mark, four for 15 years, and nine for 20 years. A few examples of PV pavements outperforming asphalt at the 10-year mark are provided in Figure 24.

Malmstrom	1%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 17,407,296.31	$ 28,703,520.51	$ 42,592,320.75
5 Year	$ 17,407,296.31	$ 25,057,721.82	$ 38,113,194.05
10 Year	$ 26,063,226.06	$ 23,274,200.90	$ 36,329,673.13
15 Year	$ 26,063,226.06	$ 21,625,656.98	$ 34,681,129.21
20 Year	$ 26,063,226.06	$ 20,116,417.72	$ 33,171,889.95

Malmstrom	2%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,722,971.79	$ 38,271,360.68	$ 56,789,761.00
5 Year	$ 20,722,971.79	$ 33,410,295.76	$ 50,817,592.07
10 Year	$ 32,264,211.47	$ 31,032,267.87	$ 48,439,564.18
15 Year	$ 32,264,211.47	$ 28,834,209.31	$ 46,241,505.62
20 Year	$ 32,264,211.47	$ 26,821,890.29	$ 44,229,186.60

Figure 24. Examples of 10 Year Performance for High Traffic Loading

The caveat with all these values though is that they reflect the best-case price for PV pavement, whereas there were zero results that portrayed PV pavements as capable of outperforming asphalt when utilizing worst-case cost values (i.e., $460/SM). Further, from all the scenarios featuring only resurfacing, not a single scenario demonstrated that PV pavements would outperform asphalt regardless of pricing.

Offutt AFB

Offutt AFB was examined next, with an electricity cost of $0.0760/kWh utilized for the evaluations. Starting with low traffic loading, the analysis produced zero scenarios in which PV pavements outperformed asphalt pavements at the 10-year mark. However, there was one scenario that was able to outperform asphalt at the 15-year mark. The scenario incorporated a relatively high amount of construction (i.e., 2% replacement) and can be seen in Figure 25.

Offutt		1%		2%		Low
		Asphalt		**PV Best Case**		**PV Worst Case**
Initial	$	2,757,221.76	$	5,609,223.02	$	8,323,363.19
5 Year	$	2,757,221.76	$	5,214,232.78	$	7,928,372.95
10 Year	$	4,556,728.22	$	4,848,003.86	$	7,562,144.03
15 Year	$	4,556,728.22	$	4,509,491.18	$	7,223,631.35
20 Year	$	4,556,728.22	$	4,199,583.37	$	6,913,723.54

Figure 25. Offutt AFB - Best of Low Traffic Loading (1% Resurface, 2% New)

Even with low resurfacing and high construction values, the PV pavement only outperformed the asphalt when comparing the best-case PV cost against asphalt. For the remainder of low traffic load evaluations, there were five instances that resulted in PV pavements outperforming asphalt at the 20-year period, which can be seen in Appendix B. The scenarios that begin to provide the best bang for the buck seem to reside in the 2% range for new construction as this begins to minimize the gap in initial construction costs.

As expected, several additional scenarios for PV pavements became viable when high traffic loading was considered the default input, which can be attributed to the increased cost of asphalt. In fact, there were three scenarios in which PV pavements outperformed asphalt at the 10-year mark, with an additional four scenarios outperforming at the 15-year mark and nine at the 20-year period. A few of the 10-year performance scenarios can be seen in Figure 26. When examining iterations only involving resurfacing, no instances existed in which PV pavements outperformed asphalt, regardless of traffic loading. Additionally, no scenarios demonstrated PV pavements outperforming asphalt when the worst-case cost of construction was utilized.

Offutt	1%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,618,853.56	$ 5,609,223.02	$ 8,323,363.19
5 Year	$ 3,618,853.56	$ 5,214,232.78	$ 7,928,372.95
10 Year	$ 5,418,360.02	$ 4,848,003.86	$ 7,562,144.03
15 Year	$ 5,418,360.02	$ 4,509,491.18	$ 7,223,631.35
20 Year	$ 5,418,360.02	$ 4,199,583.37	$ 6,913,723.54

Offutt	2%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,308,159.00	$ 7,478,964.02	$ 11,097,817.58
5 Year	$ 4,308,159.00	$ 6,952,310.37	$ 10,571,163.93
10 Year	$ 6,707,500.95	$ 6,464,005.15	$ 10,082,858.71
15 Year	$ 6,707,500.95	$ 6,012,654.90	$ 9,631,508.46
20 Year	$ 6,707,500.95	$ 5,599,444.49	$ 9,218,298.05

Figure 26. Examples of 10 Year Performance for High Traffic Loading

Peterson AFB

Peterson AFB was considered next with an electricity cost of $0.0735/kWh. While electricity was at a slightly lower cost compared to the first two installations examined, the average power generation per panel was higher for the location – coming in at 5.2 W per hour at Peterson versus a measly 3.9 W per hour at Malmstrom. Therefore, it was anticipated that Peterson would be on par with, if not outperform, both the prior locations. Looking first to low traffic loadings, the results confirmed this suspicion. There were six scenarios demonstrating better performance for PV pavements, with one case at the 15-year period and six additional cases at the 20-year mark. This was ever so slightly better than the two previous locations. The sole scenario outperforming at the 15-year mark was the same as that from Offutt AFB, which took place when resurfacing was under 2%. The scenario that had the best results is provided in Figure 27.

Peterson	1%	2%	Low
	Asphalt	**PV Best Case**	**PV Worst Case**
Initial	$ 4,754,516.45	$ 9,672,469.41	$ 14,352,696.54
5 Year	$ 4,754,516.45	$ 8,959,916.44	$ 13,640,143.57
10 Year	$ 7,857,561.41	$ 8,299,248.21	$ 12,979,475.34
15 Year	$ 7,857,561.41	$ 7,688,579.40	$ 12,368,806.53
20 Year	$ 7,857,561.41	$ 7,129,513.10	$ 11,809,740.23

Figure 27. Peterson AFB - Best of Low Traffic Loading (1% Resurface, 2% New)

Peterson continued to slightly outperform the previous two installations as well when examining high traffic loading. There were three instances in which PV pavements provided better results at the 10-year mark, along with four scenarios at the 15-year mark and ten at the 20-year mark. When evaluating the worst-case cost for PV pavements, no scenarios resulted in the pavement outperforming asphalt.

Travis AFB

Travis AFB was selected as the fourth installation to undergo examination using the model. Prior to beginning any iterations, it was determined that this location would have the best performance by quite a significant margin due to power production and cost of electricity. From a production standpoint, Travis averaged 6.1 W per hour, whereas Peterson had been the second highest at 5.2 W per hour. Additionally, Travis was the only location to break $.10/kWh, with a cost of $.132/kWh. Due to the significant electrical cost in comparison to the other locations, the savings were expected to be dramatically improved at the location. Once the evaluations began, the results confirmed that Travis AFB was the most optimal choice for incorporating this technology. Figure 28 provides an example capability for high traffic loading at Travis. Even at low traffic loading, 13 iterations demonstrated that PV pavements would outperform asphalt at the 10-year mark, with the remaining 17 iterations proving their worth at the 15-year period.

However, if the worst-case cost for PV pavement construction was used ($460/SM), no scenarios demonstrated viability once again.

	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,437,435.20	$ 10,979,071.01	$ 16,291,524.73
5 Year	$ 7,437,435.20	$ 9,209,390.90	$ 14,521,844.62
10 Year	$ 11,687,398.17	$ 7,719,367.73	$ 13,031,821.45
15 Year	$ 11,687,398.17	$ 6,464,808.21	$ 11,777,261.93
20 Year	$ 11,687,398.17	$ 5,408,502.76	$ 10,720,956.47

Figure 28. Travis Best of High Traffic Loading (1% Resurface, 2% New)

United States Air Force Academy

The final location to be analyzed was the USAFA. At first thought this location would seemingly perform much like Peterson AFB due to their relative proximity. However, as the relative inputs for each installation were examined, it becomes apparent that is not the case. For instance, overall power production at the USAFA is almost 1 W per hour less than at Peterson. This discrepancy is likely due to two reasons, with the first being that the USAFA is roughly 1100' higher in altitude than Peterson AFB. Secondly, the USAFA had the most months of any location replicated. Due to that, the values for the USAFA are likely to trend downwards as the worst-case values were selected for replication. Besides just power production though, the USAFA had the lowest cost of electricity out of all five installations, which can be attributed to the massive solar generation farm that exists on base property. These two factors combined made the location unlikely to be optimal for PV pavements. The results from the iterations confirmed that information, with no scenarios showing PV pavements outperforming asphalt. Examining high traffic loading, only one scenario existed in which PV pavements outperformed asphalt at the 10-year mark, which can be seen in Figure 29. There were an additional two scenarios at the 20-year period that showed PV pavements outperforming asphalt. No situation existed in which the PV pavement outperformed asphalt when only resurfacing was considered for the existing pavements.

USAFA	1%	2%	High
	Asphalt	**PV Best Case**	**PV Worst Case**
Initial	$ 10,805,311.61	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 10,805,311.61	$ 16,157,296.68	$ 24,261,280.39
10 Year	$ 16,178,346.96	$ 15,609,389.54	$ 23,713,373.25
15 Year	$ 16,178,346.96	$ 15,102,948.06	$ 23,206,931.76
20 Year	$ 16,178,346.96	$ 14,639,301.71	$ 22,743,285.42

Figure 29. USAFA Best of High Traffic Loading (1% Resurface, 2% New)

Data Trends

After having evaluated the potential performance of PV pavements at each of the installations, there were a few key trends that were realized regarding overall capability. The first major conclusion is that not a single instance existed in which PV pavements would be viable when examining their worst-case construction cost, which for the analysis was $460/SM. These were a few scenarios in which the worst-case cost came close, all of which were at Travis AFB, but none could outperform asphalt. Electricity costs would have to increase substantially in order to realize a price point at which PV pavements could overcome the higher construction cost value. Even if the cost of electricity increased, poor generation values at some locations would still prevent the technology from being viable.

Another result was that as the amount of pavement to be resurfaced increased, the likelihood that PV pavements would be viable decreased. This resulted from the significant difference in costs between simply resurfacing a pavement and the cost of constructing a new PV pavement. As it stands, the best-case cost for PV pavements was $310/SM, which is a far cry from the $120/SM used for the cost of resurfacing asphalt. While asphalt prices do vary by location, it is virtually impossible to see a scenario in which asphalt resurfacing would outprice the cost of an entirely new pavement surface. Additionally, as new roads are rarely constructed on Air Force installations, it is unlikely that many installations would consider this technology. Instead, PV pavements would likely only be a potential option if a road was constructed so poorly in the first place that it would need to be fully replaced, which is not often. If a major expansion was planned at a base though this technology could be a viable alternative to asphalt.

Electricity Cost Sensitivity Analysis

As stated, electricity costs would have to undergo substantial price increases to make PV pavements a viable technology. In looking to determine the exact price point that would be required, a sensitivity analysis was performed. While there were five locations under examination during previous efforts, the sensitivity analysis initially focused on Malmstrom. Malmstrom was the starting point for the analysis as it had the lowest power generation value, 3.9 W per hour (per panel). Therefore, should Malmstrom be considered viable, the remaining locations could likely be considered cost-effective as well, albeit slightly varied due to location factors. Several price points were examined in determining the corresponding electrical cost that would ensure cost-effectiveness when utilizing the best-case cost for PV pavements, as well as the worst-case cost. Initial trial values evaluated were selected based on observations from the previous analysis, i.e., cost values that were close to viability previously were selected as the initial starting points. These values were then incrementally increased or decreased by $.0025/kWh until cost effectiveness was achieved. When examining best-case cost scenarios, it seemed that an electrical cost of $.1075/kWh began to approach the breakeven point. As can be seen in Figure 30, when evaluating 10% resurfacing at that cost, PV pavements were only slightly over $300K more expensive at the 20-year mark.

Installation	Resurface %	Replacement %	Traffic
Malmstrom	10%	0%	Low
	Asphalt	**PV Best Case**	**PV Worst Case**
Initial	$ 35,273,143.48	$ 95,678,401.69	$ 141,974,402.50
5 Year	$ 33,156,754.87	$ 82,210,281.61	$ 125,728,522.38
10 Year	$ 62,009,854.05	$ 75,045,539.51	$ 118,563,780.28
15 Year	$ 62,009,854.05	$ 68,423,025.63	$ 111,941,266.40
20 Year	$ 62,009,854.05	$ 62,360,125.01	$ 105,878,365.78

Figure 30. Malmstrom AFB - 10% Resurfacing - $0.1075/kWh

Due to this, a price point of $0.1100/kWh was evaluated as well. When looking at the resulting scenarios, which can be referenced in the Appendix, PV pavements demonstrated a lower cost at the twenty-year mark for every scenario. As such, if electricity costs rose to $0.1100/kWh nationwide, PV pavements could be considered viable should their initial construction price point reach the $310/SM that was utilized for analysis.

Performing the analysis for the best-case scenario was beneficial, but true viability would be ensuring cost-effectiveness at the worst-case construction cost for PV pavements, which is $460/SM. After acknowledging that that there was significant gap in costs with an electricity cost of $.1100/kWh, the analysis began by evaluating costs above $.2/kWh for Malmstrom. However, even that was not high enough to ensure that the PV pavements would outperform. Instead, PV pavement costs began to approach equivalence with asphalt at an electrical cost of $.2725/kWh, with the 10% resurfacing scenario demonstrating a cost less than $300K more expensive than asphalt, as can be seen in Figure 31. This led to examining a cost of electricity at a value of $.2800/kWh, which finally demonstrated that PV pavements could outperform asphalt for every scenario.

Installation	Resurface %	Replacement %	Traffic
Malmstrom	10%	0%	Low
	Asphalt	**PV Best Case**	**PV Worst Case**
Initial	$ 35,273,143.48	$ 95,678,401.69	$ 141,974,402.50
5 Year	$ 33,156,754.87	$ 69,990,181.94	$ 113,508,422.71
10 Year	$ 62,009,854.05	$ 51,495,149.99	$ 95,013,390.76
15 Year	$ 62,009,854.05	$ 34,399,823.48	$ 77,918,064.24
20 Year	$ 62,009,854.05	$ 18,749,080.00	$ 62,267,320.77

Figure 31. Malmstrom AFB - 10% Resurfacing - $.2875/kWh

After establishing price points for Malmstrom, each of the remaining locations underwent similar analyses to determine more precise values. The process was much the same as Malmstrom, although it was known that each location would likely have a lower electricity cost value due to panel generation. The summarized results are seen in Figure 32, which provides the electricity cost for both initial PV pavement construction costs.

Cost Effective Electricity Cost ($/kWH)					
PV Cost	**Malmstrom**	**Offutt**	**Peterson**	**Travis**	**USAFA**
$310/SM	0.1100	0.0950	0.0875	N/A	0.1075
$460/SM	0.2800	0.2425	0.2225	0.2050	0.2700

Figure 32. Location Specific Electricity Costs for PV Pavement Cost Effectiveness

PV Construction Cost Sensitivity Analysis

While performing a sensitivity analysis on the cost of electricity was beneficial, it was decided that varying the PV construction cost could provide additional insight into product viability. Therefore, the initial construction value for PV pavements underwent a sensitivity analysis beginning with the best-case cost, $310/SM, as the initial point of evaluation. Subsequent evaluations for viability featured decreases in price by $5 increments, until more closely approaching cost effectiveness at which time $1 increments were utilized. The resulting values for each installation can be seen in Figure 33.

PV Construction Cost ($/SM)				
Malmstrom	**Offutt**	**Peterson**	**Travis**	**USAFA**
292	291	295	N/A	252

Figure 33. Location Specific PV Construction Costs for PV Pavement Cost Effectiveness

Conclusion

The analyses discussed throughout the chapter sought to demonstrate that PV pavements were a cost-effective technology. As can be seen from the results presented, there are several stipulations when trying to confidently say that the technology is viable. The biggest stipulation, or parameter, that affected performance was the initial cost of construction for the PV pavements. As such, a sensitivity analysis was performed on the construction cost to determine the cost-effective price point. However, the initial PV costs utilized were only idealized price points, therefore a second sensitivity analysis was performed. The subsequent analysis, which focused on varying electricity costs, revealed specific values in which PV pavements could become viable in relation to both the best-case construction cost, and the worst-case construction cost.

V. CONCLUSION

This section is meant to be a summarization of the information presented in the prior chapters, as well provide recommendations to future researchers. The overarching goal of the efforts in this thesis was to examine alternative renewable energy sources and analyze their cost effectiveness. The discussion primarily centered around photovoltaic pavements due to land use constraints that are either physically or artificially imposed on Air Force installations. After examining the literature and conducting independent research efforts, it has been determined that at specific pavement and electricity costs, photovoltaic pavements could be a cost-effective alternative for renewable energy.

PV Pavement Economic Viability

Prior to examining the cost effectiveness of PV pavements, a mathematical model had to be created that could measure lifecycle costs over a time period of 20 years. The model developed is represented in Equation 9, which accounts for several variables such as location specific generation values and the cost of electricity.

$$NPV_{k,m,l,j,i,N} = PIC_{k,m,l,j} - \left(\left(\frac{P}{A_{k,m,l}}, i_N, N\right) * A_{k,m,l}\right)$$

Equation 9. Photovoltaic Net Present Value

Lifecycle costs were accounted for by differentiating savings generation values at the 5, 10, 15 and 20-year time periods. The model was then employed a total of 300 times in order to provide a realistic outlook at the pavements, with the scenarios ranging up to 10% pavement replacement and up to 2% total reconstruction/new pavement. The results of these scenarios have been subsequently summarized, specifically for the best-case cost of PV pavements, in Figures 34, 35, 36, and 37. Each figure is meant to demonstrate the number of cases for the corresponding time period that PV pavements, utilizing the best-case cost of $310/SM, outperform asphalt. For example, Figure 36 shows that for Offutt AFB there was one scenario at the 15-year mark, with an additional five results at the 20-year period, in which PV pavements outperformed asphalt.

Resurface Low (10)					
	Malmstrom	Offutt	Peterson	Travis	USAFA
10 Years	0	0	0	0	0
15 Years	0	0	0	10	0
20 Years	0	0	0	0	0

Figure 34. Best Case Cost for Resurfacing Only (Low)

Resurface High (10)					
	Malmstrom	Offutt	Peterson	Travis	USAFA
10 Years	0	0	0	0	0
15 Years	0	0	0	10	0
20 Years	0	0	0	0	0

Figure 35. Best Case Cost for Resurfacing Only (High)

Low Traffic Loading (20)					
	Malmstrom	Offutt	Peterson	Travis	USAFA
10 Years	0	0	0	13	0
15 Years	1	1	1	7	0
20 Years	5	5	6	0	0

Figure 36. Best Case Cost Summary for Low Traffic

High Traffic Loading (20)					
	Malmstrom	Offutt	Peterson	Travis	USAFA
10 Years	3	3	3	20	1
15 Years	4	4	4	0	0
20 Years	9	9	10	0	2

Figure 37. Best Case Cost Summary for High Traffic

As can be immediately noticed in the figures, the USAFA is not an ideal candidate for PV pavements regardless of traffic loading values. This can be primarily attributed to the low cost of electricity from existing PV farms at the installation. Additionally, the location featured the greatest data replication efforts of the five installations, thereby decreasing generation values more than may be realistic. When viewing Figure 37, it is seen that the remaining four installations each demonstrate cost-effectiveness at the high-traffic loading stage. This can be realized as there is a 20-case maximum for PV pavements to outperform asphalt, with Malmstrom and Offutt both having 16 cases in which that goal is accomplished. Further, those installations demonstrate some viability when evaluating them at the low-traffic loading stage. The caveat with all the outputs summarized above though is that they represent a price point of $310/SM for the PV pavement, which was the best-case scenario. If the worst-case scenario cost was utilized, no base would be able to currently consider the technology a cost-effective replacement for roadways. This drove corresponding sensitivity analyses which provided specific price points for electrical costs as well as construction costs to demonstrate viability. Malmstrom AFB had the worst viability when evaluating electrical costs, coming in at $.2800/kWh for reaching cost effectiveness. For evaluating initial construction costs, USAFA required the lowest cost at a value of $252/SM.

Assumptions & Limitations

The tool constructed for this research effort heavily relies on the quality of background data. Therefore, accuracy issues with any background data can have compounding effects on the overall analysis quality. One weakness of the tool is the data respective to power output readings at each location. Specifically, there were several days throughout the year that were missing at least a few, if not multiple, readings from the selected locations. In addition, some locations were even missing entire months, as opposed to initial conceptions that the chosen locations had high data integrity. This led to replication efforts for a total of 16,656 data points out of the anticipated 94,900 data points. For many of these values, the deviation from reality should not be large, due to implementation of 15-minute intervals. However, power readings produced for the replicated months could be significantly higher or lower than the data averages used in the tool.

Another potential issue with data provided to the tool is regarding the pavement values associated with each installation. Each installation had two sheets of information provided, which encompassed regular roads and other miscellaneous fixtures on the base, as seen in Table 9 and Table 10.

