Got Solar Energy?: A Clean, Cost-Effective Alternative Fuel for Ground Support Equipment

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Executive Summary

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Every large commercial airport contributes to the volume of air pollutants. Aircraft, airport equipment, passenger vehicles and commercial motor vehicles use mostly nonrenewable petroleum-based fuels. Ground Support Equipment (GSE) used at commercial airports consumes large amounts of nonrenewable energy. The problem examined is how best to decrease GSE consumption of nonrenewable energy by converting the equipment to an alternate renewable energy source that can improve an airport's use of energy and reduce overall emissions.

The proposal team consists of a group of employees of the City of Phoenix Department of Aviation, students in a program partnered by Phoenix Sky Harbor International Airport and Embry-Riddle Aeronautical University. After careful study of the options for converting GSE to a "greener" alternative energy source including financial considerations, the team proposed the purchase and installation of thin-film solar modules on the roof areas of airport terminals' concourses. Inverters to change direct current (DC) produced by the panels to alternating current (AC) and fast-charging stations would be located on the concourse ramps, where GSE would park to recharge their motors.

Airlines, which own the GSE equipment, would be motivated to convert to electrical vehicles by the prospect of eliminating the cost of traditional fuel for those vehicles and by the commercial incentives for conversion to solar power available from the local utility. Funding for the purchase and installation of the solar system and the charging stations could be covered in large part by AIP grants and passenger facility charges applied for and authorized upon the airport's application and acceptance to the federal Voluntary Airport Low Emissions program.

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Problem Statement and Background on the Design Challenge

Ground Support Equipment (GSE) is one of the largest consumers of nonrenewable energy at large commercial airports. By decreasing GSE consumption of nonrenewable energy through an alternative renewable energy source we can improve an airport's use of energy and reduce overall emissions.

The city of Phoenix, Arizona and the greater Phoenix metropolitan area lies in a subtropical zone where summertime high pressure provides hot, dry conditions and generally clear skies. During May and June there is very little precipitation, while even though the months of July through September bring evening thunderstorms, skies are mainly clear during the morning and afternoon. The abundant sunlight reacts chemically with volatile organic compounds (VOCs), nitrogen oxides (NOx) and carbon monoxide (CO) emitted through the day by petroleum-fueled vehicles to form ozone, a pollutant which causes respiratory health problems and interferes with plant photosynthesis (Arizona Department of Environmental Quality, 2000).

In 1997 Maricopa County, which includes Phoenix and its greater metropolitan area, was designated an ozone non-attainment area, classified as "serious". A 1996 base year ozone emission inventory covering July through September revealed that non-road mobile sources, including airport GSE, accounted for 19.2% of VOCs, 13.2% of NOx and 49.5% of CO emissions produced daily. These percentages mean that in 1996, non-road emissions sources delivered to the atmosphere 66 tons of VOCs, 32 tons of NOx, and 622 tons of CO every day during the three months inventoried (ADEQ, 2000).

In the years since that inventory, great strides have been made in the effort to reduce and control emissions in the Phoenix area. A stringent vehicle emissions inspection program has been adopted, and statutes regulate emission levels from the manufacture of products ranging from vitamins to rubber sports balls. Still, a 2005 Maricopa County inventory reported that daily emissions from airport GSE alone totaled over a ton of NOx, and Phoenix Sky Harbor International Airport was responsible for 89% of that output, as well as for 86% of airport GSE output of CO (Maricopa County Department of Air Quality, 2005). By 2006, CO standards were being achieved each year, in large part due to vehicle modification requirements; however, NOx emissions were still responsible for 5% of the visibility reduction in Phoenix. Of the total NOx emissions, 27% came from off-road vehicles, which were also responsible for 27% of the ozone produced in the greater Phoenix area (ADEQ, 2007). Population increases, with the associated increase in numbers of vehicles, have erased some of the progress made since 1996 and have increased other power demands as well. A report released in February 2008 by the environmental group Western Resource Advocates ("A clean electric energy strategy for Arizona", 2008) concludes that Arizona will need twice as much electricity in 20 years as is used currently, and that one third of that increase could be provided by renewable energy.

Phoenix Sky Harbor International Airport, one of the largest in the nation, accommodates a GSE fleet of mostly petroleum-fueled vehicles. The airport encompasses several unused or vacant areas large enough to contain sizeable installations of solar panels capable of capturing the abundant sunshine and producing enough electrical power to fuel a fleet of GSE retrofitted with electrical engines, or of new or replacement electrical vehicles. The implementation of such a plan would greatly reduce pollutant emissions as well as the reliance on nonrenewable fuels.

Summary of Literature Review

According to the United States Department of Energy, there are several available alternative energy sources and technologies that could be used to fuel airport GSE. The proposal team studied the following energy sources:

- Bioenergy
- Hydrogen
- Electric

Following is a summary of the team's research of each alternative energy source, its availability, performance characteristics, and emissions.

Bioenergy

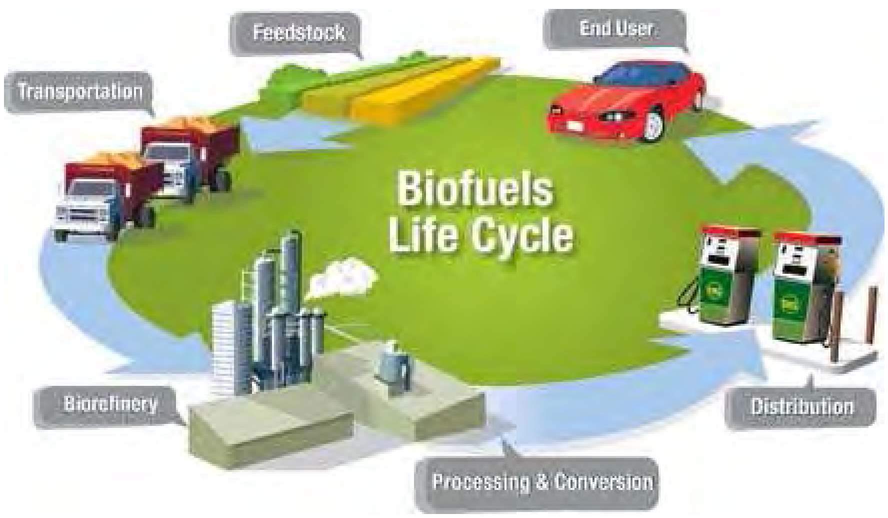
Bioenergy technologies use renewable biomass resources to produce energy products such as electricity, gas and liquid fuels, and other recyclable materials. The term "biomass" refers to any renewable organic matter. This can include a variety of crops, plants, municipal and industry produced wastes, and animal wastes. Bioenergy ranks second (to hydropower) in renewable U.S. primary energy production and accounts for three percent of the primary energy production in the United States. (U.S. Department of Energy, 2008).

BioEnergy systems produce ethanol which has become more commercially available in the United States for flexible fuel vehicles. The Secondary Energy Infobook (National Education Energy Development Project, 2007) defines Ethanol as "an alcohol fuel made by fermenting the sugars found in grains, such as corn and wheat, as well as potato wastes, cheese whey, corn fiber, rice straw, sawdust, urban wastes, and yard clippings." According to the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE) Alternative

Fuels and Advance Vehicles Data Center (2007), ethanol blended with gasoline significantly reduces carbon monoxide emissions.

Figure 1

Biofuels Life Cycle (U.S. Department of Energy – EERE 2008)



Depending on the cost of production and distribution, ethanol prices fluctuate and, as a result, ethanol may not be less expensive than gasoline. Additionally, ethanol is typically less efficient than gasoline.

Integrated Environmental Technologies, LLC (2007) is one of the first companies to commercially market a system that uses the process of vaporizing organic material to produce bioenergy sources at individual plant locations. The company trademarked the Plasma Enhanced Melter (PEM) Process Hearth which is a vessel that uses a plasma arc to disintegrate all types of municipal and hazardous waste. The by-product of the process is hydrogen rich syngas which can be converted to ethanol. The capital cost of this type of on-site bioenergy system is high. Once the system is running it actually produces enough power to sustain itself. Larger PEM systems can produce more power than they use and excess power can be used to provide a local power source. The systems are quite costly and seem most appropriate for large plants that produce large and steady quantities of waste, particularly hazardous waste that is costly to dispose of.

These systems are designed primarily for environmentally friendly waste management. While the PEM system does produce hydrogen rich syngas which can be converted to ethanol, these systems seem more appropriate for large industrial plants or large municipalities that produce large quantities of waste products, particularly those that produce hazardous waste. These systems require a large capital investment and a significant amount of space which does not seem suitable for an airport environment. This type of system is not readily available as a commercial contract service provider.

According to a report by the Energy Information Administration section of the Department of Energy (2008), capital costs to construct municipal solid waste (MSW) waste-to-energy plants are very high. In the past, to be financially viable, a plant would have to rely on a consistent supply of waste, and a municipality would sign a “flow contract” with a specific plant which received its solid waste. A waste-to-energy plant could develop a monopoly on a municipality’s waste, and in 1994 The U. S. Supreme Court upheld a challenge to waste flow control which voided many of the contracts. The decision created such a constraint on the industry that few plants have been able to begin operations since then.

