



U.S. Department of Energy  
Energy Efficiency and Renewable Energy

INL/EXT-07-12270

***U.S. Department of Energy***  
**FreedomCAR & Vehicle Technologies Program**  
**Advanced Vehicle Testing Activity**

# **Cost Benefit Analysis Modeling Tool for Electric vs. ICE Airport Ground Support Equipment — Development and Results**

**Kevin Morrow  
Dimitri Hochard  
James Francfort**

**February 2007**

The Idaho National Laboratory is a U.S. Department of Energy National Laboratory  
Operated by Battelle Energy Alliance

# **Cost Benefit Analysis Modeling Tool for Electric vs. ICE Airport Ground Support Equipment — Development and Results**

**Kevin Morrow<sup>1</sup>  
Dimitri Hochard<sup>1</sup>  
James Francfort<sup>2</sup>**

**February 2007**

**Idaho National Laboratory  
Transportation Technology Department  
Idaho Falls, Idaho 83415**

**Prepared for the  
U.S. Department of Energy  
Assistant Secretary for Energy Efficiency and Renewable Energy  
Under DOE Idaho Operations Office  
Contract DE-AC07-05ID14517**

---

<sup>1</sup> Electric Transportation Engineering Corporation

<sup>2</sup> Idaho National Laboratory

### ***Disclaimers***

This document highlights work sponsored by agencies of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any of its employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

This report was prepared by the Electric Transportation Engineering Corporation in the course of performing work sponsored by the U.S. Department of Energy's Advanced Vehicle Testing Activity, Electric Power Research Institute, Southern California Edison Company, Sacramento Municipal Utility District, Southwest Airlines, Georgia Power Company, and Delta Airlines ("Sponsors"). The opinions expressed in this report do not necessarily reflect those of the Sponsors, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, the Sponsors and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed and/or referred to in this report. The Sponsors and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, or referred to in this report.

## **ABSTRACT**

This report documents efforts to develop a computer tool for modeling the economic payback for comparative airport ground support equipment (GSE) that are propelled by either electric motors or gasoline and diesel engines. The types of GSE modeled are pushback tractors, baggage tractors, and belt loaders. The GSE modeling tool includes an emissions module that estimates the amount of tailpipe emissions saved by replacing internal combustion engine GSE with electric GSE. This report contains modeling assumptions, methodology, a user's manual, and modeling results. The model was developed based on the operations of two airlines at four United States airports.

# TABLE OF CONTENTS

1.	EXECUTIVE SUMMARY .....	1
1.1	Results—Financial Analysis .....	1
1.2	Results—Emissions.....	3
1.3	Conclusions .....	4
2.	STUDY INTRODUCTION.....	5
3.	MODEL DEVELOPMENT .....	6
3.1	Task 1: Development of High-Level Input Variables for the Ground Support Equipment Cost-Benefit Model .....	6
3.2	Task 2: Development of Logic Data Tree Structures for Each High-Level Input Variable ..	7
3.3	Task 3: Incorporation of Participant Comments on Tasks 1 and 2 Deliverables and Development of the Model Code .....	7
4.	AIRPORT ANALYSIS .....	12
4.1	Airport “A” .....	12
4.1.1	Emissions .....	17
4.2	Airport “B” .....	17
4.2.1	Emissions .....	21
4.3	Airport “C” .....	21
4.3.1	Emissions .....	27
4.4	Airport “D” .....	27
4.4.1	Emissions .....	31
5.	SENSITIVITY ANALYSIS .....	32
6.	COST-REDUCTION STRATEGIES.....	35
6.1	Ground Support Equipment Capital Cost-Reduction Strategies .....	35
6.2	Battery Replacement .....	35
6.3	Charging Infrastructure .....	35
6.3.1	Capital Purchase of Chargers .....	35
6.3.2	Electrical Supply and Installation .....	36
6.3.3	Operating and Maintenance Expenses (Including Electricity Costs) .....	36
7.	ASSUMPTIONS .....	37
8.	CONCLUSIONS .....	38
	Appendix A - Airport “A” Input Data and Results Summary .....	A-1
	Appendix B - Airport “B” Input Data and Results Summary .....	B-1
	Appendix C - Airport “C” Input Data and Results Summary .....	C-1
	Appendix D - Airport “D” Input Data and Results Summary .....	D-1
	Appendix E - High-Level Data Trees .....	E-1
	Attachment A - Ground Support Equipment Cost Model Operating Guide .....	1

## FIGURES

1-1. Airport “A” sensitivity analysis for all three ground support equipment types combined .....	2
1-2. Airport “A” sensitivity analysis for baggage tractors.....	2
1-3. Airport “A” sensitivity analysis for belt loaders.....	3
1-4. Airport “A” sensitivity analysis for pushback tractors .....	3
3-1. High-level data chart .....	6
3-2. Ground support equipment cost model main page .....	8
3-3. Fuel usages, cost, and escalator .....	8
3-4. Emissions results .....	9
3-5. Unit operating cost .....	10
3-6. Vehicle edit table.....	10
3-7. Charger edit table .....	11
4-1. Results of Airport “A” main screen.....	13
4-2. Airport “A” fuel and labor parameters .....	13
4-3. Airport “A” unit operating costs.....	14
4-4. Airport “A” breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for all three types of ground support equipment .....	14
4-5. Airport “A” sensitivity analysis for all three ground support equipment types.....	15
4-6. Airport “A” sensitivity analysis for baggage tractors.....	16
4-7. Airport “A” sensitivity analysis for pushback tractors .....	16
4-8. Airport “A” sensitivity analysis for belt loaders.....	17
4-9. Results of Airport “B” main screen.....	18
4-10. Airport “B” fuel and labor parameters .....	19
4-11. Airport “B” unit operating costs.....	19
4-12. Airport “B” breakeven point for electric ground support equipment versus internal combustion engine ground support equipment .....	20
4-13. Airport “B” sensitivity analysis for baggage tractors years 0 through 3 .....	20
4-14. Airport “B” sensitivity analysis for baggage tractors years 3 through 20 .....	21
4-15. Results of Airport “C” main screen.....	23
4-16. Airport “C” fuel and labor parameters .....	23
4-17. Airport “C” unit operating costs.....	24
4-18. Airport “C” breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for all ground support equipment.....	24
4-19. Airport “C” sensitivity analysis for all three ground support equipment types.....	25
4-20. Airport “C” sensitivity analysis for baggage tractors .....	25
4-21. Airport “C” sensitivity analysis for belt loaders.....	26
4-22. Airport “C” sensitivity analysis for pushback tractors .....	26
4-23. Results of Airport “D” main screen.....	28
4-24. Airport “D” fuel and labor parameters .....	28
4-25. Airport “D” unit operating costs.....	29

4-26. Airport “D” breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for the bag tractor and belt loader .....	29
4-27. Airport “D” sensitivity analysis for baggage tractor and belt loader.....	30
4-28. Airport “D” sensitivity analysis for baggage tractor .....	30
4-29. Airport “D” sensitivity analysis for belt loader .....	31
5-1. Electricity escalation rate versus years .....	32
5-2. Energy escalation rates versus years .....	33
5-3. Electric ground support equipment capital cost subsidy versus years.....	33
5-4. Service labor rates versus years.....	34

## TABLES

1-1. Airport “A” emissions savings in tons per year.....	4
4-1. Airport “A” electric ground support equipment included in study.....	12
4-2. Airport “A” electric ground support equipment battery chargers.....	12
4-3. Airport “A” emissions savings in tons per year.....	17
4-4. Airport “B” ground support equipment included in the study.....	18
4-5. Airport “B” electric ground support equipment battery chargers.....	18
4-6. Airport “B” emissions savings in tons per year.....	21
4-7. Airport “C” ground support equipment included in the study .....	22
4-8. Airport “C” electric ground support equipment battery chargers.....	22
4-9. Airport “C” emissions savings in tons per year.....	27
4-10. Airport “D” ground support equipment included in the study .....	27
4-11. Airport “D” electric ground support equipment battery chargers.....	27
4-12. Airport “D” emissions savings in tons per year.....	31

# 1. EXECUTIVE SUMMARY

Airlines are going through a very challenging period; they are faced with many cost pressures, compliance issues, and operational challenges caused by competition and growth in the industry. Ground support equipment (GSE) operations are an area impacted by these challenges, including the rising cost of fuel and pressure to reduce air pollutants in many of the cities airlines operate in. This is especially true in Environmental Protection Agency (EPA)-designated non-attainment cities. Many airlines, power utilities, and other GSE industry stakeholders are examining the cost-effectiveness of utilizing electric ground support equipment (eGSE) versus gasoline and diesel-fueled internal combustion engine (ICE) alternatives.

This study evaluates the costs associated with operating three main types of GSE—baggage tractors, belt loaders, and pushback tractors. A cost model was developed as part of this project to assist airlines and other stakeholders in future evaluations of deploying GSE. The approach included visiting four airports (two west coast, one mid-west, and one in the northeast) and working directly with two airline study participants to obtain available data on every aspect of GSE costs. These costs include capital costs, operating and maintenance (O&M) costs, and any associated infrastructure costs. Where costs were undocumented, or otherwise unavailable, methodologies were established to collect or determine the undocumented data and are described herein.

## 1.1 Results—Financial Analysis

Sensitivity analyses were performed to understand and identify the significant cost drivers that would help airline executives make informed GSE decisions when looking solely at economics. Fuel costs for ICE GSE were found to be the single largest variable impacting costs. Therefore, airports with higher fuel-use amounts typically resulted in a faster return on investment when purchasing eGSE over the lower fuel-use airports. Figure 1-1 shows Airport “A” eGSE payback results in years for fossil fuel escalation rates from 0 to 20% per annum. In this case, the model was run for a period of 20 years. This airport was designated a “medium-use” airport based on a review of the tarmac terrain, distances required of the GSE to travel, and number of daily flights at the airport. The analysis for Airport “A” assumed that a mix of 40 ICE GSE vehicles were replaced with eGSE, including 17 baggage tractors, 16 belt loaders, and 7 pushback tractors. The charger system is defined as a fast-charge, multi-port type system, providing one port for every two vehicles. For example, when looking at Figure 1-1 and assuming an average annual 9% increase in fuel costs, eGSE has a payback within approximately 5 years.

Again referring to Figure 1-1, if fuel cost increases remain relatively low with a 4% average annual increase, the payback for eGSE is approximately 13 years. Figures 1-2, 1-3, and 1-4 show the sensitivities of each individual piece of equipment with all other parameters treated the same as before. Electric baggage tractors have by far the fastest payback of the three types of GSE vehicles analyzed in this study, followed by belt loaders, and lastly pushback tractors. Not surprisingly, baggage tractors are also the heaviest fuel users of the three GSE-type vehicles.

Because pushback tractors have a higher initial capital cost and lower fuel use, the pushback tractors have a longer payback than the baggage tractors and belt loaders. If capital costs to the user could be significantly lowered through grant cost-share programs, or in the case of vehicle conversions of gas or diesel to electric, payback can be much sooner, making the electric pushback tractors also attractive.



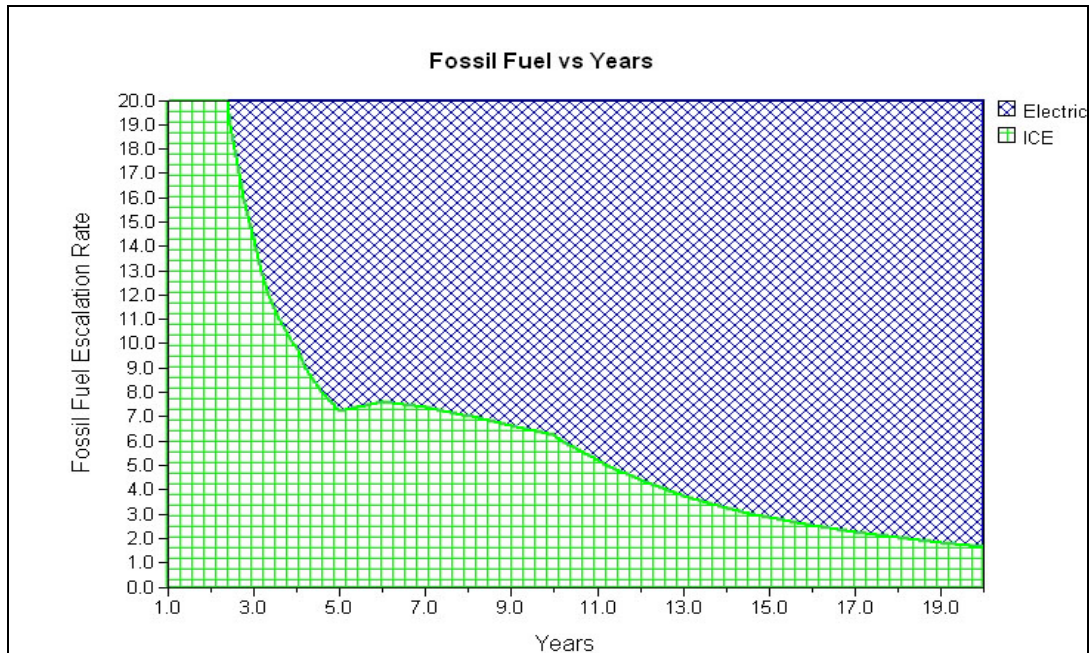


Figure 1-1. Airport “A” sensitivity analysis for all three ground support equipment types combined.

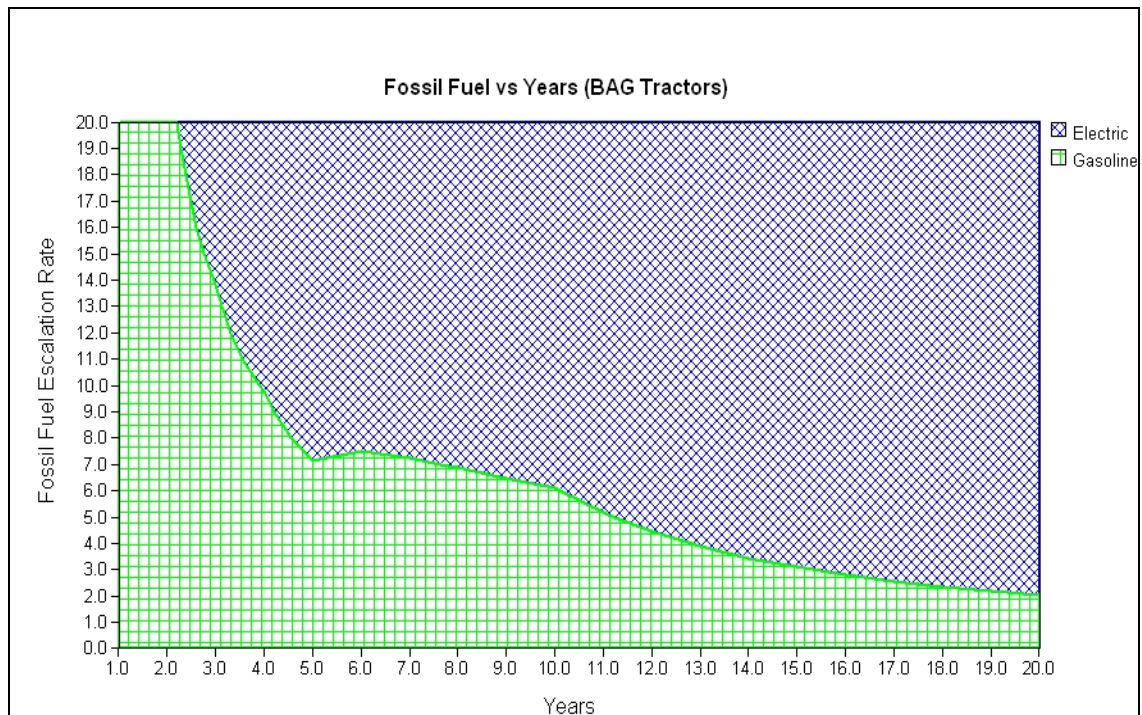


Figure 1-2. Airport “A” sensitivity analysis for baggage tractors.

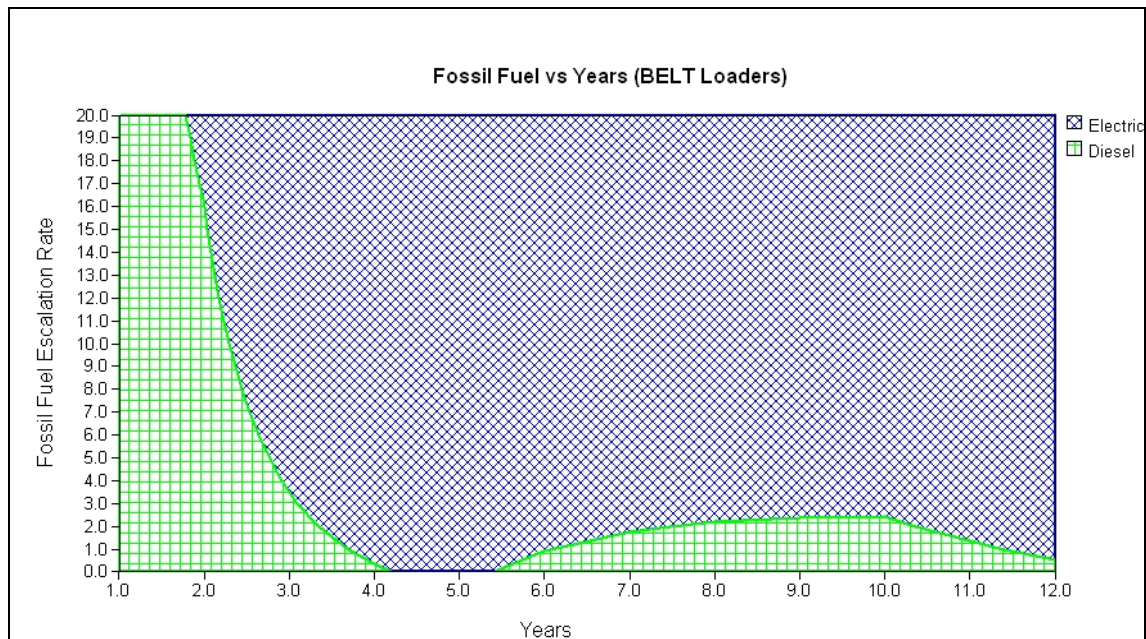


Figure 1-3. Airport “A” sensitivity analysis for belt loaders.