OBJECT	ROADAREAID	SDSID	SDSFEATURE	SDSFEATU	SDSMETAD	AREASIZ	AREASIZE	PERIMETE	PERIMETE	LATITUD	LONGITU	MGRSCENTR	CATCO	FA
66436	TDKA_TDKA0000082	{7D2B656B-BF1F-4768-9D03-44C8A11F0A61}	Selfridge St	ROAD	2	1.20167991	squareFoot	11.99148508	foot	4297729.688	526250.5649	13SEC2625197730	851147	8511
66437	TDKA_TDKA0000099	{A90D6900-FD52-4C72-9B07-CBCAB13BEA21}	Kirtland Ln	ROAD	2	5771.162675	squareFoot	830.028757	foot	4297471.572	526254.1338	13SEC2625497471	851147	8511
66438	TDKA_TDKA0000100	{606886A9-D3E6-4A86-8F8A-AEABD2E1541A}	McChord St	ROAD	2	0.22042544	squareFoot	6.60651232	foot	4297515.043	526287.9888	13SEC2628897515	851147	8511
66439	TDKA_TDKA0000101	{8609328E-5812-49E8-BB30-E80AE3BFB624}	Youngstown St	ROAD	2	0.42424137	squareFoot	8.39693232	foot	4297553.892	526093.4311	13SEC2609397554	851147	8511
66440	TDKA_TDKA0000102	{A3FCB953-5F41-45EE-A774-8BC723636DEB}	Youngstown St	ROAD	2	1.38995232	squareFoot	12.15698174	foot	4297566.591	526088.043	13SEC2608897567	851147	8511
66441	TDKA_TDKA0000098	{F2ADE27F-7DFA-4870-BD62-012B779D44C2}	McChord St	ROAD	2	0.35767313	squareFoot	7.70118967	foot	4297505.844	526297.6574	13SEC2629897506	851147	8511
66442	TDKA_TDKA0000152	{807A4F87-CE6A-4937-B540-293ABB36AE20}	Dirt Road	ROAD UNSURF	1	9389.349039	squareFoot	1589.65267	foot	4296492.047	526652.8779	13SEC2665196503	851201	99999
66461	TDKA_TDKA0000104	{7959203D-4885-489C-A723-DBA788DBDF5F}	Kirtland Ln	ROAD	2	28570.19842	squareFoot	2471.832948	foot	4297533.451	526151.0572	13SEC2612197522	851147	8511
66462	TDKA_TDKA0000105	{6A2F2C6B-1D6A-40F0-B456-139781D410B1}	Larson Ln	ROAD	2	6350.240666	squareFoot	799.9816036	foot	4297491.608	526399.4465	13SEC2639997493	851147	8511

Table 9. Partial Road Area Sheet

OBJECT	pavementBranchIDPK	sdsID	sdsFeatureNam	sdsFeatureDescription	sdsMetadataID	areaSize	areaSizeU	perimeterS	perime
1	TDKA-TDKA0001-PM-PBA-1	{515487BA-C91D-4BD4-A2E4-B13917FC1DC4}	TBD	Static Display Foundation	TBD	197.5902415	squareFoot	54.23688074	foot
2	TDKA-TDKA0001-PM-PBA-2	{9046CB4B-DC85-4F0B-B667-A015AA0CE2E3}	TBD	Porch	TBD	27.75433979	squareFoot	21.07324147	foot
3	TDKA-TDKA0001-PM-PBA-3	{EACBB2EA-9700-45C5-89FF-51277161B22E}	TBD	Manhole Vault - Storm Sewer Utility	TBD	45.92853247	squareFoot	28.46110105	foot
4	TDKA-TDKA0001-PM-PBA-4	{A7E0E76C-D90B-4384-8239-6D5330CA87A4}	TBD	Manhole Vault - Storm Sewer Utility	TBD	40.10787583	squareFoot	27.41265134	foot
5	TDKA-TDKA0001-PM-PBA-5	{55D1B88D-67BB-4F85-BC73-0848152E3656}	Equipment Pad	PAD EQUIP	132133	46.81738606	squareFoot	61.09339839	foot
6	TDKA-TDKA0001-PM-PBA-6	{D3461EE8-4261-401A-BBD6-8B999D531C53}	TBD	Possible Sidewalk	TBD	138.3214653	squareFoot	60.48712887	foot
7	TDKA-TDKA0001-PM-PBA-7	{2C0295E3-09E8-46AB-B77F-21952F01F178}	TBD	Mechanical Courtyard #2025	TBD	5941.788144	squareFoot	644.2726043	foot
8	TDKA-TDKA0001-PM-PBA-8	{10F96CC3-41C8-4321-B2F4-3DD908964097}	TBD	Mechanical Courtyard #2025	TBD	4339.882581	squareFoot	598.4613173	foot
9	TDKA-TDKA0001-PM-PBA-9	{AE50ECBB-6D09-4018-AF0A-E3527888CD5C}	TBD	Static Display Foundation	TBD	11707.75866	squareFoot	454.2972758	foot
10	TDKA-TDKA0001-PM-PBA-10	{84E99619-DCED-4ECB-95E9-A06712671D7C}	TBD	Possible Equipment Pad	TBD	137.6717035	squareFoot	50.75980288	foot

Table 10. Partial Pavement Area Sheet

While there were 46 metrics associated with each sheet, several of them provided no useable information. The remaining eight variables were utilized to gather the necessary information such as the amount of pavement surface and determining validity. Many rows of information had to be manually determined which items would be considered a potential pavement source. As such, the total amount of paved surface at each of the identified locations could be inaccurate, or susceptible to different interpretation by other researchers. While specific location values may be skewed, the overall trends at each installation should still be consistent regardless of difference in pavement amounts. Additionally, these values can be easily corrected in the tool should further analysis be required.

There is an additional data quality concern that is not directly tied to the tool but affects overall results. Specifically, the life cycle analysis values for photovoltaic pavements could be artificially high or low, depending on the accuracy of electrical cost information provided. Each installation had electrical consumption values, along with the associated costs, provided to aid in the analysis. These costs were used to determine an overall average cost per kWh for electricity at each location, which was subsequently used in the final analysis. If the electricity cost was higher than it should be, it would cause the photovoltaic pavement to be more attractive, whereas a lower electricity cost would have the inverse effect. The data quality for cost measurements could be increased by gathering hourly and seasonal electricity rates at each location; however, overall model complexity would increase greatly.

A few remaining limitations pertain to supporting infrastructure as well as the technology readiness. As for infrastructure, little literature exists regarding PV pavements, but even less so for the supporting infrastructure that would be required. It is likely that extensive underground cables would be required at the minimum to support connecting into existing electrical infrastructure. In order to somewhat account for infrastructure costs, an additional 5% was added to the initial construction costs of PV pavements. The lack of literature pertaining to infrastructure plays directly in line with evaluating the overall technology readiness level of PV pavements. Technology readiness can be assessed on a scale ranging from one to nine. A one stipulates that basic principles have been observed and reported, and a score of nine demonstrates that the system has been proven through successful operations [41]. Specifically, when evaluating the product as detailed by SRI, current operations fall in line with laboratory testing. However, there has be a lack of published research supporting actual application. As such, it is hard to assess an overall score value, but it can be assumed that it would be relatively low.

Besides some of the limitations discussed previously, several assumptions were made as well to facilitate the final analysis. An issue leading toward the first assumption was that two installations did not have cost values associated with electrical consumption. A way to account for electricity cost had to be determined, which led to evaluating government provided information. It was found that average electricity prices were provided for each state, subdivided by consumer type, courtesy of the U.S. Energy Information Administration. As military installations closely resemble an industrial consumer, values of $.1320/kWh and $.0760/kWh were chosen for Travis AFB and Offutt AFB respectively [42]. Like individualized electrical costs, location specific factors were applied to construction costs for both asphalt and PV pavements. These factors were determined from the 2019 version of the Craftsman National Construction Estimator software.

Electrical generation values were subjected to assumptions as well. The first is that any soiling losses that could be expected in normal operations were already accounted for in the generation values produced during the experiment. Further, the values were subjected to a flat 15% reduction to account for potential shading effects as well as increased glass thickness. This reduction value could drastically change results if larger values were proven to be more accurate. Additionally, it is likely that the electrical generation averages would decrease steadily over a 20-year lifecycle. However, these values were assumed to be constant in order to reduce model complexity, as well as best reflect the results gathered from previous researchers. Theoretically, the data provided by those researchers incorporates an aspect of reduction due to age and other environmental factors.

The tool further compares overall life cycle costs based on 5, 10, 15, and 20-year increments. To perform an evaluation in that matter requires consideration of the time value of money. As part of that calculation, interest rates had to be considered. A real interest rate was used in order to ensure constant-dollar flows. The rate was specified as 1.5% for 20-years, although the five year increments used the specific time period rates as defined by the Office of Management and Budget [43].

The last few assumptions during tool development were in relation to how repairs would be performed for the differing pavement types. Current road surface condition truly dictates when a road requires repairs, as well as the type of repairs to be performed. However, due to the multitude of roads on an installation, as well as any other city or town, there was no realistic way to account for every single different variation. Thus, the life cycle calculations performed assumed that asphalt roads would undergo mill and overlay resurfacing at the 10-year time period (in addition to an initial resurface dependent upon user input). The resurfacing cost values assume minimal repairs are needed in between the initial resurface and the subsequent 10-year resurface. Due to lack of research available regarding long-term performance of PV pavements, it was assumed that the PV pavements would not have increased costs over the projected 20-year life cycle. However, at the very least, it can be anticipated that minor maintenance would be required for instances such as vehicle wrecks that would likely lead to damage of the PV cells.

Research Recommendations

There are a handful of opportunities that exist regarding future research in this field of effort. One of the most obvious recommendations would be to conduct additional long-term studies on the performance of horizontally oriented photovoltaics. A limitation that was previously identified is that the amount of data, as well as the quality, was particularly lacking based on the original scope undertaken. The scope for the initial experiment involved collecting data at the 37 test sites for a time period of one year. However, at the end, there were only 18 sites that had data for at least 8 months, before any further validation efforts took place. Therefore, establishing a follow-on study that not only collects data at additional sites, but for a longer time period would help to truly establish performance trends for these panels.

Another avenue for future research could be implementing a test section of the photovoltaic pavements based on commercially available products. While large scale acquisition may not be possible, the companies discussed previously do advertise product availability. As such, garnering funding to construct a sample test section at one of the five locations, or potentially at AFIT would provide immensely beneficial information regarding the performance of the pavement. These efforts could provide both generation values, as well as data relevant to the structural integrity.

A final suggestion for future research would be to expand upon the model developed in the research at hand. Specifically, while the model incorporated several variables, it is still simple in application. The model could feature increased accuracy and complexity by incorporating changing electricity rates or location specific pricing of asphalt pavements. In some instances, complexity can be unnecessary, but providing a better cost-effective portrayal of these pavements would benefit both decision makers and the taxpayer.

Conclusion

This effort has sought to provide valuable insight to decision makers regarding the performance of PV pavements. As such, several different avenues have been provided in hopes to aid this process. One source of aid has been delineated through the Appendix, which incorporates every single iteration that was ran throughout the analysis. Decision makers at the five selected locations can simply look at the values that have already been evaluated to decide if implementing PV pavements would be beneficial. However, for those at locations that experience similar weather patterns, these scenarios should provide a good reference as well. If more accurate results are desired, the methodology has detailed how the evaluation tool was created, to include the mathematical model for calculating costs. At the end of the day, many scenarios reflected that this technology is not yet at a point of viability for the Air Force. If improvements to power generation arise, as well as increases in electricity costs, then PV pavements could become a common occurrence in our everyday lives.

Appendix A – References

[1] Office of the Assistant Secretary of Defense for Energy Installations and Environment, "Installation Energy (IE)," 2018.

[2] "FedCenter - EO 13834." [Online]. Available: https://www.fedcenter.gov/programs/eo13834/. [Accessed: 23-Jan-2020].

[3] US Air Force, "U.S. Air Force Energy Flight Plan 2017-2036," pp. 1–26, 2017.

[4] "Renewable Energy," 2017. [Online]. Available: https://www.afcec.af.mil/Home/Energy/Renewable-Energy/. [Accessed: 14-Mar-2019].

[5] C. Booker, "Analysis of Temperature and Humidity Effects on Horizontal Photovoltaic Panels," Air Force Institute of Technology.

[6] J. H. Nussbaum, "Analyzing the Viability of Photovoltaic Pavement Systems: Quantifying Climate Impacts on Potential Power and the Risks of Implementation," Air Force Institute of Technology.

[7] J. A. Applebee, "A Method to Determine the Viability of Photovoltaic Systems in Various Climate Regions," Air Force Institute of Technology.

[8] G. Knier, "How do Photovoltaics Work?," *NASA Science*, 2008. [Online]. Available: https://science.nasa.gov/science-news/science-at-nasa/2002/solarcells. [Accessed: 04-Apr-2019].

[9] S. Aldous, "Converting Photons to Electrons Silicon in Solar Cells N-type Plus P-type Silicon," 2000.

[10] M. Gradella Villalva, J. Rafael Gazoli, and E. Ruppert Filho, "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays," *IEEE Trans. Power Electron.*, vol. 24, no. 5, pp. 1198–1208, 2009.

[11] "Solar Electricity Basics," *Florida Solar Energy Center*. [Online]. Available: http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/index.htm. [Accessed: 04-Apr-2019].

[12] A. Mohammad Bagher, M. Mahmoud Abadi Vahid, and M. Mohsen, "Types of Solar Cells and Application," *Types Sol. Cells Appl. Am. J. Opt. Photonics*, vol. 3, no. 5, pp. 94–113, 2015.

[13] M. A. Green *et al.*, "Solar cell efficiency tables (Version 53)," *Prog. Photovoltaics Res. Appl.*, vol. 27, no. 1, pp. 3–12, 2019.

[14] "Which Solar Panel Type is Best? Mono-, Polycrystalline or Thin Film?," *Energy Informative*, 2012. [Online]. Available: https://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. [Accessed: 24-Apr-2019].

[15] M. Lave and J. Kleissl, "Optimum fixed orientations and benefits of tracking for capturing solar radiation in the continental United States," *Renew. Energy*, vol. 36, pp. 1145–1152, 2011.

[16] M. Kacira, M. Simsek, Y. Babur, and S. Demirkol, "Determining optimum tilt angles and orientations of photovoltaic panels in Sanliurfa, Turkey," *Renew. Energy*, vol. 29, no. 8, pp. 1265–1275, 2004.

[17] M. Z. Jacobson and V. Jadhav, "World estimates of PV optimal tilt angles and ratios of sunlight incident upon tilted and tracked PV panels relative to horizontal panels," *Sol. Energy*, vol. 169, no. December 2017, pp. 55–66, 2018.

[18] "Solar Roadways." [Online]. Available: http://www.solarroadways.com/. [Accessed: 12-May-2019].

[19] "Wattway by Colas | Paving the way to tomorrow's energy." [Online]. Available:

http://www.wattwaybycolas.com/en/. [Accessed: 12-May-2019].

[20] K. Bradsher, “Free Power From Freeways? China Is Testing Roads Paved With Solar Panels,” *New York Times*, 2018. [Online]. Available: https://www.nytimes.com/2018/06/11/business/energy-environment/china-solar-roads-renewables.html. [Accessed: 20-May-2019].

[21] “PAVenergy.” [Online]. Available: https://pavenergy.dec.uc.pt/contacts. [Accessed: 20-May-2019].

[22] American Road & Transportation Builders Association, “Frequently Asked Questions.” [Online]. Available: https://www.artba.org/about/faq/.

[23] Florida Department of Transportation, “Long Range Estimates.” [Online]. Available: https://www.fdot.gov/programmanagement/estimates/lre/costpermilemodels/cpmsummary.shtm.

[24] F. H. Gandoman, S. H. E. Abdel Aleem, N. Omar, A. Ahmadi, and F. Q. Alenezi, “Short-term solar power forecasting considering cloud coverage and ambient temperature variation effects,” *Renew. Energy*, vol. 123, pp. 793–805, 2018.

[25] A. A. Sabziparvar and H. Shetaee, “Estimation of global solar radiation in arid and semi-arid climates of East and West Iran,” *Energy*, vol. 32, no. 5, pp. 649–655, 2007.

[26] E. D. Albizzati, G. H. Rossetti, and O. M. Alfano, “Measurements and predictions of solar radiation incident on horizontal surfaces at Santa Fe, Argentina (31° 39′S, 60° 43′W),” *Renew. Energy*, vol. 11, no. 4, pp. 469–478, 2002.

[27] M. M. Fouad, L. A. Shihata, and E. S. I. Morgan, “An integrated review of factors influencing the performance of photovoltaic panels,” *Renew. Sustain. Energy Rev.*, vol. 80, no. December, pp. 1499–1511, 2017.

[28] B. Hammad, M. Al-Abed, A. Al-Ghandoor, A. Al-Sardeah, and A. Al-Bashir, “Modeling and analysis of dust and temperature effects on photovoltaic systems’ performance and optimal cleaning frequency: Jordan case study,” *Renew. Sustain. Energy Rev.*, vol. 82, no. July 2017, pp. 2218–2234, 2018.

[29] A. Sayyah, M. N. Horenstein, and M. K. Mazumder, “Energy yield loss caused by dust deposition on photovoltaic panels,” *Sol. Energy*, vol. 107, no. March, pp. 576–604, 2014.

[30] M. Mani and R. Pillai, “Impact of dust on solar photovoltaic (PV) performance: Research status, challenges and recommendations,” 2010.

[31] DoD, “UFC 3-250-01, Pavement Design for Roads and Parking Areas,” 2016.

[32] “Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys,” *ASTM Int.*, vol. D6433, no. 11, p. 49, 2011.

[33] “AFI 32-1041, Pavement Evaluation Program,” 2017.

[34] City of Austin, “Mill and Overlay FAQ,” 2016.

[35] Columbia Public Works Department, “What is mill and overlay?,” 2016.

[36] P. Hines, “Analyzing the Efficiency of Horizontal Photovoltaic Cells at Air Force Installations in Various Climate Regions,” 2019.

[37] V. Vujović and M. Maksimović, “Raspberry Pi as a Wireless Sensor node: Performances and constraints,” *2014 37th Int. Conv. Inf. Commun. Technol. Electron. Microelectron. MIPRO 2014 - Proc.*, no. June, pp. 1013–1018, 2014.

[38] C. Pasion, “Modeling Power Output of Horizontal Solar Panels Using Multivariate Linear Regressison and Random Forest Machine Learning,” 2019.

[39] “Fill in blanks in Excel with value above/below, fill empty cells with 0.” [Online]. Available: https://www.ablebits.com/office-addins-blog/2014/05/02/fill-blanks-excel/.

[Accessed: 29-Oct-2019].

[40] "Fill a formula down into adjacent cells - Excel." [Online]. Available: https://support.office.com/en-us/article/fill-a-formula-down-into-adjacent-cells-041edfe2-05bc-40e6-b933-ef48c3f308c6. [Accessed: 29-Oct-2019].

[41] Government Accountability Office, "GAO Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects -Exposure Draft," no. GAO-16-410G, p. 147, 2016.

[42] U.S. Energy Information Administration, "2018 Average Monthly Bill - Industrial." [Online]. Available: https://www.eia.gov/electricity/sales_revenue_price/pdf/table5_c.pdf. [Accessed: 27-Nov-2019].

[43] M. Mulvaney, "2019 Discount Rates for 0MB Circular No. A-94 On," 2018.

Appendix B – Initial Analysis Outputs

Key

Location, % Resurfaced, % Replacement, Traffic Load

MALMSTROM - $.0892/kWh

Malmstrom	[illegible]	[illegible]	[illegible]
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Malmstrom	[illegible]	[illegible]	[illegible]
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Malmstrom	[illegible]	[illegible]	[illegible]
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Malmstrom	[illegible]	[illegible]	[illegible]
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Malmstrom	[illegible]	[illegible]	[illegible]
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

Minimum	1%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,361,485.90	$ 19,135,680.34	$ 28,394,880.50
5 Year	$ 10,361,485.90	$ 16,705,147.88	$ 25,408,796.03
10 Year	$ 16,132,105.73	$ 15,518,133.93	$ 24,219,782.09
15 Year	$ 16,132,105.73	$ 14,417,104.66	$ 23,120,752.81
20 Year	$ 16,132,105.73	$ 13,410,945.15	$ 22,114,593.30
Minimum	2%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 13,677,161.38	$ 28,703,520.31	$ 42,592,320.75
5 Year	$ 13,677,161.38	$ 25,057,721.82	$ 38,113,194.05
10 Year	$ 22,333,091.14	$ 23,274,200.90	$ 36,329,673.13
15 Year	$ 22,333,091.14	$ 21,625,656.98	$ 34,681,129.21
20 Year	$ 22,333,091.14	$ 20,116,417.72	$ 33,171,889.95
Minimum	3%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,992,836.87	$ 38,271,360.68	$ 56,789,761.00
5 Year	$ 16,992,836.87	$ 33,410,295.76	$ 50,817,592.07
10 Year	$ 28,534,076.54	$ 31,032,267.87	$ 48,439,564.18
15 Year	$ 28,534,076.54	$ 28,834,209.31	$ 46,241,505.62
20 Year	$ 28,534,076.54	$ 26,821,890.29	$ 44,229,186.60
Minimum	4%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,308,512.36	$ 47,839,200.84	$ 70,987,201.25
5 Year	$ 20,308,512.36	$ 41,762,869.70	$ 63,521,990.09
10 Year	$ 34,735,061.95	$ 38,790,334.84	$ 60,549,455.22
15 Year	$ 34,735,061.95	$ 36,042,761.64	$ 57,801,882.02
20 Year	$ 34,735,061.95	$ 33,527,362.87	$ 55,286,483.25
Minimum	5%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 23,624,187.85	$ 57,407,041.01	$ 85,184,641.50
5 Year	$ 23,624,187.85	$ 50,115,443.64	$ 76,226,388.10
10 Year	$ 40,936,047.35	$ 46,548,401.80	$ 72,659,346.27
15 Year	$ 40,936,047.35	$ 43,251,313.97	$ 69,362,258.43
20 Year	$ 40,936,047.35	$ 40,232,835.44	$ 66,343,779.90

Minimum	6%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 26,939,863.33	$ 66,974,881.18	$ 99,382,081.75
5 Year	$ 26,939,863.33	$ 58,468,017.58	$ 88,930,786.12
10 Year	$ 47,137,032.76	$ 54,306,468.77	$ 84,769,237.31
15 Year	$ 47,137,032.76	$ 50,459,866.29	$ 80,922,634.83
20 Year	$ 47,137,032.76	$ 46,938,308.01	$ 77,401,076.55
Minimum	7%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 30,255,538.82	$ 76,542,721.35	$ 113,579,522.00
5 Year	$ 30,255,538.82	$ 66,820,591.52	$ 101,635,184.14
10 Year	$ 53,338,018.16	$ 62,064,535.74	$ 96,879,128.35
15 Year	$ 53,338,018.16	$ 57,668,418.62	$ 92,483,011.24
20 Year	$ 53,338,018.16	$ 53,643,780.59	$ 88,458,373.20
Minimum	8%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 33,571,214.31	$ 86,110,561.52	$ 127,776,962.25
5 Year	$ 33,571,214.31	$ 75,173,165.46	$ 114,339,582.15
10 Year	$ 59,539,003.57	$ 69,822,602.71	$ 108,989,019.40
15 Year	$ 59,539,003.57	$ 64,876,970.95	$ 104,043,387.64
20 Year	$ 59,539,003.57	$ 60,349,253.16	$ 99,515,669.85
Minimum	9%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 36,886,889.79	$ 95,678,401.69	$ 141,974,402.50
5 Year	$ 36,886,889.79	$ 83,525,739.40	$ 127,043,980.17
10 Year	$ 65,739,988.97	$ 77,580,669.67	$ 121,098,910.44
15 Year	$ 65,739,988.97	$ 72,085,523.28	$ 115,603,764.05
20 Year	$ 65,739,988.97	$ 67,054,725.74	$ 110,572,966.50
Minimum	10%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 40,202,565.28	$ 105,246,241.86	$ 156,171,842.75
5 Year	$ 40,202,565.28	$ 91,878,313.34	$ 139,748,378.19
10 Year	$ 71,940,974.38	$ 85,338,736.64	$ 133,208,801.49
15 Year	$ 71,940,974.38	$ 79,294,075.61	$ 127,164,140.45
20 Year	$ 71,940,974.38	$ 73,760,198.31	$ 121,630,263.15

Minimum	1%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 17,407,298.31	$ 28,703,520.31	$ 42,592,320.75
5 Year	$ 17,407,298.31	$ 25,057,721.82	$ 38,113,194.05
10 Year	$ 26,063,226.06	$ 23,274,200.90	$ 36,329,673.13
15 Year	$ 26,063,226.06	$ 21,625,656.98	$ 34,681,129.21
20 Year	$ 26,063,226.06	$ 20,116,417.72	$ 33,171,889.95
Minimum	2%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,722,971.79	$ 38,271,360.68	$ 56,789,761.00
5 Year	$ 20,722,971.79	$ 33,410,295.76	$ 50,817,592.07
10 Year	$ 32,264,211.47	$ 31,032,267.87	$ 48,439,564.18
15 Year	$ 32,264,211.47	$ 28,834,209.31	$ 46,241,505.62
20 Year	$ 32,264,211.47	$ 26,821,890.29	$ 44,229,186.60
Minimum	3%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 24,038,647.28	$ 47,839,200.84	$ 70,987,201.25
5 Year	$ 24,038,647.28	$ 41,762,869.70	$ 63,521,990.09
10 Year	$ 38,465,196.87	$ 38,790,334.84	$ 60,549,455.22
15 Year	$ 38,465,196.87	$ 36,042,761.64	$ 57,801,882.02
20 Year	$ 38,465,196.87	$ 33,527,362.87	$ 55,286,483.25
Minimum	4%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 27,354,322.77	$ 57,407,041.01	$ 85,184,641.50
5 Year	$ 27,354,322.77	$ 50,115,443.64	$ 76,226,388.10
10 Year	$ 44,666,182.27	$ 46,548,401.80	$ 72,659,346.27
15 Year	$ 44,666,182.27	$ 43,251,313.97	$ 69,362,258.43
20 Year	$ 44,666,182.27	$ 40,232,835.44	$ 66,343,779.90
Minimum	5%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 30,669,998.26	$ 66,974,881.18	$ 99,382,081.75
5 Year	$ 30,669,998.26	$ 58,468,017.58	$ 88,930,786.12
10 Year	$ 50,867,167.68	$ 54,306,468.77	$ 84,769,237.31
15 Year	$ 50,867,167.68	$ 50,459,866.29	$ 80,922,634.83
20 Year	$ 50,867,167.68	$ 46,938,308.01	$ 77,401,076.55