Hydrogen

Hydrogen, number 1 on the periodic table of elements, is the simplest and most abundant element in the universe. However, hydrogen is rarely found alone in its natural state. On earth, hydrogen is most commonly found in water (H_2O), hydrocarbons (such as methane, CH_4), and other organic matter. Efficiently producing hydrogen from these compounds is one of the challenges of using hydrogen as a fuel. (U.S. Department of Energy, 2007).

Hydrogen fuel can be burned in internal combustion engines and fuel cells to power low emission vehicles. Significant research and development is necessary to make hydrogen as an alternative fuel source economical and practical for common use. The energy efficiency of hydrogen fuel is typically 15% to 35% of regular gasoline, and emissions still include NOx. The engines, which include hundreds of moving parts, require significant maintenance. (Kisslinger, 2008, p. 1)

With the fuel cell method, hydrogen is stored in carbon fiber tanks. The hydrogen fuel provides average power, but super capacitors are needed for quick accelerations or up-hill climbing. The fuel cell, storage tanks and super capacitors take up to four times more space than a conventional engine. Overall fuel cell technology is costly, fragile and not fully developed for commercial use. (U.S. Department of Energy, 2007)

Electric

Electricity, used to power vehicles, is usually provided through the electrical grid of the local utility company and stored in the vehicle's battery. However, alternative renewable energy sources such as solar power generation can also be used. Vehicles that run on electricity have zero tailpipe emissions. Electrical vehicles are recharged by plugging them into an electric outlet. Fueling costs for electric vehicles are reasonable compared to gasoline, especially if consumers take advantage of off-peak rates.

Electric vehicles with alternating current (AC) systems are more efficient that those with direct current (DC) systems. Electric vehicles powered by DC use about 0.4 kilowatt-hours (kWh) per mile, while those with (AC) systems use about 0.174 to 0.288 kWh per mile. If your home electricity rate is $0.13 per kWh, it would cost about $0.05 per mile for DC operation and $0.03 per mile for AC operation. Cost would be $0.12 per mile for gasoline in a vehicle that gets 25 miles per gallon when gasoline sells for $3 per gallon. (U.S. Department of Energy, 2007)

Electric motors have fewer moving parts, therefore requiring less maintenance. Also, electric motors don't idle, which saves energy. Although the battery used is heavy, GSE tractors would benefit from the weight because they need traction. And these heavy batteries are also inexpensive, recyclable and long-lasting.

Using electric motors leaves open the ability to introduce additional "green" systems. A Solar system can be used as an alternative energy source to power electric engines. Also, once there are more efficient ways to harness and use hydrogen, it can be used to power the GSE electric motors. Biomass could also be used to produce hydrogen, which would in turn power the electric motors. Different combinations are possible and can be determined by the weather and resources available at each airport. (National Energy Education Project, 2007)

Team's Problem Solving Approach to the Design Challenge

Upon assignment of the design project, team members brainstormed on design categories, solution concepts, and areas of interests. With a team consensus on the design challenge, each team member identified and researched a multitude of available data regarding alternate renewable energy and GSE. The team also decided to focus its design challenge solution on Phoenix Sky Harbor International Airport.

The team gathered information on GSE inventories of the main hub airlines and ground handling companies at Phoenix Sky Harbor. We researched what other airports have implemented in terms of electric GSE and airlines' position on electric GSE. Throughout the research, the team focused on the goal of the design challenge of increasing energy efficiency in the management of the airfield.

Why electric GSE works for the Airlines

Like most major airports, Phoenix Sky Harbor International Airport does not own the majority of the GSE on the airport. The team recognized this fact and researched the airline industry's position on electric GSE. At the September 2006 International Civil Aviation Organization Workshop on Aviation Operational Measures for Fuel and Emissions Reductions, presenters - Teresa Ehman of Air Canada and Valerie Jones of American Airlines - indicated that it is unattainable to reach 100% electric GSE due to engine power concerns for some types of GSE; however, it is applicable to convert some specific types of GSE to electric. Additionally, the presenters observed that airlines can not achieve conversion to electric GSE independent of airports and that infrastructure and GSE efficiencies are strongly linked (Ehman & Jones, 2006). Table 1 outlines the advantages and disadvantages of electric GSE identified by Ehman & Jones.

Table 1 Advantages & Disadvantages of eGSE

Advantages	**Disadvantages**
Provides emission reduction at the lowest costs of the alternatively-fueled GSE options.	Initial cost to purchase new eGSE
Has zero exhaust emissions – reduction of NOx emissions	Cost of infrastructure
Commercially available – numerous manufacturers	Ramp space reductions to accommodate charging areas
Lower maintenance costs since the GSE duty cycles are reduced due to no idle time with electric GSE	
Ability to retrofit existing internal combustion engine GSE	
Improves airline employees' occupational health	

Our team research indicates that the GSE most economical to convert to electric are the bag tugs, belt loaders, narrow-body aircraft (tugs) tractors, and passenger stairs (Gibson, 2006). Additionally, the team learned that electricity has been successfully used as a viable alternative renewable fuel for powering most types of GSE. There have been several airport pilot programs that installed charging infrastructure for airport and airline-owned electric GSE. These programs demonstrated the reduction of emissions at airports through electrification of GSE to be both economically and technologically feasible. Table 2, developed through team research, summarizes airports and airlines currently using eGSE.

Table 2

Airports With Airlines Using eGSE

Airports	**Participating Airlines**
✈ Burbank-Glendale-Pasadena (Bob Hope)	✈ Airborne Express, Alaska Airlines, American Airlines, ATA Airlines, Continental Airlines, Delta Air Lines, DHL Airways, Federal Express, Hawaiian Airlines, Jet Blue Airways Corp., Midwest Express Airlines, Northwest Airlines, Southwest Airlines, United Airlines, United Parcel Service, US Airways,
✈ Denver International	✈ Sky West Airlines, Frontier Airlines, Mesa Air, DHL Airways, United Airlines
✈ Dallas-Fort Worth	✈ American Airlines, Delta Air Lines
✈ Houston Intercontinental	✈ Continental Airlines
✈ John Wayne – Santa Ana/Orange County	✈ Airborne Express, Alaska Airlines, American Airlines, ATA Airlines, Continental Airlines, Delta Air Lines, DHL Airways, Federal Express, Hawaiian Airlines, Jet Blue Airways Corp., Midwest Express Airlines, Northwest Airlines, Southwest Airlines, United Airlines, United Parcel Service, US Airways,
✈ Long Beach Municipal	✈ Airborne Express, Alaska Airlines, American Airlines, ATA Airlines, Continental Airlines, Delta Air Lines, DHL Airways, Federal Express, Hawaiian

	Airlines, Jet Blue Airways Corp., Midwest Express Airlines, Northwest Airlines, Southwest Airlines, United Airlines, United Parcel Service, US Airways,
✈ Los Angeles International	✈ Airborne Express, Alaska Airlines, American Airlines, ATA Airlines, Continental Airlines, Delta Air Lines, DHL Airways, Federal Express, Hawaiian Airlines, Jet Blue Airways Corp., Midwest Express Airlines, Northwest Airlines, Southwest Airlines, United Airlines, United Parcel Service, US Airways,
✈ Ontario International	✈ Airborne Express, Alaska Airlines, American Airlines, ATA Airlines, Continental Airlines, Delta Air Lines, DHL Airways, Federal Express, Hawaiian Airlines, Jet Blue Airways Corp., Midwest Express Airlines, Northwest Airlines, Southwest Airlines, United Airlines, United Parcel Service, US Airways,
✈ Newark International	✈ Continental
✈ San Francisco International	✈ Continental Airlines, United Air Lines, DHL Airways, Sky West Airlines
✈ Seattle-Tacoma International *	✈ Alaska Airlines *
✈ Sacramento International	✈ United Airlines, Southwest Airlines, US Airways

* Sea-Tac & Alaska Airlines – in development

Furthermore, the conversion to eGSE and its reduction of emissions will contribute to the reduction of airline operational and maintenance expenses (Gibson, 2006). There is an initial cost to electrify GSE. Typically eGSE is 30 to 35 percent more expense than diesel GSE (Gibson, 2006). Despite this initial capital investment, however, it is reported that the capital return payback is approximately 36 months due to the reduced operating costs of eGSE equipment (Rowe, 2001).

According to the Electric Power Research Institute, airlines will save money over the life of equipment despite the higher initial cost of eGSE equipment (2007). This cost saving is a result of lower maintenance costs of eGSE in comparison to internal combustion engine GSE equipment. For example, United Airlines reported a lifecycle savings of 40 percent for new electric bag tractors over the replaced diesel units at San Francisco International Airport (FAA ILEAV Pilot Program Final Report, 2006). Additionally, many airlines have elected to retrofit their existing internal combustion engines to electric-battery engines to avoid replacing GSE prior to the end of the equipment's lifecycle. Lastly, eGSE reduces the airline's overall emissions profile as well as the airport's overall emissions profile (Electric Power Research Institute, 2007).

Why solar energy for the GSE charging infrastructure?

A key component to the successful implementation of eGSE is the use of fast charging units. Through the use of fast charging technology, airlines have the ability to charge equipment throughout employee shifts and in between flight operations. Additionally, fast charging units are commercially available with several different manufacturers. The location of the fast charging units will be fixed due to the need for a dedicated electrical supply.