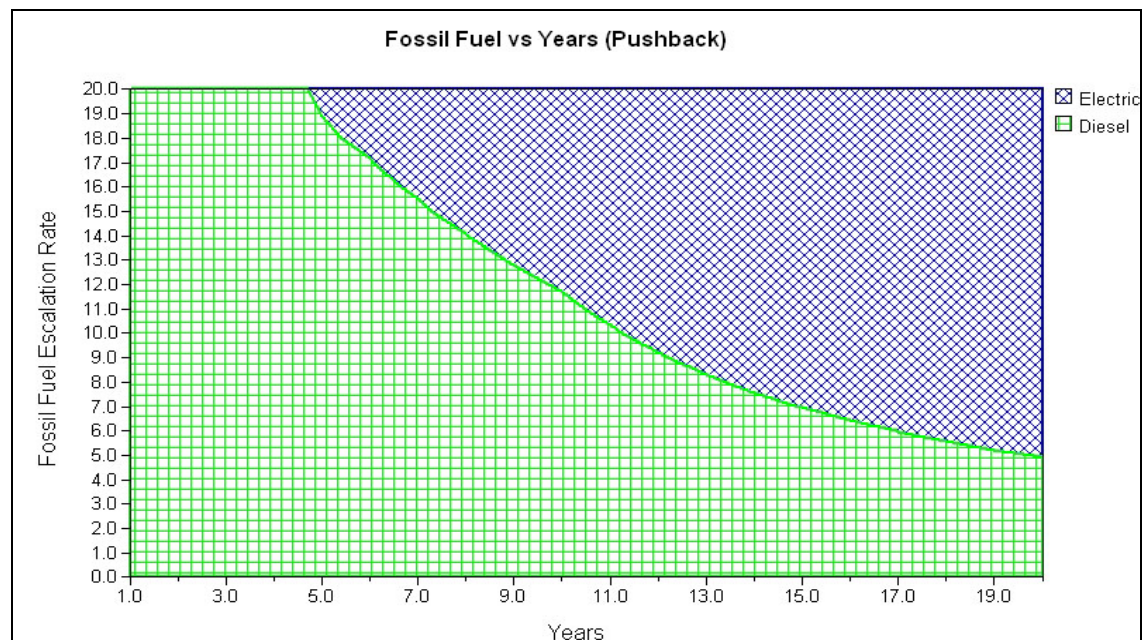


Figure 1-4. Airport “A” sensitivity analysis for pushback tractors.

## 1.2 Results—Emissions

The GSE modeling tool includes an emissions module that estimates the amount of tailpipe emissions saved by replacing ICE GSE with eGSE. Table 1-1 shows the emissions results for Airport “A.” The base emission rates were provided the Federal Aviation Administration (FAA) Emissions and Dispersion Model System (EDMS) Emissions Model Version 4.12, which provides emissions rates for each type of GSE.

Table 1-1. Airport “A” emissions savings in tons per year.

Quality	Description	CO	HC	NOx	PM
17	Baggage Tractors	700.308	25.560	14.551	0.137
16	Belt Loaders	2.802	0.675	5.686	0.640
7	Pushback Tractors	1.751	0.345	4.441	0.338
Totals		704.861	26.58	24.678	1.115
CO = carbon monoxide, HC = total hydrocarbons, NOx = oxides of nitrogen, PM = particulate matter					

## 1.3 Conclusions

The GSE cost-benefit analysis study provides airline and industry stakeholders the background, strategies, and tools needed to evaluate whether eGSE would be a cost-effective approach for a particular application. Additionally, emissions results and cost-saving strategies are provided in the analysis.

Generally, electric baggage tractors and belt loaders are a cost-effective replacement, with a reasonable payback period, over similar performance ICE GSE for most applications. At this time, pushback tractors have a much longer payback period mostly because of the premium capital cost for the eGSE and low fuel-use requirements. When taking into consideration potential cost sharing, conversions of existing equipment, and other variables, payback for all three types of GSE can be shortened, and even pushback tractors can be a very cost-effective option.

## **2. STUDY INTRODUCTION**

The purpose of this study is to better understand the costs of deploying eGSE versus ICE GSE (that uses gasoline or diesel) and, based on the findings, to provide strategies to make eGSE use more cost effective. The approach of this study was to evaluate four different airports in the continental United States—two on the west coast, one in the mid-west, and one in the northeast area. Based on data collected from these locations, a model was developed as a tool for this project and for use by the general airline industry, electric utilities, and other interested stakeholders.

In order to complete the analysis and develop the model tool, data was collected at each location through onsite evaluation, interviews, and review of existing data files. Where data was unavailable, strategies were developed to determine or estimate missing data values and incorporate them into the model.

The four airport scenario details and modeling results comparing eGSE to gas or diesel GSE that would be replaced is reported in this document. Additional sensitivity analyses were performed to determine which cost parameters had the most influence on the overall costs, especially parameters with high elasticity, such as fuel costs.

This report was prepared by the Electric Transportation Engineering Corporation in the course of performing work sponsored by the U.S. Department of Energy's Advanced Vehicle Testing Activity, Electric Power Research Institute, Southern California Edison Company, Sacramento Municipal Utility District, Southwest Airlines, Georgia Power Company, and Delta Airlines. The Advanced Vehicle Testing Activity is part of U.S. Department of Energy's FreedomCAR and Vehicle Technologies Program. The Idaho National Laboratory conducts these and other Advanced Vehicle Testing Activity testing activities for U.S. Department of Energy's FreedomCAR and Vehicle Technologies Program.



### 3. MODEL DEVELOPMENT

The model development was divided into three specific tasks as follows:

- Task 1: Development of High-Level Input Variables for the GSE Cost-Benefit Model
- Task 2: Development of Logic Data Tree Structures for Each High-Level Input Variable
- Task 3: Incorporation of Participant Comments on Tasks 1 and 2 Deliverables and Development of Model Code.

#### 3.1 Task 1: Development of High-Level Input Variables for the Ground Support Equipment Cost-Benefit Model

This task developed the first draft of the GSE Cost Model, outlining the high-level input variables necessary to provide a reasonable cost comparison of eGSE and ICE GSE.

The high-level data are broken into two major categories: (1) capital costs, which include the purchase price of GSE, GSE alterations required before putting GSE in service, battery chargers, and installation costs of the charging system; and (2) expenses, which include GSE maintenance, charging infrastructure maintenance, and fuel costs. A draft high-level data chart was initially provided to project team members for review; comments were incorporated and presented to the project team (see Figure 3-1).

	Electric			Fossil Fuel		
	eGSE Type I	eGSE Type II	eGSE Type III	GSE Type I	GSE Type II	GSE Type III
<b>Capital Costs</b>						
GSE Purchase Cost (Include destination costs)						
Required GSE Alterations (Mat'l and Labor)						
Battery Charger Purchase Cost						
Battery Charger Installation Costs (Engineering, Permitting and/or Fees, Construction)						
<b>Expenses</b>						
GSE Maintenance Expenses						
Battery Pack Replacement (Annualized Cost)						
Engine rebuild/replacement (Annualized Cost)						
Electric Motor Replacement						
Electric Controller Replacement						
Transaxle						
Other general maintenance (Annualized Cost)						
Charging Infrastructure Maint. Costs (Annualized Cost)						
Fuel Expenses						
Electric GSE - kWhrs/Day						
\$ / AC - kWhrs (At the Utility and/or Airport Meter)						
\$ / kW Demand (Ave. Monthly)						
Monthly Meter Fee						
Fossil Fuel - Gals/Day						
\$ / Fossil Fuel (Gallons)						

Figure 3-1. High-level data chart.

In many cases, some of the data parameters are not known, and therefore, a detailed data tree module (built in Task 2) must be relied on, allowing users to input the data required, if known, or calculate the high-level data based on previous assumptions built into the model as provided by the airline participants.

## **3.2 Task 2: Development of Logic Data Tree Structures for Each High-Level Input Variable**

This task developed the draft data tree charts that provided the logic required for development of the GSE Cost Model. Each major category provided in the high-level data chart (Figure 3-1) was broken down into enough detail that either the user could provide the data required (if available) or the model would make some assumptions (as provided by project team members) based on input from the user. The user is given multiple opportunities throughout the process to provide data that may be available to assist the model in providing the most accurate results possible.

The following is a list of each separate high-level data parameter that was developed into a detailed data tree chart required for the model:

- GSE equipment purchase price
- GSE alterations required
- Battery charging system
- Battery charger installation costs
- Charging infrastructure maintenance
- GSE maintenance
- Fuel expenses.

Where detailed data were not available, project team members were asked to complete the assumptions made. Each detailed data tree chart is provided in Appendix E.

## **3.3 Task 3: Incorporation of Participant Comments on Tasks 1 and 2 Deliverables and Development of the Model Code**

This task was built on the deliverables of Tasks 1 and 2, which defined the high-level cost model and the detailed data tree interface. The result of this task is a working GSE Cost Model that is easy to use, but has the flexibility to either use default input data or user-provided data.

The model's main page (shown in Figure 3-2) provides main input to the program, including the number and type of GSE. The user is prompted to input the number of each type of GSE in the three main categories of baggage tractors, belt loaders, and pushback tractors. A choice of either diesel or gasoline ICE vehicles is available, and with the electric, the user can select either a DC or AC drive system and specify flooded or sealed batteries.

The model can run various time periods between 1 to 5 years and 1 to 25 years. The life of the equipment is established in the main data files, which can be changed by the user, if so desired. In order to categorize airport usage, the user can select three general intensity settings: low, medium, or high. These settings impact daily fuel (i.e., gas, diesel, or electricity) consumption of the GSE. Upon selection of these items, the user can select "Run Analysis," and the model pulls up a page of fuel cost estimates and the GSE labor rate (shown in Figure 3-3). These parameters can either be changed or left as the default parameters. Upon selecting "Okay," the model calculates costs and produces the emission results table as shown in Figure 3-4 and found under the "Tools" header. The GSE emissions are generated utilizing emission rates from the EDMS Version 4.3. This produces annual estimates based on GSE usage selected for input by the user. The model also is designed to run and compare two different scenarios so the user can review different alternatives.

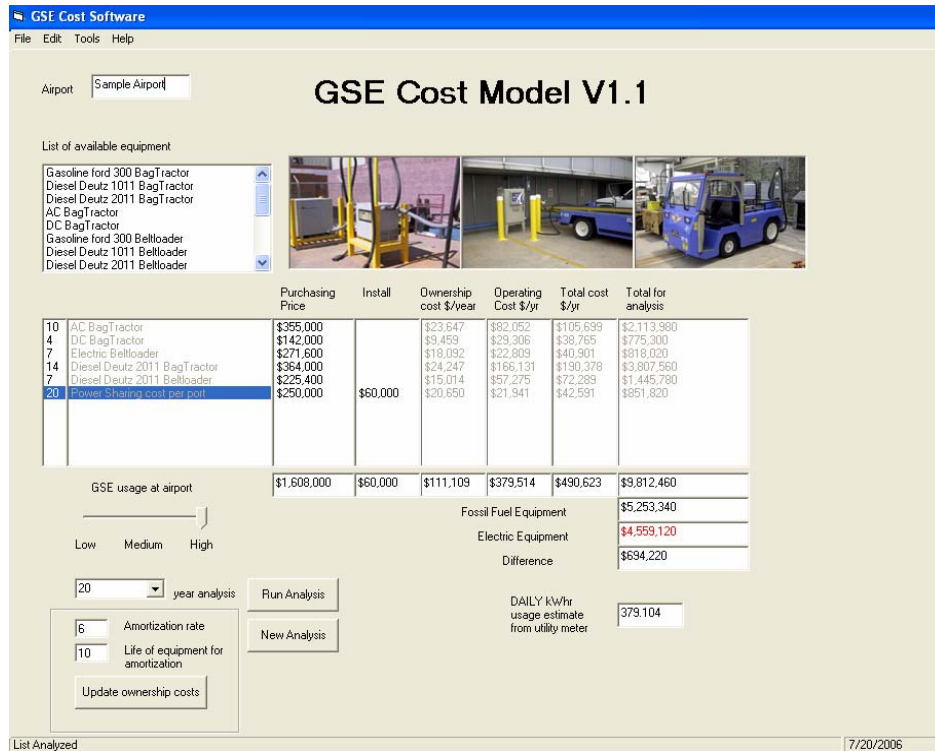


Figure 3-2. Ground support equipment cost model main page.

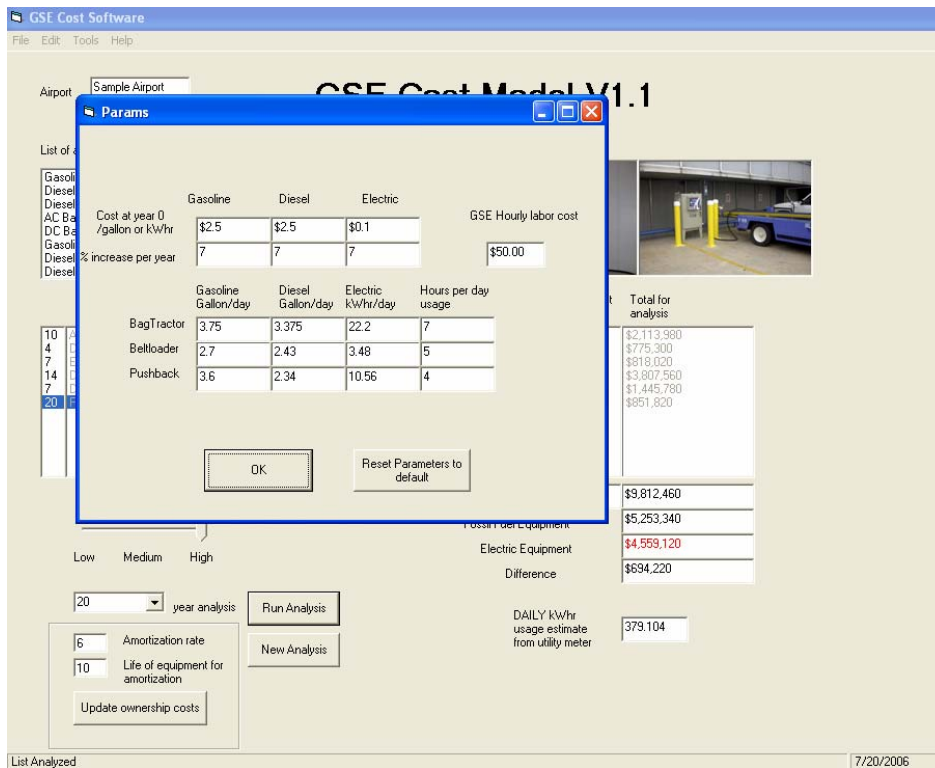


Figure 3-3. Fuel usages, cost, and escalator.

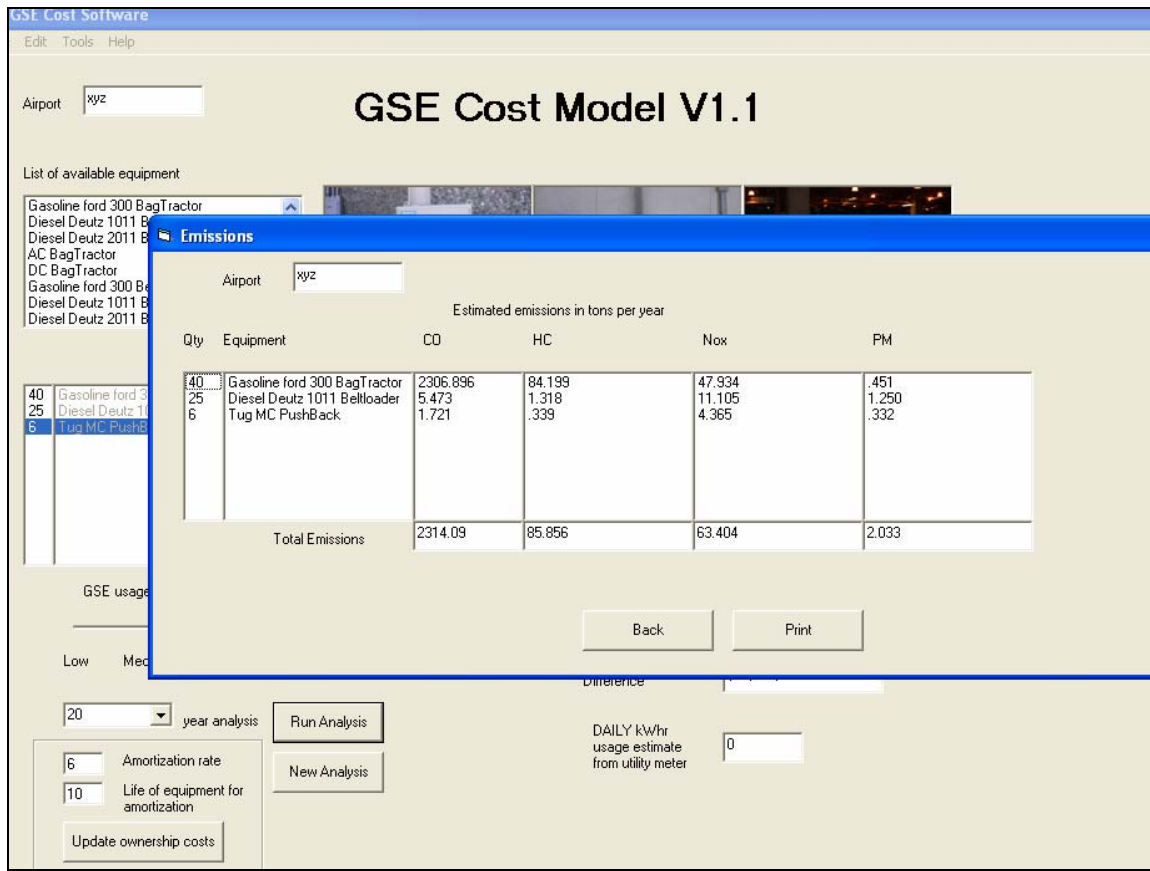


Figure 3-4. Emissions results.

Another feature under the “Tools” section is a table that itemizes O&M costs for each piece of equipment selected (shown in Figure 3-5). This provides the user with a quick rundown of the individual O&M cost components. It is important to note that for eGSE, the initial battery pack is included in the purchase of the equipment, and replacement battery purchases are treated as an O&M expense and fall under the “General Maintenance” category in the unit operating cost table.

The model provides a database of both vehicles and chargers, but also allows the user to input their own vehicle or charger data for customized model runs. Figures 3-6 and 3-7 show an example of the vehicle input table and charger input table. The tables are accessed by selecting “Edit” at the top of the main page. Under the “Help” section of the model, there is an “Assumptions” write-up and a user “Manual” to assist with understanding and using the model.