Minimum	6%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 33,985,673.74	$ 76,542,721.35	$ 113,579,522.00
5 Year	$ 33,985,673.74	$ 66,820,591.52	$ 101,635,184.14
10 Year	$ 57,068,153.08	$ 62,064,535.74	$ 96,879,128.35
15 Year	$ 57,068,153.08	$ 57,668,418.62	$ 92,483,011.24
20 Year	$ 57,068,153.08	$ 53,643,780.59	$ 88,458,373.20
Minimum	7%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 37,301,349.23	$ 86,110,561.52	$ 127,776,962.25
5 Year	$ 37,301,349.23	$ 75,173,165.46	$ 114,339,582.15
10 Year	$ 63,269,138.49	$ 69,822,602.71	$ 108,989,019.40
15 Year	$ 63,269,138.49	$ 64,876,970.95	$ 104,043,387.64
20 Year	$ 63,269,138.49	$ 60,349,253.16	$ 99,515,669.85
Minimum	8%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 40,617,024.72	$ 95,678,401.69	$ 141,974,402.50
5 Year	$ 40,617,024.72	$ 83,525,739.40	$ 127,043,980.17
10 Year	$ 69,470,123.89	$ 77,580,669.67	$ 121,098,910.44
15 Year	$ 69,470,123.89	$ 72,085,523.28	$ 115,603,764.05
20 Year	$ 69,470,123.89	$ 67,054,725.74	$ 110,572,966.50
Minimum	9%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 43,932,700.20	$ 105,246,241.86	$ 156,171,842.75
5 Year	$ 43,932,700.20	$ 91,878,313.34	$ 139,748,378.19
10 Year	$ 75,671,109.30	$ 85,338,736.64	$ 133,208,801.49
15 Year	$ 75,671,109.30	$ 79,294,075.61	$ 127,164,140.45
20 Year	$ 75,671,109.30	$ 73,760,198.31	$ 121,630,263.15
Minimum	10%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 47,248,375.69	$ 114,814,082.03	$ 170,369,283.01
5 Year	$ 47,248,375.69	$ 100,230,887.28	$ 152,452,776.21
10 Year	$ 81,872,094.70	$ 93,096,803.61	$ 145,318,692.53
15 Year	$ 81,872,094.70	$ 86,502,627.93	$ 138,724,516.85
20 Year	$ 81,872,094.70	$ 80,465,670.88	$ 132,687,559.80

OFFUTT - $.0760/kWh

Offset	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 689,305.44	$ 1,869,741.01	$ 2,774,454.40
5 Year	$ 689,305.44	$ 1,738,077.59	$ 2,642,790.98
10 Year	$ 1,289,140.93	$ 1,616,001.29	$ 2,520,714.68
15 Year	$ 1,289,140.93	$ 1,503,163.73	$ 2,407,877.12
20 Year	$ 1,289,140.93	$ 1,399,861.12	$ 2,304,574.51
Offset	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,378,610.88	$ 3,739,482.01	$ 5,548,908.79
5 Year	$ 1,378,610.88	$ 3,476,155.19	$ 5,285,581.97
10 Year	$ 2,578,281.85	$ 3,232,002.57	$ 5,041,429.35
15 Year	$ 2,578,281.85	$ 3,006,327.45	$ 4,815,754.23
20 Year	$ 2,578,281.85	$ 2,799,722.24	$ 4,609,149.02
Offset	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,067,916.32	$ 5,609,223.02	$ 8,323,363.19
5 Year	$ 2,067,916.32	$ 5,214,232.78	$ 7,928,372.95
10 Year	$ 3,867,422.78	$ 4,848,003.86	$ 7,562,144.03
15 Year	$ 3,867,422.78	$ 4,509,491.18	$ 7,223,631.35
20 Year	$ 3,867,422.78	$ 4,199,583.37	$ 6,913,723.54
Offset	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,757,221.76	$ 7,478,964.02	$ 11,097,817.58
5 Year	$ 2,757,221.76	$ 6,952,310.37	$ 10,571,163.93
10 Year	$ 5,156,563.71	$ 6,464,005.15	$ 10,082,858.71
15 Year	$ 5,156,563.71	$ 6,012,654.90	$ 9,631,508.46
20 Year	$ 5,156,563.71	$ 5,599,444.49	$ 9,218,298.05
Offset	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,446,527.20	$ 9,348,705.03	$ 13,872,271.98
5 Year	$ 3,446,527.20	$ 8,690,387.97	$ 13,213,954.92
10 Year	$ 6,445,704.64	$ 8,080,006.44	$ 12,603,573.39
15 Year	$ 6,445,704.64	$ 7,515,818.63	$ 12,039,385.58
20 Year	$ 6,445,704.64	$ 6,999,305.61	$ 11,522,872.56

Offset	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,135,832.64	$ 11,218,446.04	$ 16,646,726.37
5 Year	$ 4,135,832.64	$ 10,428,465.56	$ 15,856,745.90
10 Year	$ 7,734,845.56	$ 9,696,007.72	$ 15,124,288.06
15 Year	$ 7,734,845.56	$ 9,018,982.35	$ 14,447,262.69
20 Year	$ 7,734,845.56	$ 8,399,166.73	$ 13,827,447.07
Offset	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,825,138.08	$ 13,088,187.04	$ 19,421,180.77
5 Year	$ 4,825,138.08	$ 12,166,543.15	$ 18,499,536.88
10 Year	$ 9,023,986.49	$ 11,312,009.01	$ 17,645,002.74
15 Year	$ 9,023,986.49	$ 10,522,146.08	$ 16,855,139.81
20 Year	$ 9,023,986.49	$ 9,799,027.85	$ 16,132,021.58
Offset	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,514,443.52	$ 14,957,928.05	$ 22,195,635.17
5 Year	$ 5,514,443.52	$ 13,904,620.74	$ 21,142,327.86
10 Year	$ 10,313,127.42	$ 12,928,010.30	$ 20,165,717.42
15 Year	$ 10,313,127.42	$ 12,025,309.80	$ 19,263,016.92
20 Year	$ 10,313,127.42	$ 11,198,888.97	$ 18,436,596.09
Offset	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,203,748.96	$ 16,827,669.05	$ 24,970,089.56
5 Year	$ 6,203,748.96	$ 15,642,698.34	$ 23,785,118.85
10 Year	$ 11,602,268.35	$ 14,544,011.58	$ 22,686,432.09
15 Year	$ 11,602,268.35	$ 13,528,473.53	$ 21,670,894.04
20 Year	$ 11,602,268.35	$ 12,598,750.10	$ 20,741,170.61
Offset	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,893,054.40	$ 18,697,410.06	$ 27,744,543.96
5 Year	$ 6,893,054.40	$ 17,380,775.93	$ 26,427,909.83
10 Year	$ 12,891,409.27	$ 16,160,012.87	$ 25,207,146.77
15 Year	$ 12,891,409.27	$ 15,031,637.25	$ 24,078,771.15
20 Year	$ 12,891,409.27	$ 13,998,611.22	$ 23,045,745.12

Offset	1%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,723,263.60	$ 3,739,482.01	$ 5,548,908.79
5 Year	$ 1,723,263.60	$ 3,476,155.19	$ 5,285,581.97
10 Year	$ 2,922,934.57	$ 3,232,002.57	$ 5,041,429.35
15 Year	$ 2,922,934.57	$ 3,006,327.45	$ 4,815,754.23
20 Year	$ 2,922,934.57	$ 2,799,722.24	$ 4,609,149.02
Offset	2%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,412,569.04	$ 5,609,223.02	$ 8,323,363.19
5 Year	$ 2,412,569.04	$ 5,214,232.78	$ 7,928,372.95
10 Year	$ 4,212,075.50	$ 4,848,003.86	$ 7,562,144.03
15 Year	$ 4,212,075.50	$ 4,509,491.18	$ 7,223,631.35
20 Year	$ 4,212,075.50	$ 4,199,583.37	$ 6,913,723.54
Offset	3%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,101,874.48	$ 7,478,964.02	$ 11,097,817.58
5 Year	$ 3,101,874.48	$ 6,952,310.37	$ 10,571,163.93
10 Year	$ 5,501,216.43	$ 6,464,005.15	$ 10,082,858.71
15 Year	$ 5,501,216.43	$ 6,012,654.90	$ 9,631,508.46
20 Year	$ 5,501,216.43	$ 5,599,444.49	$ 9,218,298.05
Offset	4%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,791,179.92	$ 9,348,705.03	$ 13,872,271.98
5 Year	$ 3,791,179.92	$ 8,690,387.97	$ 13,213,954.92
10 Year	$ 6,790,357.36	$ 8,080,006.44	$ 12,603,573.39
15 Year	$ 6,790,357.36	$ 7,515,818.63	$ 12,039,385.58
20 Year	$ 6,790,357.36	$ 6,999,305.61	$ 11,522,872.56
Offset	5%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,480,485.36	$ 11,218,446.04	$ 16,646,726.37
5 Year	$ 4,480,485.36	$ 10,428,465.56	$ 15,856,745.90
10 Year	$ 8,079,498.28	$ 9,696,007.72	$ 15,124,288.06
15 Year	$ 8,079,498.28	$ 9,018,982.35	$ 14,447,262.69
20 Year	$ 8,079,498.28	$ 8,399,166.73	$ 13,827,447.07

Offset	6%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,169,790.80	$ 13,088,187.04	$ 19,421,180.77
5 Year	$ 5,169,790.80	$ 12,166,543.15	$ 18,499,536.88
10 Year	$ 9,368,639.21	$ 11,312,009.01	$ 17,645,002.74
15 Year	$ 9,368,639.21	$ 10,522,146.08	$ 16,855,139.81
20 Year	$ 9,368,639.21	$ 9,799,027.85	$ 16,132,021.58
Offset	7%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,859,096.24	$ 14,957,928.05	$ 22,195,635.17
5 Year	$ 5,859,096.24	$ 13,904,620.74	$ 21,142,327.86
10 Year	$ 10,657,780.14	$ 12,928,010.30	$ 20,165,717.42
15 Year	$ 10,657,780.14	$ 12,025,309.80	$ 19,263,016.92
20 Year	$ 10,657,780.14	$ 11,198,888.97	$ 18,436,596.09
Offset	8%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,548,401.68	$ 16,827,669.05	$ 24,970,089.56
5 Year	$ 6,548,401.68	$ 15,642,698.34	$ 23,785,118.85
10 Year	$ 11,946,921.07	$ 14,544,011.58	$ 22,686,432.09
15 Year	$ 11,946,921.07	$ 13,528,473.53	$ 21,670,894.04
20 Year	$ 11,946,921.07	$ 12,598,750.10	$ 20,741,170.61
Offset	9%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,237,707.12	$ 18,697,410.06	$ 27,744,543.96
5 Year	$ 7,237,707.12	$ 17,380,775.93	$ 26,427,909.83
10 Year	$ 13,236,061.99	$ 16,160,012.87	$ 25,207,146.77
15 Year	$ 13,236,061.99	$ 15,031,637.25	$ 24,078,771.15
20 Year	$ 13,236,061.99	$ 13,998,611.22	$ 23,045,745.12
Offset	10%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,927,012.56	$ 20,567,151.06	$ 30,518,998.35
5 Year	$ 7,927,012.56	$ 19,118,853.52	$ 29,070,700.81
10 Year	$ 14,525,202.92	$ 17,778,014.16	$ 27,727,861.45
15 Year	$ 14,525,202.92	$ 16,534,800.98	$ 26,486,648.27
20 Year	$ 14,525,202.92	$ 15,398,472.34	$ 25,350,319.63

Offset	1%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,757,221.76	$ 5,609,223.02	$ 8,323,363.19
5 Year	$ 2,757,221.76	$ 5,214,232.78	$ 7,928,372.95
10 Year	$ 4,556,728.22	$ 4,848,003.86	$ 7,562,144.03
15 Year	$ 4,556,728.22	$ 4,509,491.18	$ 7,223,631.35
20 Year	$ 4,556,728.22	$ 4,199,583.37	$ 6,913,723.54

Offset	2%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,446,527.20	$ 7,478,964.02	$ 11,097,817.58
5 Year	$ 3,446,527.20	$ 6,952,310.37	$ 10,571,163.93
10 Year	$ 5,845,869.15	$ 6,464,005.15	$ 10,082,858.71
15 Year	$ 5,845,869.15	$ 6,012,654.90	$ 9,631,508.46
20 Year	$ 5,845,869.15	$ 5,599,444.49	$ 9,218,298.05

Offset	3%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,135,832.64	$ 9,348,705.03	$ 13,872,271.98
5 Year	$ 4,135,832.64	$ 8,690,387.97	$ 13,213,954.92
10 Year	$ 7,135,010.08	$ 8,080,006.44	$ 12,603,573.39
15 Year	$ 7,135,010.08	$ 7,515,818.63	$ 12,039,385.58
20 Year	$ 7,135,010.08	$ 6,999,305.61	$ 11,522,872.56

Offset	4%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,825,138.08	$ 11,218,446.04	$ 16,646,726.37
5 Year	$ 4,825,138.08	$ 10,428,465.56	$ 15,856,745.90
10 Year	$ 8,424,151.00	$ 9,696,007.72	$ 15,124,288.06
15 Year	$ 8,424,151.00	$ 9,018,982.35	$ 14,447,262.69
20 Year	$ 8,424,151.00	$ 8,399,166.73	$ 13,827,447.07

Offset	5%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,514,443.52	$ 13,088,187.04	$ 19,421,180.77
5 Year	$ 5,514,443.52	$ 12,166,543.15	$ 18,499,536.88
10 Year	$ 9,713,291.93	$ 11,312,009.01	$ 17,645,002.74
15 Year	$ 9,713,291.93	$ 10,522,146.08	$ 16,855,139.81
20 Year	$ 9,713,291.93	$ 9,799,027.85	$ 16,132,021.58

Offset	6%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,203,748.96	$ 14,957,928.05	$ 22,195,635.17
5 Year	$ 6,203,748.96	$ 13,904,620.74	$ 21,142,327.86
10 Year	$ 11,002,432.86	$ 12,928,010.30	$ 20,165,717.42
15 Year	$ 11,002,432.86	$ 12,025,309.80	$ 19,263,016.92
20 Year	$ 11,002,432.86	$ 11,198,888.97	$ 18,436,596.09

Offset	7%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,893,054.40	$ 16,827,669.05	$ 24,970,089.56
5 Year	$ 6,893,054.40	$ 15,642,698.34	$ 23,785,118.85
10 Year	$ 12,291,573.79	$ 14,544,011.58	$ 22,686,432.09
15 Year	$ 12,291,573.79	$ 13,528,473.53	$ 21,670,894.04
20 Year	$ 12,291,573.79	$ 12,598,750.10	$ 20,741,170.61

Offset	8%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,582,359.84	$ 18,697,410.06	$ 27,744,543.96
5 Year	$ 7,582,359.84	$ 17,380,775.93	$ 26,427,909.83
10 Year	$ 13,580,714.71	$ 16,160,012.87	$ 25,207,146.77
15 Year	$ 13,580,714.71	$ 15,031,637.25	$ 24,078,771.15
20 Year	$ 13,580,714.71	$ 13,998,611.22	$ 23,045,745.12

Offset	9%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,271,665.28	$ 20,567,151.06	$ 30,518,998.35
5 Year	$ 8,271,665.28	$ 19,118,853.52	$ 29,070,700.81
10 Year	$ 14,869,855.64	$ 17,776,014.16	$ 27,727,861.45
15 Year	$ 14,869,855.64	$ 16,534,800.98	$ 26,486,648.27
20 Year	$ 14,869,855.64	$ 15,398,472.34	$ 25,350,319.63

Offset	10%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,960,970.72	$ 22,436,892.07	$ 33,293,452.75
5 Year	$ 8,960,970.72	$ 20,856,931.12	$ 31,713,491.80
10 Year	$ 16,158,996.57	$ 19,392,015.44	$ 30,248,576.12
15 Year	$ 16,158,996.57	$ 18,037,964.70	$ 28,894,525.38
20 Year	$ 16,158,996.57	$ 16,798,333.46	$ 27,654,894.14

Offset	1%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 689,305.44	$ 1,869,741.01	$ 2,774,454.40
5 Year	$ 689,305.44	$ 1,738,077.59	$ 2,642,790.98
10 Year	$ 1,289,140.93	$ 1,616,001.29	$ 2,520,714.68
15 Year	$ 1,289,140.93	$ 1,503,163.73	$ 2,407,877.12
20 Year	$ 1,289,140.93	$ 1,399,861.12	$ 2,304,574.51

Offset	2%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,378,610.88	$ 3,739,482.01	$ 5,548,908.79
5 Year	$ 1,378,610.88	$ 3,476,155.19	$ 5,285,581.97
10 Year	$ 2,578,281.85	$ 3,232,002.57	$ 5,041,429.35
15 Year	$ 2,578,281.85	$ 3,006,327.45	$ 4,815,754.23
20 Year	$ 2,578,281.85	$ 2,799,722.24	$ 4,609,149.02

Offset	3%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,067,916.32	$ 5,609,223.02	$ 8,323,363.19
5 Year	$ 2,067,916.32	$ 5,214,232.78	$ 7,928,372.95
10 Year	$ 3,867,422.78	$ 4,848,003.86	$ 7,562,144.03
15 Year	$ 3,867,422.78	$ 4,509,491.18	$ 7,223,631.35
20 Year	$ 3,867,422.78	$ 4,199,583.37	$ 6,913,723.54

Offset	4%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,757,221.76	$ 7,478,964.02	$ 11,097,817.58
5 Year	$ 2,757,221.76	$ 6,952,310.37	$ 10,571,163.93
10 Year	$ 5,156,563.71	$ 6,464,005.15	$ 10,082,858.71
15 Year	$ 5,156,563.71	$ 6,012,654.90	$ 9,631,508.46
20 Year	$ 5,156,563.71	$ 5,599,444.49	$ 9,218,298.05

Offset	5%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,446,527.20	$ 9,348,705.03	$ 13,872,271.98
5 Year	$ 3,446,527.20	$ 8,690,387.97	$ 13,213,954.92
10 Year	$ 6,445,704.64	$ 8,080,006.44	$ 12,603,573.39
15 Year	$ 6,445,704.64	$ 7,515,818.63	$ 12,039,385.58
20 Year	$ 6,445,704.64	$ 6,999,305.61	$ 11,522,872.56

Offset	6%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,135,832.64	$ 11,218,446.04	$ 16,646,726.37
5 Year	$ 4,135,832.64	$ 10,428,465.56	$ 15,856,745.90
10 Year	$ 7,734,845.56	$ 9,696,007.72	$ 15,124,288.06
15 Year	$ 7,734,845.56	$ 9,018,982.35	$ 14,447,262.69
20 Year	$ 7,734,845.56	$ 8,399,166.73	$ 13,827,447.07

Offset	7%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,825,138.08	$ 13,088,187.04	$ 19,421,180.77
5 Year	$ 4,825,138.08	$ 12,166,543.15	$ 18,499,536.88
10 Year	$ 9,023,986.49	$ 11,312,009.01	$ 17,645,002.74
15 Year	$ 9,023,986.49	$ 10,522,146.08	$ 16,855,139.81
20 Year	$ 9,023,986.49	$ 9,799,027.85	$ 16,132,021.58

Offset	8%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,514,443.52	$ 14,957,928.05	$ 22,195,635.17
5 Year	$ 5,514,443.52	$ 13,904,620.74	$ 21,142,327.86
10 Year	$ 10,313,127.42	$ 12,928,010.30	$ 20,165,717.42
15 Year	$ 10,313,127.42	$ 12,025,309.80	$ 19,263,016.92
20 Year	$ 10,313,127.42	$ 11,198,888.97	$ 18,436,596.09

Offset	9%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,203,748.96	$ 16,827,669.05	$ 24,970,089.56
5 Year	$ 6,203,748.96	$ 15,642,698.34	$ 23,785,118.85
10 Year	$ 11,602,268.35	$ 14,544,011.58	$ 22,686,432.09
15 Year	$ 11,602,268.35	$ 13,528,473.53	$ 21,670,894.04
20 Year	$ 11,602,268.35	$ 12,598,750.10	$ 20,741,170.61

Offset	10%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,893,054.40	$ 18,697,410.06	$ 27,744,543.96
5 Year	$ 6,893,054.40	$ 17,380,775.93	$ 26,427,909.83
10 Year	$ 12,891,409.27	$ 16,160,012.87	$ 25,207,146.77
15 Year	$ 12,891,409.27	$ 15,031,637.25	$ 24,078,771.15
20 Year	$ 12,891,409.27	$ 13,998,611.22	$ 23,045,745.12

Offset	1%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,154,079.50	$ 3,739,482.01	$ 5,548,908.79
5 Year	$ 2,154,079.50	$ 3,476,155.19	$ 5,285,581.97
10 Year	$ 3,353,750.47	$ 3,232,002.57	$ 5,041,429.35
15 Year	$ 3,353,750.47	$ 3,006,327.45	$ 4,815,754.23
20 Year	$ 3,353,750.47	$ 2,799,722.24	$ 4,609,149.02

Offset	2%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,843,384.94	$ 5,609,223.02	$ 8,323,363.19
5 Year	$ 2,843,384.94	$ 5,214,232.78	$ 7,928,372.95
10 Year	$ 4,642,891.40	$ 4,848,003.86	$ 7,562,144.03
15 Year	$ 4,642,891.40	$ 4,509,491.18	$ 7,223,631.35
20 Year	$ 4,642,891.40	$ 4,199,583.37	$ 6,913,723.54

Offset	3%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,532,690.38	$ 7,478,964.02	$ 11,097,817.58
5 Year	$ 3,532,690.38	$ 6,952,310.37	$ 10,571,163.93
10 Year	$ 5,932,032.33	$ 6,464,005.15	$ 10,082,858.71
15 Year	$ 5,932,032.33	$ 6,012,654.90	$ 9,631,508.46
20 Year	$ 5,932,032.33	$ 5,599,444.49	$ 9,218,298.05

Offset	4%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,221,995.82	$ 9,348,705.03	$ 13,872,271.98
5 Year	$ 4,221,995.82	$ 8,690,387.97	$ 13,213,954.92
10 Year	$ 7,221,173.26	$ 8,080,006.44	$ 12,603,573.39
15 Year	$ 7,221,173.26	$ 7,515,818.63	$ 12,039,385.58
20 Year	$ 7,221,173.26	$ 6,999,305.61	$ 11,522,872.56