Our design proposal includes the airport retaining ownership of the charging infrastructure to ensure and preserve the ramp as common-use ramp while maintaining the greatest flexibility for the airport. Table 3 represents the commonly used types of GSE, engine-types, and quantities. From this hub GSE population at Phoenix Sky Harbor, the airlines currently operate 24 percent of all GSE equipment as electric GSE.

Table 3

Hub Airline GSE Population at Phoenix Sky Harbor International Airport - 2008

Equipment Type	Diesel	Gasoline	Propane	Electric
Baggage Tractors (Tug)	92	125	0	15
Belt Loader	39	72	0	78
Cargo loaders	2	1	7	1
Ground Power Unit	9	0	0	25
Aircraft Tug – narrow body	4	29	0	13
Aircraft Tug – wide body	0	9	0	0
Air stairs Unit	7	3	0	0
Lavatory Cart	4	9	0	0
Bobtail	0	0	0	0
TOTAL	157	248	7	132

Source – Phoenix Sky Harbor Survey to Hub Airlines: US Airways, Southwest (2008)

Our design proposal recommends 50 percent of total fleets for baggage tractors (tugs), belt loaders, narrow-body aircraft tugs, and passenger air stair units to be converted from fossil-fuel engines to electric engines.

The team recognized that the project design would need to include increased power supply for the anticipated eGSE usage. However, the team was concerned about the sensitivity of shifting the energy source for GSE from fossil-fuel based (gas) to another fossil-fuel derived energy source of electricity. Coal and natural gas are the primary sources of electricity generation in the United States including Arizona. Although the electricity generation would occur off airport, the team concluded that any emission reductions at the airport would be offset by the overall increased emissions from the increased power demand associated with the fast charging units. The team proposed the use of solar energy as the alternative renewable source of electricity for the fast charging units.

Fast Charging Units

There are few manufacturers of GSE charging stations on the market today. PosiCharge, by Aerovironment, Power Designers and Electric Transportation Engineering Corporation

(ETEC), are just some of those manufacturers. ETEC has worked on many power conversion projects, including the Sacramento Airport project (California Environmental Protection Agency, 2005).

While there are different manufacturers and numerous types of chargers, each airport would have to decide which options would be best suited for their own unique situation. The amount of available space, cost and the number of pieces of GSE on hand are some issues that have to be considered.

The charging station that would be best suited for this project is the ETEC SuperCharge™ - GSE-200 DP. This model requires minimal space. It is 64”H x 30” W x 27”D. It is a dual port (DP) charger that will accommodate two pieces of GSE. It may be mounted either indoors or outdoors. This unit is rated to operate in a wide temperature range (-25 C to +40 C). The amount of time needed to recharge GSE depends on how low the batteries have been drained. Typically, the normal charging time varies from 1-2 hours. The cost to purchase one of these units is $26,500 (Electric Transportation Engineering Corporation, 2007).

Solar Energy

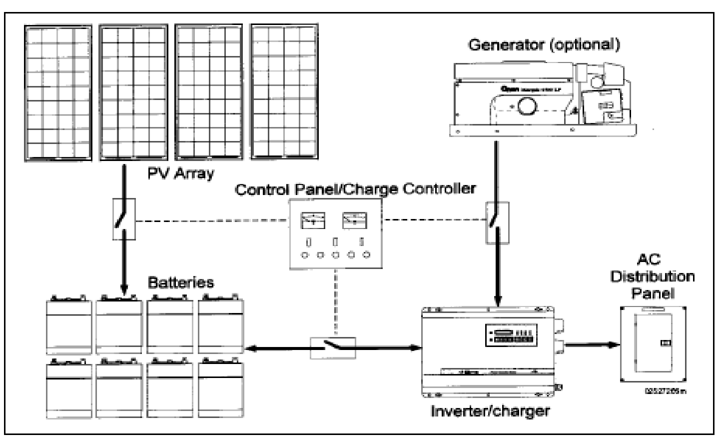
Solar energy is a general term referring to any process that turns sunlight into energy. There are a variety of technologies that have been developed to take advantage of solar energy. One of these technologies that can be used at Phoenix Sky Harbor International Airport is a Photovoltaic system.

Photovoltaic (PV for short) is a word derived from “photo”, meaning light, and “voltaic”, meaning voltage producing. PV cells work by transforming the photon energy in solar radiation directly into electrical energy without an intermediate mechanical or thermal process. A PV cell consists of layers of semiconductor materials in contact with each other and fitted with metallic contacts to transfer the released electrons to the external load. Most commercial PV cells now available are manufactured from crystalline silicon, which is doped to provide the required semiconductor qualities. This is then fitted with the metallic contacts and encapsulated for protection.

The standard element of a PV system is the PV module. Individual solar cells are interconnected, encapsulated, laminated on glass, and framed to form a module. Modules are strung together in an electrical series with cables and wires to form a PV array. Direct or diffused light (usually sunlight) shining on the solar cells induces the PV effect, generating unregulated DC electric power. This DC power can be used; stored in a battery system, or fed into an inverter that transforms and synchronizes the power into AC electricity. The electricity can be used in the building or exported to a utility company through a grid interconnection. (Eiffert and Kiss, 2001) Figures 2 and 3 illustrate these systems.

Figure 2

A Typical Stand-alone PV System



(Credit: Eiffert and Kiss, 2001)

Figure 3

Utility-Interactive System without Batteries

(Credit: newssociety.com/titleimages/pv_ch1.pdf)

Advantages of photovoltaic system

There are many advantages to environmentally friendly photovoltaic (PV) systems. For instance, conversion from sunlight to electricity is direct; therefore, bulky mechanical generator systems are not necessary. PV arrays can be installed quickly and in any size required or allowed. The environmental impact caused is minimal, since PV systems require no water for cooling and generate no harmful by-products.

Solar cells are low maintenance. In fact, 75 percent of the cost of a cell's lifetime is in the initial manufacturing. As a result, the cells are reliable and do not require ongoing technical attention. A standard cell produces only .6 to 1.2 volts. Therefore, mass systems are created by grouping these cells in a series to increase voltage or in parallel to increase current. Another advantage of PV technology is that it can be combined with construction materials and be built into a building rather than added on the roof of a building. Finally, the energy available from the sun is massive and endless. The amount of sunlight that reaches the continental United States is about 4,000 times more energy than is used each year.

Disadvantages of photovoltaic system

The biggest environmental consideration of PV cells is their disposal. The material contains toxic substances that need to be properly disposed of. Another problem with solar energy is that it is dependent on the weather. Clouds alone significantly reduce the production of solar cells from their maximum potential. Yet a greater problem to solar cells is that they are too expensive. The price for the production of solar energy cannot compete with current coal and natural gas power plants on a massive scale.

Incentives and Funding

One of the more challenging aspects of the project proposal involved a determination of how best to finance the project. Once the decision was made to focus on development of an on-airport solar system which would provide the power source for electric-motored GSE equipment, the team began looking into resources available for funding the construction of such a system. Opportunities for incentivizing and funding airport infrastructure modifications which yield reductions in criteria pollutant emissions are widely available from several sectors. In all but 13 states in the nation, non-residential customers are eligible for direct incentives from power utilities for photovoltaic projects, and many local and state agencies provide loans and credits against power usage and taxes as incentives for photovoltaic projects (Database of State Incentives for Renewables and Efficiency, 2007).

At Fresno Yosemite International Airport in California, a solar powered system was approved to be installed on airport property to provide electricity to the planned Consolidated

Rental Car facility. The system is being constructed and is owned and maintained by a private company with which the airport has negotiated a 20-year fixed price per kilowatt hour. The state of California will provide rebates to the airport of several millions of dollars, and the airport expects to realize savings in power costs of almost $13 million over the course of the agreement, projected at 25 years to include a 5-year extension. Additionally, the system is projected to result in emission reductions of NOx, SOx and CO_2 by almost 19 tons annually and 474 tons over the 25 years (City of Fresno, California, 2007).

On the east coast, the Long Island (New York) Power Authority has invested $185 million in a program offering rebates of $4.50 per watt DC to government facilities unable to take advantage of the tax incentives available to residential and commercial customers, for solar power systems (New York Incentives for Renewable Energy, 2000). Meanwhile, the New York State Energy Research and Development Authority (PV Incentive Program, 2008) offers rebates for photovoltaic systems to eligible installers who must pass the incentives on to their customers. The $5 per watt (up to 25 kilowatts) for municipalities equates to a rebate of $125,000. In the state of Arizona the Arizona Public Service utility, which provides service to Phoenix Sky Harbor International Airport, has initiated a net-metering program which credits power generated by eligible systems, including photovoltaics, against power consumption (Arizona Incentives for Renewal and Efficiency, 2007).

At the federal level, the U.S. Department of Energy offers technical assistance to large-scale solar installation projects. The agency also provides funding and technical support to 12 U.S. cities per year for city-wide solar technology (U.S. Department of Energy, 2007). The Voluntary Airport Low Emission program (VALE) was created by the FAA in 2005 to administer the provisions of *Vision 100*, a reauthorization act which provided for an airport ground emissions voluntary reduction program at commercial airports in the NPIAS. An eligible airport, in conjunction with its state's air quality agency (which must agree to provide airport emission reduction credits to the airport) applies to the VALE program and, once accepted, is eligible to apply for Airport Improvement Program (AIP) grants and for permission to impose Passenger Facility Charges (PFCs) for infrastructure modifications such as photovoltaic projects (FAA VALE Program, 2007). The state-issued airport emission reduction credits (AERCs) may be applied by the airport to future projects to offset the impact of the earlier emission reductions on the emissions baseline under the EPA's new source review (NSR) program (United States Environmental Protection Agency, 2004).