GSE Cost Software

File Edit Tools Help

### Cost Break - Unit Operating Cost

Equipment List	General Maintenance	Energy/Fuel	Engine	Transmission/Transaxle	Controller	Cords	Charger Repair	Fast Charge Interface
AC BagTractor	\$90,407	\$38,894	\$4,520	\$13,640	\$15,443	\$000	\$000	\$1,200
DC BagTractor	\$63,640	\$56,008	\$12,624	\$6,062	\$6,994	\$000	\$000	\$1,200
Electric Beltloader	\$40,880	\$7,316	\$5,664	\$4,468	\$5,639	\$000	\$000	\$1,200
Diesel Deutz 2011 BagTractor	\$59,230	\$150,042	\$18,758	\$9,249	\$000	\$000	\$000	\$000
Diesel Deutz 2011 Beltloader	\$38,500	\$108,031	\$9,949	\$7,162	\$000	\$000	\$000	\$000
Power Sharing cost per port	\$16,000	\$000	\$000	\$000	\$000	\$4,511	\$1,430	\$000

Back

Low Medium High

Electric Equipment Difference \$694,220

20 year analysis Run Analysis

6 Amortization rate New Analysis

10 Life of equipment for amortization

Update ownership costs

DAILY kW/hr usage estimate from utility meter 379.104

List Analyzed 7/20/2006

Figure 3-5. Unit operating cost.

GSE Cost Software

File Edit Tools Help

### Edit Properties

Vehicle Name: Gasoline ford 300 BagTractor

Purchase Price: 26000 \$

Engine replacement cost: 1700

Time to replace in hrs: 32

Energy source: Gasoline

Preventive Maintenance: Yearly cost of parts 1205, Yearly hours 26.7

Transmission Failure Rate: 6500 hrs, replacement cost 900 \$, Time to replace 16 hrs

Emissions: Load factor 55 %, Horsepower 107 hp, emissions in g/(hp hour): CO 347.957, HC 12.7, Nox 7.23, PM .068

Back

List Analyzed

Figure 3-6. Vehicle edit table.



## 4. AIRPORT ANALYSIS

This project reviewed four existing airport operations to accomplish the following objectives:

- Understand and retrieve available data to develop default parameters for the model, and run specific cost analysis at each airport location
- Develop strategies for achieving data that is not readily available
- Analyze a diverse group of airports to ensure the GSE Cost Model is flexible enough to be applied to a broad mix of airport scenarios.

The four airports scenarios analyzed in this study are labeled “A,” “B,” “C,” and “D.” Each airport is a major commercial airport and is described in general terms in order to justify the parameters selected in the model analysis. Each airport in the four scenarios either currently has, or expects to have in the near future, eGSE as described in each analysis.

### 4.1 Airport “A”

Airport “A” has a mild winter climate, with warm to hot summer months, and very flat terrain with no ramps or grades to contend with. Based on a review of the number of flights per day (approximately 80 flights per day), the number of equipment, and the terrain, Airport “A” is considered a medium-duty airport in regards to fuel use and hours of operation. The eGSE equipment and battery chargers analyzed for the Airport “A” scenario are shown in Tables 4-1 and 4-2, respectively.

Table 4-1. Airport “A” electric ground support equipment included in study.

GSE Type	Original GSE Equipment	Replacement GSE	Battery Type	Quantity
Baggage Tractor	Gasoline Ford 300 Baggage Tractor	Electric Baggage Tractor—DC Drive Type	Flooded	17
Belt Loaders	Diesel Deutz 1011 Belt Loader	Electric Belt Loader	Flooded	16
Pushback Tractors	GT 1628/GT35 Diesel Pushback Tractors	350E Pushback Tractors	Flooded	7
Total				40

Table 4-2. Airport “A” electric ground support equipment battery chargers.

Charger Type	Quantity
Multi-port Fast Chargers (number of ports)	4
Single Port Fast Chargers	8
Total Ports	12
Total DC Output Capacity—153 kW	

Financial results of running scenario Airport “A” are shown in Figure 4-1, which is a screen print of the main page of the model after inputting all parameters and running the model. Also provided in Figure 4-1 are some of the initial input parameters, including the vehicle type and amounts and the charger(s) selected for this airport. Additionally, the number of years selected by the user to run the model, amortization rates, and equipment life are shown. Figure 4-2 provides fuel consumption estimates, based on a medium-duty airport, starting point for the fuel with escalation rates, and the labor rate.

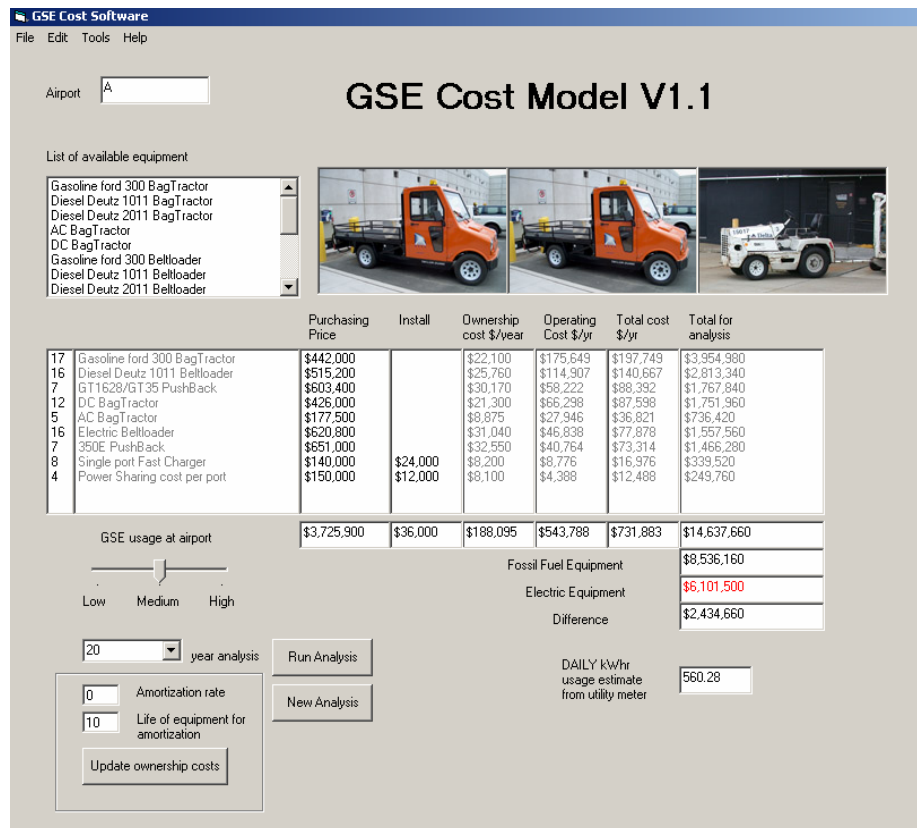


Figure 4-1. Results of Airport “A” main screen.

**Params**

	Gasoline	Diesel	Electric	
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	GSE Hourly labor cost <input type="text" value="\$50.00"/>
% increase per year	7	7	2.5	

	Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
BagTractor	3.125	2.8125	18.5	5
Beltloader	2.25	2.025	2.9	4
Pushback	3	1.95	8.8	3

OK

Reset Parameters to default

Figure 4-2. Airport “A” fuel and labor parameters.

Figure 4-3 provides operating costs on a unit basis for all equipment, including the charge stations. As can be seen, energy fuel costs for ICE GSE is by far the largest cost component driving overall economics of the model.

Equipment List	General Maintenance	Energy/Fuel	Engine	Transmission/Transaxle	Controller	Cords	Charger Repair	Fast Charge Interface
Gasoline ford 300 BagTractor	\$50,800	\$138,928	\$9,755	\$7,162	\$000	\$000	\$000	\$000
Diesel Deutz 1011 Beltloader	\$39,500	\$90,025	\$8,127	\$5,982	\$000	\$000	\$000	\$000
GT1628/GT35 PushBack	\$44,900	\$86,691	\$16,340	\$18,217	\$000	\$000	\$000	\$000
DC BagTractor	\$63,640	\$25,281	\$10,269	\$4,468	\$5,639	\$000	\$000	\$1,200
AC BagTractor	\$63,640	\$21,068	\$3,374	\$10,053	\$12,451	\$000	\$000	\$1,200
Electric Beltloader	\$40,880	\$3,303	\$4,712	\$3,632	\$4,821	\$000	\$000	\$1,200
350E PushBack	\$53,640	\$10,021	\$26,317	\$21,708	\$3,883	\$000	\$000	\$1,200
Single port Fast Charger	\$16,000	\$000	\$000	\$000	\$000	\$4,511	\$1,430	\$000
Power Sharing cost per port	\$16,000	\$000	\$000	\$000	\$000	\$4,511	\$1,430	\$000

Back

Figure 4-3. Airport “A” unit operating costs.

Figure 4-4 shows results of Airport “A” being analyzed in this study by plotting the total cumulative costs versus years.

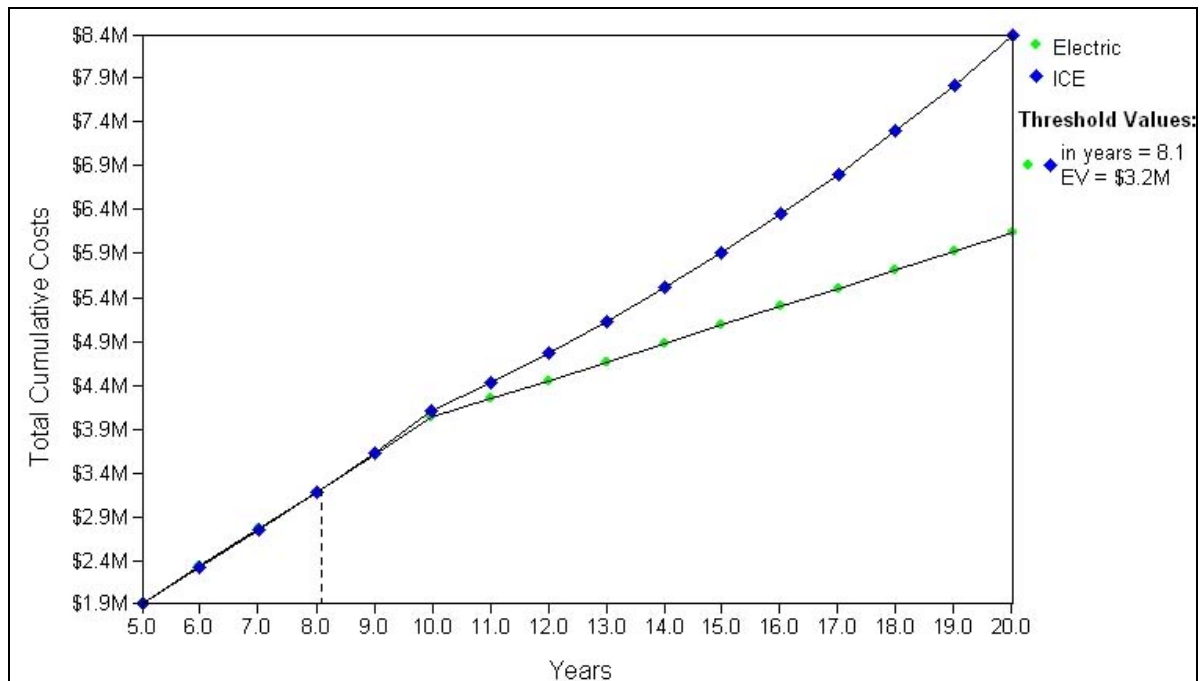


Figure 4-4. Airport “A” breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for all three types of ground support equipment.

This airport is a medium-use airport from a fuel-use standpoint. This airport replaced a mix of 40 ICE GSE vehicles (17 baggage tractors, 16 belt loaders, and 7 pushback tractors) with eGSE. The charger system is a fast-charge, multi-port type that provides one port for every two vehicles. The

breakeven point in this scenario is 8.1 years with annual fuel escalators at 7% for fossil fuel and 2.5% for electricity.

To further understand the impacts of varying fossil fuel escalation rates, Figure 4-5 plots a varying fossil fuel escalation rate per year versus years of analysis. In Figure 4-5, if there is a 9% average annual increase in fossil fuel costs, then eGSE has a payback within approximately 5 years. If fuel cost increases remain relatively low at 4% annually, then the payback for eGSE is approximately 13 years.

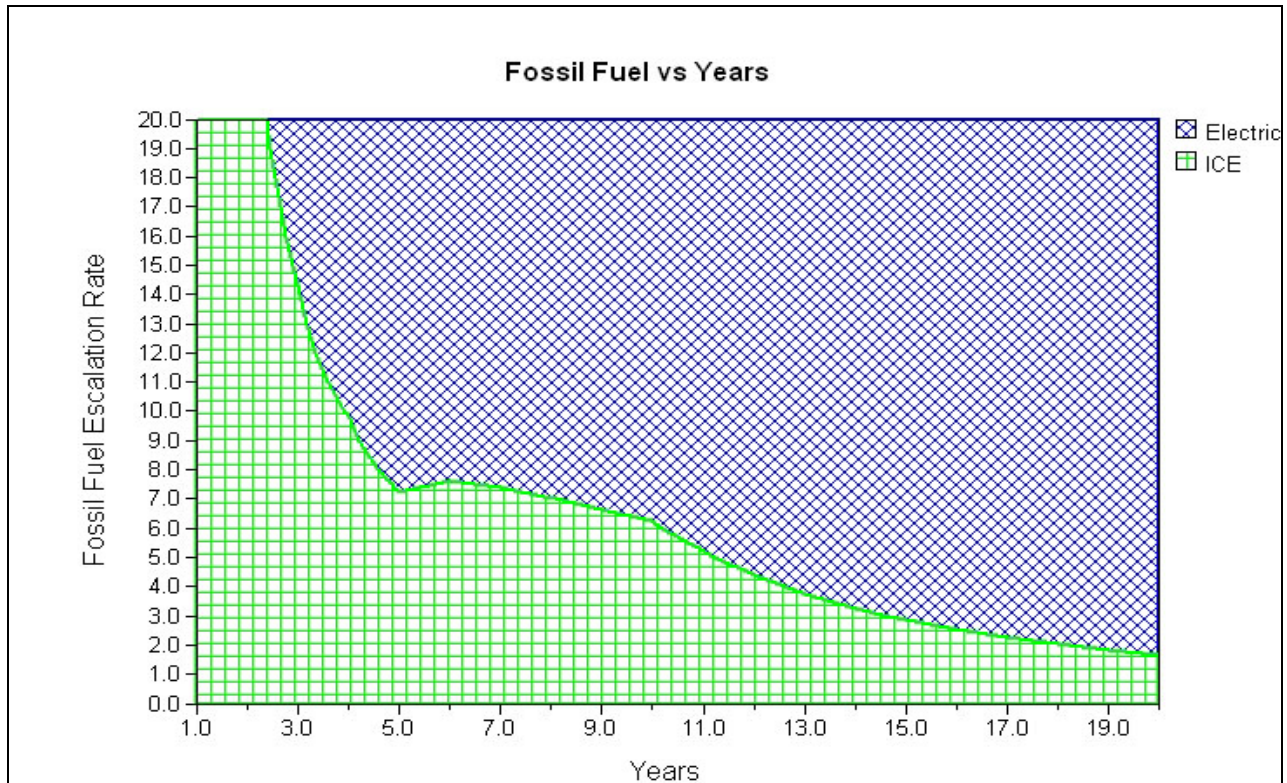


Figure 4-5. Airport “A” sensitivity analysis for all three ground support equipment types.

Figures 4-6 through 4-8 show the sensitivities of each individual piece of equipment with all other parameters treated the same as before. The electric baggage tractors have by far the fastest payback of the three GSE vehicles presented in this study, followed by the belt loaders and then the pushback tractors. Not surprisingly, the baggage tractors are also the heaviest fuel users of the three GSE vehicles. Figures 4-7 and 4-8 also show payback sensitivity of the pushback tractors and belt loaders when purchased new.

Because of higher capital cost and lower fuel use, the pushback tractors have a longer payback than the baggage tractors and belt loaders. If capital costs are significantly lowered through grant cost-share programs or conversion of gas or diesel to electric, payback can occur much sooner, making the electric pushback tractors very attractive.



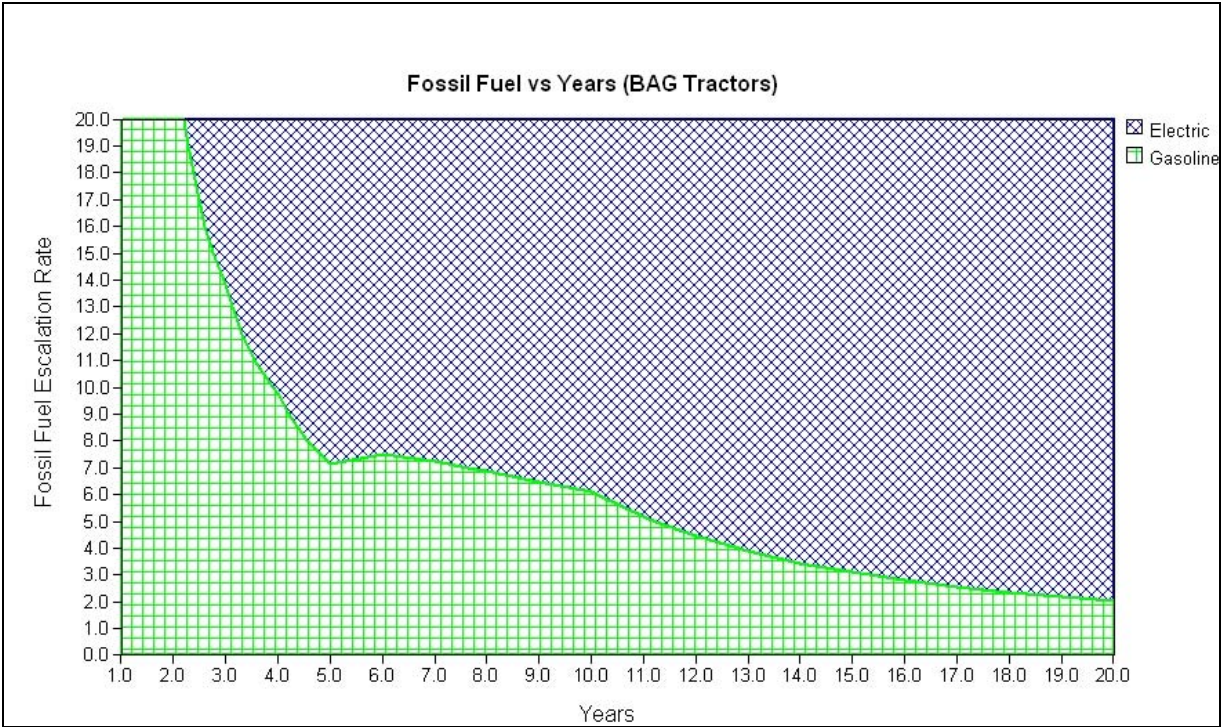


Figure 4-6. Airport “A” sensitivity analysis for baggage tractors.

