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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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

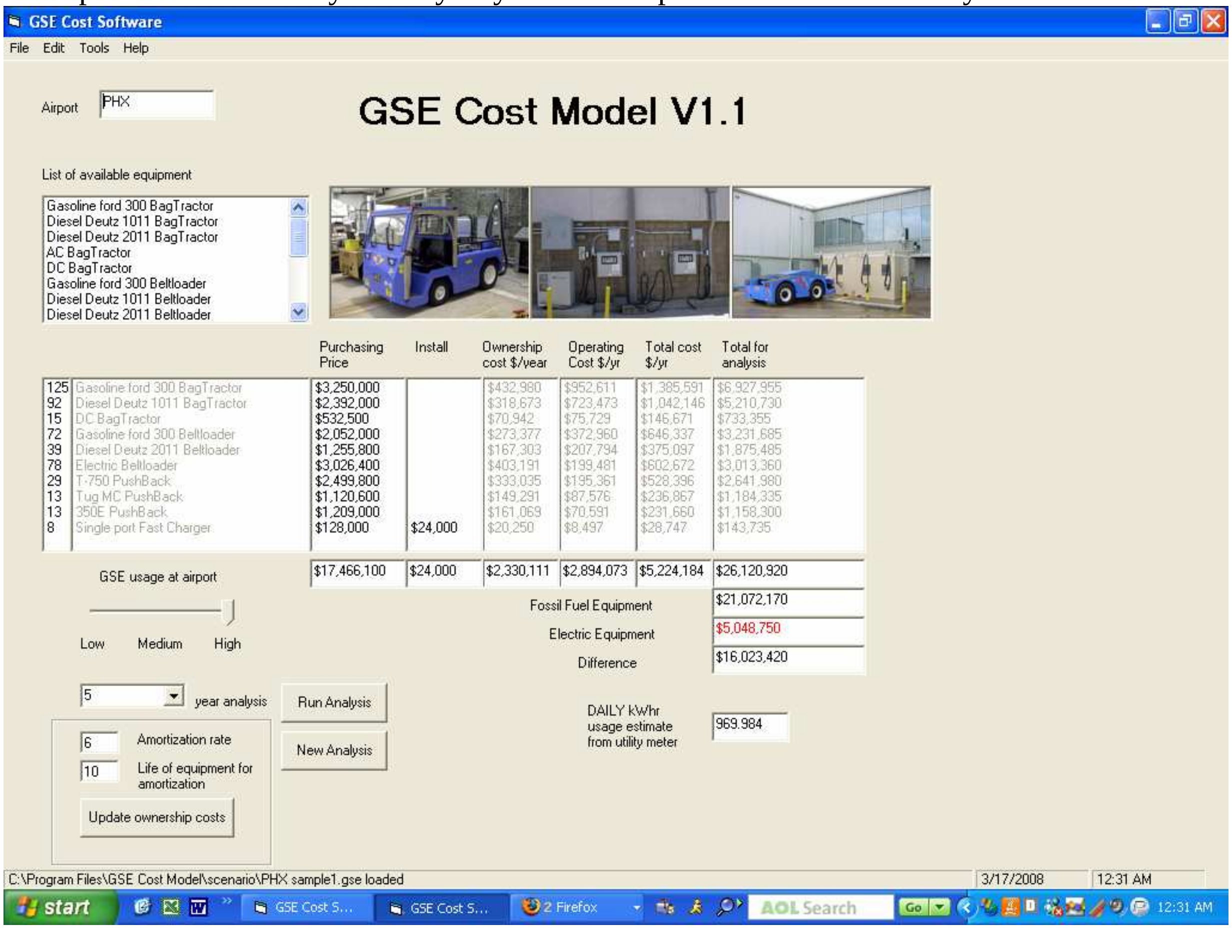
GSE Cost Model V1.1 High Level Variables