The project team concluded that the airport's best course of action would be to take advantage of the AIP and PFC opportunities available within the VALE program. The costs of the solar project would be largely covered by grants and passenger fees, and the emissions credits would be applied to upcoming construction projects which are currently in early planning stages.

Safety Risk Assessment

In analyzing the risks and hazards associated with our design solution, the Safety Management System (SMS) developed by the Federal Aviation Administration (FAA) became an important tool. The objective of the SMS is to help achieve the premier goal of the FAA which is to ensure the safety of the flying public. While the safety management system outlines a specific way to assess safety risks associated with changes to or impacts on the National Airspace System (NAS), its basic principles serve as a systematic way to assess risk in general.

When developing our design solution we spent a great deal of time thinking about potential risks, and more importantly, potential impacts our proposed solution would have on the

NAS. Because our design solution revolves around solar power, and the only solar systems we were initially aware of were the large, seemingly reflective panels, we were extremely concerned about the effect its potential reflectivity would have on pilots entering the airspace around the airport. After additional research and the consideration of various design options we chose thin film solar modules that have an antireflection coating (U.S. Dept. of Energy, National Renewable Energy Laboratory, 1996). With the reflectivity issue resolved we were able to rule out any potential impact to the NAS and therefore, were able to circumvent the risk analysis process outlined in the SMS Manual.

While a full safety risk assessment, as outlined in the SMS, was not warranted for our design solution, we chose to outline other potential risks, analyze their threat and identify ways to minimize the risk. The identified risks are discussed below.

First, our research uncovered a concern voiced by Fire Fighters in California who, while extremely supportive and excited about solar energy, had a very legitimate concern about the risk of electrocution while trying to fight a fire on a home or business with solar panel systems installed. This immediately caught our attention as this would also be a concern for solar panels installed on terminal buildings. In discussion with Mr. Michael Perfette, Deputy Director, City of Phoenix Public Works, he noted that firefighters, and all maintenance personnel, must remember that solar systems are second sources of electricity when the sun is out and that the system must be properly de-energized to avoid shock hazards. We followed this conversation up with a call to our on-airport fire department to inquire about any training programs they may be working on in regards to this very subject. What we found with the fire department located on Phoenix Sky Harbor Airport is that no specific training programs had been developed regarding combating a blaze involving solar panel. Lieutenant Tim Gift with the Phoenix Fire Department noted that when solar systems are involved, the fire immediately becomes a hazmat situation as battery packs are usually stored nearby. He stressed that when these systems are involved signage and communication become critical. As a result, to help mitigate this risk we advise all airports adopting this design solution to notify all maintenance staff and local firefighters of the potential shock hazards and how to most effectively go about de-energizing the system.

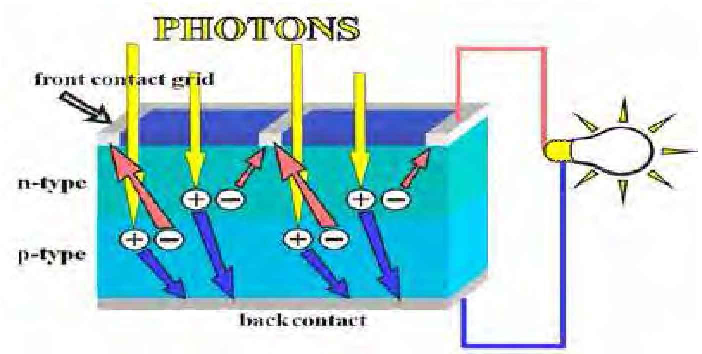
Second, also after consultation with Mr. Michael Perfette we found that when a sharp object pierces a panel it can cause a short. As a result, it is imperative that adequate warning signage be placed around the system to alert people to this fact. It is also important that anyone working on the system or coming in close contact with it be trained in the proper way to interact around the system.

In conclusion, after thorough thought and research we are comfortable in recommending this as a safe and virtually risk free system. While no piece of technology is entirely risk free, when treated appropriately and with respect it comes close. The most important thing an airport installing this particular design can do is educate those that may have direct involvement with the system as to its potential hazards.

Description of How Technical Aspects are Addressed

Figure 4

How Sunlight Interacts With Solar Panels To Create Electricity

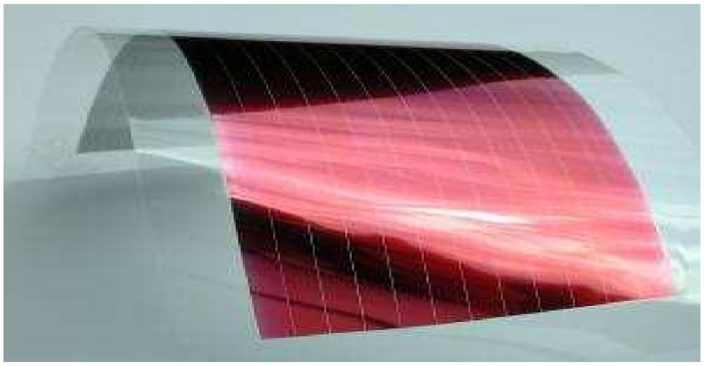


CIGS Photovoltiac Solar Technology Global Solar Energy (2008)

Photons, the energy particles in sunlight, are absorbed by the photovoltaic material. Their energy is then transferred to the electrons of atoms in the PV material. The energized electrons escape from their orbits around the atoms and become part of the current in an electrical circuit.

Figure 5

The flexible solar module is as small as the page of a book.

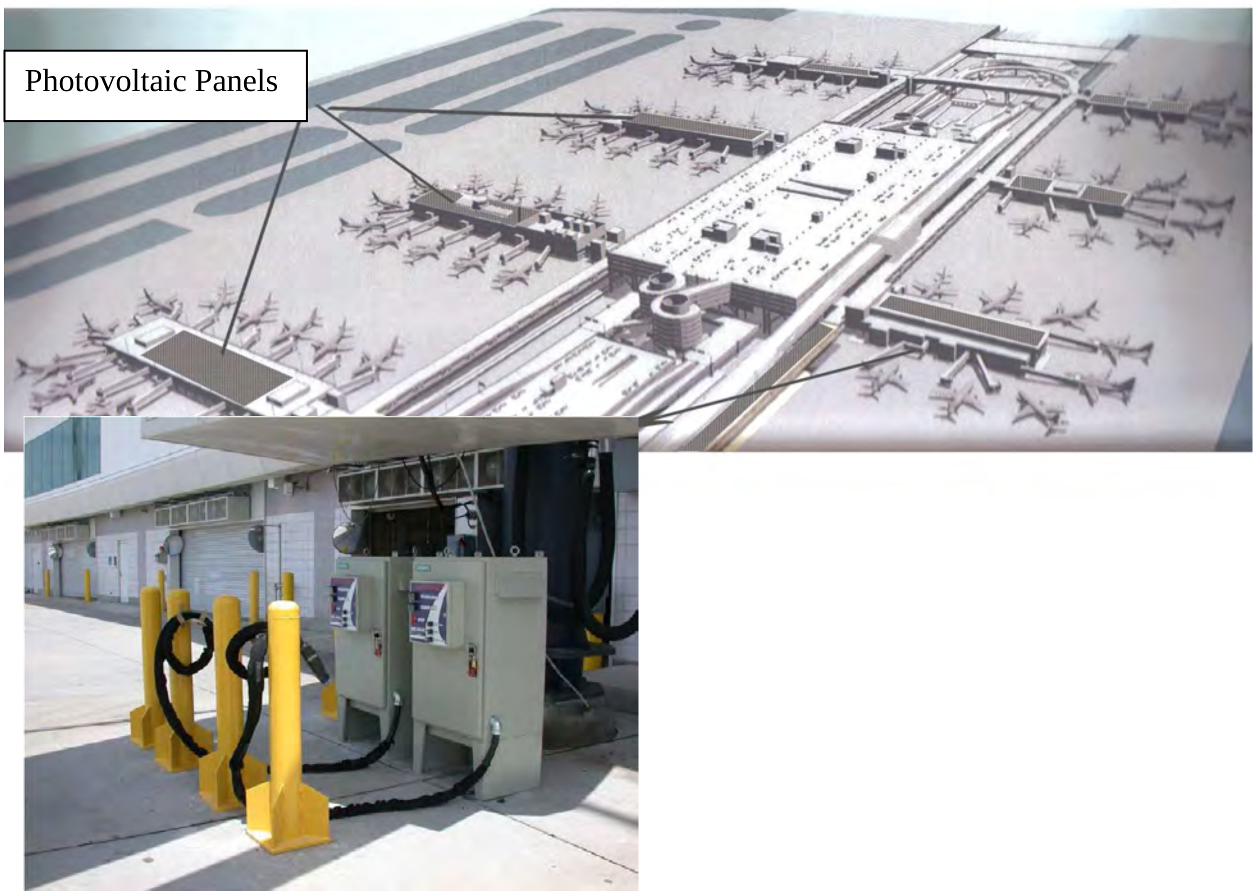


(Credit: Copyright Fraunhofer ISE)

Previous solar panels have used indium tin oxide, a transparent material, as the outer layer facing the sun; this material, however, is expensive to produce. The Fraunhofer Company has developed an outer transparent polymer backed with highly conductive metal, a much less costly construction which has already been patented. (Fraunhofer-Gesellschaft, 2008, February 7)

Figure 6

How a Photovoltaic System Would Be Installed At Sky Harbor Airport's Terminal 4



ETEC Super Charge GSE – 200SP Outdoor Installation
Source: Buysellgse.com/images/directory/brochures/GSE-200SP_DP_250DP.pdf

The illustration shows how thin-film photovoltaic modules would be applied to the flat roof surfaces of the concourses of one of the three terminals at Sky Harbor International Airport. The installation of photovoltaic panels would be performed on the roof surfaces of the other terminals' concourses as well.