Offset	5%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,911,301.26	$ 11,218,446.04	$ 16,646,726.37
5 Year	$ 4,911,301.26	$ 10,428,465.56	$ 15,856,745.90
10 Year	$ 8,510,314.18	$ 9,696,007.72	$ 15,124,288.06
15 Year	$ 8,510,314.18	$ 9,018,982.35	$ 14,447,262.69
20 Year	$ 8,510,314.18	$ 8,399,166.73	$ 13,827,447.07

Offset	6%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,600,606.70	$ 13,088,187.04	$ 19,421,180.77
5 Year	$ 5,600,606.70	$ 12,166,543.15	$ 18,499,536.88
10 Year	$ 9,799,455.11	$ 11,312,009.01	$ 17,645,002.74
15 Year	$ 9,799,455.11	$ 10,522,146.08	$ 16,855,139.81
20 Year	$ 9,799,455.11	$ 9,799,027.85	$ 16,132,021.58

Offset	7%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,289,912.14	$ 14,957,928.05	$ 22,195,635.17
5 Year	$ 6,289,912.14	$ 13,904,620.74	$ 21,142,327.86
10 Year	$ 11,088,596.04	$ 12,928,010.30	$ 20,165,717.42
15 Year	$ 11,088,596.04	$ 12,025,309.80	$ 19,263,016.92
20 Year	$ 11,088,596.04	$ 11,198,888.97	$ 18,436,596.09

Offset	8%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,979,217.58	$ 16,827,669.05	$ 24,970,089.56
5 Year	$ 6,979,217.58	$ 15,642,698.34	$ 23,785,118.85
10 Year	$ 12,377,736.97	$ 14,544,011.58	$ 22,686,432.09
15 Year	$ 12,377,736.97	$ 13,528,473.53	$ 21,670,894.04
20 Year	$ 12,377,736.97	$ 12,598,750.10	$ 20,741,170.61

Offset	9%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,668,523.02	$ 18,697,410.06	$ 27,744,543.96
5 Year	$ 7,668,523.02	$ 17,380,775.93	$ 26,427,909.83
10 Year	$ 13,666,877.89	$ 16,160,012.87	$ 25,207,146.77
15 Year	$ 13,666,877.89	$ 15,031,637.25	$ 24,078,771.15
20 Year	$ 13,666,877.89	$ 13,998,611.22	$ 23,045,745.12

Offset	10%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,357,828.46	$ 20,567,151.06	$ 30,518,998.35
5 Year	$ 8,357,828.46	$ 19,118,853.52	$ 29,070,700.81
10 Year	$ 14,956,018.82	$ 17,776,014.16	$ 27,727,861.45
15 Year	$ 14,956,018.82	$ 16,534,800.98	$ 26,486,648.27
20 Year	$ 14,956,018.82	$ 15,398,472.34	$ 25,350,319.63

Offset	1%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,618,853.56	$ 5,609,223.02	$ 8,323,363.19
5 Year	$ 3,618,853.56	$ 5,214,232.78	$ 7,928,372.95
10 Year	$ 5,418,360.02	$ 4,848,003.86	$ 7,562,144.03
15 Year	$ 5,418,360.02	$ 4,509,491.18	$ 7,223,631.35
20 Year	$ 5,418,360.02	$ 4,199,583.37	$ 6,913,723.54

Offset	2%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,308,159.00	$ 7,478,964.02	$ 11,097,817.58
5 Year	$ 4,308,159.00	$ 6,952,310.37	$ 10,571,163.93
10 Year	$ 6,707,500.95	$ 6,464,005.15	$ 10,082,858.71
15 Year	$ 6,707,500.95	$ 6,012,654.90	$ 9,631,508.46
20 Year	$ 6,707,500.95	$ 5,599,444.49	$ 9,218,298.05

Offset	3%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,997,464.44	$ 9,348,705.03	$ 13,872,271.98
5 Year	$ 4,997,464.44	$ 8,690,387.97	$ 13,213,954.92
10 Year	$ 7,996,641.88	$ 8,080,006.44	$ 12,603,573.39
15 Year	$ 7,996,641.88	$ 7,515,818.63	$ 12,039,385.58
20 Year	$ 7,996,641.88	$ 6,999,305.61	$ 11,522,872.56

Offset	4%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,686,769.88	$ 11,218,446.04	$ 16,646,726.37
5 Year	$ 5,686,769.88	$ 10,428,465.56	$ 15,856,745.90
10 Year	$ 9,285,782.80	$ 9,696,007.72	$ 15,124,288.06
15 Year	$ 9,285,782.80	$ 9,018,982.35	$ 14,447,262.69
20 Year	$ 9,285,782.80	$ 8,399,166.73	$ 13,827,447.07

Offset	5%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,376,075.32	$ 13,088,187.04	$ 19,421,180.77
5 Year	$ 6,376,075.32	$ 12,166,543.15	$ 18,499,536.88
10 Year	$ 10,574,923.73	$ 11,312,009.01	$ 17,645,002.74
15 Year	$ 10,574,923.73	$ 10,522,146.08	$ 16,855,139.81
20 Year	$ 10,574,923.73	$ 9,799,027.85	$ 16,132,021.58

Offset	6%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,065,380.76	$ 14,957,928.05	$ 22,195,635.17
5 Year	$ 7,065,380.76	$ 13,904,620.74	$ 21,142,327.86
10 Year	$ 11,864,064.66	$ 12,928,010.30	$ 20,165,717.42
15 Year	$ 11,864,064.66	$ 12,025,309.80	$ 19,263,016.92
20 Year	$ 11,864,064.66	$ 11,198,888.97	$ 18,436,596.09

Offset	7%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,754,686.20	$ 16,827,669.05	$ 24,970,089.56
5 Year	$ 7,754,686.20	$ 15,642,698.34	$ 23,785,118.85
10 Year	$ 13,153,205.59	$ 14,544,011.58	$ 22,686,432.09
15 Year	$ 13,153,205.59	$ 13,528,473.53	$ 21,670,894.04
20 Year	$ 13,153,205.59	$ 12,598,750.10	$ 20,741,170.61

Offset	8%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,443,991.64	$ 18,697,410.06	$ 27,744,543.96
5 Year	$ 8,443,991.64	$ 17,380,775.93	$ 26,427,909.83
10 Year	$ 14,442,346.51	$ 16,160,012.87	$ 25,207,146.77
15 Year	$ 14,442,346.51	$ 15,031,637.25	$ 24,078,771.15
20 Year	$ 14,442,346.51	$ 13,998,611.22	$ 23,045,745.12

Offset	9%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,133,297.08	$ 20,567,151.06	$ 30,518,998.35
5 Year	$ 9,133,297.08	$ 19,118,853.52	$ 29,070,700.81
10 Year	$ 15,731,487.44	$ 17,776,014.16	$ 27,727,861.45
15 Year	$ 15,731,487.44	$ 16,534,800.98	$ 26,486,648.27
20 Year	$ 15,731,487.44	$ 15,398,472.34	$ 25,350,319.63

Offset	10%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,822,602.52	$ 22,436,892.07	$ 33,293,452.75
5 Year	$ 9,822,602.52	$ 20,856,931.12	$ 31,713,491.80
10 Year	$ 17,020,628.37	$ 19,392,015.44	$ 30,248,576.12
15 Year	$ 17,020,628.37	$ 18,037,964.70	$ 28,894,525.38
20 Year	$ 17,020,628.37	$ 16,798,333.46	$ 27,654,894.14

PETERSON - $.0735/kWh

Peterson	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,188,629.11	$ 3,224,156.47	$ 4,784,232.18
5 Year	$ 1,188,629.11	$ 2,986,638.81	$ 4,546,714.52
10 Year	$ 2,222,977.43	$ 2,766,416.07	$ 4,326,491.78
15 Year	$ 2,222,977.43	$ 2,562,859.80	$ 4,122,935.51
20 Year	$ 2,222,977.43	$ 2,376,504.37	$ 3,936,580.08

Peterson	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,377,258.23	$ 6,448,312.94	$ 9,568,464.36
5 Year	$ 2,377,258.23	$ 5,973,277.63	$ 9,093,429.05
10 Year	$ 4,445,954.87	$ 5,532,832.14	$ 8,652,983.56
15 Year	$ 4,445,954.87	$ 5,125,719.60	$ 8,245,871.02
20 Year	$ 4,445,954.87	$ 4,753,008.73	$ 7,873,160.16

Peterson	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,565,887.34	$ 9,672,469.41	$ 14,352,696.54
5 Year	$ 3,565,887.34	$ 8,959,916.44	$ 13,640,143.57
10 Year	$ 6,668,932.30	$ 8,299,248.21	$ 12,979,475.34
15 Year	$ 6,668,932.30	$ 7,688,579.40	$ 12,368,806.53
20 Year	$ 6,668,932.30	$ 7,129,513.10	$ 11,809,740.23

Peterson	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,754,516.45	$ 12,896,625.88	$ 19,136,928.72
5 Year	$ 4,754,516.45	$ 11,946,555.25	$ 18,186,858.10
10 Year	$ 8,891,909.73	$ 11,065,664.28	$ 17,305,967.12
15 Year	$ 8,891,909.73	$ 10,251,439.20	$ 16,491,742.04
20 Year	$ 8,891,909.73	$ 9,506,017.47	$ 15,746,320.31

Peterson	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,943,145.57	$ 16,120,782.35	$ 23,921,160.90
5 Year	$ 5,943,145.57	$ 14,933,194.07	$ 22,733,572.62
10 Year	$ 11,114,887.16	$ 13,832,080.35	$ 21,632,458.90
15 Year	$ 11,114,887.16	$ 12,814,299.00	$ 20,614,677.55
20 Year	$ 11,114,887.16	$ 11,882,521.84	$ 19,682,900.39

Peterson	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,131,774.68	$ 19,344,938.81	$ 28,705,393.08
5 Year	$ 7,131,774.68	$ 17,919,832.88	$ 27,280,287.15
10 Year	$ 13,337,864.60	$ 16,598,496.42	$ 25,958,950.68
15 Year	$ 13,337,864.60	$ 15,377,158.80	$ 24,737,613.06
20 Year	$ 13,337,864.60	$ 14,259,026.20	$ 23,619,480.47

Peterson	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,320,403.79	$ 22,569,095.28	$ 33,489,625.26
5 Year	$ 8,320,403.79	$ 20,906,471.69	$ 31,827,001.67
10 Year	$ 15,560,842.03	$ 19,364,912.49	$ 30,285,442.46
15 Year	$ 15,560,842.03	$ 17,940,018.60	$ 28,860,548.57
20 Year	$ 15,560,842.03	$ 16,635,530.57	$ 27,556,060.55

Peterson	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,509,032.90	$ 25,793,251.75	$ 38,273,857.44
5 Year	$ 9,509,032.90	$ 23,893,110.51	$ 36,373,716.19
10 Year	$ 17,783,819.46	$ 22,131,328.55	$ 34,611,934.24
15 Year	$ 17,783,819.46	$ 20,502,878.40	$ 32,983,484.08
20 Year	$ 17,783,819.46	$ 19,012,034.94	$ 31,492,640.62

Peterson	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,697,662.02	$ 29,017,408.22	$ 43,058,089.62
5 Year	$ 10,697,662.02	$ 26,879,749.32	$ 40,920,430.72
10 Year	$ 20,006,796.89	$ 24,897,744.62	$ 38,938,426.02
15 Year	$ 20,006,796.89	$ 23,065,738.20	$ 37,106,419.59
20 Year	$ 20,006,796.89	$ 21,388,539.31	$ 35,429,220.70

Peterson	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,886,291.13	$ 32,241,564.69	$ 47,842,321.80
5 Year	$ 11,886,291.13	$ 29,866,388.13	$ 45,467,145.24
10 Year	$ 22,229,774.33	$ 27,664,160.69	$ 43,264,917.80
15 Year	$ 22,229,774.33	$ 25,628,598.00	$ 41,229,355.10
20 Year	$ 22,229,774.33	$ 23,765,043.67	$ 39,365,800.78

Peterson	1%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,971,572.78	$ 6,448,312.94	$ 9,568,464.36
5 Year	$ 2,971,572.78	$ 5,973,277.63	$ 9,093,429.05
10 Year	$ 5,040,269.42	$ 5,532,832.14	$ 8,652,983.56
15 Year	$ 5,040,269.42	$ 5,125,719.60	$ 8,245,871.02
20 Year	$ 5,040,269.42	$ 4,753,008.73	$ 7,873,160.16

Peterson	2%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,160,201.90	$ 9,672,469.41	$ 14,352,696.54
5 Year	$ 4,160,201.90	$ 8,959,916.44	$ 13,640,143.57
10 Year	$ 7,263,246.85	$ 8,299,248.21	$ 12,979,475.34
15 Year	$ 7,263,246.85	$ 7,688,579.40	$ 12,368,806.53
20 Year	$ 7,263,246.85	$ 7,129,513.10	$ 11,809,740.23

Peterson	3%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,348,831.01	$ 12,896,625.88	$ 19,136,928.72
5 Year	$ 5,348,831.01	$ 11,946,555.25	$ 18,186,858.10
10 Year	$ 9,486,224.29	$ 11,065,664.28	$ 17,305,967.12
15 Year	$ 9,486,224.29	$ 10,251,439.20	$ 16,491,742.04
20 Year	$ 9,486,224.29	$ 9,506,017.47	$ 15,746,320.31

Peterson	4%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,537,460.12	$ 16,120,782.35	$ 23,921,160.90
5 Year	$ 6,537,460.12	$ 14,933,194.07	$ 22,733,572.62
10 Year	$ 11,709,201.72	$ 13,832,080.35	$ 21,632,458.90
15 Year	$ 11,709,201.72	$ 12,814,299.00	$ 20,614,677.55
20 Year	$ 11,709,201.72	$ 11,882,521.84	$ 19,682,900.39

Peterson	5%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,726,089.23	$ 19,344,938.81	$ 28,705,393.08
5 Year	$ 7,726,089.23	$ 17,919,832.88	$ 27,280,287.15
10 Year	$ 13,932,179.15	$ 16,598,496.42	$ 25,958,950.68
15 Year	$ 13,932,179.15	$ 15,377,158.80	$ 24,737,613.06
20 Year	$ 13,932,179.15	$ 14,259,026.20	$ 23,619,480.47

Peterson	6%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,914,718.35	$ 22,569,095.28	$ 33,489,625.26
5 Year	$ 8,914,718.35	$ 20,906,471.69	$ 31,827,001.67
10 Year	$ 16,155,156.58	$ 19,364,912.49	$ 30,285,442.46
15 Year	$ 16,155,156.58	$ 17,940,018.60	$ 28,860,548.57
20 Year	$ 16,155,156.58	$ 16,635,530.57	$ 27,556,060.55

Peterson	7%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,103,347.46	$ 25,793,251.75	$ 38,273,857.44
5 Year	$ 10,103,347.46	$ 23,893,110.51	$ 36,373,716.19
10 Year	$ 18,378,134.02	$ 22,131,328.55	$ 34,611,934.24
15 Year	$ 18,378,134.02	$ 20,502,878.40	$ 32,983,484.08
20 Year	$ 18,378,134.02	$ 19,012,034.94	$ 31,492,640.62

Peterson	8%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,291,976.57	$ 29,017,408.22	$ 43,058,089.62
5 Year	$ 11,291,976.57	$ 26,879,749.32	$ 40,920,430.72
10 Year	$ 20,601,111.45	$ 24,897,744.62	$ 38,938,426.02
15 Year	$ 20,601,111.45	$ 23,065,738.20	$ 37,106,419.59
20 Year	$ 20,601,111.45	$ 21,388,539.31	$ 35,429,220.70

Peterson	9%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,480,605.69	$ 32,241,564.69	$ 47,842,321.80
5 Year	$ 12,480,605.69	$ 29,866,388.13	$ 45,467,145.24
10 Year	$ 22,824,088.88	$ 27,664,160.69	$ 43,264,917.80
15 Year	$ 22,824,088.88	$ 25,628,598.00	$ 41,229,355.10
20 Year	$ 22,824,088.88	$ 23,765,043.67	$ 39,365,800.78

Peterson	10%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 13,669,234.80	$ 35,465,721.16	$ 52,626,553.98
5 Year	$ 13,669,234.80	$ 32,853,026.95	$ 50,013,859.77
10 Year	$ 25,047,066.32	$ 30,430,576.76	$ 47,591,409.58
15 Year	$ 25,047,066.32	$ 28,191,457.79	$ 45,352,290.61
20 Year	$ 25,047,066.32	$ 26,141,548.04	$ 43,302,380.86

Peterson	1%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,754,516.45	$ 9,672,469.41	$ 14,352,696.54
5 Year	$ 4,754,516.45	$ 8,959,916.44	$ 13,640,143.57
10 Year	$ 7,857,561.41	$ 8,299,248.21	$ 12,979,475.34
15 Year	$ 7,857,561.41	$ 7,688,579.40	$ 12,368,806.53
20 Year	$ 7,857,561.41	$ 7,129,513.10	$ 11,809,740.23

Peterson	2%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,943,145.57	$ 12,896,625.88	$ 19,136,928.72
5 Year	$ 5,943,145.57	$ 11,946,555.25	$ 18,186,858.10
10 Year	$ 10,080,538.84	$ 11,065,664.28	$ 17,305,967.12
15 Year	$ 10,080,538.84	$ 10,251,439.20	$ 16,491,742.04
20 Year	$ 10,080,538.84	$ 9,506,017.47	$ 15,746,320.31

Peterson	3%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,131,774.68	$ 16,120,782.35	$ 23,921,160.90
5 Year	$ 7,131,774.68	$ 14,933,194.07	$ 22,733,572.62
10 Year	$ 12,303,516.28	$ 13,832,080.35	$ 21,632,458.90
15 Year	$ 12,303,516.28	$ 12,814,299.00	$ 20,614,677.55
20 Year	$ 12,303,516.28	$ 11,882,521.84	$ 19,682,900.39

Peterson	4%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,320,403.79	$ 19,344,938.81	$ 28,705,393.08
5 Year	$ 8,320,403.79	$ 17,919,832.88	$ 27,280,287.15
10 Year	$ 14,526,493.71	$ 16,598,496.42	$ 25,958,950.68
15 Year	$ 14,526,493.71	$ 15,377,158.80	$ 24,737,613.06
20 Year	$ 14,526,493.71	$ 14,259,026.20	$ 23,619,480.47

Peterson	5%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,509,032.90	$ 22,569,095.28	$ 33,489,625.26
5 Year	$ 9,509,032.90	$ 20,906,471.69	$ 31,827,001.67
10 Year	$ 16,749,471.14	$ 19,364,912.49	$ 30,285,442.46
15 Year	$ 16,749,471.14	$ 17,940,018.60	$ 28,860,548.57
20 Year	$ 16,749,471.14	$ 16,635,530.57	$ 27,556,060.55

Peterson	6%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,697,662.02	$ 25,793,251.75	$ 38,273,857.44
5 Year	$ 10,697,662.02	$ 23,893,110.51	$ 36,373,716.19
10 Year	$ 18,972,448.57	$ 22,131,328.55	$ 34,611,934.24
15 Year	$ 18,972,448.57	$ 20,502,878.40	$ 32,983,484.08
20 Year	$ 18,972,448.57	$ 19,012,034.94	$ 31,492,640.62

Peterson	7%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,886,291.13	$ 29,017,408.22	$ 43,058,089.62
5 Year	$ 11,886,291.13	$ 26,879,749.32	$ 40,920,430.72
10 Year	$ 21,195,426.01	$ 24,897,744.62	$ 38,938,426.02
15 Year	$ 21,195,426.01	$ 23,065,738.20	$ 37,106,419.59
20 Year	$ 21,195,426.01	$ 21,388,539.31	$ 35,429,220.70

Peterson	8%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 13,074,920.24	$ 32,241,564.69	$ 47,842,321.80
5 Year	$ 13,074,920.24	$ 29,866,388.13	$ 45,467,145.24
10 Year	$ 23,418,403.44	$ 27,664,160.69	$ 43,264,917.80
15 Year	$ 23,418,403.44	$ 25,628,598.00	$ 41,229,355.10
20 Year	$ 23,418,403.44	$ 23,765,043.67	$ 39,365,800.78

Peterson	9%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,263,549.36	$ 35,465,721.16	$ 52,626,553.98
5 Year	$ 14,263,549.36	$ 32,853,026.95	$ 50,013,859.77
10 Year	$ 25,641,380.87	$ 30,430,576.76	$ 47,591,409.58
15 Year	$ 25,641,380.87	$ 28,191,457.79	$ 45,352,290.61
20 Year	$ 25,641,380.87	$ 26,141,548.04	$ 43,302,380.86

Peterson	10%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 15,452,178.47	$ 38,689,877.63	$ 57,410,786.16
5 Year	$ 15,452,178.47	$ 35,839,665.76	$ 54,560,574.29
10 Year	$ 27,864,358.30	$ 33,196,992.83	$ 51,917,901.36
15 Year	$ 27,864,358.30	$ 30,754,317.59	$ 49,475,226.12
20 Year	$ 27,864,358.30	$ 28,518,052.41	$ 47,238,960.94

Peterson	1%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,188,629.11	$ 3,224,156.47	$ 4,784,232.18
5 Year	$ 1,188,629.11	$ 2,986,638.81	$ 4,546,714.52
10 Year	$ 2,222,977.43	$ 2,766,416.07	$ 4,326,491.78
15 Year	$ 2,222,977.43	$ 2,562,859.80	$ 4,122,935.51
20 Year	$ 2,222,977.43	$ 2,376,504.37	$ 3,936,580.08

Peterson	2%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,377,258.23	$ 6,448,312.94	$ 9,568,464.36
5 Year	$ 2,377,258.23	$ 5,973,277.63	$ 9,093,429.05
10 Year	$ 4,445,954.87	$ 5,532,832.14	$ 8,652,983.56
15 Year	$ 4,445,954.87	$ 5,125,719.60	$ 8,245,871.02
20 Year	$ 4,445,954.87	$ 4,753,008.73	$ 7,873,160.16

Peterson	3%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,565,887.34	$ 9,672,469.41	$ 14,352,696.54
5 Year	$ 3,565,887.34	$ 8,959,916.44	$ 13,640,143.57
10 Year	$ 6,668,932.30	$ 8,299,248.21	$ 12,979,475.34
15 Year	$ 6,668,932.30	$ 7,688,579.40	$ 12,368,806.53
20 Year	$ 6,668,932.30	$ 7,129,513.10	$ 11,809,740.23

Peterson	4%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,754,516.45	$ 12,896,625.88	$ 19,136,928.72
5 Year	$ 4,754,516.45	$ 11,946,555.25	$ 18,186,858.10
10 Year	$ 8,891,909.73	$ 11,065,664.28	$ 17,305,967.12
15 Year	$ 8,891,909.73	$ 10,251,439.20	$ 16,491,742.04
20 Year	$ 8,891,909.73	$ 9,506,017.47	$ 15,746,320.31

Peterson	5%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,943,145.57	$ 16,120,782.35	$ 23,921,160.90
5 Year	$ 5,943,145.57	$ 14,933,194.07	$ 22,733,572.62
10 Year	$ 11,114,887.16	$ 13,832,080.35	$ 21,632,458.90
15 Year	$ 11,114,887.16	$ 12,814,299.00	$ 20,614,677.55
20 Year	$ 11,114,887.16	$ 11,882,521.84	$ 19,682,900.39