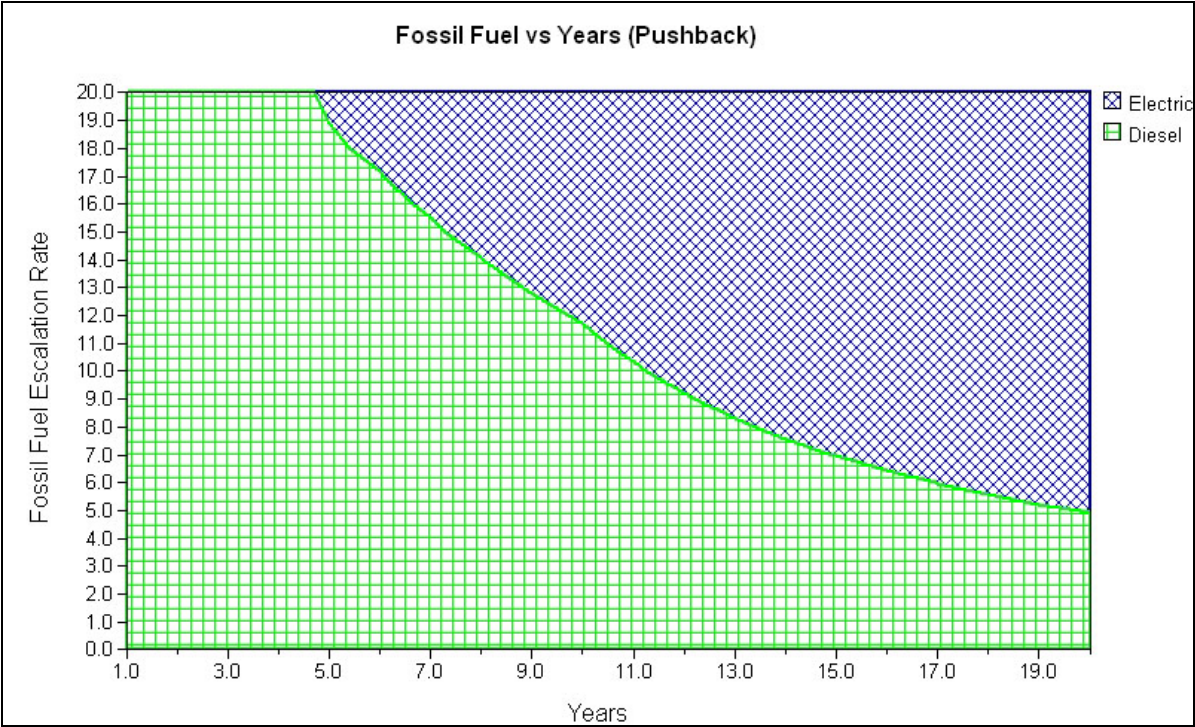


Figure 4-7. Airport “A” sensitivity analysis for pushback tractors.

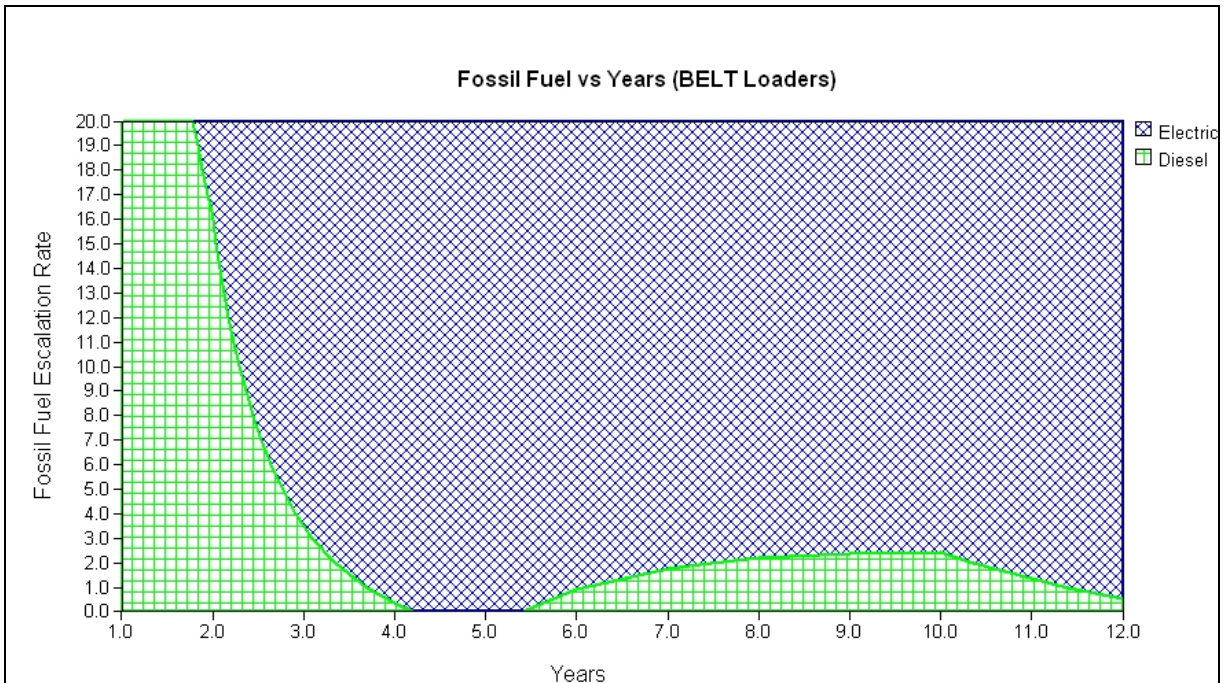


Figure 4-8. Airport “A” sensitivity analysis for belt loaders.

#### 4.1.1 Emissions

The GSE Cost Model includes an emissions module that estimates the amount of tailpipe emissions saved by replacing ICE GSE with eGSE. Table 4-3 shows emissions results for Airport “A.” The base emissions rates were provided by the FAA EDMS Emissions Model Version 4.12, which provides emissions rates for each type of GSE.

Table 4-3. Airport “A” emissions savings in tons per year.

Quantity	Description	CO	HC	NO <sub>x</sub>	PM
17	Baggage Tractors	700.308	25.560	14.551	0.137
16	Belt Loaders	2.802	0.675	5.686	0.640
7	Pushback Tractors	1.751	0.345	4.441	0.338
Totals		704.861	26.58	24.678	1.115
CO = carbon monoxide, HC = total hydrocarbons, NO <sub>x</sub> = oxides of nitrogen, PM = particulate matter					

## 4.2 Airport “B”

Airport “B” has a cold winter climate with mild to warm summer months. Terrain is very challenging with a long, steep ramp underground to the baggage make-up area. Airport “B” has only baggage tractors included in this analysis. Based on a review of the number of flights per day (approximately 209 flights per day), the number of equipment, and the terrain, Airport “B” is designated as a high-duty airport scenario. The GSE equipment and battery chargers analyzed for the Airport “B” scenario are shown in Tables 4-4 and 4-5, respectively.



Table 4-4. Airport “B” ground support equipment included in the study.

GSE Type	Original GSE Equipment	Replacement GSE	Battery Type	Quantity
Baggage Tractor	Diesel Deutz 1011	Electric Baggage Tractor—AC Drive Type	Sealed—GEL	27

Table 4-5. Airport “B” electric ground support equipment battery chargers.

Charger Type	Quantity
Multi-port Fast Chargers	0
Single Port Fast Chargers	10
Total	10
Total DC Output Capacity—150 kW	

As can be seen in Figure 4-9, over a 20-year period the eGSE option saved a little over \$1.7 million, with operating costs accounting for the overall savings of the eGSE. Daily energy use by the eGSE totals 599.4 kWh.

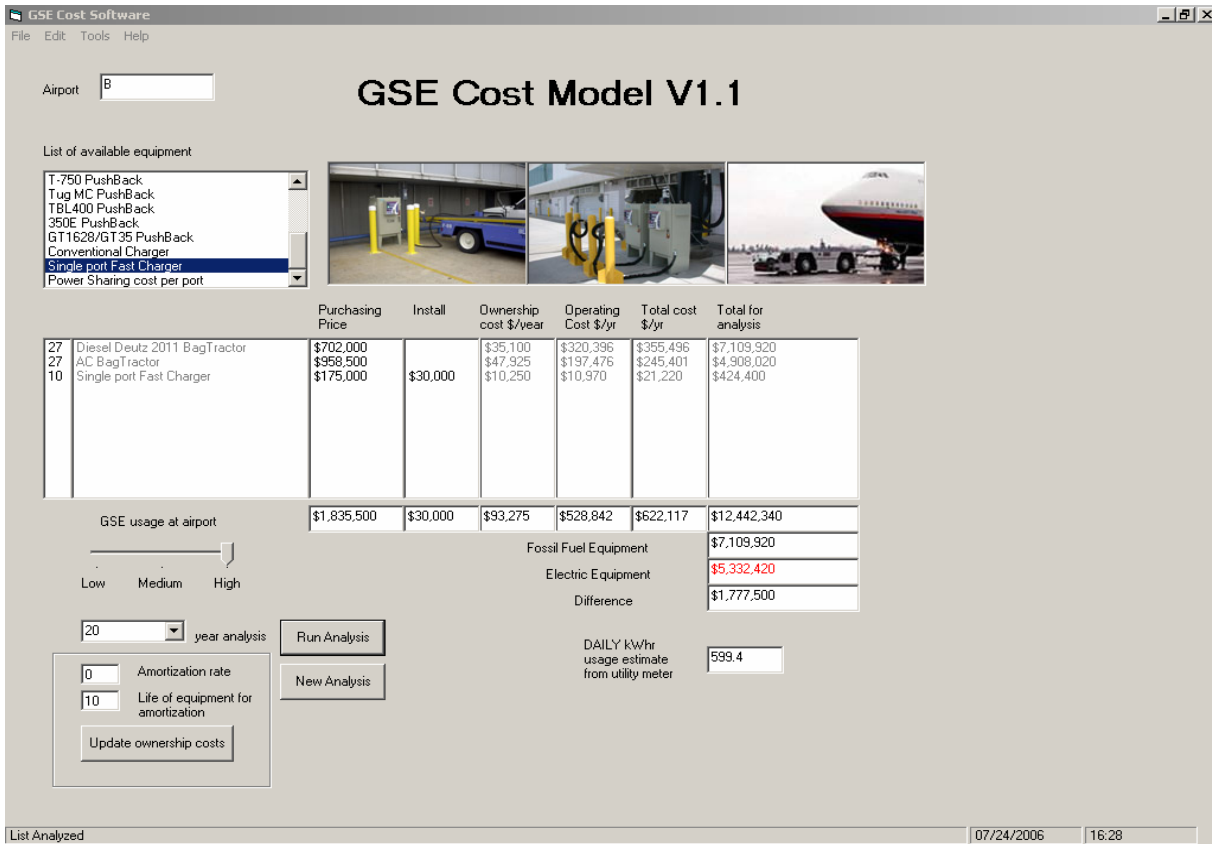


Figure 4-9. Results of Airport “B” main screen.

Figure 4-10 shows fuel costs, fuel escalators, and labor rate for this particular analysis. Default parameters were used with diesel fuel starting at \$2.50/gal, with an annual escalation rate of 7%, and electricity starting at 10 cents per kWh, with a 2.5% annual escalation rate.

The 'Params' window displays the following parameters:

	Gasoline	Diesel	Electric	
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	GSE Hourly labor cost \$50.00
% increase per year	7	7	2.5	

	Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
BagTractor	3.75	3.375	22.2	7
Beltloader	2.7	2.43	3.48	5
Pushback	3.6	2.34	10.56	4

Buttons: OK, Reset Parameters to default

Figure 4-10. Airport “B” fuel and labor parameters.

Figure 4-11 shows unit operating costs for each type of GSE and charging equipment. The general maintenance component for eGSE includes battery pack replacement costs over a 20-year period, which was included in this scenario.

Equipment List	General Maintenance	Energy/Fuel	Engine	Transmission/Transaxle	Controller	Cords	Charger Repair	Fast Charge Interface
Diesel Deutz 2011 BagTractor	\$59,280	\$150,042	\$18,758	\$9,249	\$000	\$000	\$000	\$000
AC BagTractor	\$90,407	\$21,068	\$4,520	\$13,640	\$15,443	\$000	\$000	\$1,200
Single port Fast Charger	\$16,000	\$000	\$000	\$000	\$000	\$4,511	\$1,430	\$000

Button: Back

Figure 4-11. Airport “B” unit operating costs.

The breakeven point is provided in Figure 4-12, which plots total costs for Airport “B” versus years. There are three crossover points at years 2.3, 3.7, and 10.1, with the last crossover point sustaining the eGSE cost advantage. The crossover point takes longer for Airport “B” because of additional battery costs due to a requirement of utilizing sealed batteries.

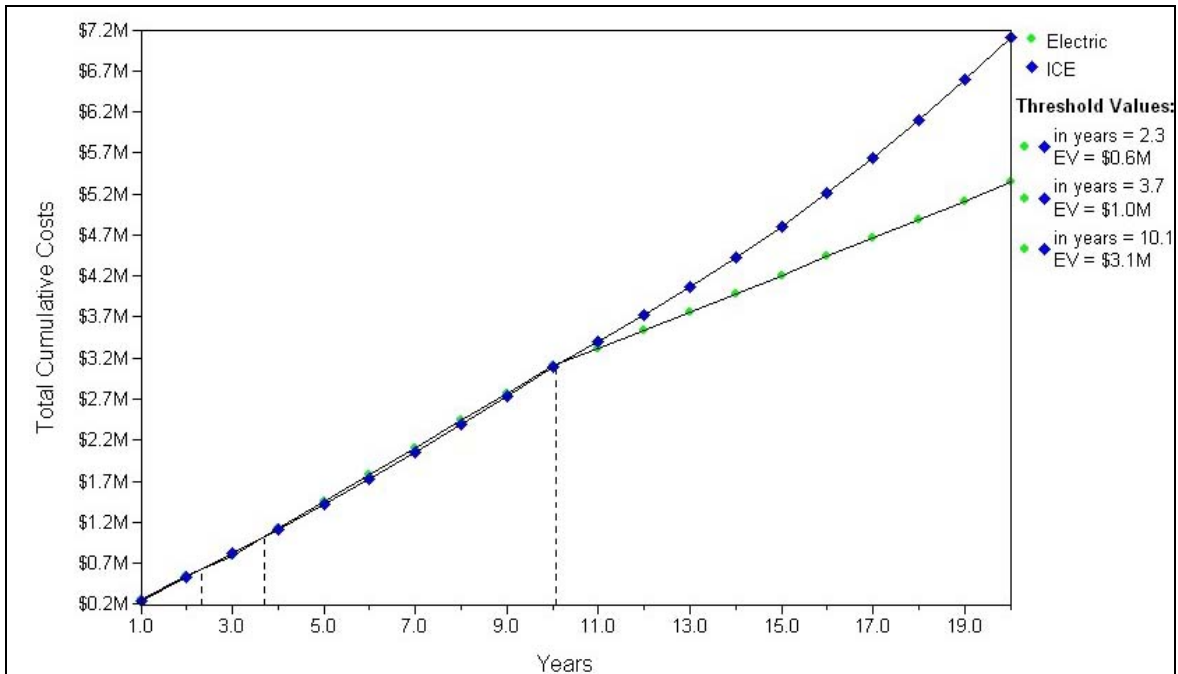


Figure 4-12. Airport “B” breakeven point for electric ground support equipment versus internal combustion engine ground support equipment.

Figures 4-13 and 4-14 are sensitivity graphs that show fossil fuel annual escalation rates versus years of operation. Figure 4-13 shows an anomaly where it appears that after the first 3 years, eGSE is cost effective at close to zero fuel escalation, but that is only temporary until the batteries are replaced at the end of the third year, increasing the costs of the eGSE. Reviewing the results of Figure 4-14 shows that after the sharp initial increase due to battery pack purchases beginning at the end of the third year, electric tops out at about a 9% annual fossil fuel escalation rate after about 5.5 years.

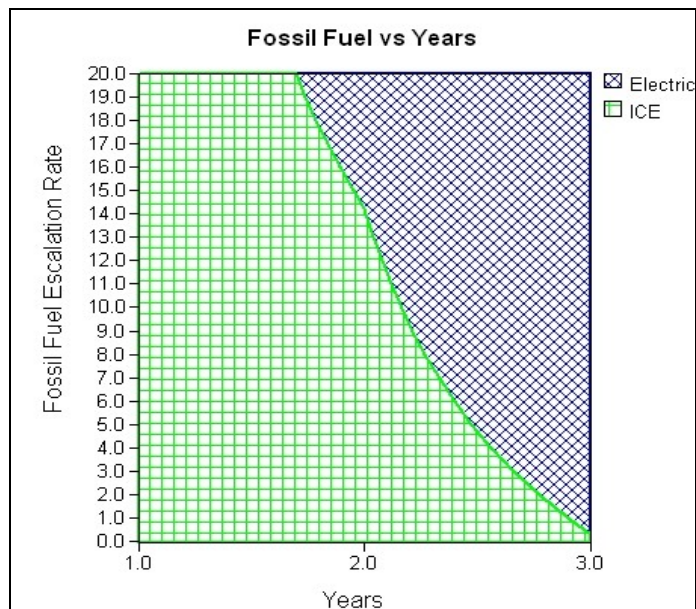


Figure 4-13. Airport “B” sensitivity analysis for baggage tractors years 0 through 3.