Electricity generated by the PV modules would be directed to inverters installed at ground level of each concourse, where the electricity would be changed from direct current to alternating curren, or AC. This current would then flow to fast-charging units placed at convenient locations at ground level. Electric GSE would park and recharge within a 2-hour period at the charging stations.

Description of Interactions with Airport Operations and Industry Experts

The project team contacted several airport operators and industry experts. Our primary contacts have been airport operators and officials at Phoenix Sky Harbor International. Additionally we communicated with several other airport operators and industry experts throughout the United States.

The project team contacted Jessica S. Steinhibler of Airport Council International –North America (ACI-NA) to discuss the current VALE funding program and to clarify if airlines have access to VALE funding for new electric-motored GSE. Ms. Steinhibler shared that VALE funding is available to only the airports. She also directed us to the U.S. Department of Energy Cost Benefit Analysis Modeling Tool for Electric vs. ICE (Internal Combustion Engine) Ground Support Equipment Development and Result. The team utilized this modeling tool to analyze the cost-benefit of electric GSE.

The project team spoke with Mr. Kevin Meikle, Airport Planning Manager at the City of Fresno, Department of Airports regarding Fresno International Airport's experience with solar panel system. Mr. Meikle was candid about the experience and sent the project team information on their solar panel system including City Council report, NEPA documents and reflectivity study.

The project team also spoke with Fred Pena, Superintendent – Airport Operations at Daugherty Field Long Beach Airport about their implementation of rapid charging units for electric ground service equipment. Mr. Pena discussed Long Beach's specific reasons why electric ground service equipment and the process of installing rapid charging units. He noted that the installation of units was mutually beneficial for both the airport and the airlines and with the charging infrastructure in place the airlines have started converting GSE over to electricity with the encouragement of the airport.

In addition, we contacted via email both Nellis Air Force Base and Sun Corporation to gain additional information on the costs, maintenance issues or unseen problems that may have occurred with the Nellis AFB system. Despite our efforts, we did not receive any feedback from these companies.

The team spoke with Mr. Greg Rowe, Senior Environmental Analyst at the Planning Department of the Sacramento County Airport System regarding his experience with the FAA's ILEAV Program, which Sacramento participated in beginning in 2001. Mr. Rowe was very forthcoming and shared a valuable retrospective progress report written in September 2005. He pointed out the importance of communicating early with internal finance staff regarding funding expectations and ensuring that there are no misunderstandings of difference of expectations among all partnering entities. Although the ILEAV program has now been replaced with the VALE program, many of the experience and lessons learned from navigating the ILEAV program are applicable to participating in the VALE program, which the team was careful to take into account in the projected impacts of the new solar and electric system for powering GSE.

The team contacted Dr. Richard deNeufville, a professor of Engineering Systems and Civil and Environmental Engineering at MIT who was listed as an expert advisor for the FAA competition. Dr. deNeufville described the Airport Cooperative Research Program (ACRP) and directed the team to its website, where staff learned about a current study named “Onsite Solar Hydrogen Production Demonstration for GSE Emissions Reduction and Airport Facility Alternative Energy Source”. This two-year study is being carried out by the Toledo Express Airport in Swanton, Ohio and points out in its summary the desire to use hydrogen because of the existing drawbacks of photovoltaic panels. According to Paul L. Toth, Jr., P.E. , the Toledo Express Airport Director, typical photovoltaic (PV) panels in use today produce electricity that is difficult to store for use as dispatchable power. Mr. Toth states that the IPE panels potentially solve this dilemma by directly producing hydrogen gas that can be stored until it’s needed. (Toth, 2004).

When researching the cost of a fast charging unit, team members contacted Kevin Morrow of ETEC who provided an estimate for a two-port charger like the GSE-200DP Fast Charger of $25,000. Mr. Morrow advised the team that some airlines, such as Southwest Airlines, can run up to four electric bag tractors off of one dual port GSE-2000DP, but other airlines, such as American Airlines, may require a port for every vehicle. Mr. Morrow also described and directed the team to an automated resource for calculating cost-benefit analyses. The resource is a cost model he helped develop for the U. S. Department of Energy and is posted on the Idaho National Lab webpage.

Don Vanderbrook of HEC is another industry expert contacted while researching the feasibility of hydrogen-powered GSE. Mr. Vanderbrook quoted a price range of $12,000 for converting the engine of one GSE from a regular fuel internal combustion engine to an electric one.

The team spoke with Cynthia Parker, Environmental Coordinator for Phoenix Sky Harbor International Airport about solar panel installations in runway protection zone (RPZ) of the airfields. Ms. Parker confirmed that solar panels could be located in the RPX zone without concerns of glare impacting flight operations. Ms. Parker also provide the project team with a list of other airport contacts to discuss eGSE including Denver International Airport, and Los Angeles International Airport. She also contacted Seattle-Tacoma International to further inquiry into their proposed eGSE charging infrastructure project. We also spoke with David Hensley, Deputy Aviation Director, Design and Construction for Phoenix Sky Harbor International Airport. Mr. Hensley as the airport's chief engineer provided guidance on proposed fixed locations for the electric charging infrastructure.

The project team also interviewed Mike Perfette, Deputy Public Works Director for City of Phoenix Public Works Department. City of Phoenix Public Works Department is coordinating a large-scale solar installation similar to the team's design proposal. Mr. Perfette provided both practical and technical considerations for the solar installation. The project team learned of alternative solar panel installation – thin film roof membrane - than the traditional solar panels. Mr. Perfette confirmed that the thin film product does not provide reflectivity. This new solar product provided greater flexibility of roof installation while maximizing the placement. The team learned the importance of the solar placement in order to maintain a short distance for the point of attachment into airport power grid. Mr. Perfette shared line diagrams and drawings on the solar installation as well as additional funding resources to research.

Lastly, the project team contacted the two hub airlines for Phoenix Sky Harbor, US Airways and Southwest Airlines, as well as the main ground handling companies, ASIG and Penuille Servisair, to gather data on their current GSE inventory including equipment types and engine type. Each person provided the team with a detailed inventory. This inventory information is outlined in Table 4.

Table 4
Airlines/Grounding Handling Contacts at Phoenix Sky Harbor International Airport

Company	Contact	Title
Southwest Airlines	Mike Miller	Phoenix Station Manager
US Airways	Joe Fretto	Phoenix Ramp Operations
ASIG	Tom Hindmon	Phoenix General Manager
Penuille Servisair	Dana Perry	Phoenix General Manager

Description of the Projected Impacts of the Design and Findings

One of the main objectives driving this design project is to meet goals set forth by the FAA. In reviewing the FAA's current Flight Plan goals, it is apparent that this project addresses several of its goals (U. S. Department of Transportation, 2004). The four goals set forth in the plan are:

- Increased Safety
- Greater Capacity
- International Leadership
- Organizational Excellence

Under the first goal of Increased Safety, the FAA discusses runway safety. By converting GSE to electric vehicles, there will be a reduced risk of fuel spills and therefore increased airside safety. Also, employee safety is improved by reducing harmful emissions, which is one of the causes of occupational health problems among GSE operators. Under the second goal of Greater Capacity, Objective 4 is to "address environmental issues associated with capacity enhancements" and "increase emissions mitigation activities" (U.S. Department of Transportation, 2004, p. 29). Clearly, conversion to solar energy and electric GSE will assist in meeting this goal. Under the plan's third goal of International Leadership, the FAA supports efforts to maximize the use of limited resources in developing countries. By carving the path towards innovative ways to use alternate energy sources, the FAA will surely become a reputable leader to all countries, especially those where resources are scarce. Overall, the FAA Flight Plan's vision is "to improve continuously the safety and efficiency of aviation, while being responsive to our customers and accountable to the public" (U.S. Department of Transportation, 2004, p. 3). There is no better way to be accountable to the public by protecting its natural resources while increasing safety.

In addition to meeting FAA goals, this design project also supports other federal goals regarding renewable energy, such as the Clean Air Act of 1990 and the Energy Policy Act of 2005 which focuses on reducing emissions through the use of renewable energy.

Aside from the FAA goals to lower emissions and increase runway safety, this design project will assist the FAA by exemplifying a successful participation in the VALE program. Other airports will surely follow once there is an additional example of a successful VALE participant as large as the Sky Harbor International Airport. The commercialization of this project at both Sky Harbor and other airports is logical, as solar energy is a growingly common form of utilizing alternate energy and electric vehicles are equally common. And, although solar energy is obviously a great alternate energy choice for a city such as Phoenix, which has a high percentage of sunny days per year, it is actually very feasible for most any other U.S. City.