Peterson	6%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,131,774.68	$ 19,344,938.81	$ 28,705,393.08
5 Year	$ 7,131,774.68	$ 17,919,832.88	$ 27,280,287.15
10 Year	$ 13,337,864.60	$ 16,598,496.42	$ 25,958,950.68
15 Year	$ 13,337,864.60	$ 15,377,158.80	$ 24,737,613.06
20 Year	$ 13,337,864.60	$ 14,259,026.20	$ 23,619,480.47

Peterson	7%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,320,403.79	$ 22,569,095.28	$ 33,489,625.26
5 Year	$ 8,320,403.79	$ 20,906,471.69	$ 31,827,001.67
10 Year	$ 15,560,842.03	$ 19,364,912.49	$ 30,285,442.46
15 Year	$ 15,560,842.03	$ 17,940,018.60	$ 28,860,548.57
20 Year	$ 15,560,842.03	$ 16,635,530.57	$ 27,556,060.55

Peterson	8%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,509,032.90	$ 25,793,251.75	$ 38,273,857.44
5 Year	$ 9,509,032.90	$ 23,893,110.51	$ 36,373,716.19
10 Year	$ 17,783,819.46	$ 22,131,328.55	$ 34,611,934.24
15 Year	$ 17,783,819.46	$ 20,502,878.40	$ 32,983,484.08
20 Year	$ 17,783,819.46	$ 19,012,034.94	$ 31,492,640.62

Peterson	9%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,697,662.02	$ 29,017,408.22	$ 43,058,089.62
5 Year	$ 10,697,662.02	$ 26,879,749.32	$ 40,920,430.72
10 Year	$ 20,006,796.89	$ 24,897,744.62	$ 38,938,426.02
15 Year	$ 20,006,796.89	$ 23,065,738.20	$ 37,106,419.59
20 Year	$ 20,006,796.89	$ 21,388,539.31	$ 35,429,220.70

Peterson	10%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,886,291.13	$ 32,241,564.69	$ 47,842,321.80
5 Year	$ 11,886,291.13	$ 29,866,388.13	$ 45,467,145.24
10 Year	$ 22,229,774.33	$ 27,664,160.69	$ 43,264,917.80
15 Year	$ 22,229,774.33	$ 25,628,598.00	$ 41,229,355.10
20 Year	$ 22,229,774.33	$ 23,765,043.67	$ 39,365,800.78

Peterson	6%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	7%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	8%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	9%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	10%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

Travis	6%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	7%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	8%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	9%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	10%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

Peterson	1%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	2%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	3%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	4%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	5%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

Travis	1%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	2%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	3%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	4%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	5%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

Peterson	6%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	7%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	8%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	9%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	10%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

Travis	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

Peterson	1%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	2%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	3%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	4%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Peterson	5%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

TRAVIS- $.1320/kWh

Travis	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]
Travis	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	[illegible]	[illegible]	[illegible]
5 Year	[illegible]	[illegible]	[illegible]
10 Year	[illegible]	[illegible]	[illegible]
15 Year	[illegible]	[illegible]	[illegible]
20 Year	[illegible]	[illegible]	[illegible]

Travis	1%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,666,617.30	$ 11,528,024.56	$ 17,106,100.96
5 Year	$ 6,063,280.51	$ 10,554,156.08	$ 16,522,697.83
10 Year	$ 10,020,493.02	$ 8,902,997.51	$ 14,871,539.26
15 Year	$ 10,020,493.02	$ 7,376,798.75	$ 13,345,340.49
20 Year	$ 10,020,493.02	$ 5,979,566.27	$ 11,948,108.02

Travis	2%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,083,271.62	$ 15,370,699.41	$ 22,808,134.62
5 Year	$ 7,579,100.63	$ 14,072,208.11	$ 22,030,263.77
10 Year	$ 12,855,383.99	$ 11,870,663.35	$ 19,828,719.01
15 Year	$ 12,855,383.99	$ 9,835,731.66	$ 17,793,787.33
20 Year	$ 12,855,383.99	$ 7,972,755.03	$ 15,930,810.70

Travis	3%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,499,925.94	$ 19,213,374.27	$ 28,510,168.27
5 Year	$ 9,094,920.76	$ 17,590,260.14	$ 27,537,829.72
10 Year	$ 15,690,274.95	$ 14,838,329.18	$ 24,785,898.76
15 Year	$ 15,690,274.95	$ 12,294,664.58	$ 22,242,234.16
20 Year	$ 15,690,274.95	$ 9,965,943.79	$ 19,913,513.37

Travis	4%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,916,580.27	$ 23,056,049.12	$ 34,212,201.92
5 Year	$ 10,610,740.89	$ 21,108,312.16	$ 33,045,395.66
10 Year	$ 18,525,165.92	$ 17,805,995.02	$ 29,743,078.52
15 Year	$ 18,525,165.92	$ 14,753,597.49	$ 26,690,680.99
20 Year	$ 18,525,165.92	$ 11,959,132.55	$ 23,896,216.04

Travis	5%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,333,234.59	$ 26,898,723.98	$ 39,914,235.58
5 Year	$ 12,126,561.01	$ 24,626,364.19	$ 38,552,961.60
10 Year	$ 21,360,056.88	$ 20,773,660.86	$ 34,700,258.27
15 Year	$ 21,360,056.88	$ 17,212,530.41	$ 31,139,127.82
20 Year	$ 21,360,056.88	$ 13,952,321.30	$ 27,878,918.72

Travis	6%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,749,888.92	$ 30,741,398.83	$ 45,616,269.23
5 Year	$ 13,642,381.14	$ 28,144,416.22	$ 44,060,527.55
10 Year	$ 24,194,947.85	$ 23,741,328.69	$ 39,657,438.02
15 Year	$ 24,194,947.85	$ 19,671,463.32	$ 35,587,574.65
20 Year	$ 24,194,947.85	$ 15,945,510.06	$ 31,861,621.39

Travis	7%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,166,543.24	$ 34,584,073.68	$ 51,318,302.89
5 Year	$ 15,158,201.27	$ 31,662,468.24	$ 49,568,093.49
10 Year	$ 27,029,838.81	$ 26,708,992.53	$ 44,614,617.78
15 Year	$ 27,029,838.81	$ 22,130,396.24	$ 40,036,021.48
20 Year	$ 27,029,838.81	$ 17,938,698.82	$ 35,844,324.06

Travis	8%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 15,583,197.56	$ 38,426,748.54	$ 57,020,336.54
5 Year	$ 16,674,021.39	$ 35,180,520.27	$ 55,075,659.43
10 Year	$ 29,864,729.78	$ 29,676,658.37	$ 49,571,797.53
15 Year	$ 29,864,729.78	$ 24,589,329.15	$ 44,484,468.32
20 Year	$ 29,864,729.78	$ 19,931,887.58	$ 39,827,026.74

Travis	9%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,999,851.89	$ 42,269,423.39	$ 62,722,370.19
5 Year	$ 18,189,841.52	$ 38,698,572.30	$ 60,583,225.38
10 Year	$ 32,699,620.74	$ 32,644,324.20	$ 54,528,977.28
15 Year	$ 32,699,620.74	$ 27,048,262.07	$ 48,932,915.15
20 Year	$ 32,699,620.74	$ 21,925,076.31	$ 43,809,729.41

Travis	10%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,416,506.23	$ 46,112,098.24	$ 68,424,403.85
5 Year	$ 19,705,661.65	$ 42,216,624.32	$ 66,090,791.32
10 Year	$ 35,534,511.71	$ 35,611,990.04	$ 59,486,157.04
15 Year	$ 35,534,511.71	$ 29,507,194.99	$ 53,381,361.98
20 Year	$ 35,534,511.71	$ 23,918,265.09	$ 47,792,432.09

Travis	1%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,315,820.13	$ 3,842,674.85	$ 5,702,033.65
5 Year	$ 1,315,820.13	$ 3,518,052.03	$ 5,507,565.94
10 Year	$ 2,834,890.97	$ 2,967,665.84	$ 4,957,179.75
15 Year	$ 2,834,890.97	$ 2,458,932.92	$ 4,448,446.83
20 Year	$ 2,834,890.97	$ 1,993,188.76	$ 3,982,702.67

Travis	2%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,031,640.25	$ 7,685,349.71	$ 11,404,067.31
5 Year	$ 3,031,640.25	$ 7,036,104.05	$ 11,015,131.89
10 Year	$ 5,669,781.93	$ 5,935,331.67	$ 9,914,359.51
15 Year	$ 5,669,781.93	$ 4,917,865.83	$ 8,896,893.66
20 Year	$ 5,669,781.93	$ 3,986,377.52	$ 7,965,405.35

Travis	3%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,547,460.38	$ 11,528,024.56	$ 17,106,100.96
5 Year	$ 4,547,460.38	$ 10,554,156.08	$ 16,522,697.83
10 Year	$ 8,504,672.90	$ 8,902,997.51	$ 14,871,539.26
15 Year	$ 8,504,672.90	$ 7,376,798.75	$ 13,345,340.49
20 Year	$ 8,504,672.90	$ 5,979,566.27	$ 11,948,108.02

Travis	4%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,063,280.51	$ 15,370,699.41	$ 22,808,134.62
5 Year	$ 6,063,280.51	$ 14,072,208.11	$ 22,030,263.77
10 Year	$ 11,339,563.86	$ 11,870,663.35	$ 19,828,719.01
15 Year	$ 11,339,563.86	$ 9,835,731.66	$ 17,793,787.33
20 Year	$ 11,339,563.86	$ 7,972,755.03	$ 15,930,810.70

Travis	5%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,579,100.63	$ 19,213,374.27	$ 28,510,168.27
5 Year	$ 7,579,100.63	$ 17,590,260.14	$ 27,537,829.72
10 Year	$ 14,174,454.83	$ 14,838,329.18	$ 24,785,898.76
15 Year	$ 14,174,454.83	$ 12,294,664.58	$ 22,242,234.16
20 Year	$ 14,174,454.83	$ 9,965,943.79	$ 19,913,513.37

Travis	6%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,094,920.76	$ 23,056,049.12	$ 34,212,201.92
5 Year	$ 9,094,920.76	$ 21,108,312.16	$ 33,045,395.66
10 Year	$ 17,009,345.79	$ 17,805,995.02	$ 29,743,078.52
15 Year	$ 17,009,345.79	$ 14,753,597.49	$ 26,690,680.99
20 Year	$ 17,009,345.79	$ 11,959,132.55	$ 23,896,216.04

Travis	7%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,610,740.89	$ 26,898,723.98	$ 39,914,235.58
5 Year	$ 10,610,740.89	$ 24,626,364.19	$ 38,552,961.60
10 Year	$ 19,844,236.76	$ 20,773,660.86	$ 34,700,258.27
15 Year	$ 19,844,236.76	$ 17,212,530.41	$ 31,139,127.82
20 Year	$ 19,844,236.76	$ 13,952,321.30	$ 27,878,918.72

Travis	8%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,126,561.01	$ 30,741,398.83	$ 45,616,269.23
5 Year	$ 12,126,561.01	$ 28,144,416.22	$ 44,060,527.55
10 Year	$ 22,679,127.72	$ 23,741,328.69	$ 39,657,438.02
15 Year	$ 22,679,127.72	$ 19,671,463.32	$ 35,587,574.65
20 Year	$ 22,679,127.72	$ 15,945,510.06	$ 31,861,621.39

Travis	9%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 13,642,381.14	$ 34,584,073.68	$ 51,318,302.89
5 Year	$ 13,642,381.14	$ 31,662,468.24	$ 49,568,093.49
10 Year	$ 25,514,018.69	$ 26,708,992.53	$ 44,614,617.78
15 Year	$ 25,514,018.69	$ 22,130,396.24	$ 40,036,021.48
20 Year	$ 25,514,018.69	$ 17,938,698.82	$ 35,844,324.06

Travis	10%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 15,158,201.27	$ 38,426,748.54	$ 57,020,336.54
5 Year	$ 15,158,201.27	$ 35,180,520.27	$ 55,075,659.43
10 Year	$ 28,348,909.65	$ 29,676,658.37	$ 49,571,797.53
15 Year	$ 28,348,909.65	$ 24,589,329.15	$ 44,484,468.32
20 Year	$ 28,348,909.65	$ 19,931,887.58	$ 39,827,026.74

Travis	1%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,736,937.90	$ 7,685,349.71	$ 11,404,067.31
5 Year	$ 4,736,937.90	$ 7,036,104.05	$ 11,015,131.89
10 Year	$ 7,373,079.57	$ 5,935,331.67	$ 9,914,359.51
15 Year	$ 7,373,079.57	$ 4,917,865.83	$ 8,896,893.66
20 Year	$ 7,373,079.57	$ 3,986,377.52	$ 7,965,405.35

Travis	2%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,252,758.02	$ 11,528,024.56	$ 17,106,100.96
5 Year	$ 6,252,758.02	$ 10,554,156.08	$ 16,522,697.83
10 Year	$ 10,209,970.54	$ 8,902,997.51	$ 14,871,539.26
15 Year	$ 10,209,970.54	$ 7,376,798.75	$ 13,345,340.49
20 Year	$ 10,209,970.54	$ 5,979,566.27	$ 11,948,108.02

Travis	3%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,768,578.15	$ 15,370,699.41	$ 22,808,134.62
5 Year	$ 7,768,578.15	$ 14,072,208.11	$ 22,030,263.77
10 Year	$ 13,044,861.50	$ 11,870,663.35	$ 19,828,719.01
15 Year	$ 13,044,861.50	$ 9,835,731.66	$ 17,793,787.33
20 Year	$ 13,044,861.50	$ 7,972,755.03	$ 15,930,810.70

Travis	4%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,284,398.28	$ 19,213,374.27	$ 28,510,168.27
5 Year	$ 9,284,398.28	$ 17,590,260.14	$ 27,537,829.72
10 Year	$ 15,879,752.47	$ 14,838,329.18	$ 24,785,898.76
15 Year	$ 15,879,752.47	$ 12,294,664.58	$ 22,242,234.16
20 Year	$ 15,879,752.47	$ 9,965,943.79	$ 19,913,513.37

Travis	5%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,800,218.40	$ 23,056,049.12	$ 34,212,201.92
5 Year	$ 10,800,218.40	$ 21,108,312.16	$ 33,045,395.66
10 Year	$ 18,714,643.43	$ 17,805,995.02	$ 29,743,078.52
15 Year	$ 18,714,643.43	$ 14,753,597.49	$ 26,690,680.99
20 Year	$ 18,714,643.43	$ 11,959,132.55	$ 23,896,216.04

Travis	6%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,316,038.53	$ 26,898,723.98	$ 39,914,235.58
5 Year	$ 12,316,038.53	$ 24,626,364.19	$ 38,552,961.60
10 Year	$ 21,549,534.40	$ 20,773,660.86	$ 34,700,258.27
15 Year	$ 21,549,534.40	$ 17,212,530.41	$ 31,139,127.82
20 Year	$ 21,549,534.40	$ 13,952,321.30	$ 27,878,918.72

Travis	7%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 13,831,858.66	$ 30,741,398.83	$ 45,616,269.23
5 Year	$ 13,831,858.66	$ 28,144,416.22	$ 44,060,527.55
10 Year	$ 24,384,425.36	$ 23,741,328.69	$ 39,657,438.02
15 Year	$ 24,384,425.36	$ 19,671,463.32	$ 35,587,574.65
20 Year	$ 24,384,425.36	$ 15,945,510.06	$ 31,861,621.39

Travis	8%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 15,347,678.78	$ 34,584,073.68	$ 51,318,302.89
5 Year	$ 15,347,678.78	$ 31,662,468.24	$ 49,568,093.49
10 Year	$ 27,219,316.33	$ 26,708,992.53	$ 44,614,617.78
15 Year	$ 27,219,316.33	$ 22,130,396.24	$ 40,036,021.48
20 Year	$ 27,219,316.33	$ 17,938,698.82	$ 35,844,324.06

Travis	9%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,863,498.91	$ 38,426,748.54	$ 57,020,336.54
5 Year	$ 16,863,498.91	$ 35,180,520.27	$ 55,075,659.43
10 Year	$ 30,054,207.29	$ 29,676,658.37	$ 49,571,797.53
15 Year	$ 30,054,207.29	$ 24,589,329.15	$ 44,484,468.32
20 Year	$ 30,054,207.29	$ 19,931,887.58	$ 39,827,026.74

Travis	10%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,379,319.04	$ 42,269,423.39	$ 62,722,370.19
5 Year	$ 18,379,319.04	$ 38,698,572.30	$ 60,583,225.38
10 Year	$ 32,889,098.26	$ 32,644,324.20	$ 54,528,977.28
15 Year	$ 32,889,098.26	$ 27,048,262.07	$ 48,932,915.15
20 Year	$ 32,889,098.26	$ 21,925,076.31	$ 43,809,729.41

Travis	1%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,958,055.66	$ 11,528,024.56	$ 17,106,100.96
5 Year	$ 7,958,055.66	$ 10,554,156.08	$ 16,522,697.83
10 Year	$ 11,915,268.18	$ 8,902,997.51	$ 14,871,539.26
15 Year	$ 11,915,268.18	$ 7,376,798.75	$ 13,345,340.49
20 Year	$ 11,915,268.18	$ 5,979,566.27	$ 11,948,108.02

Travis	2%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,473,875.79	$ 15,370,699.41	$ 22,808,134.62
5 Year	$ 9,473,875.79	$ 14,072,208.11	$ 22,030,263.77
10 Year	$ 14,750,159.15	$ 11,870,663.35	$ 19,828,719.01
15 Year	$ 14,750,159.15	$ 9,835,731.66	$ 17,793,787.33
20 Year	$ 14,750,159.15	$ 7,972,755.03	$ 15,930,810.70

Travis	3%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,989,695.92	$ 19,213,374.27	$ 28,510,168.27
5 Year	$ 10,989,695.92	$ 17,590,260.14	$ 27,537,829.72
10 Year	$ 17,585,050.11	$ 14,838,329.18	$ 24,785,898.76
15 Year	$ 17,585,050.11	$ 12,294,664.58	$ 22,242,234.16
20 Year	$ 17,585,050.11	$ 9,965,943.79	$ 19,913,513.37

Travis	4%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,505,516.04	$ 23,056,049.12	$ 34,212,201.92
5 Year	$ 12,505,516.04	$ 21,108,312.16	$ 33,045,395.66
10 Year	$ 20,419,941.08	$ 17,805,995.02	$ 29,743,078.52
15 Year	$ 20,419,941.08	$ 14,753,597.49	$ 26,690,680.99
20 Year	$ 20,419,941.08	$ 11,959,132.55	$ 23,896,216.04

Travis	5%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,021,336.17	$ 26,898,723.98	$ 39,914,235.58
5 Year	$ 14,021,336.17	$ 24,626,364.19	$ 38,552,961.60
10 Year	$ 23,254,832.04	$ 20,773,660.86	$ 34,700,258.27
15 Year	$ 23,254,832.04	$ 17,212,530.41	$ 31,139,127.82
20 Year	$ 23,254,832.04	$ 13,952,321.30	$ 27,878,918.72

Travis	6%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 15,537,156.30	$ 30,741,398.83	$ 45,616,269.23
5 Year	$ 15,537,156.30	$ 28,144,416.22	$ 44,060,527.55
10 Year	$ 26,089,723.01	$ 23,741,328.69	$ 39,657,438.02
15 Year	$ 26,089,723.01	$ 19,671,463.32	$ 35,587,574.65
20 Year	$ 26,089,723.01	$ 15,945,510.06	$ 31,861,621.39

Travis	7%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 17,052,976.42	$ 34,584,073.68	$ 51,318,302.89
5 Year	$ 17,052,976.42	$ 31,662,468.24	$ 49,568,093.49
10 Year	$ 28,924,613.97	$ 26,708,992.53	$ 44,614,617.78
15 Year	$ 28,924,613.97	$ 22,130,396.24	$ 40,036,021.48
20 Year	$ 28,924,613.97	$ 17,938,698.82	$ 35,844,324.06

Travis	8%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,568,796.55	$ 38,426,748.54	$ 57,020,336.54
5 Year	$ 18,568,796.55	$ 35,180,520.27	$ 55,075,659.43
10 Year	$ 31,759,504.94	$ 29,676,658.37	$ 49,571,797.53
15 Year	$ 31,759,504.94	$ 24,589,329.15	$ 44,484,468.32
20 Year	$ 31,759,504.94	$ 19,931,887.58	$ 39,827,026.74

Travis	9%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,084,616.68	$ 42,269,423.39	$ 62,722,370.19
5 Year	$ 20,084,616.68	$ 38,698,572.30	$ 60,583,225.38
10 Year	$ 34,594,395.90	$ 32,644,324.20	$ 54,528,977.28
15 Year	$ 34,594,395.90	$ 27,048,262.07	$ 48,932,915.15
20 Year	$ 34,594,395.90	$ 21,925,076.31	$ 43,809,729.41

Travis	10%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 21,600,436.80	$ 46,112,098.24	$ 68,424,403.85
5 Year	$ 21,600,436.80	$ 42,216,624.32	$ 66,090,791.32
10 Year	$ 37,429,286.87	$ 35,611,990.04	$ 59,486,157.04
15 Year	$ 37,429,286.87	$ 29,507,194.99	$ 53,381,361.98
20 Year	$ 37,429,286.87	$ 23,918,265.09	$ 47,792,432.09

USAFA - $.0427/kWh

USAFA	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,058,154.59	$ 5,582,744.33	$ 8,284,072.24
5 Year	$ 2,058,154.59	$ 5,385,765.56	$ 8,087,093.46
10 Year	$ 3,849,166.37	$ 5,203,129.85	$ 7,904,457.75
15 Year	$ 3,849,166.37	$ 5,034,316.02	$ 7,735,643.92
20 Year	$ 3,849,166.37	$ 4,879,767.24	$ 7,581,095.14

USAFA	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,116,309.19	$ 11,165,488.67	$ 16,568,144.47
5 Year	$ 4,116,309.19	$ 10,771,531.12	$ 16,174,186.92
10 Year	$ 7,698,332.75	$ 10,406,259.69	$ 15,808,915.50
15 Year	$ 7,698,332.75	$ 10,068,632.04	$ 15,471,287.84
20 Year	$ 7,698,332.75	$ 9,759,534.47	$ 15,162,190.28

USAFA	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,174,463.78	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 6,174,463.78	$ 16,157,296.68	$ 24,261,280.39
10 Year	$ 11,547,499.12	$ 15,609,389.54	$ 23,713,373.25
15 Year	$ 11,547,499.12	$ 15,102,948.06	$ 23,206,931.76
20 Year	$ 11,547,499.12	$ 14,639,301.71	$ 22,743,285.42

USAFA	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,232,618.37	$ 22,330,977.33	$ 33,136,288.95
5 Year	$ 8,232,618.37	$ 21,543,062.23	$ 32,348,373.85
10 Year	$ 15,396,665.50	$ 20,812,519.38	$ 31,617,831.00
15 Year	$ 15,396,665.50	$ 20,137,264.07	$ 30,942,575.69
20 Year	$ 15,396,665.50	$ 19,519,068.94	$ 30,324,380.55