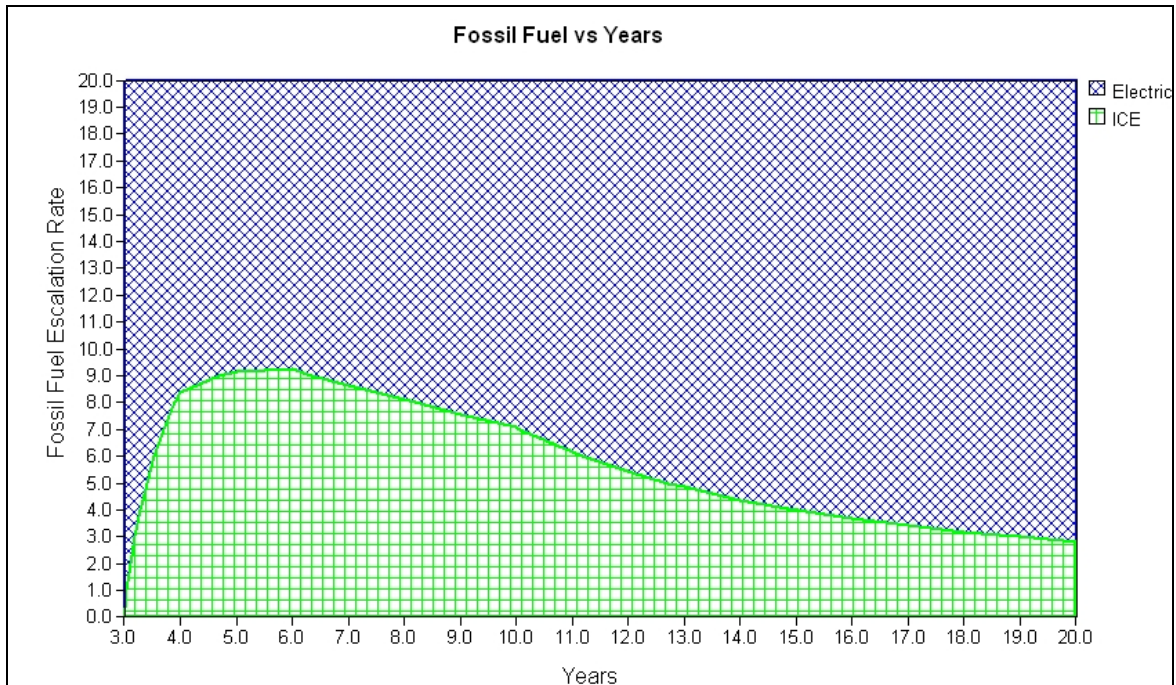


Figure 4-14. Airport “B” sensitivity analysis for baggage tractors years 3 through 20.

#### 4.2.1 Emissions

Emissions results for Airport “B,” where all 27 vehicles replaced were diesel baggage tractors, are shown in Table 4-6.

Table 4-6. Airport “B” emissions savings in tons per year.

Quantity	Description	CO	HC	NOx	PM
27	Baggage Tractors	5.078	2.138	17.074	2.480
CO = carbon monoxide, HC = total hydrocarbons, NOx = oxides of nitrogen, PM = particulate matter					

### 4.3 Airport “C”

Airport “C” is similar to Airport “A” in that it has a mild winter climate with warm summer months, occasional hot days, and very flat terrain with no ramps or grades to contend with. Based on the flights per day (approximately 56 flights per day), the number of equipment, and the terrain, this airport is designated as a medium-duty airport scenario. The GSE equipment and battery chargers analyzed for the Airport “C” scenario are shown in Tables 4-7 and 4-8, respectively.

Table 4-7. Airport “C” ground support equipment included in the study.

GSE Type	Original GSE Equipment	Replacement GSE	Battery Type	Quantity
Baggage Tractor	Gasoline Ford 300 Baggage Tractor	Electric Baggage Tractor—DC Drive Type	Flooded	16
Belt Loaders	(7) Diesel Deutz 1011 Belt Loader and (7) Ford 300 Belt Loader	Electric Belt Loader—DC Drive Type	Flooded	14
Pushback Tractors	GT 1628/GT35 Diesel Pushback Tractors	350E Pushback Tractors	Flooded	6
Total				36

Table 4-8. Airport “C” electric ground support equipment battery chargers.

Charger Type	Quantity
Multi-port Fast Chargers	12
Single Port Fast Chargers	0
Total Ports	12
Total DC Output Capacity—93 kW	

Figure 4-15 presents the main screen of Airport “C” and shows that over a 20-year period, at a 0% amortization rate, eGSE savings over ICE GSE amount to \$2.1 million. Electricity sales from the eGSE amount to 561 kWh daily.

Figure 4-16 shows fuel cost, fuel use, and labor use for Airport “C,” a medium-duty airport. Built into this scenario is gasoline and diesel starting at \$2.50 per gallon, with a 7% annual escalator rate, and electricity starting at 10 cents per kWh, with a 2.5% annual escalator rate.

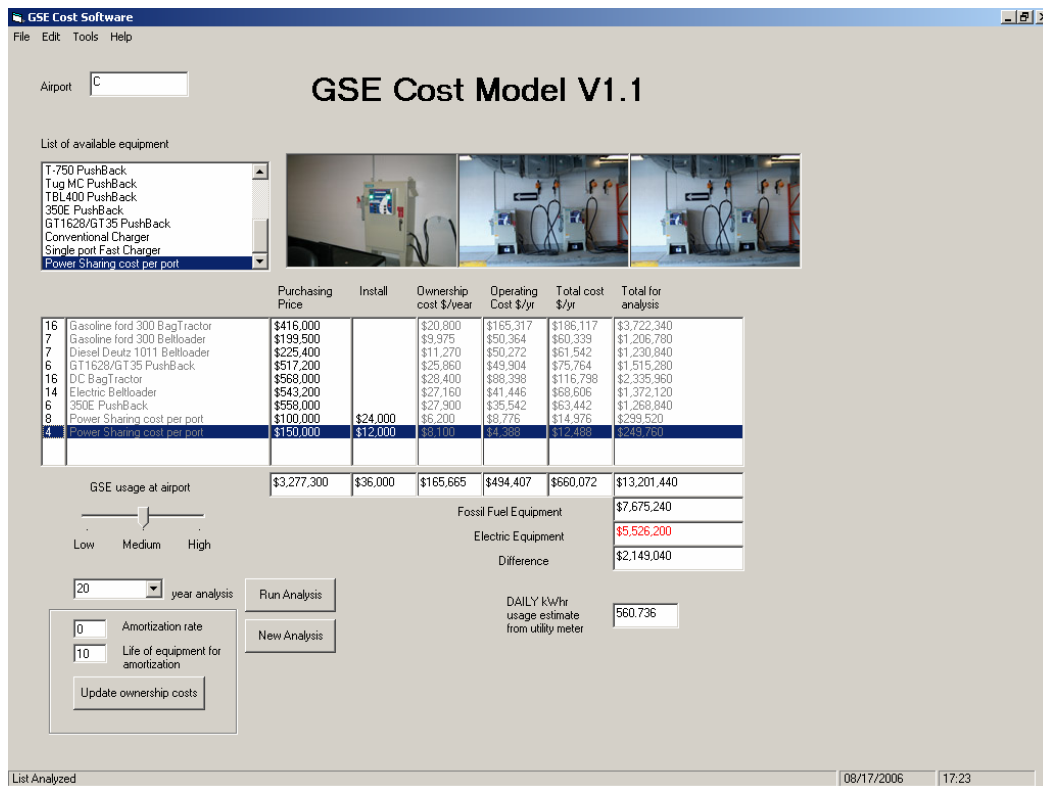


Figure 4-15. Results of Airport “C” main screen.

**Params**

	Gasoline	Diesel	Electric	
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	GSE Hourly labor cost \$50.00
% increase per year	7	7	2.5	

	Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
BagTractor	3.125	2.8125	18.5	5
Beltloader	2.25	2.025	2.9	4
Pushback	3	1.95	8.8	3

OK

Reset Parameters to default

Figure 4-16. Airport “C” fuel and labor parameters.

Unit operating costs are provided in Figure 4-17, with fuel costs being the major driver for ICE GSE, and the general maintenance category being the main driver for eGSE (mostly due to battery replacement costs).

Equipment List	General Maintenance	Energy/Fuel	Engine	Transmission/Transaxle	Controller	Cords	Charger Repair	Fast Charge Interface
Gasoline ford 300 BagTractor	\$50,800	\$138,928	\$9,755	\$7,162	\$000	\$000	\$000	\$000
Gasoline ford 300 Beltloader	\$32,300	\$100,028	\$5,587	\$5,982	\$000	\$000	\$000	\$000
Diesel Deutz 1011 Beltloader	\$39,500	\$90,025	\$8,127	\$5,982	\$000	\$000	\$000	\$000
GT1628/GT35 PushBack	\$44,900	\$86,691	\$16,540	\$18,217	\$000	\$000	\$000	\$000
DC BagTractor	\$63,640	\$25,281	\$10,269	\$4,468	\$5,639	\$000	\$000	\$1,200
Electric Beltloader	\$40,880	\$3,963	\$4,712	\$3,632	\$4,821	\$000	\$000	\$1,200
350E PushBack	\$53,640	\$12,026	\$26,017	\$21,708	\$3,883	\$000	\$000	\$1,200
Power Sharing cost per port	\$16,000	\$000	\$000	\$000	\$000	\$4,511	\$1,430	\$000
Power Sharing cost per port	\$16,000	\$000	\$000	\$000	\$000	\$4,511	\$1,430	\$000

Figure 4-17. Airport “C” unit operating costs.

Figure 4-18 shows a graph of the total cost versus years using a 7% fuel escalator. The breakeven point is at 4.9 years, and a real divergence in terms of savings appears beginning in the tenth year.

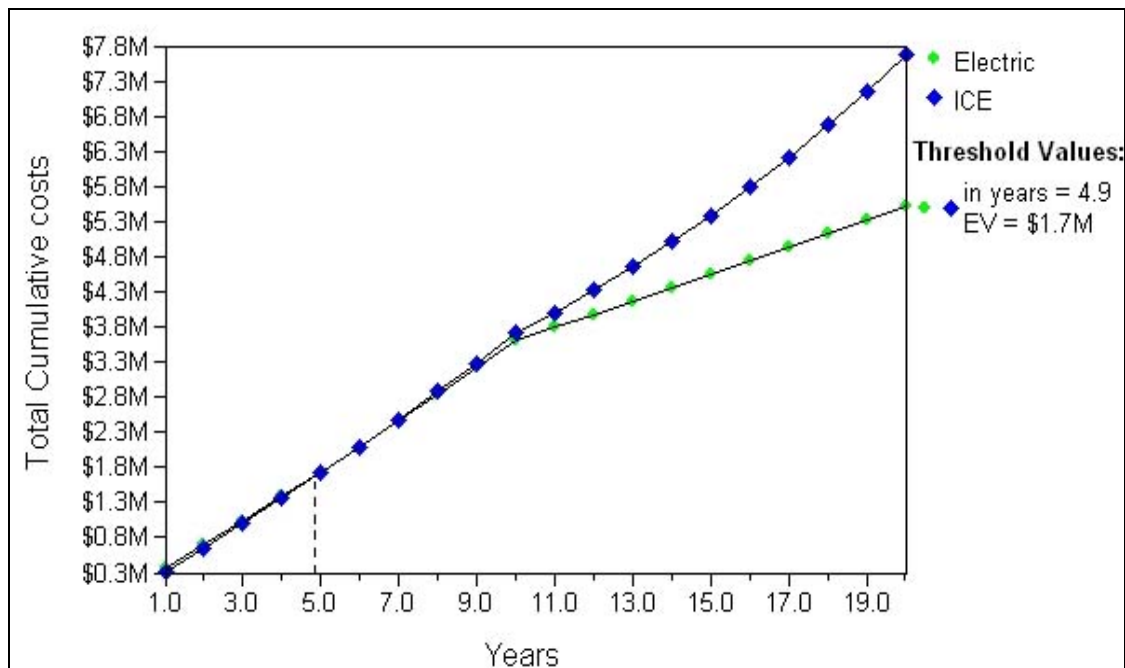


Figure 4-18. Airport “C” breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for all ground support equipment.

To further understand the impacts of the varying fossil fuel escalation, Figure 4-19 plots a varying fossil fuel escalation rate per year versus years of analysis. If there is a 7% average annual increase in fossil fuel costs, then eGSE has a payback within approximately 5 years. If fuel cost increases remain relatively low at 4% annually, then the payback for eGSE is approximately 12 years.



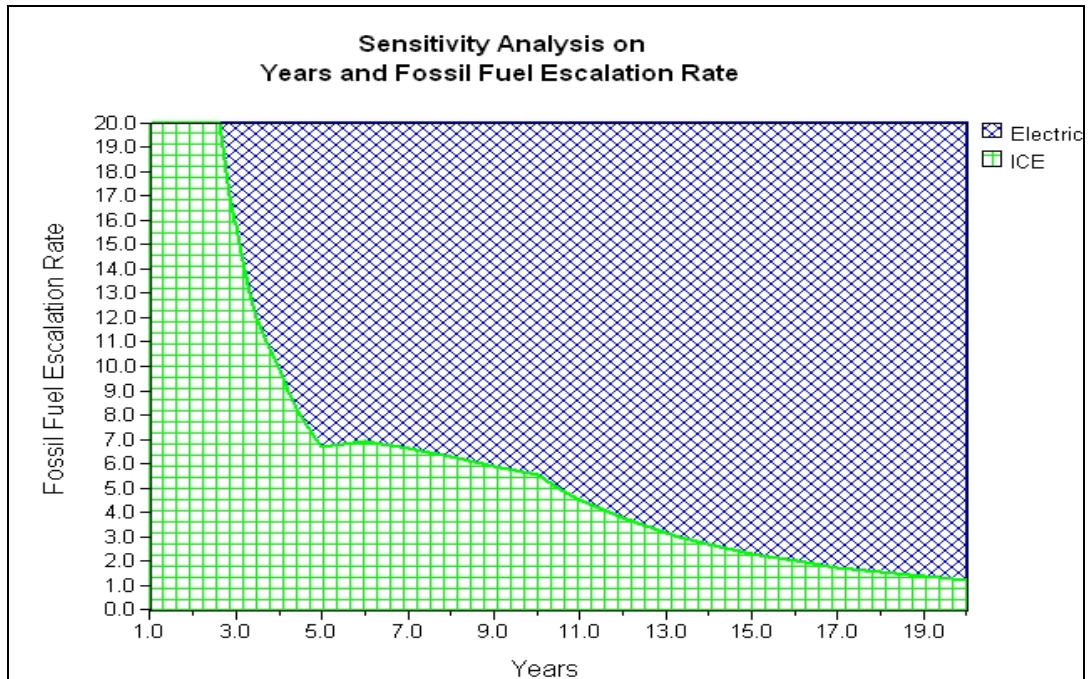


Figure 4-19. Airport “C” sensitivity analysis for all three ground support equipment types.

Figure 4-20 represents the sensitivity analysis for comparing a gasoline baggage tractor to an electric baggage tractor. In the electric configuration, one charge port was modeled for every three vehicles. Capital cost of the charge port, including installation, is assumed to be \$15,500, amortized over 10 years. Batteries are \$6,000 and replaced every 5 years. A fuel escalation rate at 4% or higher has a payback for electric within 4 years or less.

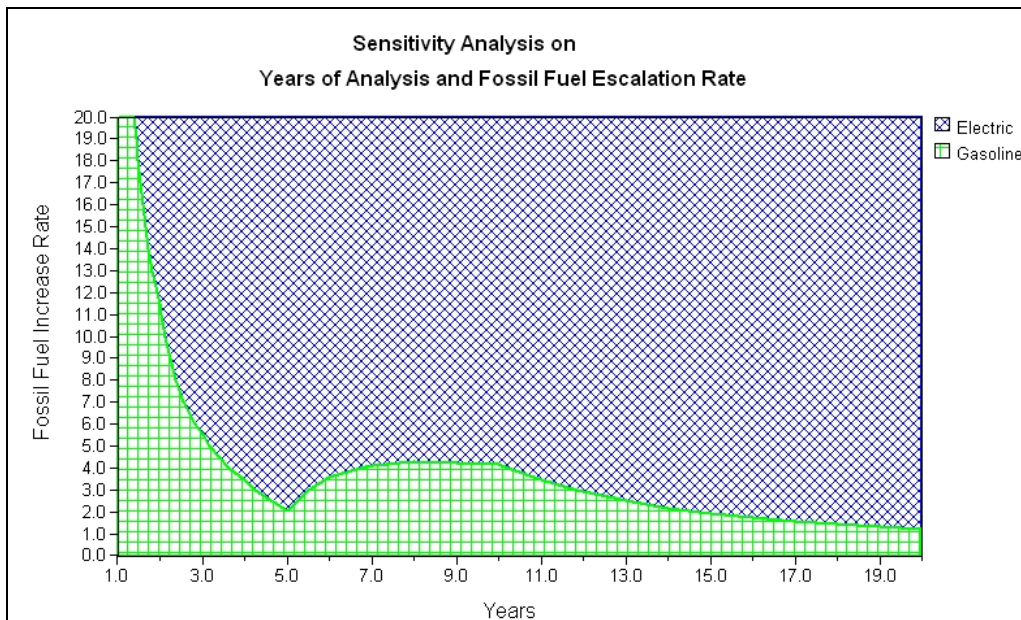


Figure 4-20. Airport “C” sensitivity analysis for baggage tractors.

Figure 4-21 shows the sensitivity analysis for comparing fossil fuel belt loaders to electric ones. The same assumptions were made as for the baggage tractors, except the battery packs are smaller and



less expensive at \$4,000 per pack (versus baggage tractors at \$6,000), resulting in a faster payoff for belt loaders over baggage tractors.

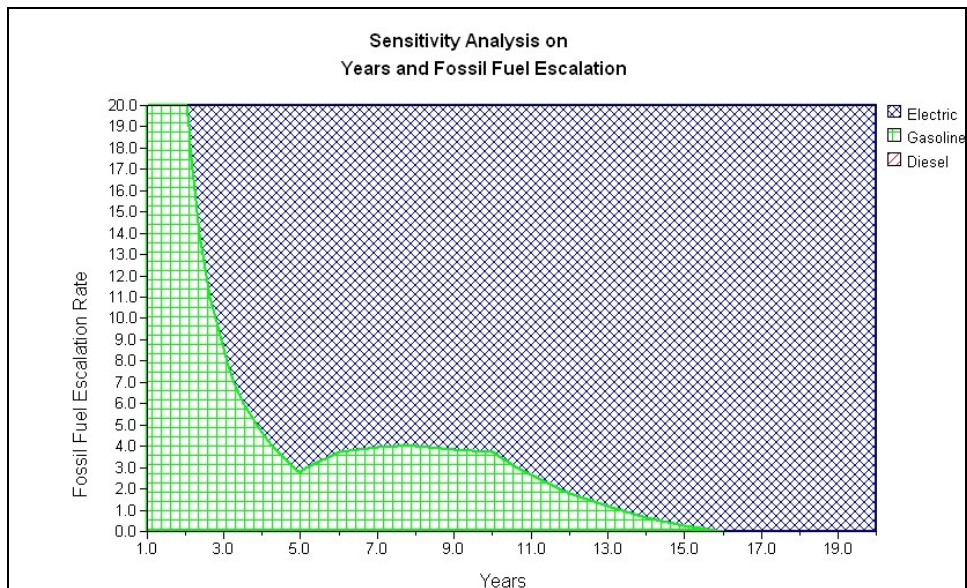


Figure 4-21. Airport “C” sensitivity analysis for belt loaders.