For example, even the state of New York has a growing pursuit for solar energy and, in fact, the 2009 Solar Society Conference will take place in Buffalo, New York. Northeastern states are committed to expanding their use of solar energy, and conference information reports that a house in Maine would only need 25 percent more photovoltaic solar panels than a house in Los Angeles, California (American Solar Energy Society, 2008).

It may perhaps be logical for an airport to pursue different alternate energy sources, such as hydraulic, wind, hydrogen, bio-fuel, or perhaps some other green option aside from solar. All of these possibilities continue to work in harmony with this design project, since the alternate energy generation can be applied towards the common denominator of powering electric GSE. Even as green technologies for generating energy continue to evolve and become more cost effective, electric GSE will last many years in operation due to their durability and low maintenance requirements.

The feasibility of electric GSE is also well founded, as we already have many examples of airlines successfully using them. At Phoenix Sky Harbor Airport, for instance, Southwest Airlines currently uses electric tugs and belt loaders.

Furthermore, there are examples of successful GSE conversions from diesel to electric without the use of FAA funding. One such example is that of Delta Airlines at New York's La Guardia airport. In 2006, Delta converted its GSE with significant funding assistance from the Queens Clean Air Project (QCAP) and the New York Power Authority (NYPA). The total cost to convert 15 pieces of GSE was $1.1 million, of which $494,000 came from the QCAP and another $160,000 from NYPA (Clean Air Communities, et. al. 2007). As it is clearly possible to leverage local and state funds for this type of project, the success of similar attempts to convert GSE at other airports is very probable with the addition of federal grant support such as that through the VALE program. By taking advantage of incentive programs such as VALE and local utility incentives, it becomes more economically feasible for both the airport and the airlines to carry out a similar project.

Converting to electric-powered GSE leaves open the door for future initiatives to improve the environment. Currently, Continental Airlines is testing the use of bio-fuels, refined from their used catering oil, to run their GSE (Commitment to the Environment, Continental Airlines, April 2007). By having already converted the GSE, new innovations such as this can be easily added to the overall goal of using alternate fuels for the sake of the environment.

Similarly, harnessing solar power initiates the possibility for future expansion in terms of solar energy for other uses at the airport. For example, if additional locations are identified or new buildings are constructed with PV panels, solar energy may become a significant source of energy to power buildings and equipment beyond GSE.

As Continental Airlines demonstrated, a secret to successfully implementing eGSE is employee involvement (Electric Power Research Institute 2007). A small group of corporate management executives and two new committees were dedicated to the transition. In addition, employee "Agent Groups" were formed to overcome initial resistance among GSE operators. These agents educated co-workers on the new technology and helped develop a training program. Every staff member's input was valued, leading to buy-in of the project by staff at all levels. Other airlines can achieve the same results by following similar implementation procedures. This includes a model in which every staff member's input is valued, resulting in a sense of ownership of the project's success throughout the organization.

In terms of the solar energy part of this design project, additional wisdom is offered from the Nellis Airforce Base group who realized that it was important to gain empowerment among those involved, as well as ensuring that expertise existed within the core staff group for the contracting, technical, legal, and economics aspects of the project (Dumont, 2007).

Financing the solar portion of this design project will be possible through the use PFC and AIP funds, which would be secured through participation in the VALE program. The Phoenix Sky Harbor International Airport can apply this funding towards the procurement and installation of the solar panels and charging stations. In regards to the eGSE, the Airport will be able to provide significant incentive to the airlines to convert to electric GSE by offering free or discounted electricity for the equipment. Because electric GSE save the airlines substantial operating and maintenance cost over time, the initial capital investment is worthwhile for the airlines. These cost savings over time will assist in the airlines in becoming more financially sound and successful.

The applicability of this design project at other airports is very feasible. The Sky Harbor Airport would choose to apply the VALE funding towards the solar energy system and not pursue overly ambitious goals of also funding the eGSE. However, other airports have that additional option available. In addition, other airports may pursue scenarios as that of the Fresno Yosemite International Airport, which had the solar power system constructed and owned by a private company in exchange for a long term fixed price per kilowatt. Depending on each state's incentives, as described earlier, as well as potential partners, an airport can take advantage of different combinations of funding sources.

Cost-Benefit Analyses

To conduct a cost-benefit analysis on this design project, the team used the Modeling Tool for Electric vs. ICE GSE developed by Kevin Morrow, Dimitri Hochard and James Francfort for the U.S. Department of Energy (Morrow 2007). The tool takes into account many variables, which ultimately relate to the high-level variables in the following table.

Table 5

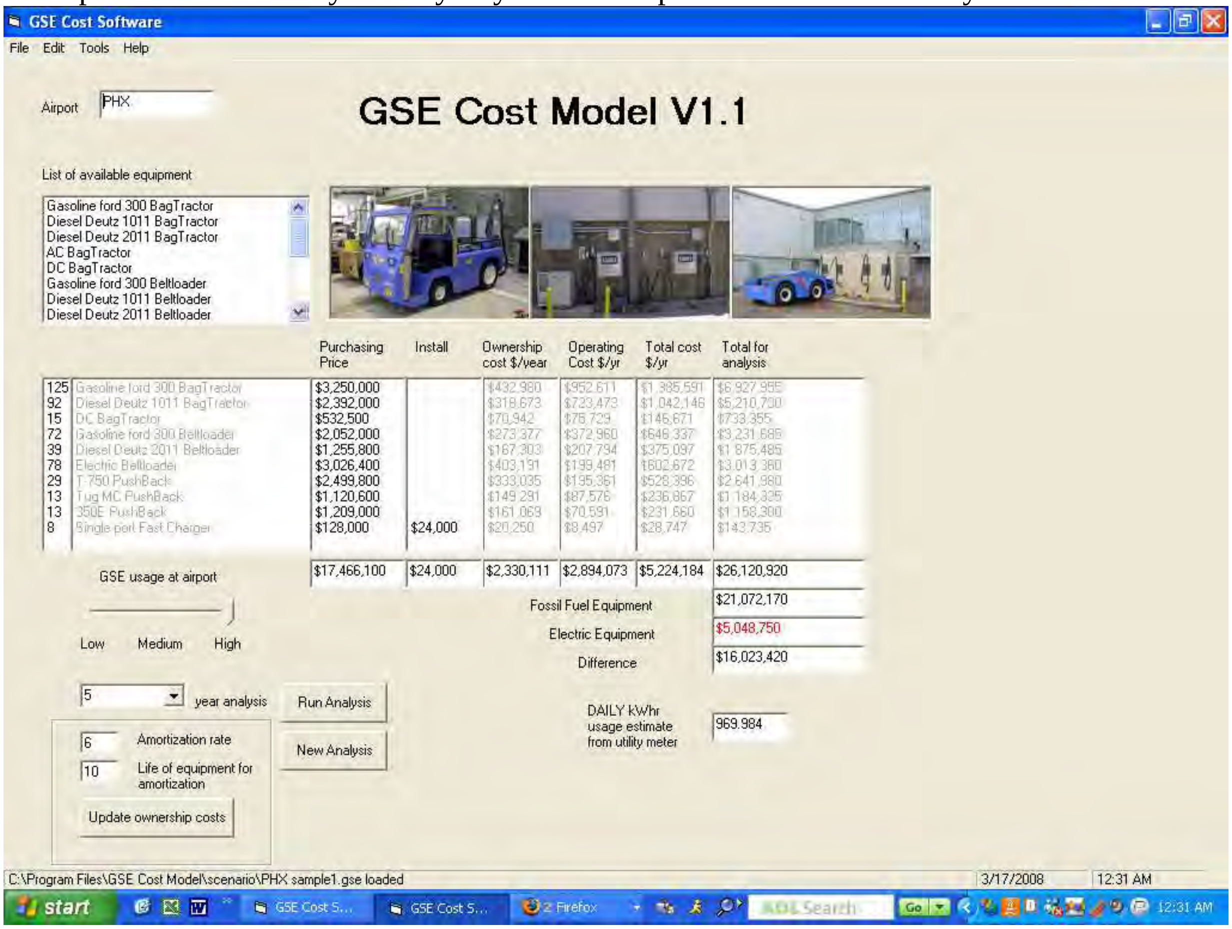
GSE Cost Model V1.1 High Level Variables

Capital Costs	**Expenses**	
GSE Purchase	GSE Maintenance	Charging Infrastructure Maint.
GSE Alterations	Battery Pack Replacement	Fuel
Battery Charger Purchase	Engine Rebuild/Replacement	kwhrs/Day
Battery Charger Installation	Electric Motor Replacement	$/ AC - kwhrs
	Electric Controller Replacement	$/ kw Demand
	Transaxle	Monthly Meter Fee
	Other General Maintenance	ICE Fuel - gallons/day
		$/ ICE Fuel - gallons

Using the cost estimating model, the team ran various scenarios to determine the expected cost savings caused by electric GSE over time. Among the hub airlines, there are a total of 370 traditional ICE GSE and 106 electric GSE. Figure 7 depicts the GSE currently in use at the Phoenix Sky Harbor International Airport by the hub airlines over a period of five years. As the model illustrates, the ICE GSE costs $21,072,170, while the eGSE costs $4,896,750. On average, the expense for one ICE GSE over five years is $56,952, while that for one eGSE is $46,196. This is approximately 18.8% less expensive to operate an eGSE versus an ICE GSE during a five-year period.