USAFA	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,290,772.96	$ 27,913,721.67	$ 41,420,361.18
5 Year	$ 10,290,772.96	$ 26,928,827.79	$ 40,435,467.31
10 Year	$ 19,245,831.87	$ 26,015,649.23	$ 39,522,288.75
15 Year	$ 19,245,831.87	$ 25,171,580.09	$ 38,678,219.61
20 Year	$ 19,245,831.87	$ 24,398,836.18	$ 37,905,475.69

USAFA	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,348,927.56	$ 33,496,466.00	$ 49,704,433.42
5 Year	$ 12,348,927.56	$ 32,314,593.35	$ 48,522,560.77
10 Year	$ 23,094,998.24	$ 31,218,779.08	$ 47,426,746.50
15 Year	$ 23,094,998.24	$ 30,205,896.11	$ 46,413,863.53
20 Year	$ 23,094,998.24	$ 29,278,603.41	$ 45,486,570.83

USAFA	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,407,082.15	$ 39,079,210.33	$ 57,988,505.65
5 Year	$ 14,407,082.15	$ 37,700,358.91	$ 56,609,654.23
10 Year	$ 26,944,164.62	$ 36,421,908.92	$ 55,331,204.25
15 Year	$ 26,944,164.62	$ 35,240,212.13	$ 54,149,507.45
20 Year	$ 26,944,164.62	$ 34,158,370.65	$ 53,067,665.97

USAFA	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,465,236.74	$ 44,661,954.67	$ 66,272,577.89
5 Year	$ 16,465,236.74	$ 43,086,124.47	$ 64,696,747.69
10 Year	$ 30,793,330.99	$ 41,625,038.77	$ 63,235,661.99
15 Year	$ 30,793,330.99	$ 40,274,528.15	$ 61,885,151.37
20 Year	$ 30,793,330.99	$ 39,038,137.88	$ 60,648,761.11

USAFA	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,523,391.34	$ 50,244,699.00	$ 74,556,650.13
5 Year	$ 18,523,391.34	$ 48,471,890.03	$ 72,783,841.16
10 Year	$ 34,642,497.36	$ 46,828,168.62	$ 71,140,119.74
15 Year	$ 34,642,497.36	$ 45,308,844.17	$ 69,620,795.29
20 Year	$ 34,642,497.36	$ 43,917,905.12	$ 68,229,856.25

USAFA	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,581,545.93	$ 55,827,443.33	$ 82,840,722.36
5 Year	$ 20,581,545.93	$ 53,857,655.59	$ 80,870,934.62
10 Year	$ 38,491,663.74	$ 52,031,298.46	$ 79,044,577.49
15 Year	$ 38,491,663.74	$ 50,343,160.18	$ 77,356,439.22
20 Year	$ 38,491,663.74	$ 48,797,672.35	$ 75,810,951.38

USAFA	1%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,145,386.48	$ 11,165,488.67	$ 16,568,144.47
5 Year	$ 5,145,386.48	$ 10,771,531.12	$ 16,174,186.92
10 Year	$ 8,727,410.04	$ 10,406,259.69	$ 15,808,915.50
15 Year	$ 8,727,410.04	$ 10,068,632.04	$ 15,471,287.84
20 Year	$ 8,727,410.04	$ 9,759,534.47	$ 15,162,190.28

USAFA	2%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,203,541.08	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 7,203,541.08	$ 16,157,296.68	$ 24,261,280.39
10 Year	$ 12,576,576.42	$ 15,609,389.54	$ 23,713,373.25
15 Year	$ 12,576,576.42	$ 15,102,948.06	$ 23,206,931.76
20 Year	$ 12,576,576.42	$ 14,639,301.71	$ 22,743,285.42

USAFA	3%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,261,695.67	$ 22,330,977.33	$ 33,136,288.95
5 Year	$ 9,261,695.67	$ 21,543,062.23	$ 32,348,373.85
10 Year	$ 16,425,742.79	$ 20,812,519.38	$ 31,617,831.00
15 Year	$ 16,425,742.79	$ 20,137,264.07	$ 30,942,575.69
20 Year	$ 16,425,742.79	$ 19,519,068.94	$ 30,324,380.55

USAFA	4%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,319,850.26	$ 27,913,721.67	$ 41,420,361.18
5 Year	$ 11,319,850.26	$ 26,928,827.79	$ 40,435,467.31
10 Year	$ 20,274,909.17	$ 26,015,649.23	$ 39,522,288.75
15 Year	$ 20,274,909.17	$ 25,171,580.09	$ 38,678,219.61
20 Year	$ 20,274,909.17	$ 24,398,836.18	$ 37,905,475.69

USAFA	5%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 13,378,004.85	$ 33,496,466.00	$ 49,704,433.42
5 Year	$ 13,378,004.85	$ 32,314,593.35	$ 48,522,560.77
10 Year	$ 24,124,075.54	$ 31,218,779.08	$ 47,426,746.50
15 Year	$ 24,124,075.54	$ 30,205,896.11	$ 46,413,863.53
20 Year	$ 24,124,075.54	$ 29,278,603.41	$ 45,486,570.83

USAFA	6%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 15,436,159.45	$ 39,079,210.33	$ 57,988,505.65
5 Year	$ 15,436,159.45	$ 37,700,358.91	$ 56,609,654.23
10 Year	$ 27,973,241.91	$ 36,421,908.92	$ 55,331,204.25
15 Year	$ 27,973,241.91	$ 35,240,212.13	$ 54,149,507.45
20 Year	$ 27,973,241.91	$ 34,158,370.65	$ 53,067,665.97

USAFA	7%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 17,494,314.04	$ 44,661,954.67	$ 66,272,577.89
5 Year	$ 17,494,314.04	$ 43,086,124.47	$ 64,696,747.69
10 Year	$ 31,822,408.29	$ 41,625,038.77	$ 63,235,661.99
15 Year	$ 31,822,408.29	$ 40,274,528.15	$ 61,885,151.37
20 Year	$ 31,822,408.29	$ 39,038,137.88	$ 60,648,761.11

USAFA	8%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 19,552,468.63	$ 50,244,699.00	$ 74,556,650.13
5 Year	$ 19,552,468.63	$ 48,471,890.03	$ 72,783,841.16
10 Year	$ 35,671,574.66	$ 46,828,168.62	$ 71,140,119.74
15 Year	$ 35,671,574.66	$ 45,308,844.17	$ 69,620,795.29
20 Year	$ 35,671,574.66	$ 43,917,905.12	$ 68,229,856.25

USAFA	9%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 21,610,623.23	$ 55,827,443.33	$ 82,840,722.36
5 Year	$ 21,610,623.23	$ 53,857,655.59	$ 80,870,934.62
10 Year	$ 39,520,741.03	$ 52,031,298.46	$ 79,044,577.49
15 Year	$ 39,520,741.03	$ 50,343,160.18	$ 77,356,439.22
20 Year	$ 39,520,741.03	$ 48,797,672.35	$ 75,810,951.38

USAFA	10%	1%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 23,668,777.82	$ 61,410,187.67	$ 91,124,794.60
5 Year	$ 23,668,777.82	$ 59,243,421.14	$ 88,958,028.08
10 Year	$ 43,369,907.41	$ 57,234,428.31	$ 86,949,035.24
15 Year	$ 43,369,907.41	$ 55,377,476.20	$ 85,092,083.14
20 Year	$ 43,369,907.41	$ 53,677,439.59	$ 83,392,046.52

USAFA	1%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,232,618.37	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 8,232,618.37	$ 16,157,296.68	$ 24,261,280.39
10 Year	$ 13,605,653.71	$ 15,609,389.54	$ 23,713,373.25
15 Year	$ 13,605,653.71	$ 15,102,948.06	$ 23,206,931.76
20 Year	$ 13,605,653.71	$ 14,639,301.71	$ 22,743,285.42

USAFA	2%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,290,772.98	$ 22,330,977.33	$ 33,136,288.95
5 Year	$ 10,290,772.98	$ 21,543,062.23	$ 32,348,373.85
10 Year	$ 17,454,820.09	$ 20,812,519.38	$ 31,617,831.00
15 Year	$ 17,454,820.09	$ 20,137,264.07	$ 30,942,575.69
20 Year	$ 17,454,820.09	$ 19,519,068.94	$ 30,324,380.55

USAFA	3%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,348,927.56	$ 27,913,721.67	$ 41,420,361.18
5 Year	$ 12,348,927.56	$ 26,928,827.79	$ 40,435,467.31
10 Year	$ 21,303,986.46	$ 26,015,649.23	$ 39,522,288.75
15 Year	$ 21,303,986.46	$ 25,171,580.09	$ 38,678,219.61
20 Year	$ 21,303,986.46	$ 24,398,836.18	$ 37,905,475.69

USAFA	4%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,407,082.15	$ 33,496,466.00	$ 49,704,433.42
5 Year	$ 14,407,082.15	$ 32,314,593.35	$ 48,522,560.77
10 Year	$ 25,153,152.84	$ 31,218,779.08	$ 47,426,746.50
15 Year	$ 25,153,152.84	$ 30,205,896.11	$ 46,413,863.53
20 Year	$ 25,153,152.84	$ 29,278,603.41	$ 45,486,570.83

USAFA	5%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,465,236.74	$ 39,079,210.33	$ 57,988,505.65
5 Year	$ 16,465,236.74	$ 37,700,358.91	$ 56,609,654.23
10 Year	$ 29,002,319.21	$ 36,421,908.92	$ 55,331,204.25
15 Year	$ 29,002,319.21	$ 35,240,212.13	$ 54,149,507.45
20 Year	$ 29,002,319.21	$ 34,158,370.65	$ 53,067,665.97

USAFA	6%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,523,391.34	$ 44,661,954.67	$ 66,272,577.89
5 Year	$ 18,523,391.34	$ 43,086,124.47	$ 64,696,747.69
10 Year	$ 32,851,485.58	$ 41,625,038.77	$ 63,235,661.99
15 Year	$ 32,851,485.58	$ 40,274,528.15	$ 61,885,151.37
20 Year	$ 32,851,485.58	$ 39,038,137.88	$ 60,648,761.11

USAFA	7%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,581,545.93	$ 50,244,699.00	$ 74,556,650.13
5 Year	$ 20,581,545.93	$ 48,471,890.03	$ 72,783,841.16
10 Year	$ 36,700,651.96	$ 46,828,168.62	$ 71,140,119.74
15 Year	$ 36,700,651.96	$ 45,308,844.17	$ 69,620,795.29
20 Year	$ 36,700,651.96	$ 43,917,905.12	$ 68,229,856.25

USAFA	8%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 22,639,700.52	$ 55,827,443.33	$ 82,840,722.36
5 Year	$ 22,639,700.52	$ 53,857,655.59	$ 80,870,934.62
10 Year	$ 40,549,818.33	$ 52,031,298.46	$ 79,044,577.49
15 Year	$ 40,549,818.33	$ 50,343,160.18	$ 77,356,439.22
20 Year	$ 40,549,818.33	$ 48,797,672.35	$ 75,810,951.38

USAFA	9%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 24,697,855.11	$ 61,410,187.67	$ 91,124,794.60
5 Year	$ 24,697,855.11	$ 59,243,421.14	$ 88,958,028.08
10 Year	$ 44,398,984.71	$ 57,234,428.31	$ 86,949,035.24
15 Year	$ 44,398,984.71	$ 55,377,476.20	$ 85,092,083.14
20 Year	$ 44,398,984.71	$ 53,677,439.59	$ 83,392,046.52

USAFA	10%	2%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 26,756,009.71	$ 66,992,932.00	$ 99,408,866.84
5 Year	$ 26,756,009.71	$ 64,629,186.70	$ 97,045,121.54
10 Year	$ 48,248,151.08	$ 62,437,558.15	$ 94,853,492.99
15 Year	$ 48,248,151.08	$ 60,411,792.22	$ 92,827,727.06
20 Year	$ 48,248,151.08	$ 58,557,206.82	$ 90,973,141.66

USAFA	1%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,058,154.59	$ 5,582,744.33	$ 8,284,072.24
5 Year	$ 2,058,154.59	$ 5,385,765.56	$ 8,087,093.46
10 Year	$ 3,849,166.37	$ 5,203,129.85	$ 7,904,457.75
15 Year	$ 3,849,166.37	$ 5,034,316.02	$ 7,735,643.92
20 Year	$ 3,849,166.37	$ 4,879,767.24	$ 7,581,095.14

USAFA	2%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,116,309.19	$ 11,165,488.67	$ 16,568,144.47
5 Year	$ 4,116,309.19	$ 10,771,531.12	$ 16,174,186.92
10 Year	$ 7,698,332.75	$ 10,406,259.69	$ 15,808,915.50
15 Year	$ 7,698,332.75	$ 10,068,632.04	$ 15,471,287.84
20 Year	$ 7,698,332.75	$ 9,759,534.47	$ 15,162,190.28

USAFA	3%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,174,463.78	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 6,174,463.78	$ 16,157,296.68	$ 24,261,280.39
10 Year	$ 11,547,499.12	$ 15,609,389.54	$ 23,713,373.25
15 Year	$ 11,547,499.12	$ 15,102,948.06	$ 23,206,931.76
20 Year	$ 11,547,499.12	$ 14,639,301.71	$ 22,743,285.42

USAFA	4%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,232,618.37	$ 22,330,977.33	$ 33,136,288.95
5 Year	$ 8,232,618.37	$ 21,543,062.23	$ 32,348,373.85
10 Year	$ 15,396,665.50	$ 20,812,519.38	$ 31,617,831.00
15 Year	$ 15,396,665.50	$ 20,137,264.07	$ 30,942,575.69
20 Year	$ 15,396,665.50	$ 19,519,068.94	$ 30,324,380.55

USAFA	5%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,290,772.96	$ 27,913,721.67	$ 41,420,361.18
5 Year	$ 10,290,772.96	$ 26,928,827.79	$ 40,435,467.31
10 Year	$ 19,245,831.87	$ 26,015,649.23	$ 39,522,288.75
15 Year	$ 19,245,831.87	$ 25,171,580.09	$ 38,678,219.61
20 Year	$ 19,245,831.87	$ 24,398,836.18	$ 37,905,475.69

USAFA	6%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,348,927.56	$ 33,496,466.00	$ 49,704,433.42
5 Year	$ 12,348,927.56	$ 32,314,593.35	$ 48,522,560.77
10 Year	$ 23,094,998.24	$ 31,218,779.08	$ 47,426,746.50
15 Year	$ 23,094,998.24	$ 30,205,896.11	$ 46,413,863.53
20 Year	$ 23,094,998.24	$ 29,278,603.41	$ 45,486,570.83

USAFA	7%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,407,082.15	$ 39,079,210.33	$ 57,988,505.65
5 Year	$ 14,407,082.15	$ 37,700,358.91	$ 56,609,654.23
10 Year	$ 26,944,164.62	$ 36,421,908.92	$ 55,331,204.25
15 Year	$ 26,944,164.62	$ 35,240,212.13	$ 54,149,507.45
20 Year	$ 26,944,164.62	$ 34,158,370.65	$ 53,067,665.97

USAFA	8%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,465,236.74	$ 44,661,954.67	$ 66,272,577.89
5 Year	$ 16,465,236.74	$ 43,086,124.47	$ 64,696,747.69
10 Year	$ 30,793,330.99	$ 41,625,038.77	$ 63,235,661.99
15 Year	$ 30,793,330.99	$ 40,274,528.15	$ 61,885,151.37
20 Year	$ 30,793,330.99	$ 39,038,137.88	$ 60,648,761.11

USAFA	9%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,523,391.34	$ 50,244,699.00	$ 74,556,650.13
5 Year	$ 18,523,391.34	$ 48,471,890.03	$ 72,783,841.16
10 Year	$ 34,642,497.36	$ 46,828,168.62	$ 71,140,119.74
15 Year	$ 34,642,497.36	$ 45,308,844.17	$ 69,620,795.29
20 Year	$ 34,642,497.36	$ 43,917,905.12	$ 68,229,856.25

USAFA	10%	0%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,581,545.93	$ 55,827,443.33	$ 82,840,722.36
5 Year	$ 20,581,545.93	$ 53,857,655.59	$ 80,870,934.62
10 Year	$ 38,491,663.74	$ 52,031,298.46	$ 79,044,577.49
15 Year	$ 38,491,663.74	$ 50,343,160.18	$ 77,356,439.22
20 Year	$ 38,491,663.74	$ 48,797,672.35	$ 75,810,951.38

USAFA	1%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,431,733.10	$ 11,165,488.87	$ 16,568,144.47
5 Year	$ 6,431,733.10	$ 10,771,531.12	$ 16,174,186.92
10 Year	$ 10,013,756.66	$ 10,406,259.69	$ 15,808,915.50
15 Year	$ 10,013,756.66	$ 10,068,632.04	$ 15,471,287.84
20 Year	$ 10,013,756.66	$ 9,759,534.47	$ 15,162,190.28

USAFA	2%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,489,887.70	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 8,489,887.70	$ 16,157,296.68	$ 24,261,280.39
10 Year	$ 13,862,923.04	$ 15,609,389.54	$ 23,713,373.25
15 Year	$ 13,862,923.04	$ 15,102,948.06	$ 23,206,931.78
20 Year	$ 13,862,923.04	$ 14,639,301.71	$ 22,743,285.42

USAFA	3%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,548,042.29	$ 22,330,977.33	$ 33,136,288.95
5 Year	$ 10,548,042.29	$ 21,543,062.23	$ 32,348,373.85
10 Year	$ 17,712,089.41	$ 20,812,519.38	$ 31,617,831.00
15 Year	$ 17,712,089.41	$ 20,137,264.07	$ 30,942,575.69
20 Year	$ 17,712,089.41	$ 19,519,068.94	$ 30,324,380.55

USAFA	4%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,606,196.88	$ 27,913,721.67	$ 41,420,361.18
5 Year	$ 12,606,196.88	$ 26,928,827.79	$ 40,435,467.31
10 Year	$ 21,561,255.79	$ 26,015,649.23	$ 39,522,288.75
15 Year	$ 21,561,255.79	$ 25,171,580.09	$ 38,678,219.61
20 Year	$ 21,561,255.79	$ 24,398,836.18	$ 37,905,475.69

USAFA	5%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,664,351.47	$ 33,496,466.00	$ 49,704,433.42
5 Year	$ 14,664,351.47	$ 32,314,593.35	$ 48,522,560.77
10 Year	$ 25,410,422.16	$ 31,218,779.08	$ 47,426,746.50
15 Year	$ 25,410,422.16	$ 30,205,896.11	$ 46,413,863.53
20 Year	$ 25,410,422.16	$ 29,278,603.41	$ 45,486,570.83

USAFA	6%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,722,506.07	$ 39,079,210.33	$ 57,988,505.65
5 Year	$ 16,722,506.07	$ 37,700,358.91	$ 56,809,654.23
10 Year	$ 29,259,588.53	$ 36,421,908.92	$ 55,331,204.25
15 Year	$ 29,259,588.53	$ 35,240,212.13	$ 54,149,507.45
20 Year	$ 29,259,588.53	$ 34,158,370.65	$ 53,067,665.97

USAFA	7%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,780,660.66	$ 44,661,954.67	$ 66,272,577.89
5 Year	$ 18,780,660.66	$ 43,086,124.47	$ 64,696,747.69
10 Year	$ 33,108,754.91	$ 41,625,038.77	$ 63,235,661.99
15 Year	$ 33,108,754.91	$ 40,274,528.15	$ 61,885,151.37
20 Year	$ 33,108,754.91	$ 39,038,137.88	$ 60,648,761.11

USAFA	8%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,838,815.25	$ 50,244,699.00	$ 74,556,650.13
5 Year	$ 20,838,815.25	$ 48,471,890.03	$ 72,783,841.16
10 Year	$ 36,957,921.28	$ 46,828,168.62	$ 71,140,119.74
15 Year	$ 36,957,921.28	$ 45,308,844.17	$ 69,620,795.29
20 Year	$ 36,957,921.28	$ 43,917,905.12	$ 68,229,856.25

USAFA	9%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 22,896,969.83	$ 55,827,443.33	$ 82,840,722.36
5 Year	$ 22,896,969.83	$ 53,857,655.59	$ 80,870,934.62
10 Year	$ 40,807,087.66	$ 52,031,298.46	$ 79,044,577.49
15 Year	$ 40,807,087.66	$ 50,343,160.18	$ 77,356,439.22
20 Year	$ 40,807,087.66	$ 48,797,672.35	$ 75,810,951.38

USAFA	10%	1%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 24,955,124.44	$ 61,410,187.67	$ 91,124,794.60
5 Year	$ 24,955,124.44	$ 59,243,421.14	$ 88,958,028.08
10 Year	$ 44,656,254.03	$ 57,234,428.31	$ 86,949,035.24
15 Year	$ 44,656,254.03	$ 55,377,476.20	$ 85,092,083.14
20 Year	$ 44,656,254.03	$ 53,677,439.59	$ 83,392,046.52

USAFA	1%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,805,311.61	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 10,805,311.61	$ 16,157,296.68	$ 24,261,280.39
10 Year	$ 16,178,346.96	$ 15,609,389.54	$ 23,713,373.25
15 Year	$ 16,178,346.96	$ 15,102,948.06	$ 23,206,931.78
20 Year	$ 16,178,346.96	$ 14,639,301.71	$ 22,743,285.42

USAFA	2%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,863,466.21	$ 22,330,977.33	$ 33,136,288.95
5 Year	$ 12,863,466.21	$ 21,543,062.23	$ 32,348,373.85
10 Year	$ 20,027,513.33	$ 20,812,519.38	$ 31,617,831.00
15 Year	$ 20,027,513.33	$ 20,137,264.07	$ 30,942,575.69
20 Year	$ 20,027,513.33	$ 19,519,068.94	$ 30,324,380.55

USAFA	3%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,921,620.80	$ 27,913,721.67	$ 41,420,361.18
5 Year	$ 14,921,620.80	$ 26,928,827.79	$ 40,435,467.31
10 Year	$ 23,876,679.70	$ 26,015,649.23	$ 39,522,288.75
15 Year	$ 23,876,679.70	$ 25,171,580.09	$ 38,678,219.61
20 Year	$ 23,876,679.70	$ 24,398,836.18	$ 37,905,475.69

USAFA	4%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,979,775.39	$ 33,496,466.00	$ 49,704,433.42
5 Year	$ 16,979,775.39	$ 32,314,593.35	$ 48,522,560.77
10 Year	$ 27,725,846.08	$ 31,218,779.08	$ 47,426,746.50
15 Year	$ 27,725,846.08	$ 30,205,896.11	$ 46,413,863.53
20 Year	$ 27,725,846.08	$ 29,278,603.41	$ 45,486,570.83

USAFA	5%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 19,037,929.98	$ 39,079,210.33	$ 57,988,505.65
5 Year	$ 19,037,929.98	$ 37,700,358.91	$ 56,809,654.23
10 Year	$ 31,575,012.45	$ 36,421,908.92	$ 55,331,204.25
15 Year	$ 31,575,012.45	$ 35,240,212.13	$ 54,149,507.45
20 Year	$ 31,575,012.45	$ 34,158,370.65	$ 53,067,665.97

USAFA	6%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 21,096,084.38	$ 44,661,954.67	$ 66,272,577.89
5 Year	$ 21,096,084.38	$ 43,086,124.47	$ 64,696,747.69
10 Year	$ 35,424,178.82	$ 41,625,038.77	$ 63,235,661.99
15 Year	$ 35,424,178.82	$ 40,274,528.15	$ 61,885,151.37
20 Year	$ 35,424,178.82	$ 39,038,137.88	$ 60,648,761.11