Figure 4-22 shows the sensitivity analysis of comparing a diesel fuel pushback tractor to an electric pushback tractor. The general assumptions were the same as for the other pieces of GSE. Pushback tractors have the longest payback of all three types of equipment due to the high capital cost of eGSE, high maintenance, cost of the batteries, and the fact that fuel does not play a large role because pushback tractors are only used for short durations; therefore, they have low fuel use.

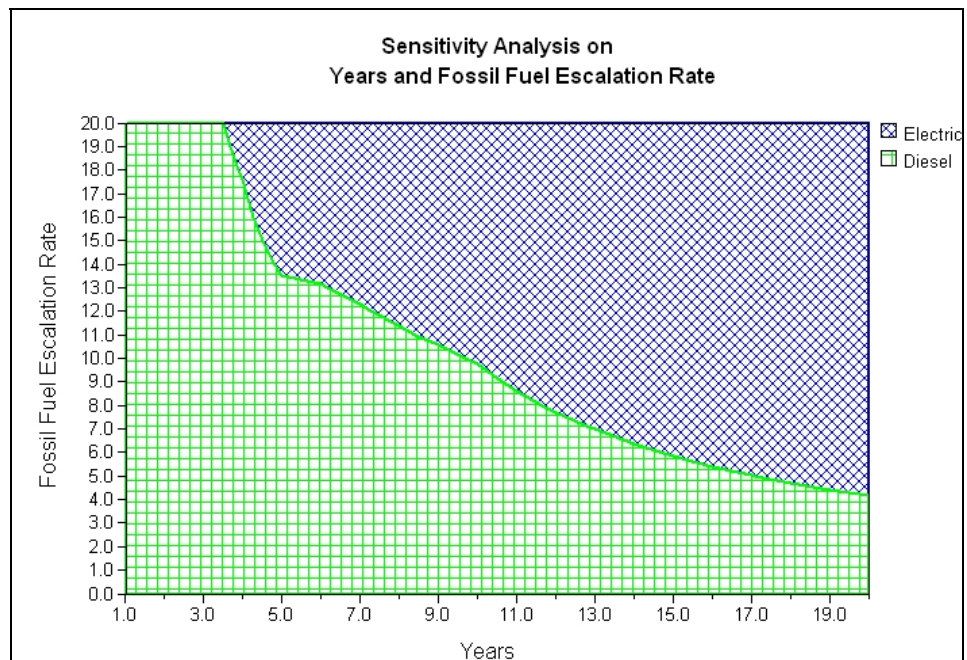


Figure 4-22. Airport “C” sensitivity analysis for pushback tractors.

### 4.3.1 Emissions

Table 4-9 lists the emissions savings for Airport “C,” showing that replacing the gasoline baggage tractors have by far the largest reduction in emissions.

Table 4-9. Airport “C” emissions savings in tons per year.

Quantity	Description	CO	HC	NOx	PM
16	Baggage Tractors	659.1	24.0	13.7	0.1
14	Belt Loaders	146.5	6.3	6.9	0.3
6	Pushback Tractors	1.5	0.3	3.8	0.3
Totals		807.1	30.7	24.4	0.7
CO = carbon monoxide, HC = total hydrocarbons, NOx = oxides of nitrogen, PM = particulate matter					

## 4.4 Airport “D”

Airport “D” has a mild winter climate with warm to hot summer months. Terrain is flat but the travel distance to the baggage make-up area is very long. Based on actual data, a review of the flights per day (approximately 2,000 flights per day), and terrain, Airport “D” is designated as a high-duty airport scenario. The GSE equipment and battery chargers analyzed for the Airport “D” scenario are shown in Tables 4-10 and 4-11, respectively.

Table 4-10. Airport “D” ground support equipment included in the study.

GSE Type	Original GSE Equipment	Replacement GSE	Battery Type	Quantity
Baggage Tractor	Gasoline Ford 300 Baggage Tractor (91) and Diesel Deutz 1011 (71)	Electric Baggage Tractor – DC Drive Type (77); AC Type (85)	Flooded	162
Belt Loader	Gasoline Ford 300 (9) and Diesel Deutz (3)	Electric Belt Loader – DC Drive Type	Flooded	12
Total				174

Table 4-11. Airport “D” electric ground support equipment battery chargers.

Charger Type	Quantity
Multi-port Fast Chargers	72
Single Port Fast Chargers	0
Conventional Chargers	77
Total	149
Estimated Total DC Output Capacity—688 kW	

Figure 4-23 shows the main screen results for Airport “D” and calculates an approximate savings of \$14.5 million for electric versus ICE GSE over a 20-year period (174 pieces of GSE equipment).

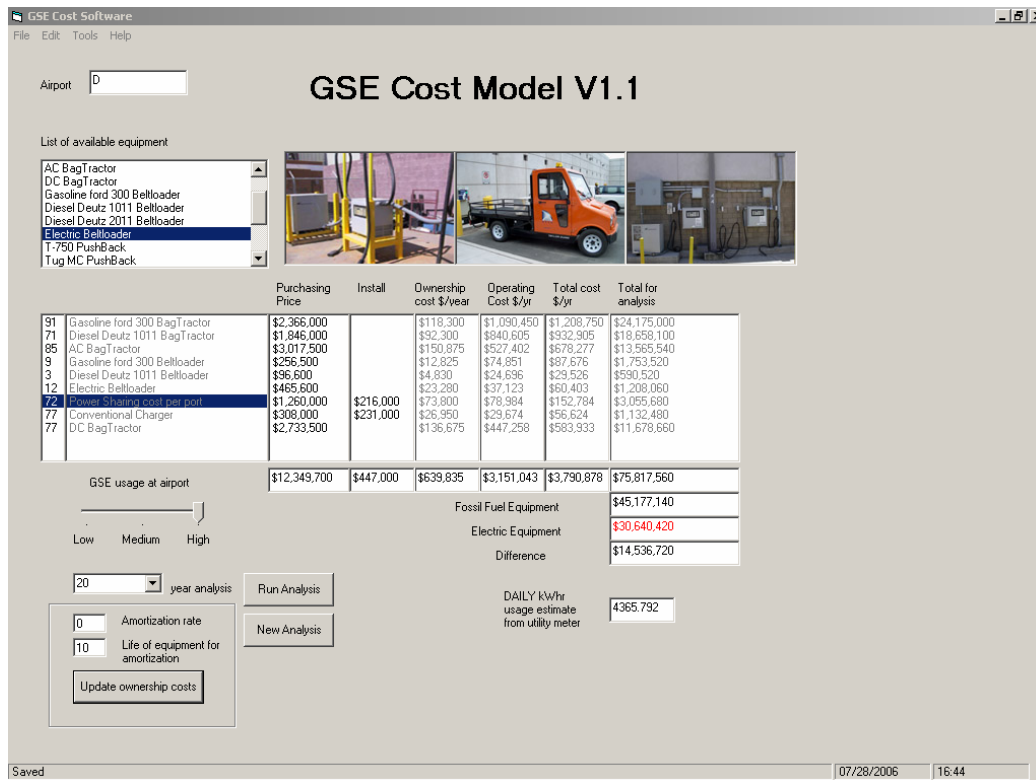


Figure 4-23. Results of Airport “D” main screen.

Figure 4-24 shows the default parameters used for fossil fuel, starting at \$2.50 per gallon, with an escalation rate of 7% per year, and electricity costs starting at 10 cents per kWh, with an escalation rate of 2.5% per year.

**Params**

	Gasoline	Diesel	Electric	
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	GSE Hourly labor cost
% increase per year	7	7	2.5	\$50.00

	Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
BagTractor	3.75	3.375	22.2	7
Beltloader	2.7	2.43	3.48	5
Pushback	3.6	2.34	10.56	4

OK Reset Parameters to default

Figure 4-24. Airport “D” fuel and labor parameters.

Figure 4-25 outlines unit operating costs for each piece of GSE and the charging infrastructure. The largest cost component for ICE GSE is fuel cost. For electric (although it is more evenly spread out) the general maintenance cost is the largest cost component due to the battery replacements.

Equipment List	General Maintenance	Energy/Fuel	Engine	Transmission/Transaxle	Controller	Cords	Charger Repair	Fast Charge Interface
Gasoline ford 300 BagTractor	\$50,800	\$166,714	\$12,896	\$9,249	\$000	\$000	\$000	\$000
Diesel Deutz 1011 BagTractor	\$58,740	\$150,042	\$18,758	\$9,249	\$000	\$000	\$000	\$000
AC BagTractor	\$63,640	\$25,651	\$4,520	\$13,640	\$15,443	\$000	\$000	\$1,200
Gasoline ford 300 Beltloader	\$32,300	\$120,034	\$6,840	\$7,162	\$000	\$000	\$000	\$000
Diesel Deutz 1011 Beltloader	\$39,500	\$108,031	\$9,949	\$7,162	\$000	\$000	\$000	\$000
Electric Beltloader	\$40,880	\$4,021	\$5,664	\$4,468	\$5,639	\$000	\$000	\$1,200
Power Sharing cost per port	\$16,000	\$000	\$000	\$000	\$000	\$4,511	\$1,430	\$000
Conventional Charger	\$5,000	\$000	\$000	\$000	\$000	\$1,278	\$1,430	\$000
DC BagTractor	\$63,640	\$25,651	\$12,624	\$6,062	\$6,994	\$000	\$000	\$1,200

Back

Figure 4-25. Airport “D” unit operating costs.

The breakeven point is shown in Figure 4-26 at 8.5 years for the default parameters selected. Noticeable divergence occurs at about 9.5 years into the analysis as fossil fuel costs continue to play a larger role in the overall cost components.

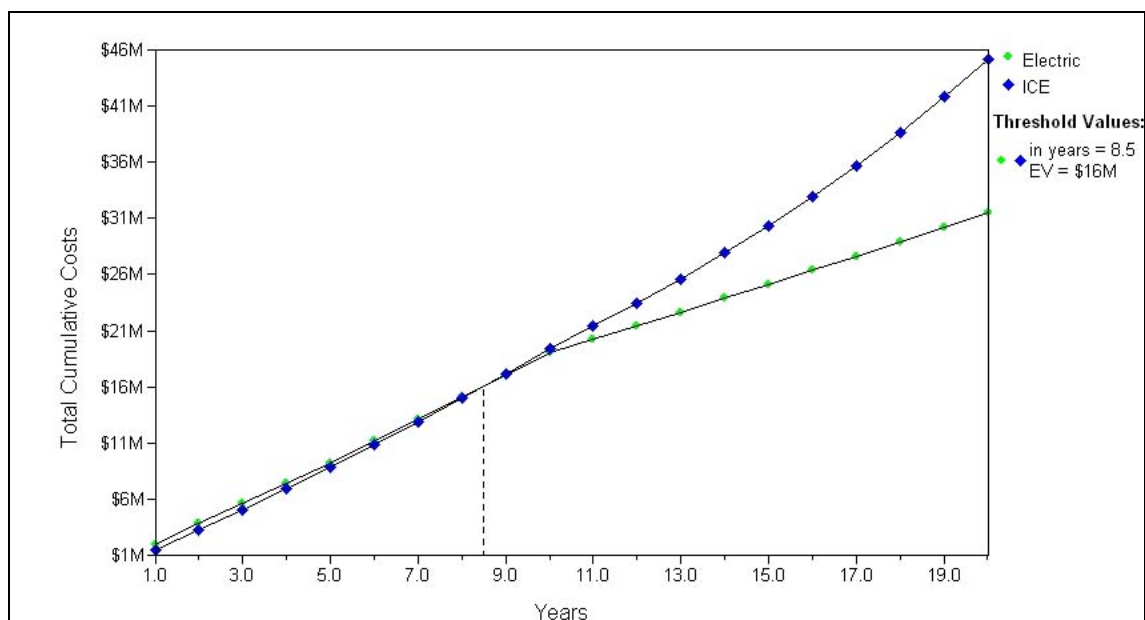


Figure 4-26. Airport “D” breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for the bag tractor and belt loader.

Figure 4-27 shows a sensitivity analysis for the fossil fuel escalation rate versus years of operation for all equipment at Airport “D.” At 3% annual fossil fuel escalation, payback is approximately 15 years. At 10% annual fossil fuel escalation, payback is reduced to 6 years.

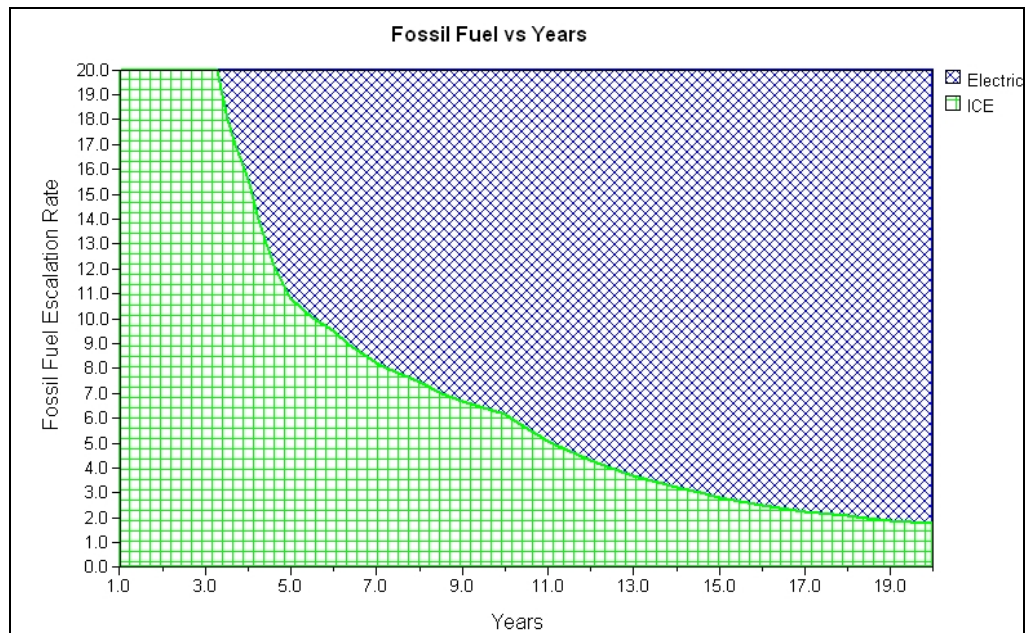


Figure 4-27. Airport “D” sensitivity analysis for baggage tractor and belt loader.

Figures 4-28 and 4-29 are sensitivity graphs that show fossil fuel escalation rates versus years for comparison of a single gasoline and a single electric baggage tractor, and a single gasoline and a single electric belt loader, respectively. For the eGSE, one charge port is assumed to support two GSE vehicles.

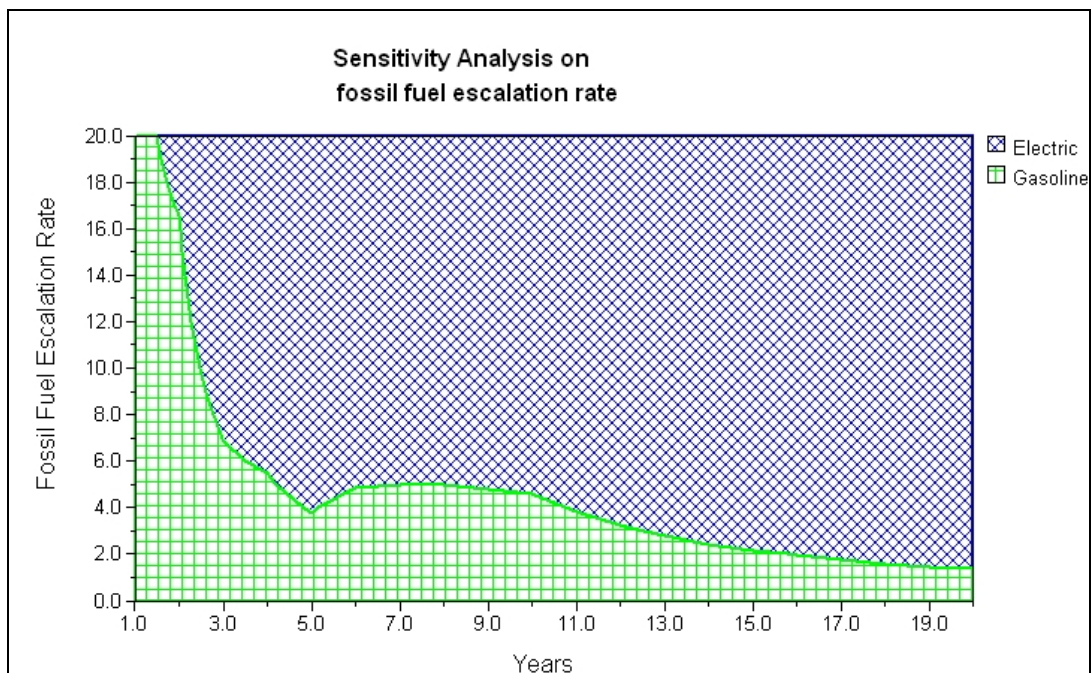


Figure 4-28. Airport “D” sensitivity analysis for baggage tractor.



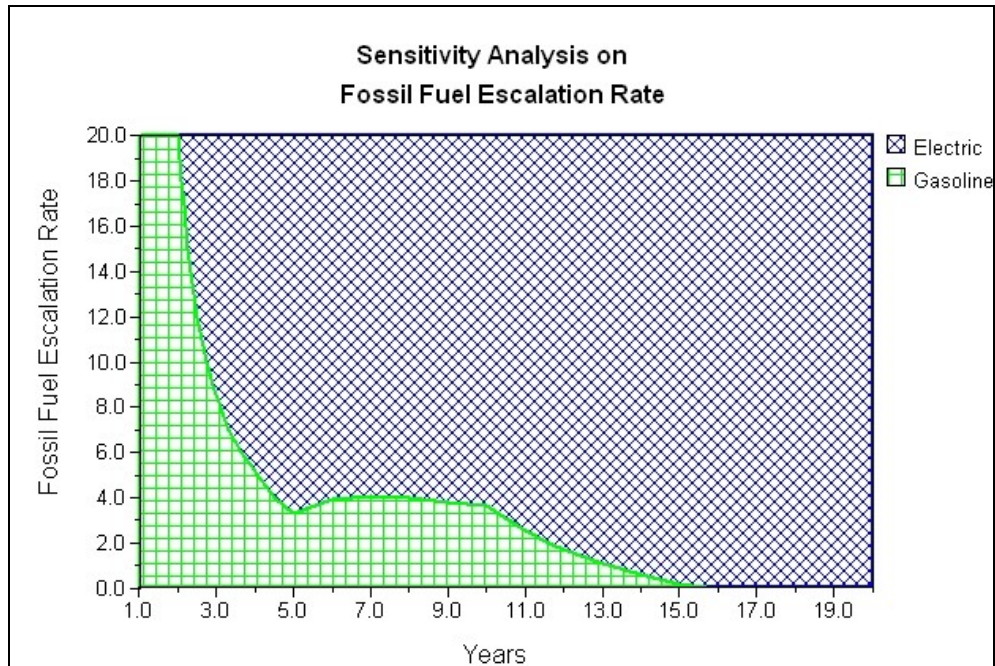


Figure 4-29. Airport “D” sensitivity analysis for belt loader.