Figure 7

Example of GSE currently used by Sky Harbor Airport's Hub Airlines – 5 years

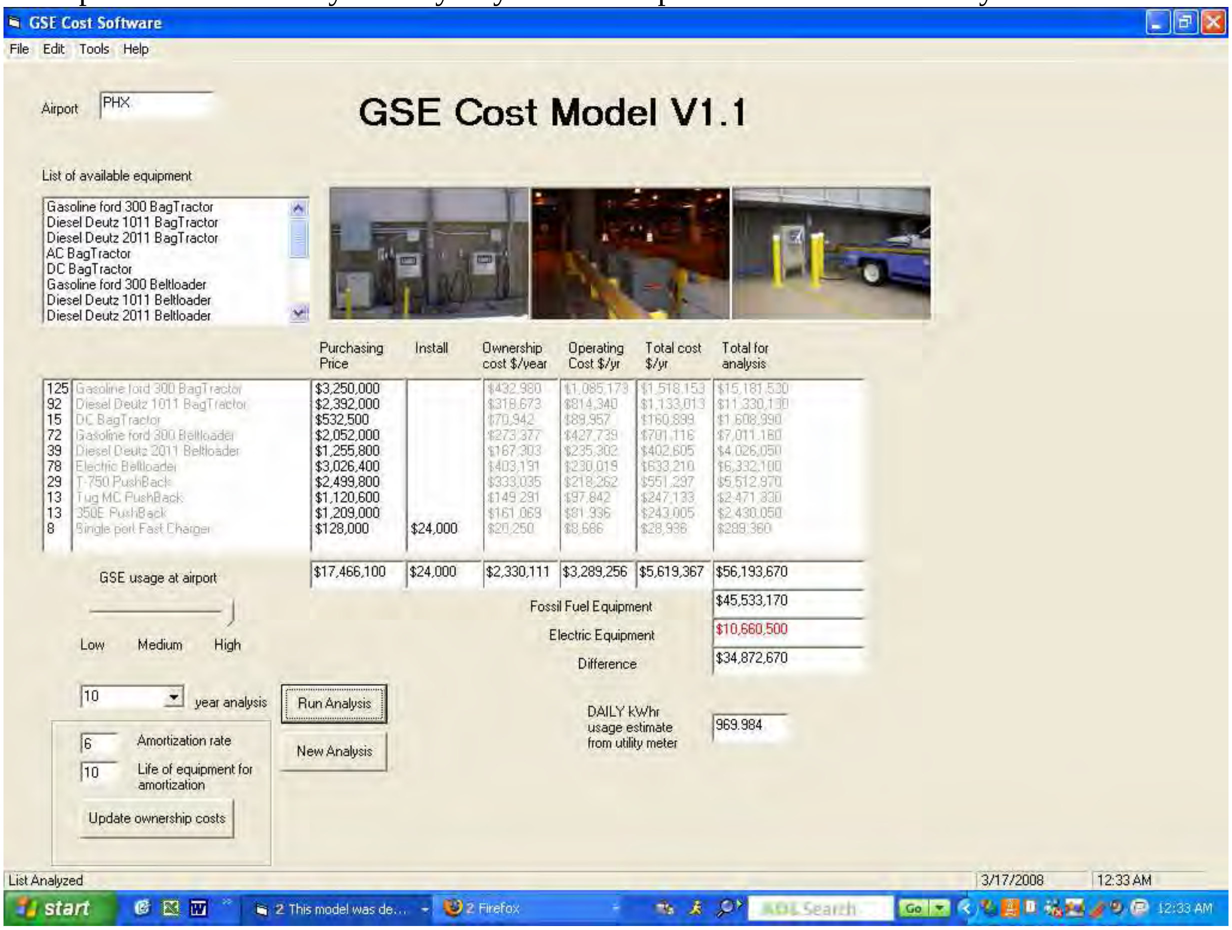


Source: Calculated using GSE Cost Model V1.1 – Downloadable from http://avt.inl.gov/groundsupport.shtml

Figure 8 illustrates the increasing rate of cost savings realized by electric GSE over a doubled period of time – from five years to ten. Assuming the exact same types and quantity of GSE, the difference in cost between ICE and electric GSE over the ten-year period is $35,024,670, which is more than twice the difference under the five-year scenario. In the ten-year scenario, the average cost for one ICE GSE is $123,063 while the average cost for one eGSE is $99,137. Therefore, it is approximately 19.4% less expensive to operate an eGSE than an ICE GSE during a 10-year period. Clearly, as time increases, the rate of cost savings due to electric GSE also increases.

Figure 8

Example of GSE currently used by Sky Harbor Airport's Hub Airlines – 10 years



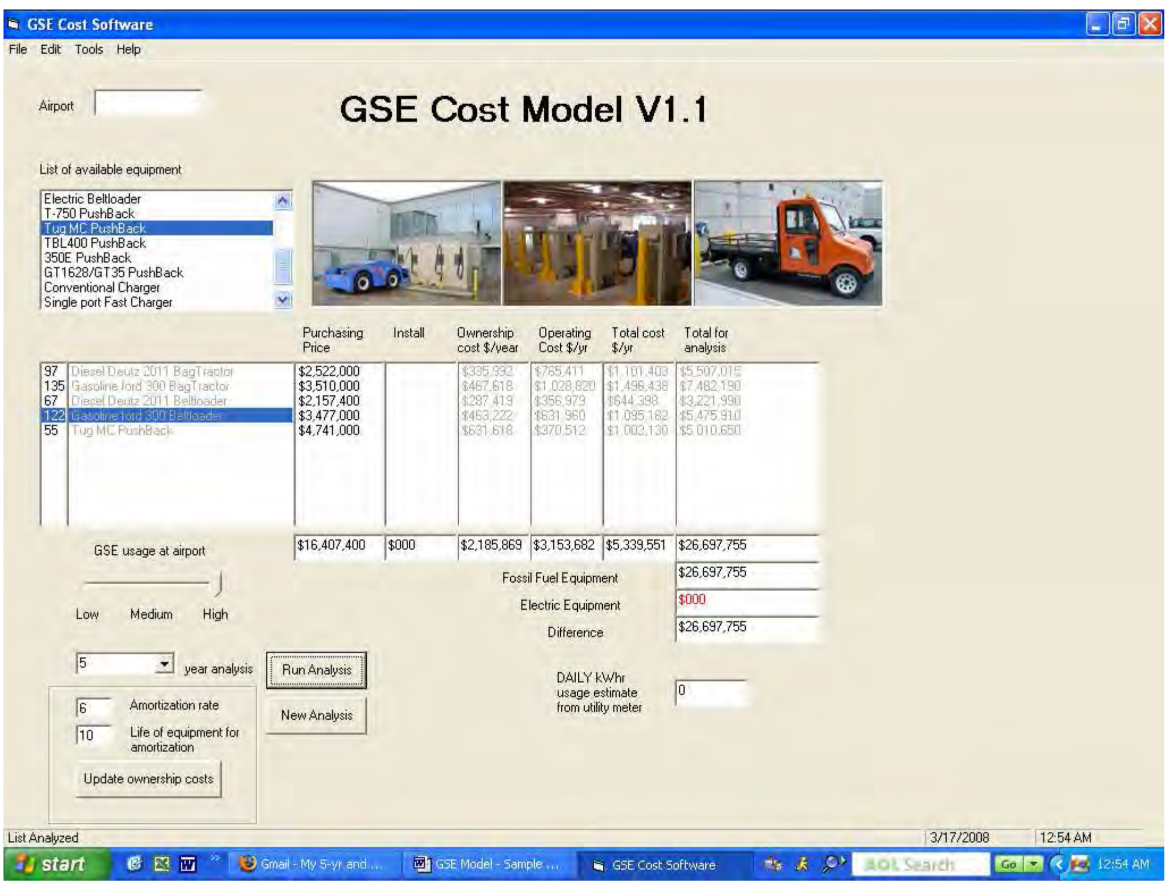
Source: Calculated using GSE Cost Model V1.1 – Downloadable from http://avt.inl.gov/groundsupport.shtml

Electric belt loaders are the type of GSE that creates the quickest net profit. In fact, the investment for an electric belt loader is paid off in approximately four years. Therefore, belt loaders are worth-while to convert because, although they have the lowest emissions, they pay off monetarily much sooner. Electric baggage tractors take about 12.5 years to be worth their cost, but since they produce much more CO emissions, the benefit of greatly reduced emissions justifies the investment. The GSE with the slowest payoff of about 19 years is the pushback tug, however, due to the significant emission savings, which is higher than belt loaders, it is logical to convert them as well (Morrow 2007).

To further illustrate the long-term savings derived from the use of electric GSE instead of ICE GSE, the team ran a hypothetical scenario in which *all* of the GSE currently used by the Sky Harbor Airport's hub airlines were of traditional fuel engines, and a second scenario in which *all* were electric. As depicted in Figure 9, the cost of operating only ICE GSE over a five-year period totals $26,697,755.