USAFA	7%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 23,154,239.17	$ 50,244,699.00	$ 74,556,650.13
5 Year	$ 23,154,239.17	$ 48,471,890.03	$ 72,783,841.16
10 Year	$ 39,273,345.20	$ 46,828,168.62	$ 71,140,119.74
15 Year	$ 39,273,345.20	$ 45,308,844.17	$ 69,620,795.29
20 Year	$ 39,273,345.20	$ 43,917,905.12	$ 68,229,856.25

USAFA	8%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 25,212,393.76	$ 55,827,443.33	$ 82,840,722.36
5 Year	$ 25,212,393.76	$ 53,857,655.59	$ 80,870,934.62
10 Year	$ 43,122,511.57	$ 52,031,298.46	$ 79,044,577.49
15 Year	$ 43,122,511.57	$ 50,343,160.18	$ 77,356,439.22
20 Year	$ 43,122,511.57	$ 48,797,672.35	$ 75,810,951.38

USAFA	9%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 27,270,548.36	$ 61,410,187.67	$ 91,124,794.60
5 Year	$ 27,270,548.36	$ 59,243,421.14	$ 88,958,028.08
10 Year	$ 46,971,677.95	$ 57,234,428.31	$ 86,949,035.24
15 Year	$ 46,971,677.95	$ 55,377,476.20	$ 85,092,083.14
20 Year	$ 46,971,677.95	$ 53,677,439.59	$ 83,392,046.52

USAFA	10%	2%	High
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 29,328,702.95	$ 66,992,932.00	$ 99,408,866.84
5 Year	$ 29,328,702.95	$ 64,629,186.70	$ 97,045,121.54
10 Year	$ 50,820,844.32	$ 62,437,558.15	$ 94,853,492.99
15 Year	$ 50,820,844.32	$ 60,411,792.22	$ 92,827,727.06
20 Year	$ 50,820,844.32	$ 58,557,206.82	$ 90,973,141.66

Appendix C – Electric Cost Sensitivity Analysis Outputs

Key
Location, % Resurfaced, % Replacement, Traffic Load

MALMSTROM - $.1100/kWh

Malmstrom	% Resurfaced	Asphalt	% Replacement	PV Best Case	Traffic Load	PV Worst Case
	1%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	2%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	3%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	4%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	5%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]

Malmstrom	% Resurfaced	Asphalt	% Replacement	PV Best Case	Traffic Load	PV Worst Case
	6%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	7%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	8%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	9%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	10%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]

MALMSTROM - $.2800/kWh

Malmstrom	% Resurfaced	Asphalt	% Replacement	PV Best Case	Traffic Load	PV Worst Case
	1%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	2%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	3%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	4%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	5%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]

Malmstrom	% Resurfaced	Asphalt	% Replacement	PV Best Case	Traffic Load	PV Worst Case
	6%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	7%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	8%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	9%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	10%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]

OFFUTT - $.0950/kWh

Offutt	% Resurfaced	Asphalt	% Replacement	PV Best Case	Traffic Load	PV Worst Case
	1%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	2%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	3%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	4%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	5%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]

Offutt	% Resurfaced	Asphalt	% Replacement	PV Best Case	Traffic Load	PV Worst Case
	6%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	7%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	8%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	9%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	10%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]

OFFUTT - $.2425/kWh

Offutt	% Resurfaced	Asphalt	% Replacement	PV Best Case	Traffic Load	PV Worst Case
	1%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	2%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	3%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	4%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	5%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]

Offutt	% Resurfaced	Asphalt	% Replacement	PV Best Case	Traffic Load	PV Worst Case
	6%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	7%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	8%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	9%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]
	10%		0%		Low	
Initial		$ [illegible]		$ [illegible]		$ [illegible]
5 Year		$ [illegible]		$ [illegible]		$ [illegible]
10 Year		$ [illegible]		$ [illegible]		$ [illegible]
15 Year		$ [illegible]		$ [illegible]		$ [illegible]
20 Year		$ [illegible]		$ [illegible]		$ [illegible]

PETERSON - $.0875/kWh

Peterson	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,188,629.11	$ 3,224,156.47	$ 4,784,232.18
5 Year	$ 1,188,629.11	$ 2,941,397.36	$ 4,501,473.07
10 Year	$ 2,222,977.43	$ 2,679,227.42	$ 4,239,303.13
15 Year	$ 2,222,977.43	$ 2,436,898.53	$ 3,996,974.24
20 Year	$ 2,222,977.43	$ 2,213,046.82	$ 3,773,122.53

Peterson	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,377,258.23	$ 6,448,312.94	$ 9,568,464.36
5 Year	$ 2,377,258.23	$ 5,882,794.71	$ 9,002,946.13
10 Year	$ 4,445,954.87	$ 5,358,454.84	$ 8,478,606.27
15 Year	$ 4,445,954.87	$ 4,873,797.06	$ 7,993,948.48
20 Year	$ 4,445,954.87	$ 4,430,093.65	$ 7,550,245.07

Peterson	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,565,887.34	$ 9,672,469.41	$ 14,352,696.54
5 Year	$ 3,565,887.34	$ 8,824,192.07	$ 13,504,419.20
10 Year	$ 6,668,932.30	$ 8,037,682.27	$ 12,717,909.40
15 Year	$ 6,668,932.30	$ 7,310,695.59	$ 11,990,922.72
20 Year	$ 6,668,932.30	$ 6,645,140.47	$ 11,325,367.60

Peterson	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,754,516.45	$ 12,896,625.88	$ 19,136,928.72
5 Year	$ 4,754,516.45	$ 11,765,589.42	$ 18,005,892.26
10 Year	$ 8,891,909.73	$ 10,716,909.69	$ 16,957,212.53
15 Year	$ 8,891,909.73	$ 9,747,594.12	$ 15,987,896.96
20 Year	$ 8,891,909.73	$ 8,860,187.30	$ 15,100,490.14

Peterson	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,943,145.57	$ 16,120,782.35	$ 23,921,160.90
5 Year	$ 5,943,145.57	$ 14,706,986.78	$ 22,507,365.33
10 Year	$ 11,114,887.16	$ 13,396,137.11	$ 21,196,515.66
15 Year	$ 11,114,887.16	$ 12,184,492.65	$ 19,984,871.20
20 Year	$ 11,114,887.16	$ 11,075,234.12	$ 18,875,612.67

Peterson	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,131,774.68	$ 19,344,938.81	$ 28,705,393.08
5 Year	$ 7,131,774.68	$ 17,648,384.13	$ 27,008,838.40
10 Year	$ 13,337,864.60	$ 16,075,364.53	$ 25,435,818.80
15 Year	$ 13,337,864.60	$ 14,621,391.17	$ 23,981,845.44
20 Year	$ 13,337,864.60	$ 13,290,280.94	$ 22,650,735.21

Peterson	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,320,403.79	$ 22,569,095.28	$ 33,489,625.26
5 Year	$ 8,320,403.79	$ 20,589,781.49	$ 31,510,311.46
10 Year	$ 15,560,842.03	$ 18,754,591.95	$ 29,675,121.93
15 Year	$ 15,560,842.03	$ 17,058,289.70	$ 27,978,819.68
20 Year	$ 15,560,842.03	$ 15,505,327.77	$ 26,425,857.74

Peterson	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,509,032.90	$ 25,793,251.75	$ 38,273,857.44
5 Year	$ 9,509,032.90	$ 23,531,178.84	$ 36,011,784.53
10 Year	$ 17,783,819.46	$ 21,433,819.37	$ 33,914,425.06
15 Year	$ 17,783,819.46	$ 19,495,188.23	$ 31,975,793.92
20 Year	$ 17,783,819.46	$ 17,720,374.59	$ 30,200,980.28

Peterson	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,697,662.02	$ 29,017,408.22	$ 43,058,089.62
5 Year	$ 10,697,662.02	$ 26,472,576.20	$ 40,513,257.59
10 Year	$ 20,006,796.89	$ 24,113,046.80	$ 38,153,728.19
15 Year	$ 20,006,796.89	$ 21,932,086.76	$ 35,972,768.16
20 Year	$ 20,006,796.89	$ 19,935,421.42	$ 33,976,102.81

Peterson	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,886,291.13	$ 32,241,564.69	$ 47,842,321.80
5 Year	$ 11,886,291.13	$ 29,413,973.55	$ 45,014,730.66
10 Year	$ 22,229,774.33	$ 26,792,274.22	$ 42,393,031.33
15 Year	$ 22,229,774.33	$ 24,368,985.29	$ 39,969,742.40
20 Year	$ 22,229,774.33	$ 22,150,468.24	$ 37,751,225.35

PETERSON - $.2225/kWh

Peterson	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,188,629.11	$ 3,224,156.47	$ 4,784,232.18
5 Year	$ 1,188,629.11	$ 2,505,140.44	$ 4,065,216.15
10 Year	$ 2,222,977.43	$ 1,838,479.75	$ 3,398,555.46
15 Year	$ 2,222,977.43	$ 1,222,271.99	$ 2,782,347.70
20 Year	$ 2,222,977.43	$ 658,134.80	$ 2,218,210.51

Peterson	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,377,258.23	$ 6,448,312.94	$ 9,568,464.36
5 Year	$ 2,377,258.23	$ 5,010,280.87	$ 8,130,432.29
10 Year	$ 4,445,954.87	$ 3,676,959.50	$ 6,797,110.92
15 Year	$ 4,445,954.87	$ 2,444,543.99	$ 5,564,695.41
20 Year	$ 4,445,954.87	$ 1,316,269.60	$ 4,436,421.02

Peterson	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,565,887.34	$ 9,672,469.41	$ 14,352,696.54
5 Year	$ 3,565,887.34	$ 7,515,421.31	$ 12,195,648.44
10 Year	$ 6,668,932.30	$ 5,515,439.25	$ 10,195,666.38
15 Year	$ 6,668,932.30	$ 3,666,815.98	$ 8,347,043.11
20 Year	$ 6,668,932.30	$ 1,974,404.40	$ 6,654,631.53

Peterson	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,754,516.45	$ 12,896,625.88	$ 19,136,928.72
5 Year	$ 4,754,516.45	$ 10,020,561.75	$ 16,260,864.59
10 Year	$ 8,891,909.73	$ 7,353,919.00	$ 13,594,221.84
15 Year	$ 8,891,909.73	$ 4,889,087.97	$ 11,129,390.82
20 Year	$ 8,891,909.73	$ 2,632,539.20	$ 8,872,842.04

Peterson	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,943,145.57	$ 16,120,782.35	$ 23,921,160.90
5 Year	$ 5,943,145.57	$ 12,525,702.18	$ 20,326,080.74
10 Year	$ 11,114,887.16	$ 9,192,398.74	$ 16,992,777.30
15 Year	$ 11,114,887.16	$ 6,111,359.97	$ 13,911,738.52
20 Year	$ 11,114,887.16	$ 3,290,674.00	$ 11,091,052.56

Peterson	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,131,774.68	$ 19,344,938.81	$ 28,705,393.08
5 Year	$ 7,131,774.68	$ 15,030,842.62	$ 24,391,296.88
10 Year	$ 13,337,864.60	$ 11,030,878.49	$ 20,391,332.76
15 Year	$ 13,337,864.60	$ 7,333,631.96	$ 16,694,086.22
20 Year	$ 13,337,864.60	$ 3,948,808.80	$ 13,309,263.07

Peterson	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,320,403.79	$ 22,569,095.28	$ 33,489,625.26
5 Year	$ 8,320,403.79	$ 17,535,983.05	$ 28,456,513.03
10 Year	$ 15,560,842.03	$ 12,869,358.24	$ 23,789,888.22
15 Year	$ 15,560,842.03	$ 8,555,903.95	$ 19,476,433.93
20 Year	$ 15,560,842.03	$ 4,606,943.60	$ 15,527,473.58

Peterson	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,509,032.90	$ 25,793,251.75	$ 38,273,857.44
5 Year	$ 9,509,032.90	$ 20,041,123.49	$ 32,521,729.18
10 Year	$ 17,783,819.46	$ 14,707,837.99	$ 27,188,443.68
15 Year	$ 17,783,819.46	$ 9,778,175.94	$ 22,258,781.63
20 Year	$ 17,783,819.46	$ 5,265,078.40	$ 17,745,684.09

Peterson	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,697,662.02	$ 29,017,408.22	$ 43,058,089.62
5 Year	$ 10,697,662.02	$ 22,546,263.93	$ 36,586,945.32
10 Year	$ 20,006,796.89	$ 16,546,317.74	$ 30,586,999.14
15 Year	$ 20,006,796.89	$ 11,000,447.94	$ 25,041,129.34
20 Year	$ 20,006,796.89	$ 5,923,213.20	$ 19,963,894.60

Peterson	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,886,291.13	$ 32,241,564.69	$ 47,842,321.80
5 Year	$ 11,886,291.13	$ 25,051,404.36	$ 40,652,161.47
10 Year	$ 22,229,774.33	$ 18,384,797.49	$ 33,985,554.60
15 Year	$ 22,229,774.33	$ 12,222,719.93	$ 27,823,477.04
20 Year	$ 22,229,774.33	$ 6,581,348.00	$ 22,182,105.11

TRAVIS - $.2050/kWh

Travis	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,416,654.32	$ 3,842,674.85	$ 5,702,033.65
5 Year	$ 1,515,820.13	$ 3,188,767.67	$ 5,179,281.59
10 Year	$ 2,834,890.97	$ 2,335,001.24	$ 4,324,515.16
15 Year	$ 2,834,890.97	$ 1,544,923.60	$ 3,534,437.51
20 Year	$ 2,834,890.97	$ 821,608.81	$ 2,811,122.72

Travis	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,833,308.65	$ 7,685,349.71	$ 11,404,067.31
5 Year	$ 3,031,640.25	$ 6,379,535.34	$ 10,358,583.18
10 Year	$ 5,669,781.93	$ 4,670,002.48	$ 8,649,030.31
15 Year	$ 5,669,781.93	$ 3,089,847.19	$ 7,068,875.03
20 Year	$ 5,669,781.93	$ 1,643,217.61	$ 5,622,245.45

Travis	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,249,962.97	$ 11,528,024.56	$ 17,106,100.96
5 Year	$ 4,547,460.38	$ 9,569,303.02	$ 15,537,844.76
10 Year	$ 8,504,672.90	$ 7,005,003.72	$ 12,973,545.47
15 Year	$ 8,504,672.90	$ 4,634,770.79	$ 10,603,312.54
20 Year	$ 8,504,672.90	$ 2,464,826.42	$ 8,433,368.17

Travis	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,666,617.30	$ 15,370,699.41	$ 22,808,134.62
5 Year	$ 6,063,280.51	$ 12,759,070.69	$ 20,717,126.35
10 Year	$ 11,339,563.86	$ 9,340,004.96	$ 17,298,060.63
15 Year	$ 11,339,563.86	$ 6,179,694.39	$ 14,137,750.05
20 Year	$ 11,339,563.86	$ 3,286,435.23	$ 11,244,490.89

Travis	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,083,271.62	$ 19,213,374.27	$ 28,510,168.27
5 Year	$ 7,579,100.63	$ 15,948,838.36	$ 25,896,407.94
10 Year	$ 14,174,454.83	$ 11,675,006.20	$ 21,622,575.78
15 Year	$ 14,174,454.83	$ 7,724,617.99	$ 17,672,187.57
20 Year	$ 14,174,454.83	$ 4,108,044.03	$ 14,055,613.61

Travis	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,499,925.94	$ 23,056,049.12	$ 34,212,201.92
5 Year	$ 9,094,920.76	$ 19,138,606.03	$ 31,075,689.53
10 Year	$ 17,009,345.79	$ 14,010,007.44	$ 25,947,090.94
15 Year	$ 17,009,345.79	$ 9,269,541.58	$ 21,206,625.08
20 Year	$ 17,009,345.79	$ 4,929,652.84	$ 16,866,736.34

Travis	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,916,580.27	$ 26,898,723.98	$ 39,914,235.58
5 Year	$ 10,610,740.89	$ 22,328,373.70	$ 36,254,971.12
10 Year	$ 19,844,236.76	$ 16,345,008.68	$ 30,271,606.09
15 Year	$ 19,844,236.76	$ 10,814,463.18	$ 24,741,062.59
20 Year	$ 19,844,236.76	$ 5,751,261.65	$ 19,677,859.06

Travis	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,333,234.59	$ 30,741,398.83	$ 45,616,269.23
5 Year	$ 12,126,561.01	$ 25,518,141.38	$ 41,434,252.71
10 Year	$ 22,679,127.72	$ 18,680,009.92	$ 34,596,121.25
15 Year	$ 22,679,127.72	$ 12,359,388.78	$ 28,275,500.11
20 Year	$ 22,679,127.72	$ 6,572,870.41	$ 22,488,981.78

Travis	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,749,888.92	$ 34,584,073.68	$ 51,318,302.89
5 Year	$ 13,642,381.14	$ 28,707,909.05	$ 46,613,534.29
10 Year	$ 25,514,018.69	$ 21,015,011.16	$ 38,920,636.41
15 Year	$ 25,514,018.69	$ 13,904,312.38	$ 31,809,937.62
20 Year	$ 25,514,018.69	$ 7,394,479.26	$ 25,300,104.51

Travis	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,166,543.24	$ 38,426,748.54	$ 57,020,336.54
5 Year	$ 15,158,201.27	$ 31,897,676.72	$ 51,792,815.88
10 Year	$ 28,348,909.65	$ 23,350,012.40	$ 43,245,151.56
15 Year	$ 28,348,909.65	$ 15,449,235.97	$ 35,344,375.13
20 Year	$ 28,348,909.65	$ 8,216,088.07	$ 28,111,227.23

USAFA - $.1075/kWh

USAFA	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,058,154.59	$ 5,582,744.33	$ 8,284,072.24
5 Year	$ 2,058,154.59	$ 5,086,837.58	$ 7,788,165.49
10 Year	$ 3,849,166.37	$ 4,627,040.41	$ 7,328,368.32
15 Year	$ 3,849,166.37	$ 4,202,040.73	$ 6,903,368.63
20 Year	$ 3,849,166.37	$ 3,812,954.22	$ 6,514,282.12

USAFA	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,116,309.19	$ 11,165,488.67	$ 16,568,144.47
5 Year	$ 4,116,309.19	$ 10,173,675.16	$ 15,576,330.97
10 Year	$ 7,698,332.75	$ 9,254,080.83	$ 14,656,736.63
15 Year	$ 7,698,332.75	$ 8,404,081.46	$ 13,806,737.27
20 Year	$ 7,698,332.75	$ 7,625,908.43	$ 13,028,564.24

USAFA	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,174,463.78	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 6,174,463.78	$ 15,260,512.75	$ 23,364,496.46
10 Year	$ 11,547,499.12	$ 13,881,121.24	$ 21,985,104.95
15 Year	$ 11,547,499.12	$ 12,606,122.19	$ 20,710,105.90
20 Year	$ 11,547,499.12	$ 11,438,862.65	$ 19,542,846.36

USAFA	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,232,618.37	$ 22,330,977.33	$ 33,136,288.95
5 Year	$ 8,232,618.37	$ 20,347,350.33	$ 31,152,661.94
10 Year	$ 15,396,665.50	$ 18,508,161.66	$ 29,313,473.27
15 Year	$ 15,396,665.50	$ 16,808,162.92	$ 27,613,474.54
20 Year	$ 15,396,665.50	$ 15,251,816.86	$ 26,057,128.47

USAFA	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,290,772.96	$ 27,913,721.67	$ 41,420,361.18
5 Year	$ 10,290,772.96	$ 25,434,187.91	$ 38,940,827.43
10 Year	$ 19,245,831.87	$ 23,135,202.07	$ 36,641,841.59
15 Year	$ 19,245,831.87	$ 21,010,203.65	$ 34,516,843.17
20 Year	$ 19,245,831.87	$ 19,064,771.08	$ 32,571,410.59

USAFA	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,348,927.56	$ 33,496,466.00	$ 49,704,433.42
5 Year	$ 12,348,927.56	$ 30,521,025.49	$ 46,728,992.91
10 Year	$ 23,094,998.24	$ 27,762,242.48	$ 43,970,209.90
15 Year	$ 23,094,998.24	$ 25,212,244.38	$ 41,420,211.80
20 Year	$ 23,094,998.24	$ 22,877,725.29	$ 39,085,692.71

USAFA	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,407,082.15	$ 39,079,210.33	$ 57,988,505.65
5 Year	$ 14,407,082.15	$ 35,607,863.07	$ 54,517,158.40
10 Year	$ 26,944,164.62	$ 32,389,282.90	$ 51,298,578.22
15 Year	$ 26,944,164.62	$ 29,414,285.11	$ 48,323,580.44
20 Year	$ 26,944,164.62	$ 26,690,679.51	$ 45,599,974.83

USAFA	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,465,236.74	$ 44,661,954.67	$ 66,272,577.89
5 Year	$ 16,465,236.74	$ 40,694,700.66	$ 62,305,323.88
10 Year	$ 30,793,330.99	$ 37,016,323.31	$ 58,626,946.54
15 Year	$ 30,793,330.99	$ 33,616,325.84	$ 55,226,949.07
20 Year	$ 30,793,330.99	$ 30,503,633.72	$ 52,114,256.95

USAFA	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,523,391.34	$ 50,244,699.00	$ 74,556,650.13
5 Year	$ 18,523,391.34	$ 45,781,538.24	$ 70,093,489.37
10 Year	$ 34,642,497.36	$ 41,643,363.72	$ 65,955,314.85
15 Year	$ 34,642,497.36	$ 37,818,366.58	$ 62,130,317.70
20 Year	$ 34,642,497.36	$ 34,316,587.94	$ 58,628,539.07

USAFA	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,581,545.93	$ 55,827,443.33	$ 82,840,722.36
5 Year	$ 20,581,545.93	$ 50,868,375.82	$ 77,881,654.85
10 Year	$ 38,491,663.74	$ 46,270,404.14	$ 73,283,683.17
15 Year	$ 38,491,663.74	$ 42,020,407.31	$ 69,033,686.34
20 Year	$ 38,491,663.74	$ 38,129,542.15	$ 65,142,821.19

USAFA - $.2700/kWh

USAFA	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,058,154.59	$ 5,582,744.33	$ 8,284,072.24
5 Year	$ 2,058,154.59	$ 4,337,211.10	$ 7,038,539.00
10 Year	$ 3,849,166.37	$ 3,182,371.70	$ 5,883,699.60
15 Year	$ 3,849,166.37	$ 2,114,930.63	$ 4,816,258.54
20 Year	$ 3,849,166.37	$ 1,137,690.08	$ 3,839,017.99

USAFA	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,116,309.19	$ 11,165,488.67	$ 16,568,144.47
5 Year	$ 4,116,309.19	$ 8,674,422.20	$ 14,077,078.00
10 Year	$ 7,698,332.75	$ 6,364,743.40	$ 11,767,399.20
15 Year	$ 7,698,332.75	$ 4,229,861.27	$ 9,632,517.07
20 Year	$ 7,698,332.75	$ 2,275,380.17	$ 7,678,035.97

USAFA	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,174,463.78	$ 16,748,233.00	$ 24,852,216.71
5 Year	$ 6,174,463.78	$ 13,011,633.29	$ 21,115,617.00
10 Year	$ 11,547,499.12	$ 9,547,115.10	$ 17,651,098.81
15 Year	$ 11,547,499.12	$ 6,344,791.90	$ 14,448,775.61
20 Year	$ 11,547,499.12	$ 3,413,070.25	$ 11,517,053.96