#### 4.4.1 Emissions

Table 4-12 presents the emissions savings for the Airport “D” analysis. Because of the large eGSE fleet and a high-usage airport, a large amount of emissions savings is achieved.

Table 4-12. Airport “D” emissions savings in tons per year.

Quantity	Description	CO	HC	NO <sub>x</sub>	PM
91	Gas Baggage Tractor	5248	191	109	1
71	Diesel Baggage Tractor	35.1	5.62	44.9	6.52
3	Diesel Belt Loaders	0.657	0.158	1.333	0.15
Totals		5517.428	207.018	162.295	7.762
CO = carbon monoxide, HC = total hydrocarbons, NO <sub>x</sub> = oxides of nitrogen, PM = particulate matter					

## 5. SENSITIVITY ANALYSIS

In order to better understand which cost variables most influence the economics of choosing electric versus fossil fuel GSE, various sensitivity analyses were performed. As shown in each individual airport scenario, fossil fuel inflation rates significantly alter the economic picture, especially in baggage tractors, the highest user of fuel. Other sensitivities reviewed are provided below and include:

- Varying electricity escalation rates only
- Varying energy (i.e., electricity and fossil fuel) rates only and at the same rate
- Varying the capital cost differential by varying electric equipment and installation cost subsidies from 0 to 20%
- Varying labor rates only.

The following analyses were performed on the Airport “A” scenario, and unless otherwise noted, the parameters remain the same as previously shown for Airport “A.”

Figure 5-1 shows the sensitivity of varying only the annual electric escalation rates. The graph shows that eGSE has a reasonable recovery as long as the annual electricity escalation rates stay below approximately 13%.

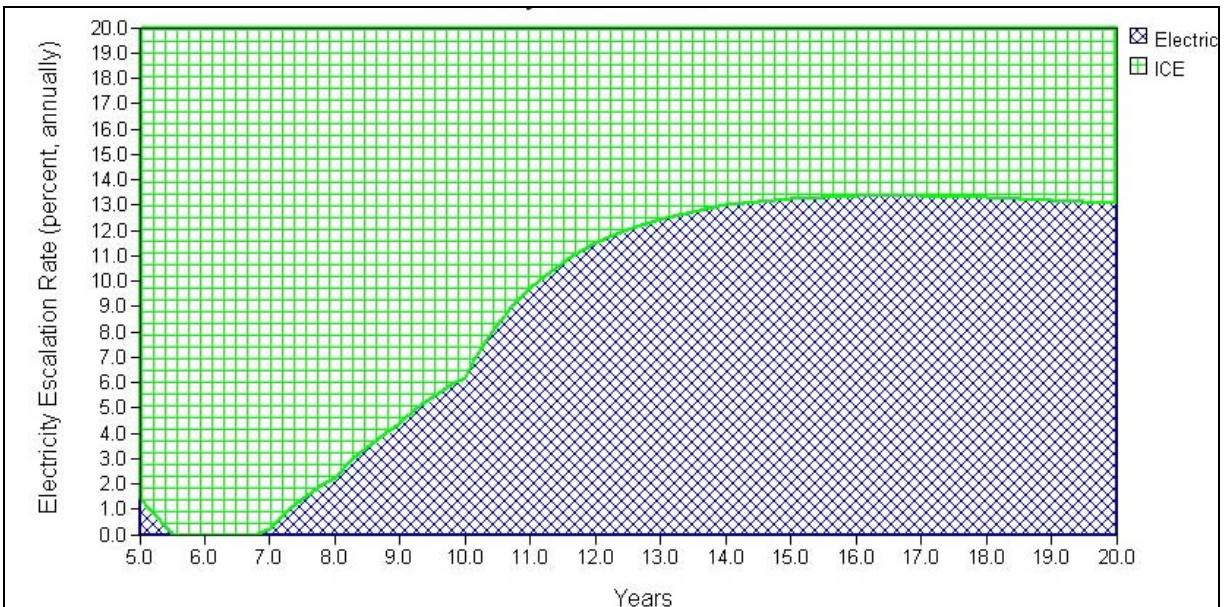


Figure 5-1. Electricity escalation rate versus years.

Figure 5-2 shows an annual energy (both electric and fossil fuel) escalation rate versus years; it shows the major influence of fossil fuel escalation on the economics for the entire operation. Even while escalating both fossil fuel and electricity at the same rates, fossil fuel has a much higher influence on the outcome. If the escalation rate is above 8.5% annually, eGSE is cost effective immediately. However, if the energy escalation rate stays below 2% annually, eGSE takes over 20 years to be cost effective.

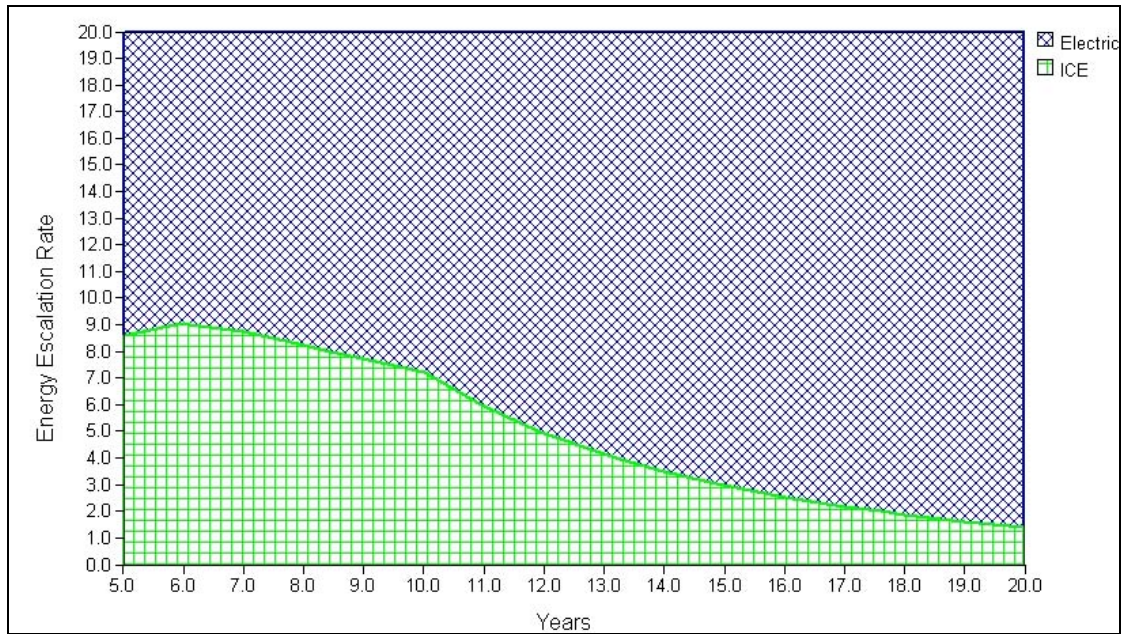


Figure 5-2. Energy escalation rates (annually) versus years.

Figure 5-3 shows GSE capital costs subsidized from 0 to 20% of the total costs, including chargers and their installations. Note that as the subsidies approach 16%, eGSE is cost effective within 1 year.

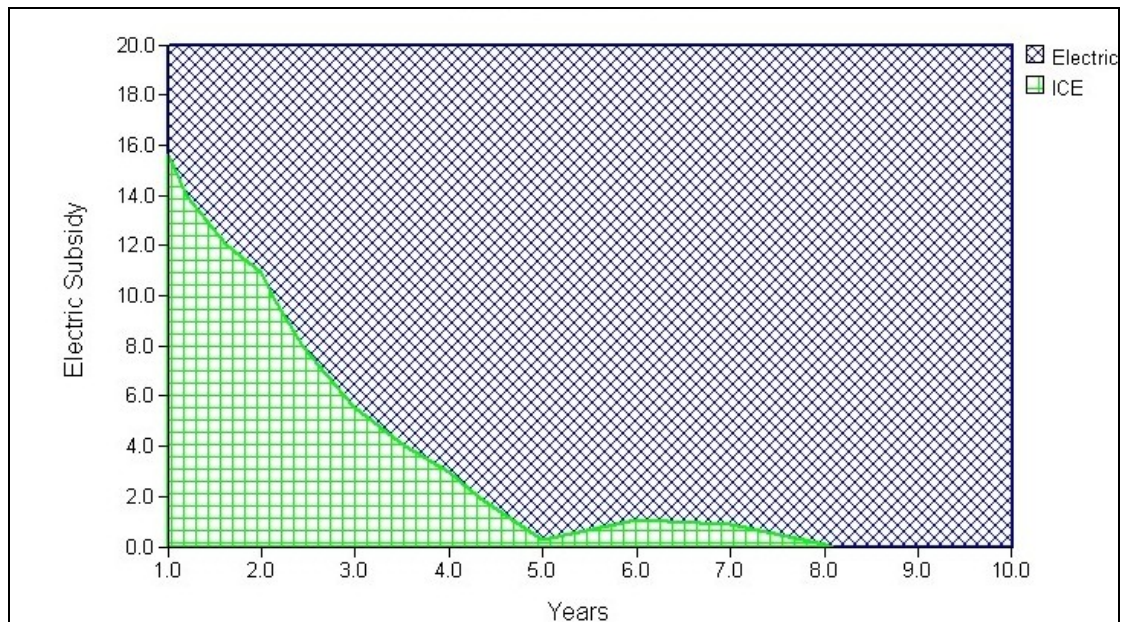


Figure 5-3. Electric ground support equipment capital cost subsidy (including charging infrastructure) versus years.

Figure 5-4 demonstrates that labor costs are almost identical between ICE GSE and eGSE with ICE GSE having a slight edge. This simply means that eGSE has a higher labor component than ICE GSE, even though ICE has a higher overall maintenance cost. This is an area that each user needs to take a close look at for their operation. Depending on various operational decisions on the eGSE, such as



utilizing sealed batteries over flooded batteries, and AC drives versus DC drives, these labor costs could swing the other way in favor of eGSE.

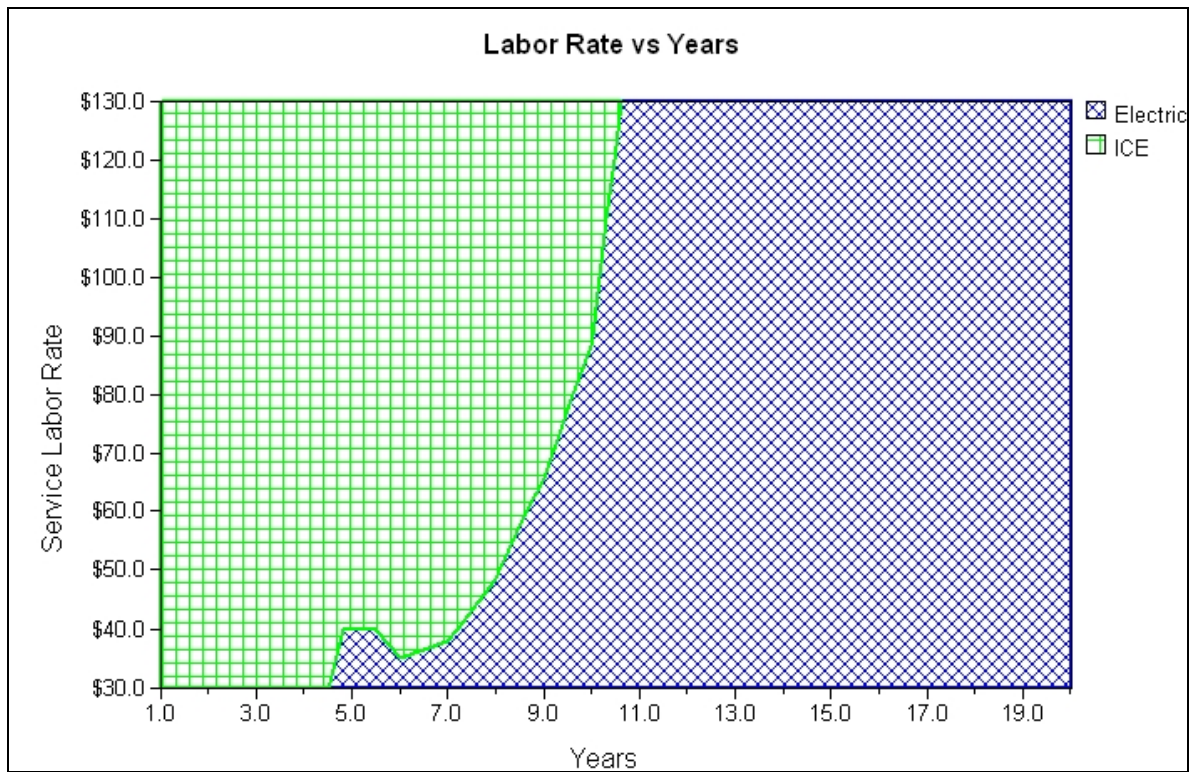


Figure 5-4. Service labor rates versus years.

## **6. COST-REDUCTION STRATEGIES**

Cost-reduction strategies for eGSE were reviewed as part of this study. Based on additional sensitivity analysis, the major costs associated with eGSE are as follows:

- Initial capital cost of GSE
- Battery replacement
- Charging infrastructure.

For eGSE, fuel costs, in the form of electricity, become a relatively small component of the overall costs because eGSE is more efficient and electricity costs from a \$/BTU standpoint are generally less than gaseous fuels.

### **6.1 Ground Support Equipment Capital Cost-Reduction Strategies**

Combining eGSE orders with other airlines to increase production run volumes may help in getting a reduced capital price on the equipment. The eGSE is still somewhat of a specialty item, even though production numbers are increasing. Higher volumes should result in lower costs for all those participating in these combined orders.

Properly sizing the battery pack for the application can help reduce the initial capital cost and O&M costs for battery pack replacement. For light-duty to medium-duty applications, a smaller battery may meet your needs. This especially can be true when utilizing fast charging, which allows eGSE the opportunity to charge throughout the day.

### **6.2 Battery Replacement**

Battery purchase costs are driven by market demand and cost of materials, primarily the cost of lead. It is best to ask for competitive bids and negotiate the best warranty possible. Proper operation and maintenance of batteries may allow an operator to extend the battery life well beyond the warranty period. Some ways of maximizing the battery life are controlling both the vehicle discharge parameters through proper vehicle controller settings and purchasing “smart” chargers with temperature compensation and battery protections built in.

### **6.3 Charging Infrastructure**

Charging infrastructure costs can be broken down into the following three main sections:

- Capital purchase of chargers
- Electrical supply and installation
- O&M expenses.

#### **6.3.1 Capital Purchase of Chargers**

When deploying universal fast chargers, the number of charge “ports” actually required based on amp-hour throughput and operational needs should be determined. In most cases, a single fast charge port can support two to four pieces of GSE equipment. Where sealed, valve-regulated, lead-acid batteries are deployed, equalizing can typically occur less often than with flooded lead-acid batteries, thus requiring fewer ports for the overall system.

When considering conventional slow chargers, a specific charger and dedicated electrical circuit will be required for each piece of equipment and battery, leaving little flexibility.

### **6.3.2 Electrical Supply and Installation**

Infrastructure costs can be the most difficult item to pin down early in the planning process, and although these costs can be significant, new strategies are now available to help minimize the installation cost such as sharing power with the jet bridge or other available circuits. Working with the local utility may also prove to be beneficial in developing some cost-saving strategies. Additionally, the fast charge systems that are currently available may have different approaches to sharing power; each should be thoroughly evaluated by a licensed electrician in order to ensure the most cost-effective decision is made.

### **6.3.3 Operating and Maintenance Expenses (Including Electricity Costs)**

Charger O&M expenses include DC output cords, charger power electronics, preventative maintenance (such as filters), and cost of energy used. Several different methods are now in use for connecting the charger to the vehicle. These methods should be evaluated by airline GSE personnel to understand the cost and operational tradeoffs of each design. If the utility bill is paid directly, checking with the local utility to understand whether or not they have preferred rates for electric equipment may be worthwhile. Additionally, if you are being charged for demand charges request, the local utility can monitor your energy use and utility bill to see if there are any strategies to help reduce costs.

## 7. ASSUMPTIONS

Default numbers are based on actual data provided by two major commercial airlines: an international carrier and a “low-cost” provider. For the specific airports studied, available data for those particular sites were utilized; where no data existed, default parameters were used. The methodology for collecting data included site visits and personnel interviews, review of maintenance records with the airline’s GSE departments or corresponding contract maintenance organizations, and spending time out on the ramp at the airport collecting and analyzing data to better understand the particular operations at each airport.

**Capital Costs**—Estimated capital costs for the vehicles and ancillary equipment required were provided by both the airlines and manufacturers. Because these items can vary based on quantity and other factors, the user can choose to input their own values.

**Fuel Costs**—Fuel costs (including gasoline, diesel, and electricity) used for the defaults were provided by airline participants, then an average of the various locations was used for the default numbers. Default inflation percentages were estimates based on looking at the previous 10-year increases. Because there are many differing opinions on this subject, the user is also able to input their own starting numbers and inflation estimates for each of the fuels.

**Battery and Charger Efficiencies**—To handle the various efficiencies of batteries and charger systems, the original model made assumptions for both conventional and universal smart chargers. Based on further review of the model by project participants, the model may be modified in the next version, allowing the user to provide the efficiency of the charger and the percent of estimated battery overcharge. The percent overcharge amount is assumed to be at only 20% of the maximum charge rate for a period of 2 hours. Although still under review at the time of this reporting, the anticipated default parameters considered for the conventional charger have an 85% efficiency rating; the universal smart chargers (multi-voltage, high-efficient insulated gated bipolar transistor IGBT or similar design) have a 90% efficiency rating. For both charge systems, a 5% overcharge for a sealed battery and a 15% overcharge for a flooded battery are anticipated.

**Maintenance Costs**—Maintenance costs were gathered at each of the four airports and from corporate GSE staff members of each participating airline. Average numbers were utilized for the default parameters for both labor and material items. Where available, actual service work orders were reviewed and cataloged.