Figure 9

All ICE GSE Scenario



Source: Calculated using GSE Cost Model V1.1 – Downloadable from http://avt.inl.gov/groundsupport.shtml

However, if all the GSE were electric, the cost to operate them for five years would be $23,760,265, as shown in Figure 10. Using all electric GSE would result in savings of over $2.9 million dollars.

Figure 10

All eGSE Scenario

Source: Calculated using GSE Cost Model V1.1 – Downloadable from http://avt.inl.gov/groundsupport.shtml

As research using the GSE Cost Model V1.1 indicates there are significant monetary benefits that outweigh the costs associated with transitioning to electric GSE. This design project's additional aspect of harnessing solar energy to power the GSE takes the overall benefit of the project one step further. The solar system realizes a neutral cost-benefit analysis in the monetary sense. However, though the system does not produce a direct financial net gain, it alleviates the demand from the airport's electric grid, which the eGSE would create. If the airport owns the property on which the solar panels are installed, such as in the case of Phoenix Sky Harbor, there will not be any additional cost for the leasing or purchase of the land. In addition, the proven benefits of solar energy in terms of reduced emissions are highly significant. As Table 6 and its associated graph illustrate below, there is a direct correlation between the size of the solar panel system and the volume of reduced CO2 emissions. Clearly, the benefit to the solar aspect of this project is beyond financial measure by contributing to the critical goal of emission reductions.

Table 6

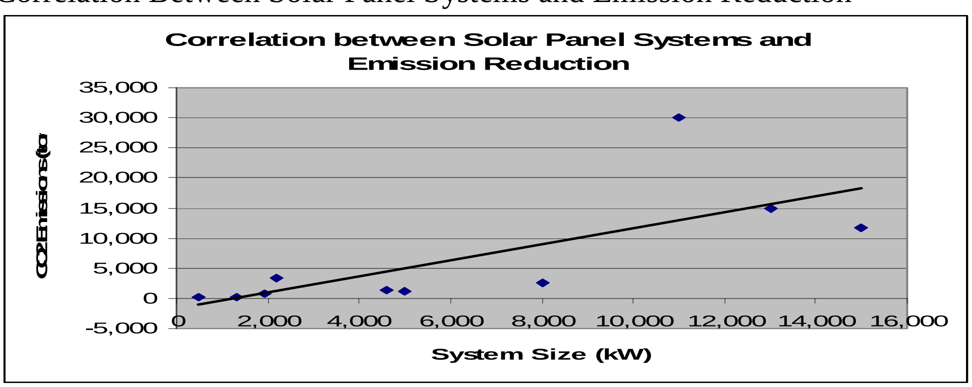
Solar Panel Systems and Emission Reductions

Organization	**System Size (kW)**	**Annual Reduction of CO2 Emissions (tons)**
Nellis Air Force Base, USA	15,000	11,640
Bavaria Solarpark, Germany	13,000	15,000
Serpa Power Plant, Portugal	11,000	30,000
Macy's, USA	8,000	2,532
Target Stores, USA	5,000	1,100
Wal-Mart, USA	4,600	1,456
Munkyeong Sp Solar Mt, Korea	2,200	3,300
Johnson & Johnson, USA	1,920	835
Tiffany & Co., USA	1,336	249
Microsoft, USA	480	151

Source: SunPower Corporation (2008)

Figure 11

Correlation Between Solar Panel Systems and Emission Reduction



Appendix A – List of Contacts

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Appendix B – Description of the University

Embry-Riddle Aeronautical University

Embry-Riddle Aeronautical University is the world's oldest, largest, and most prestigious university specializing in aviation and aerospace. It is the only accredited, aviation-oriented university in the world. Embry-Riddle was founded December 17, 1925, by barnstormer John Paul Riddle and entrepreneur T. Higbee Embry, exactly 22 years after the Wright brothers' historic flight.

Embry-Riddle is an independent, nonsectarian, not-for-profit coeducational university serving culturally diverse students seeking careers in aviation, aerospace, business, engineering, and related fields. Embry-Riddle Aeronautical University is accredited by the Commission on Colleges of the Southern Association of Colleges and Schools to award degrees at the associate, bachelor, and master levels. Combined annual enrollment for all campuses is more than 34,000.

Embry-Riddle has residential campuses in Daytona Beach, Florida, and Prescott, Arizona, as well as a Worldwide Campus dedicated to providing educational opportunities to working adults worldwide. The Worldwide Campus provides educational opportunities to off-campus students at more than 130 centers throughout the United States and Europe. In addition, degree programs can be pursued anywhere in the world through Web-based online learning.

The University offers more than 30 degree programs. These include **undergraduate programs** in aeronautical science; aerospace engineering; aviation business administration; aviation environmental science; aviation maintenance science; computer science; and more. **Graduate programs** are offered in aeronautics, aerospace engineering, business administration, human factors and systems, safety science, software engineering, and space science.

Appendix C – Description of Non-University Partners Involved in the Project

The City of Phoenix Aviation Department operates Phoenix Sky Harbor International Airport, Phoenix Deer Valley Airport, and Phoenix Goodyear Airport. The Aviation Department has a long-standing partnership with Embry-Riddle Aeronautical University to provide enhanced educational opportunities for its employees.

In 2001, Embry-Riddle Aeronautical University and the Aviation Department teamed up to develop a program designed to help employees obtain a baseline education about the aviation industry. The program, known as the Management Development Program, is made up of six courses from Embry-Riddle, which are divided into two levels. Another important component is a series of field trips designed to provide an inside look at the many aspects of operating an airport. Students who complete both Level I and Level II earn the undergraduate Airport Management Certificate of Completion from Embry-Riddle.

The students participating in this project are Aviation Department employees who are enrolled in Level II of the Management Development Program. The Aviation Department's management team wholeheartedly supports our participation in the project.

The Aviation Department has also been involved in this project as a resource for subject matter experts and a place to examine existing conditions at an airport. Throughout our research, we consulted with our colleagues, supervisors, and management team to better understand the problem and begin to identify solutions. We evaluated how proposed solutions could be implemented, what the obstacles and challenges might be, and how the solutions could have a positive impact at our airport. The input of Aviation Department staff, and the opportunity to study the problem as it directly impacts our airport, was invaluable to us in the development of this project.

Appendix E – Evaluation of The Educational Experience

The Student Team

1. Did the FAA Airport Design Competition provide a meaningful learning experience for you? Why or why not?

During the course of the project, the team members gained valuable experience in working as a team with others from all areas of the airport community. Knowledge gained included the advantages of utilizing individuals' skills and strengths to achieve a goal. Team members learned the benefit of looking at the proposal from the viewpoints of airlines, ground service providers and design and construction project management staff in order to understand what would be required of all parties in terms of equipment and infrastructure investment. Finally, the team learned a great deal about the advantages and disadvantages of several types of renewable energy sources and their potential impacts on the environment and air quality.

2. What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?

The greatest challenge to the team was a time constraint, because we were given a schedule of less than eight weeks to develop and finalize the proposal. We overcame this constraint with frequent communication on all issues with all team members, as well as ongoing communication with the course instructor. Another challenge involved narrowing the parameters of the proposal to fit within the scope as well as the schedule of the competition. The team dealt with this by quickly deciding on the competition category on which to work and the equipment sector whose conversion to a “greener” energy source would result in a significant savings in fuel cost and reduction in air pollutants at any commercial airport.

Yet another challenge faced by the team was understanding the technical aspects of the option we chose. Team members consulted various data sources and industry experts, some of whom provided us with detailed schematics to explain the requirements and operation of a solar energy system.

3. Describe the process you or your team used for developing your hypothesis.

The team reached consensus on the competition category to pursue, and then decided to focus on Ground Support Equipment because we discovered that conversion of this equipment to a “greener” energy source appears to deliver the greatest environmental benefit at a reasonable cost for all involved parties. Each team member was then assigned the exploration of one of several options for alternative fuel sources. The team as a whole reviewed the research results and selected the option least costly to the airport, the airlines, the service providers and the environment.

4. Was participation by industry appropriate, meaningful and useful? Why or why not?

As employees of a municipal commercial airport, the team members had access to many industry experts including other team members and coworkers. The team also was able to consult with airlines and airport management as well as professional and governmental organizations such as Airports Council International – North America, the Department of

Transportation and the FAA. The participation by industry members was essential to the team's development of the proposal.

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

The team members learned a great deal about alternative energy sources. As our airport continues to develop "greener" measures, we will have a solid basis of understanding of the various types of sources, their advantages and disadvantages, their requirements for infrastructure modifications, and their costs and benefits. We will all be able to contribute what we have learned to future airport projects. In addition, the diversity of the team members taught us much about the dynamics involved in working as a team.

The Faculty

1. Describe the value of the educational experience for your students participating in this Competition submission.

This educational experience provided an excellent opportunity for students to conduct individual as well as collaborative research to solve a challenging issue of importance to all airports. The learning, teamwork and spirit displayed by this student team was outstanding.

2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?

Yes, the learning experience was exceptional.

3. What challenges did the students face and overcome?

A number of challenges are discussed by the students in their evaluation. I have reviewed them and concur.

4. Would you use this Competition as an educational vehicle in the future? Why or why not?

Yes. In my opinion the Competition provides an outstanding educational opportunity and I am looking forward to next year's Competition.

5. Are there changes to the Competition that you would suggest for future years?

None.

Appendix F

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