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

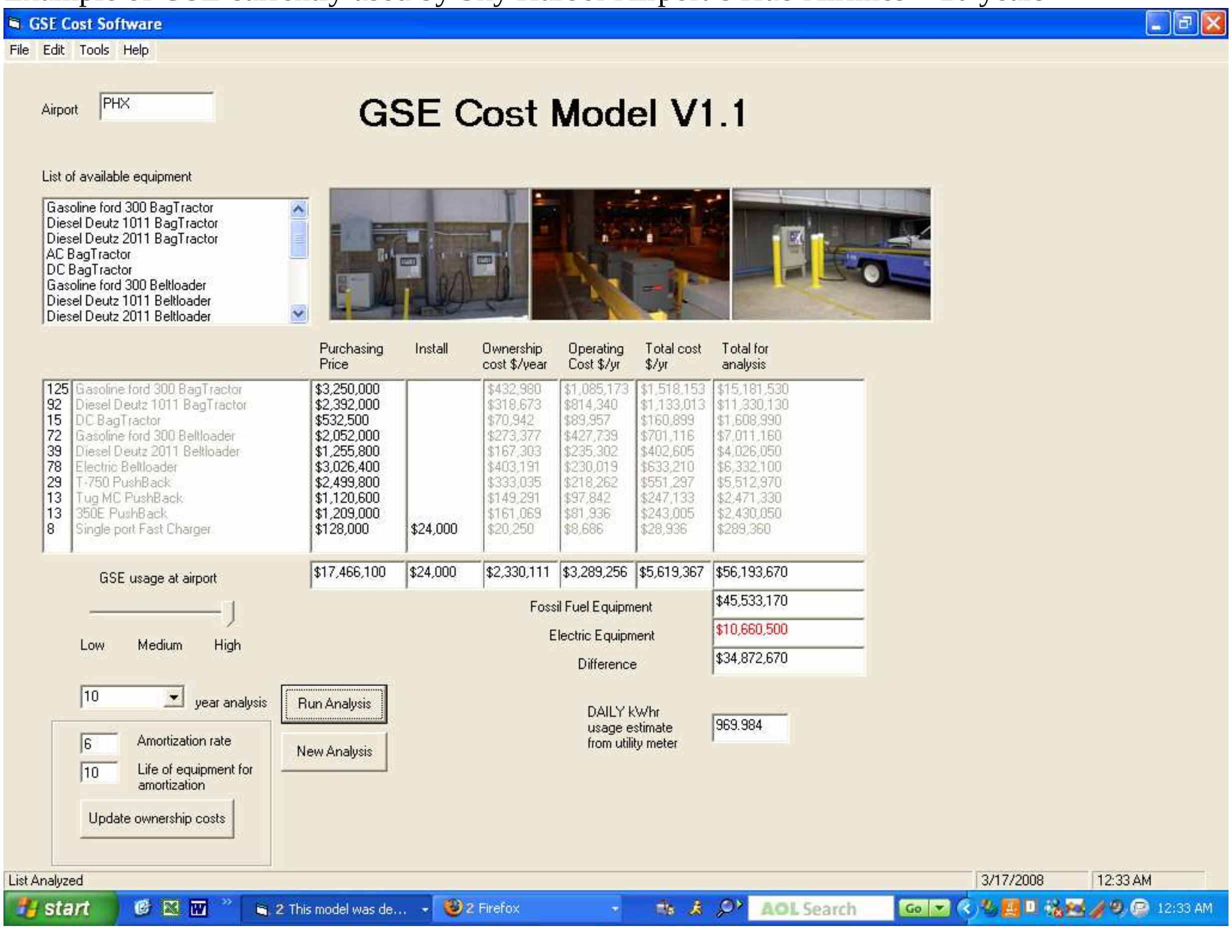


Source: Calculated using GSE Cost Model V1.1 – Downloadable from http://avt.inl.gov/groundsupport.shtml