USAFA	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,232,618.37	$ 22,330,977.33	$ 33,136,288.95
5 Year	$ 8,232,618.37	$ 17,348,844.39	$ 28,154,156.00
10 Year	$ 15,396,665.50	$ 12,729,486.79	$ 23,534,798.41
15 Year	$ 15,396,665.50	$ 8,459,722.53	$ 19,265,034.15
20 Year	$ 15,396,665.50	$ 4,550,760.34	$ 15,356,071.95

USAFA	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,290,772.96	$ 27,913,721.67	$ 41,420,361.18
5 Year	$ 10,290,772.96	$ 21,686,055.49	$ 35,192,695.00
10 Year	$ 19,245,831.87	$ 15,911,858.49	$ 29,418,498.01
15 Year	$ 19,245,831.87	$ 10,574,653.17	$ 24,081,292.68
20 Year	$ 19,245,831.87	$ 5,688,450.42	$ 19,195,089.93

USAFA	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,348,927.56	$ 33,496,466.00	$ 49,704,433.42
5 Year	$ 12,348,927.56	$ 26,023,266.59	$ 42,231,234.00
10 Year	$ 23,094,998.24	$ 19,094,230.19	$ 35,302,197.61
15 Year	$ 23,094,998.24	$ 12,689,583.80	$ 28,897,551.22
20 Year	$ 23,094,998.24	$ 6,826,140.50	$ 23,034,107.92

USAFA	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,407,082.15	$ 39,079,210.33	$ 57,988,505.65
5 Year	$ 14,407,082.15	$ 30,360,477.68	$ 49,269,773.01
10 Year	$ 26,944,164.62	$ 22,276,601.89	$ 41,185,897.21
15 Year	$ 26,944,164.62	$ 14,804,514.44	$ 33,713,809.76
20 Year	$ 26,944,164.62	$ 7,963,830.59	$ 26,873,125.91

USAFA	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,465,236.74	$ 44,661,954.67	$ 66,272,577.89
5 Year	$ 16,465,236.74	$ 34,697,688.78	$ 56,308,312.01
10 Year	$ 30,793,330.99	$ 25,458,973.59	$ 47,069,596.81
15 Year	$ 30,793,330.99	$ 16,919,445.07	$ 38,530,068.29
20 Year	$ 30,793,330.99	$ 9,101,520.67	$ 30,712,143.90

USAFA	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,523,391.34	$ 50,244,699.00	$ 74,556,650.13
5 Year	$ 18,523,391.34	$ 39,034,899.88	$ 63,346,851.01
10 Year	$ 34,642,497.36	$ 28,641,345.29	$ 52,953,296.42
15 Year	$ 34,642,497.36	$ 19,034,375.70	$ 43,346,326.83
20 Year	$ 34,642,497.36	$ 10,239,210.75	$ 34,551,161.88

USAFA	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,581,545.93	$ 55,827,443.33	$ 82,840,722.36
5 Year	$ 20,581,545.93	$ 43,372,110.98	$ 70,385,390.01
10 Year	$ 38,491,663.74	$ 31,823,716.99	$ 58,836,996.02
15 Year	$ 38,491,663.74	$ 21,149,306.34	$ 48,162,585.37
20 Year	$ 38,491,663.74	$ 11,376,900.84	$ 38,390,179.87

Appendix D – PV Cost Sensitivity Analysis Outputs

Key
Location, % Resurfaced, % Replacement, Traffic Load

MALMSTROM - $292

Malmstrom	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,527,314.35	$ 9,012,288.16	$ 14,197,440.25
5 Year	$ 3,315,675.49	$ 7,830,355.05	$ 12,704,398.02
10 Year	$ 6,200,985.40	$ 7,235,848.08	$ 12,109,891.04
15 Year	$ 6,200,985.40	$ 6,686,333.44	$ 11,560,376.40
20 Year	$ 6,200,985.40	$ 6,183,253.68	$ 11,057,296.65

Malmstrom	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,054,628.70	$ 18,024,576.32	$ 28,394,880.50
5 Year	$ 6,631,350.97	$ 15,660,710.10	$ 25,408,796.03
10 Year	$ 12,401,970.81	$ 14,471,696.16	$ 24,219,782.09
15 Year	$ 12,401,970.81	$ 13,372,666.88	$ 23,120,752.81
20 Year	$ 12,401,970.81	$ 12,366,507.37	$ 22,114,593.30

Malmstrom	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,581,943.04	$ 27,036,864.48	$ 42,592,320.75
5 Year	$ 9,947,026.46	$ 23,491,065.15	$ 38,113,194.05
10 Year	$ 18,602,956.21	$ 21,707,544.23	$ 36,329,673.13
15 Year	$ 18,602,956.21	$ 20,059,000.32	$ 34,681,129.21
20 Year	$ 18,602,956.21	$ 18,549,761.05	$ 33,171,889.95

Malmstrom	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,109,257.39	$ 36,049,152.64	$ 56,789,761.00
5 Year	$ 13,262,701.95	$ 31,321,420.20	$ 50,817,592.07
10 Year	$ 24,803,941.62	$ 28,943,392.31	$ 48,439,564.18
15 Year	$ 24,803,941.62	$ 26,745,333.75	$ 46,241,505.62
20 Year	$ 24,803,941.62	$ 24,733,014.74	$ 44,229,186.60

Malmstrom	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 17,636,571.74	$ 45,061,440.79	$ 70,987,201.25
5 Year	$ 16,578,377.44	$ 39,151,775.26	$ 63,521,990.09
10 Year	$ 31,004,927.02	$ 36,179,240.39	$ 60,549,455.22
15 Year	$ 31,004,927.02	$ 33,431,667.19	$ 57,801,882.02
20 Year	$ 31,004,927.02	$ 30,916,268.42	$ 55,286,483.25

Malmstrom	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 21,163,886.09	$ 54,073,728.95	$ 85,184,641.50
5 Year	$ 19,894,052.92	$ 46,982,130.31	$ 76,226,388.10
10 Year	$ 37,205,912.43	$ 43,415,088.47	$ 72,659,346.27
15 Year	$ 37,205,912.43	$ 40,118,000.63	$ 69,362,258.43
20 Year	$ 37,205,912.43	$ 37,099,522.11	$ 66,343,779.90

Malmstrom	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 24,691,200.44	$ 63,086,017.11	$ 99,382,081.75
5 Year	$ 23,209,728.41	$ 54,812,485.36	$ 88,930,786.12
10 Year	$ 43,406,897.83	$ 50,650,936.55	$ 84,769,237.31
15 Year	$ 43,406,897.83	$ 46,804,334.07	$ 80,922,634.83
20 Year	$ 43,406,897.83	$ 43,282,775.79	$ 77,401,076.55

Malmstrom	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 28,218,514.78	$ 72,098,305.27	$113,579,522.00
5 Year	$ 26,525,403.90	$ 62,642,840.41	$101,635,184.14
10 Year	$ 49,607,883.24	$ 57,886,784.63	$ 96,879,128.35
15 Year	$ 49,607,883.24	$ 53,490,667.51	$ 92,483,011.24
20 Year	$ 49,607,883.24	$ 49,466,029.47	$ 88,458,373.20

Malmstrom	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 31,745,829.13	$ 81,110,593.43	$127,776,962.25
5 Year	$ 29,841,079.38	$ 70,473,195.46	$114,339,582.15
10 Year	$ 55,808,868.64	$ 65,122,632.70	$108,989,019.40
15 Year	$ 55,808,868.64	$ 60,177,000.95	$104,043,387.64
20 Year	$ 55,808,868.64	$ 55,649,283.16	$ 99,515,669.85

Malmstrom	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 35,273,143.48	$ 90,122,881.59	$141,974,402.50
5 Year	$ 33,156,754.87	$ 78,303,550.51	$127,043,980.17
10 Year	$ 62,009,854.05	$ 72,358,480.78	$121,098,910.44
15 Year	$ 62,009,854.05	$ 66,863,334.39	$115,603,764.05
20 Year	$ 62,009,854.05	$ 61,832,536.84	$110,572,966.50

OFFUTT - $291

Offutt	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 689,305.44	$ 1,755,143.98	$ 2,774,454.40
5 Year	$ 689,305.44	$ 1,623,480.56	$ 2,642,790.98
10 Year	$ 1,289,140.93	$ 1,501,404.26	$ 2,520,714.68
15 Year	$ 1,289,140.93	$ 1,388,566.70	$ 2,407,877.12
20 Year	$ 1,289,140.93	$ 1,285,264.09	$ 2,304,574.51

Offutt	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,378,610.88	$ 3,510,287.95	$ 5,548,908.79
5 Year	$ 1,378,610.88	$ 3,246,961.13	$ 5,285,581.97
10 Year	$ 2,578,281.85	$ 3,002,808.52	$ 5,041,429.35
15 Year	$ 2,578,281.85	$ 2,777,133.39	$ 4,815,754.23
20 Year	$ 2,578,281.85	$ 2,570,528.18	$ 4,609,149.02

Offutt	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,067,916.32	$ 5,265,431.93	$ 8,323,363.19
5 Year	$ 2,067,916.32	$ 4,870,441.69	$ 7,928,372.95
10 Year	$ 3,867,422.78	$ 4,504,212.77	$ 7,562,144.03
15 Year	$ 3,867,422.78	$ 4,165,700.09	$ 7,223,631.35
20 Year	$ 3,867,422.78	$ 3,855,792.28	$ 6,913,723.54

Offutt	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,757,221.76	$ 7,020,575.91	$ 11,097,817.58
5 Year	$ 2,757,221.76	$ 6,493,922.25	$ 10,571,163.93
10 Year	$ 5,156,563.71	$ 6,005,617.03	$ 10,082,858.71
15 Year	$ 5,156,563.71	$ 5,554,266.78	$ 9,631,508.46
20 Year	$ 5,156,563.71	$ 5,141,056.37	$ 9,218,298.05

Offutt	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,446,527.20	$ 8,775,719.88	$ 13,872,271.98
5 Year	$ 3,446,527.20	$ 8,117,402.82	$ 13,213,954.92
10 Year	$ 6,445,704.64	$ 7,507,021.29	$ 12,603,573.39
15 Year	$ 6,445,704.64	$ 6,942,833.48	$ 12,039,385.58
20 Year	$ 6,445,704.64	$ 6,426,320.46	$ 11,522,872.56

Offutt	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,135,832.64	$ 10,530,863.86	$ 16,646,726.37
5 Year	$ 4,135,832.64	$ 9,740,883.38	$ 15,856,745.90
10 Year	$ 7,734,845.56	$ 9,008,425.55	$ 15,124,288.06
15 Year	$ 7,734,845.56	$ 8,331,400.17	$ 14,447,262.69
20 Year	$ 7,734,845.56	$ 7,711,584.55	$ 13,827,447.07

Offutt	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,825,138.08	$ 12,286,007.84	$ 19,421,180.77
5 Year	$ 4,825,138.08	$ 11,364,363.95	$ 18,499,536.88
10 Year	$ 9,023,986.49	$ 10,509,829.80	$ 17,645,002.74
15 Year	$ 9,023,986.49	$ 9,719,966.87	$ 16,855,139.81
20 Year	$ 9,023,986.49	$ 8,996,848.65	$ 16,132,021.58

Offutt	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,514,443.52	$ 14,041,151.81	$ 22,195,635.17
5 Year	$ 5,514,443.52	$ 12,987,844.51	$ 21,142,327.86
10 Year	$ 10,313,127.42	$ 12,011,234.06	$ 20,165,717.42
15 Year	$ 10,313,127.42	$ 11,108,533.17	$ 19,263,016.52
20 Year	$ 10,313,127.42	$ 10,282,112.74	$ 18,436,596.09

Offutt	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,203,748.96	$ 15,796,295.79	$ 24,970,089.56
5 Year	$ 6,203,748.96	$ 14,611,325.07	$ 23,785,118.85
10 Year	$ 11,602,268.35	$ 13,512,638.32	$ 22,686,432.09
15 Year	$ 11,602,268.35	$ 12,497,100.20	$ 21,670,894.04
20 Year	$ 11,602,268.35	$ 11,567,376.83	$ 20,741,170.61

Offutt	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,893,054.40	$ 17,551,439.76	$ 27,744,543.96
5 Year	$ 6,893,054.40	$ 16,234,805.64	$ 26,427,909.83
10 Year	$ 12,891,409.27	$ 15,014,042.58	$ 25,207,146.77
15 Year	$ 12,891,409.27	$ 13,885,666.96	$ 24,078,771.15
20 Year	$ 12,891,409.27	$ 12,852,640.92	$ 23,045,745.11

PETERSON - $295

Peterson	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 1,188,629.11	$ 3,068,148.90	$ 4,784,232.18
5 Year	$ 1,188,629.11	$ 2,830,631.24	$ 4,546,714.52
10 Year	$ 2,222,977.43	$ 2,610,408.50	$ 4,326,491.78
15 Year	$ 2,222,977.43	$ 2,406,852.23	$ 4,122,935.51
20 Year	$ 2,222,977.43	$ 2,220,496.80	$ 3,936,580.08

Peterson	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,377,258.23	$ 6,136,297.80	$ 9,568,464.36
5 Year	$ 2,377,258.23	$ 5,661,262.48	$ 9,093,429.05
10 Year	$ 4,445,954.87	$ 5,220,817.00	$ 8,652,983.56
15 Year	$ 4,445,954.87	$ 4,813,704.46	$ 8,245,871.02
20 Year	$ 4,445,954.87	$ 4,440,993.59	$ 7,873,160.16

Peterson	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 3,565,887.34	$ 9,204,446.69	$ 14,352,696.54
5 Year	$ 3,565,887.34	$ 8,491,893.73	$ 13,640,143.57
10 Year	$ 6,668,932.30	$ 7,831,225.49	$ 12,979,475.34
15 Year	$ 6,668,932.30	$ 7,220,556.69	$ 12,368,806.53
20 Year	$ 6,668,932.30	$ 6,661,490.39	$ 11,809,740.23

Peterson	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,754,516.45	$ 12,272,595.59	$ 19,136,928.72
5 Year	$ 4,754,516.45	$ 11,322,524.97	$ 18,186,858.10
10 Year	$ 8,891,909.73	$ 10,441,633.99	$ 17,305,967.12
15 Year	$ 8,891,909.73	$ 9,627,408.91	$ 16,491,742.04
20 Year	$ 8,891,909.73	$ 8,881,987.18	$ 15,746,320.31

Peterson	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 5,943,145.57	$ 15,340,744.49	$ 23,921,160.90
5 Year	$ 5,943,145.57	$ 14,153,156.21	$ 22,733,572.62
10 Year	$ 11,114,887.16	$ 13,052,042.49	$ 21,632,458.90
15 Year	$ 11,114,887.16	$ 12,034,261.14	$ 20,614,677.55
20 Year	$ 11,114,887.16	$ 11,102,483.98	$ 19,682,900.39

Peterson	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 7,131,774.68	$ 18,408,893.39	$ 28,705,393.08
5 Year	$ 7,131,774.68	$ 16,983,787.45	$ 27,280,287.15
10 Year	$ 13,337,864.60	$ 15,662,450.99	$ 25,958,950.68
15 Year	$ 13,337,864.60	$ 14,441,113.37	$ 24,737,613.06
20 Year	$ 13,337,864.60	$ 13,322,980.78	$ 23,619,480.47

Peterson	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,320,403.79	$ 21,477,042.29	$ 33,489,625.26
5 Year	$ 8,320,403.79	$ 19,814,418.70	$ 31,827,001.67
10 Year	$ 15,560,842.03	$ 18,272,859.49	$ 30,285,442.46
15 Year	$ 15,560,842.03	$ 16,847,965.60	$ 28,860,548.57
20 Year	$ 15,560,842.03	$ 15,543,477.57	$ 27,556,060.55

Peterson	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 9,509,032.90	$ 24,545,191.18	$ 38,273,857.44
5 Year	$ 9,509,032.90	$ 22,645,049.94	$ 36,373,716.19
10 Year	$ 17,783,819.46	$ 20,883,267.99	$ 34,611,934.24
15 Year	$ 17,783,819.46	$ 19,254,817.83	$ 32,983,484.08
20 Year	$ 17,783,819.46	$ 17,763,974.37	$ 31,492,640.62

Peterson	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,697,662.02	$ 27,613,340.08	$ 43,058,089.62
5 Year	$ 10,697,662.02	$ 25,475,681.18	$ 40,920,430.72
10 Year	$ 20,006,796.89	$ 23,493,676.48	$ 38,938,426.02
15 Year	$ 20,006,796.89	$ 21,661,670.06	$ 37,106,419.59
20 Year	$ 20,006,796.89	$ 19,984,471.17	$ 35,429,220.70

Peterson	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 11,886,291.13	$ 30,681,488.98	$ 47,842,321.80
5 Year	$ 11,886,291.13	$ 28,306,312.42	$ 45,467,145.24
10 Year	$ 22,229,774.33	$ 26,104,084.98	$ 43,264,917.80
15 Year	$ 22,229,774.33	$ 24,068,522.28	$ 41,229,355.10
20 Year	$ 22,229,774.33	$ 22,204,967.96	$ 39,365,800.78

USAFA - $252

USAFA	1%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 2,058,154.59	$ 4,538,230.88	$ 8,284,072.24
5 Year	$ 2,058,154.59	$ 4,341,252.10	$ 8,087,093.46
10 Year	$ 3,849,166.37	$ 4,158,616.39	$ 7,904,457.75
15 Year	$ 3,849,166.37	$ 3,989,802.56	$ 7,735,643.92
20 Year	$ 3,849,166.37	$ 3,835,253.78	$ 7,581,095.14

USAFA	2%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 4,116,309.19	$ 9,076,461.75	$ 16,568,144.47
5 Year	$ 4,116,309.19	$ 8,682,504.21	$ 16,174,186.92
10 Year	$ 7,698,332.75	$ 8,317,232.78	$ 15,808,915.50
15 Year	$ 7,698,332.75	$ 7,979,605.13	$ 15,471,287.84
20 Year	$ 7,698,332.75	$ 7,670,507.56	$ 15,162,190.28

USAFA	3%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 6,174,463.78	$ 13,614,692.63	$ 24,852,216.71
5 Year	$ 6,174,463.78	$ 13,023,756.31	$ 24,261,280.39
10 Year	$ 11,547,499.12	$ 12,475,849.17	$ 23,713,373.25
15 Year	$ 11,547,499.12	$ 11,969,407.69	$ 23,206,931.76
20 Year	$ 11,547,499.12	$ 11,505,761.34	$ 22,743,285.42

USAFA	4%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 8,232,618.37	$ 18,152,923.51	$ 33,136,288.95
5 Year	$ 8,232,618.37	$ 17,365,008.41	$ 32,348,373.85
10 Year	$ 15,396,665.50	$ 16,634,465.56	$ 31,617,831.00
15 Year	$ 15,396,665.50	$ 15,959,210.25	$ 30,942,575.69
20 Year	$ 15,396,665.50	$ 15,341,015.12	$ 30,324,380.55

USAFA	5%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 10,290,772.96	$ 22,691,154.39	$ 41,420,361.18
5 Year	$ 10,290,772.96	$ 21,706,260.51	$ 40,435,467.31
10 Year	$ 19,245,831.87	$ 20,793,081.95	$ 39,522,288.75
15 Year	$ 19,245,831.87	$ 19,949,012.81	$ 38,678,219.61
20 Year	$ 19,245,831.87	$ 19,176,268.90	$ 37,905,475.69

USAFA	6%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 12,348,927.56	$ 27,229,385.26	$ 49,704,433.42
5 Year	$ 12,348,927.56	$ 26,047,512.62	$ 48,522,560.77
10 Year	$ 23,094,998.24	$ 24,951,698.34	$ 47,426,746.50
15 Year	$ 23,094,998.24	$ 23,938,813.38	$ 46,413,863.53
20 Year	$ 23,094,998.24	$ 23,011,522.68	$ 45,486,570.83

USAFA	7%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 14,407,082.15	$ 31,767,616.14	$ 57,988,505.65
5 Year	$ 14,407,082.15	$ 30,388,764.72	$ 56,609,654.23
10 Year	$ 26,944,164.62	$ 29,110,314.73	$ 55,331,204.25
15 Year	$ 26,944,164.62	$ 27,928,617.84	$ 54,149,507.45
20 Year	$ 26,944,164.62	$ 26,846,776.48	$ 53,067,665.67

USAFA	8%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 16,465,236.74	$ 36,305,847.02	$ 66,272,577.89
5 Year	$ 16,465,236.74	$ 34,730,016.82	$ 64,696,747.69
10 Year	$ 30,793,330.99	$ 33,268,931.12	$ 63,235,661.99
15 Year	$ 30,793,330.99	$ 31,918,420.50	$ 61,885,151.37
20 Year	$ 30,793,330.99	$ 30,682,030.23	$ 60,648,761.11

USAFA	9%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 18,523,391.34	$ 40,844,077.90	$ 74,556,650.13
5 Year	$ 18,523,391.34	$ 39,071,268.92	$ 72,783,841.16
10 Year	$ 34,642,497.36	$ 37,427,547.51	$ 71,140,119.74
15 Year	$ 34,642,497.36	$ 35,908,223.06	$ 69,620,795.29
20 Year	$ 34,642,497.36	$ 34,517,284.01	$ 68,229,856.25

USAFA	10%	0%	Low
	Asphalt	PV Best Case	PV Worst Case
Initial	$ 20,581,545.93	$ 45,382,308.77	$ 82,840,722.36
5 Year	$ 20,581,545.93	$ 43,412,521.03	$ 80,870,934.62
10 Year	$ 38,491,663.74	$ 41,586,163.90	$ 79,044,577.49
15 Year	$ 38,491,663.74	$ 39,898,025.63	$ 77,356,439.22
20 Year	$ 38,491,663.74	$ 38,352,537.79	$ 75,810,951.38

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14. ABSTRACT
The United States Air Force (USAF) is the largest consumer of energy within the Department of Defense (DoD). As such, the USAF is continually looking for ways to reduce consumption, as well improving network resiliency and assuring supply. One potential method for addressing these items is focusing on applications of renewable energy. A specific application of renewable energy that could greatly benefit the USAF if viable would be photovoltaic (PV) pavements. PV pavements would be able to capitalize upon the large swathes of pavements on Air Force (AF) installations, while not being hampered by other concerns such as clear zones for aircraft.

One way to evaluate viability of a technology is through analyzing cost-effectiveness. While initial efforts were not directly focused on cost-effectiveness, the information gathered helped pave the way for such an analysis. Specifically, previous researchers at the Air Force Institute of Technology (AFIT) designed and implemented an experimental system for collecting performance data on horizontally oriented PV panels. Data was collected from 38 sites worldwide for a time period of up to one year. Five installations were then selected from the 38 original sites to utilize in determining cost-effectiveness. As part of evaluating cost-effectiveness, average power generation values were determined from the data. This information, along with pavement construction costs, helped form the basis of developing a model to evaluate life cycle costs for PV pavements. The model was then applied to each installation a total of 60 times to evaluate individual effectiveness. At the worst-case cost of construction for PV pavements, $460/SM, none of the installations evaluated would be able to consider installation PV pavements a viable alternative to traditional asphalt pavements.

15. SUBJECT TERMS
Photovoltaic Pavements, Photovoltaics, Renewable Energy

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