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

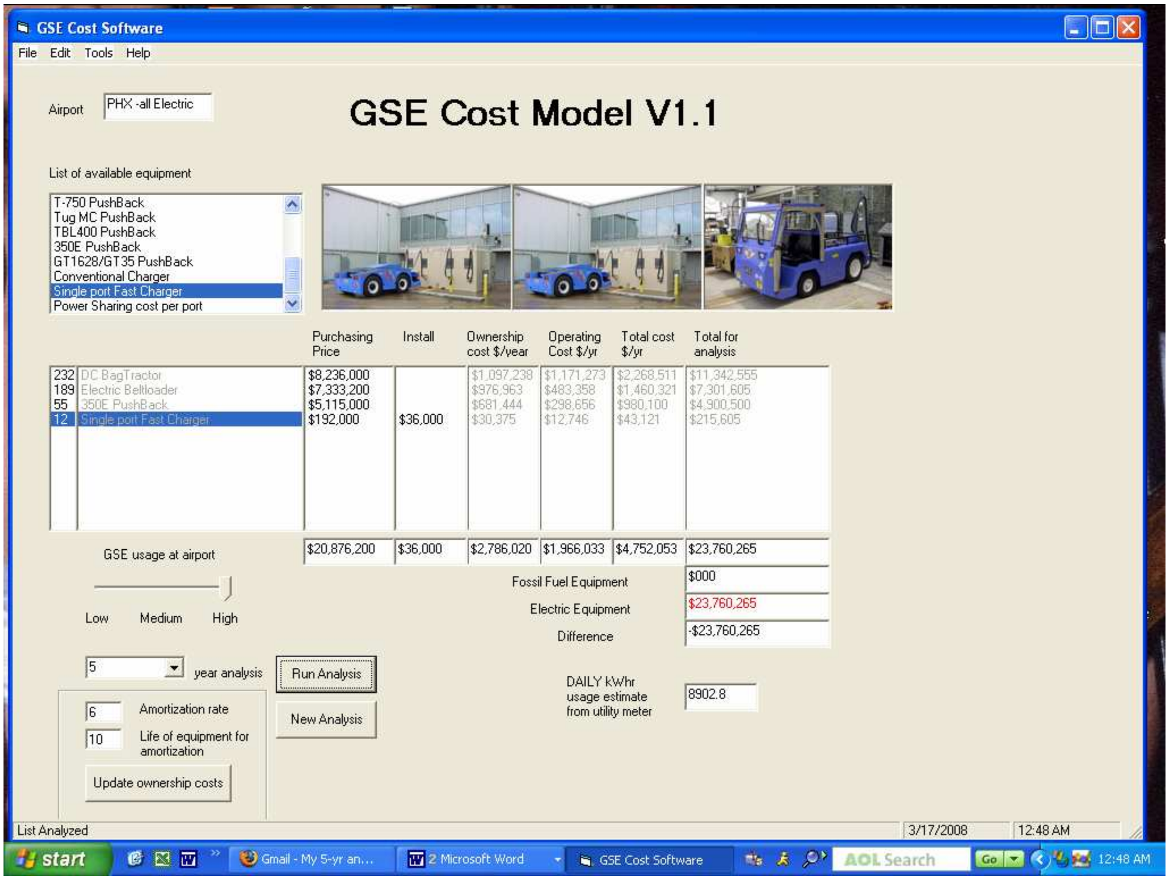
All ICE GSE Scenario

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

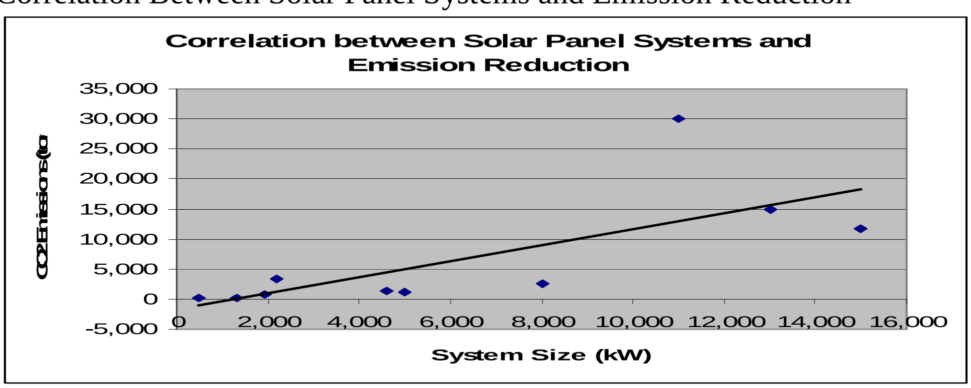
Solar Panel Systems and Emission Reductions

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

Faculty Advisor

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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.

FAA University Design Competition
Design Proposal Submission Form (Appendix D)

Note: This form should be included as Appendix D in the submitted PDF of the design package. The original with signatures must be sent along with the required print copy of the proposal.

University Embry-Riddle Aeronautical University

List other partnering universities if appropriate

Proposal Developed by: ☐ Individual Student ☒ Student Team

If Individual Student

Name

Permanent Mailing Address

Permanent Phone Number Email

If Student Team:

Student Team Lead Cynthia Cooke

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Permanent Phone Number (602) 273-4396 Email cynthia.cooke@phoenix.gov

Competition Design Challenge Addressed:

Airport Environmental Interactions

I certify that I served as the Faculty Advisor for the work presented in this Design Proposal and that the work was done by the student participant(s).

Signed [signature] *Date* 4/10/08

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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

References

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