**Emissions**—Emissions data were taken from the EDMS Model Version 4.12. The model looks only at tailpipe emissions; therefore, for gasoline and diesel, it does not take into account emissions generated from mining and reforming the fuel, or emissions from transportation of the fuel to the site. Similar with eGSE, power plant emissions are not included in the calculations.

## 8. CONCLUSIONS

The findings of this project show that the cost of fuel for ICE GSE is the main cost driver; therefore, it has the strongest influence on the payback period for electric over ICE GSE options. Where more fuel is used, such as with baggage tractors, the more profound the influence of fuel costs. The strongest influence on eGSE is the initial capital costs, infrastructure costs, and battery life-cycle costs.

Other findings include:

- The eGSE clearly has lower operating costs than ICE GSE for the baggage tractor, belt loader and pushback tractor GSE analyzed in this project.
- Capital costs for new ICE GSE are still significantly lower than new eGSE.
- Payback time for eGSE, when no cost-sharing is provided, generally ranges from 3 to 7 years.
- Where cost-sharing or grants are available, depending on the amount, payback for eGSE can be reduced from 0 to 3 years, with substantial life-cycle cost savings accruing over the life of the GSE.
- Strategies, such as converting old ICE vehicles to electric or implementing group purchases, can help lower the cost of eGSE.
- Strategies to lower infrastructure costs are available such as utilizing existing bridge supply power and utilizing smart power sharing charge systems to reduce supply requirements.

The cost model allows airlines and other interested stakeholders the opportunity to run various scenarios based on user-provided cost information and operating parameters, or by using the default parameters. Cost-saving strategies, that support a reduction in initial investments or O&M expenses, can also be integrated into the model, which provides results associated with such strategies.

Appendix A  
Airport “A” Input Data and Results Summary

**Appendix A - Airport “A” Input Data and Results Summary**



# Appendix A Airport "A" Input Data and Results Summary

A page 1/2

		Purchasing Price	Install	Ownership cost \$/year	Operating Cost \$/yr	Total cost \$/yr	Total for analysis
17	Gasoline ford 300 BagTractor	\$442,000		\$22,100	\$175,649	\$197,749	\$3,954,980
16	Diesel Deutz 1011 Beltloader	\$515,200		\$25,760	\$114,907	\$140,667	\$2,813,340
7	GT1628/GT35 PushBack	\$603,400		\$30,170	\$58,222	\$88,392	\$1,767,840
12	DC BagTractor	\$426,000		\$21,300	\$66,298	\$87,598	\$1,751,960
5	AC BagTractor	\$177,500		\$8,875	\$27,946	\$36,821	\$736,420
16	Electric Beltloader	\$620,800		\$31,040	\$46,838	\$77,878	\$1,557,560
7	350E PushBack	\$651,000		\$32,550	\$40,764	\$73,314	\$1,466,280
8	Single port Fast Charger	\$140,000	\$24,000	\$8,200	\$8,776	\$16,976	\$339,520
4	Power Sharing cost per port	\$150,000	\$12,000	\$8,100	\$4,388	\$12,488	\$249,760
		\$3,725,900	\$36,000	\$188,095	\$543,788	\$731,883	\$14,637,660

DAILY kWhr usage estimate from utility meter

560.28

Fossil Fuel Equipment

\$8,536,160

Electric Equipment

\$6,101,500

Difference

\$2,434,660

Estimated emissions in tons per year

		CO	HC	Nox	PM
17	Gasoline ford 300 BagTractor	700.308	25.560	14.551	.137
16	Diesel Deutz 1011 Beltloader	2.802	.675	5.686	.640
7	GT1628/GT35 PushBack	1.751	.345	4.441	.338
12	DC BagTractor	.000	.000	.000	.000
5	AC BagTractor	.000	.000	.000	.000
16	Electric Beltloader	.000	.000	.000	.000
7	350E PushBack	.000	.000	.000	.000
8	Single port Fast Charger	.000	.000	.000	.000
4	Power Sharing cost per port	.000	.000	.000	.000
Total Emissions		704.861	26.58	24.678	1.115

Energy cost and usage assumptions

	Gasoline	Diesel	Electric		Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	BagTractor	3.125	2.8125	18.5	5
% increase per year	7	7	2.5	Beltloader	2.25	2.025	2.9	4
				Pushback	3	1.95	8.8	3

Inputs

Number of years used for analysis	20	Labor Rate for Maintenance (\$/hr)	\$50.00
Amortization rate(%)	0		
Years of amortization	10		

## Appendix A

### Airport “A” Input Data and Results Summary

Result of analysis for xxx Page 2/2	Motor	Transmission	Controller	PM parts cost (\$/yr)	PM Labor (hrs/yr)	Battery Cost	Battery Life (yrs)	Sealed Batt	DC motor	Fast Charge
Gasoline ford 300 BagTractor	10000/1700/32	6500/900/16	0/0/0	\$1205	26.7 hrs					
Diesel Deutz 1011 Beltloader	15000/4000/16	6500/900/16	0/0/0	\$1250	14.5 hrs					
GT1628/GT35 PushBack	5000/4000/16	6500/5000/32	0/0/0	\$1520	14.5 hrs					
DC BagTractor	3250/975/10	20000/2000/16	3650/800/1.5	\$1047	24.7 hrs	\$6000	5 yrs	No	Yes	Yes
AC BagTractor	13687/1000/10	20000/5500/16	3650/1857/1.5	\$1047	24.7 hrs	\$6000	5 yrs	No	No	Yes
Electric Beltloader	7300/975/10	20000/2000/16	3650/800/1.5	\$669	15.5 hrs	\$4000	5 yrs	No	No	Yes
350E PushBack	4000/5300/20	5000/5500/16	3650/800/1.5	\$1082	14 hrs	\$6000	5 yrs	No	No	Yes

- XX/YY/ZZ represents failure rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement

	Load Factor (%)	Horse Power (hp)	CO (g/hp hr)	HC (g/hp hr)	Nox (g/hp hr)	PM (g/hp hr)	Fuel Type
Gasoline ford 300 BagTractor	55%	107	347.9577	12.7	7.23	.068	Gasoline
Diesel Deutz 1011 Beltloader	50%	71	3.06526	0.738	6.22	.7	Diesel
GT1628/GT35 PushBack	80%	100	2.59	0.51	6.57	.5	Diesel
DC BagTractor	55%	40	0	0	0	0	Electric
AC BagTractor	55%	40	0	0	0	0	Electric
Electric Beltloader	50%	40	0	0	0	0	Electric
350E PushBack	80%	100	0	0	0	0	Electric

	Cord Failure	Charger Failure	PM parts cost (\$/yr)	PM Labor (hrs/yr)
Single port Fast Charger	2/600/2	15/600/12	\$200	12 hrs
Power Sharing cost per port	2/600/2	15/600/12	\$200	12 hrs

- XX/YY/ZZ for chargers represents failure rate in years/cost of parts in \$ for replacement/ hrs of labor for replacement

## Appendix A

### Airport “A” Input Data and Results Summary

File

Vehicle Name  
Gasoline ford 300 BagTractor

Vehicle Type  
BagTractor

Purchase Price  
26000 \$

Energy source  
Gasoline

Engine

Motor

Motor failure rate in hrs  
10000

Engine replacement cost  
1700

Time to replace in hrs  
32

Preventive Maintenance

Yearly cost of parts  
1205

Yearly hours  
26.7

Transmission

Failure Rate  
6500 hrs

replacement cost  
900 \$

Time to replace  
16 hrs

Emissions

Load factor  
55 %

Horsepower  
107 hp

emissions in g/(hp hour)

CO  
347.957

HC  
12.7

Nox  
7.23

PM  
.068

File

Vehicle Name  
AC BagTractor

Vehicle Type  
BagTractor

Purchase Price  
35500 \$

Energy source  
Electric

Engine

Motor

Motor failure rate in hrs  
13687

Engine replacement cost  
1000

Time to replace in hrs  
10

Preventive Maintenance

Yearly cost of parts  
1047

Yearly hours  
24.7

Transaxle

Failure Rate  
20000 hrs

replacement cost  
5500 \$

Time to replace  
16 hrs

Controller

Failure Rate  
3650 hrs

replacement cost  
1857 \$

Time to replace  
1.5 hrs

Emissions

Load factor  
55 %

Horsepower  
40 hp

emissions in g/(hp hour)

CO  
0

HC  
0

Nox  
0

PM  
0

## Appendix A

### Airport “A” Input Data and Results Summary

File

Vehicle Name  
DC BagTractor

Vehicle Type  
BagTractor

Purchase Price  
35500 \$

Energy source  
Electric

Engine  
Motor  
Motor failure rate in hrs  
3250

Engine replacement cost  
975

Time to replace in hrs  
10

Preventive Maintenance  
Yearly cost of parts  
1047

Yearly hours  
24.7

Transaxle  
Failure Rate  
20000 hrs

replacement cost  
2000 \$

Time to replace  
16 hrs

Controller  
Failure Rate  
3650 hrs

replacement cost  
800 \$

Time to replace  
1.5 hrs

Emissions  
Load factor  
55 %

Horsepower  
40 hp

emissions in g/(hp hour)  
CO  
0

HC  
0

Nox  
0

PM  
0

File

Vehicle Name  
Diesel Deutz 1011 Beltloader

Vehicle Type  
Beltloader

Purchase Price  
32200 \$

Energy source  
Diesel

Engine  
Motor  
Motor failure rate in hrs  
15000

Engine replacement cost  
4000

Time to replace in hrs  
16

Preventive Maintenance  
Yearly cost of parts  
1250

Yearly hours  
14.5

Transmission  
Failure Rate  
6500 hrs

replacement cost  
900 \$

Time to replace  
16 hrs

Emissions  
Load factor  
50 %

Horsepower  
71 hp

emissions in g/(hp hour)  
CO  
3.06526

HC  
0.738

Nox  
6.22

PM  
.7

## Appendix A

### Airport “A” Input Data and Results Summary

<p><b>File</b></p> <p>Vehicle Name  <input type="text" value="Electric Beltloader"/></p>		<p>Transaxle</p> <p>Failure Rate  <input type="text" value="20000"/> hrs</p> <p>replacement cost  <input type="text" value="2000"/> \$</p> <p>Time to replace  <input type="text" value="16"/> hrs</p>		<p>Controller</p> <p>Failure Rate  <input type="text" value="3650"/> hrs</p> <p>replacement cost  <input type="text" value="800"/> \$</p> <p>Time to replace  <input type="text" value="1.5"/> hrs</p>	
<p>Vehicle Type  <input type="text" value="Beltloader"/></p> <p>Purchase Price  <input type="text" value="38800"/> \$</p> <p>Energy source  <input type="text" value="Electric"/></p>		<p>Engine</p> <p>Motor failure rate in hrs  <input type="text" value="7300"/></p> <p>Engine replacement cost  <input type="text" value="975"/></p> <p>Time to replace in hrs  <input type="text" value="10"/></p>		<p>Emissions</p> <p>Load factor <input type="text" value="50"/> %</p> <p>Horsepower <input type="text" value="40"/> hp</p> <p>emissions in g/(hp hour)</p> <p>CO <input type="text" value="0"/></p> <p>HC <input type="text" value="0"/></p> <p>Nox <input type="text" value="0"/></p> <p>PM <input type="text" value="0"/></p>	
<p>Preventive Maintenance</p> <p>Yearly cost of parts  <input type="text" value="669"/></p> <p>Yearly hours  <input type="text" value="15.5"/></p>					

<p><b>File</b></p> <p>Vehicle Name  <input type="text" value="GT1628/GT35 PushBack"/></p>		<p>Transmission</p> <p>Failure Rate  <input type="text" value="6500"/> hrs</p> <p>replacement cost  <input type="text" value="5000"/> \$</p> <p>Time to replace  <input type="text" value="32"/> hrs</p>		<p>Emissions</p> <p>Load factor <input type="text" value="80"/> %</p> <p>Horsepower <input type="text" value="100"/> hp</p> <p>emissions in g/(hp hour)</p> <p>CO <input type="text" value="2.59"/></p> <p>HC <input type="text" value="0.51"/></p> <p>Nox <input type="text" value="6.57"/></p> <p>PM <input type="text" value="1.5"/></p>	
<p>Vehicle Type  <input type="text" value="Pushback"/></p> <p>Purchase Price  <input type="text" value="86200"/> \$</p> <p>Energy source  <input type="text" value="Diesel"/></p>		<p>Engine</p> <p>Motor failure rate in hrs  <input type="text" value="5000"/></p> <p>Engine replacement cost  <input type="text" value="4000"/></p> <p>Time to replace in hrs  <input type="text" value="16"/></p>		<p>Preventive Maintenance</p> <p>Yearly cost of parts  <input type="text" value="1520"/></p> <p>Yearly hours  <input type="text" value="14.5"/></p>	

## Appendix A

### Airport “A” Input Data and Results Summary

File

Vehicle Name  
350E PushBack

Vehicle Type  
Pushback

Purchase Price  
93000 \$

Energy source  
Electric

Engine  
Motor  
Motor failure rate in hrs  
4000

Engine replacement cost  
5300

Time to replace in hrs  
20

Preventive Maintenance  
Yearly cost of parts  
1082

Yearly hours  
14

Transaxle  
Failure Rate  
5000 hrs

replacement cost  
5500 \$

Time to replace  
16 hrs

Controller  
Failure Rate  
3650 hrs

replacement cost  
800 \$

Time to replace  
1.5 hrs

Emissions  
Load factor  
80 %

Horsepower  
100 hp

emissions in g/(hp hour)  
CO  
0

HC  
0

Nox  
0

PM  
0

File

Single port Fast Charger

Charger Cost  
17500

Install Cost  
3000

Preventive Maintenance  
Yearly cost of parts  
200

Yearly hours  
12

Cord  
Cord failure rate in years  
2

cord replacement cost  
600

Time to replace in hrs  
2

Charger Failure  
Charger failure rate in years  
15

charger part replacement cost  
600

Time to repair in hrs  
12



Appendix A  
Airport “A” Input Data and Results Summary

File

Power Sharing cost per port

Charger Cost

**Cord**  
Cord failure rate in years

**Charger Failure**  
Charger failure rate in years

cord replacement cost

charger part replacement cost

Time to replace in hrs

Time to repair in hrs

Install Cost

**Preventive Maintenance**  
Yearly cost of parts

Yearly hours

Appendix B  
Airport “B” Input Data and Results Summary

**Appendix B - Airport “B” Input Data and Results Summary**

## Appendix B

### Airport "B" Input Data and Results Summary

V1.1.1 07/26/2006 Result of analysis for:  
B page 1/2

		Purchasing Price	Install	Ownership cost \$/year	Operating Cost \$/yr	Total cost \$/yr	Total for analysis
27	Diesel Deutz 2011 BagTractor	\$702,000		\$35,100	\$320,396	\$355,496	\$7,109,920
27	AC BagTractor	\$958,500		\$47,925	\$197,476	\$245,401	\$4,908,020
10	Single port Fast Charger	\$175,000	\$30,000	\$10,250	\$10,970	\$21,220	\$424,400
		\$1,835,500	\$30,000	\$93,275	\$528,842	\$622,117	\$12,442,340

DAILY kWhr  
usage estimate  
from utility meter

599.4

Fossil Fuel Equipment

\$7,109,920

Electric Equipment

\$5,332,420

Difference

\$1,777,500

Estimated emissions in tons per year

		CO	HC	Nox	PM
27	Diesel Deutz 2011 BagTractor	5.048	2.138	17.074	2.480
27	AC BagTractor	.000	.000	.000	.000
10	Single port Fast Charger	.000	.000	.000	.000
Total Emissions		5.048	2.138	17.074	2.48

Energy cost and usage assumptions

	Gasoline	Diesel	Electric		Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	BagTractor	3.75	3.375	22.2	7
% increase per year	7	7	2.5	Beltloader	2.7	2.43	3.48	5
				Pushback	3.6	2.34	10.56	4

Inputs

Number of years used for analysis

20

Labor Rate for Maintenance (\$/hr)

\$50.00

Amortization rate(%)

0

Years of amortization

10

## Appendix B

### Airport “B” Input Data and Results Summary

Result of analysis for B	Motor	Transmission	Controller	PM parts cost (\$/yr)	PM Labor hrs/yr)	Battery Cost	Battery Life (yrs)	Sealed Batt	DC motor	Fast Charge
Page 2/2										
Diesel Deutz 2011 BagTractor AC BagTractor	10000/4000/16 13687/1000/10	6500/900/16 20000/5500/16	0/0/0 3650/1857/1.5	\$1629 \$1047	26.7 hrs 24.7 hrs	\$7900	3 yrs	Yes	No	Yes
- XX/YY/ZZ represents failure rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement										
	Load Factor (%)	Horse Power (hp)	CO (g/hp hr)	HC (g/hp hr)	Nox (g/hp hr)	PM (g/hp hr)	Fuel Type			
Diesel Deutz 2011 BagTractor AC BagTractor	55% 55%	71 40	1.7 0	0.72 0	5.75 0	.835 0	Diesel Electric			
	Cord Failure	Charger Failure	PM parts cost (\$/yr)	PM Labor (hrs/yr)						
Single port Fast Charger	2/600/2	15/600/12	\$200	12 hrs						
- XX/YY/ZZ for chargers represents failure rate in years/cost of parts in \$ for replacement/ hrs of labor for replacement										

## Appendix B

### Airport “B” Input Data and Results Summary

File

Vehicle Name  
AC BagTractor

Vehicle Type  
BagTractor

Purchase Price  
35500 \$

Energy source  
Electric

Engine  
Motor  
Motor failure rate in hrs  
13687

Engine replacement cost  
1000

Time to replace in hrs  
10

Preventive Maintenance  
Yearly cost of parts  
1047

Yearly hours  
24.7

Transaxle  
Failure Rate  
20000 hrs

replacement cost  
5500 \$

Time to replace  
16 hrs

Controller  
Failure Rate  
3650 hrs

replacement cost  
1857 \$

Time to replace  
1.5 hrs

Emissions  
Load factor  
55 %

Horsepower  
40 hp

emissions in g/(hp hour)  
CO  
0

HC  
0

Nox  
0

PM  
0

Edit Properties

File

Vehicle Name  
Diesel Deutz 2011 BagTractor

Vehicle Type  
BagTractor

Purchase Price  
26000 \$

Energy source  
Diesel

Engine  
Motor  
Motor failure rate in hrs  
10000

Engine replacement cost  
4000

Time to replace in hrs  
16

Preventive Maintenance  
Yearly cost of parts  
1629

Yearly hours  
26.7

Transmission  
Failure Rate  
6500 hrs

replacement cost  
900 \$

Time to replace  
16 hrs

Emissions  
Load factor  
55 %

Horsepower  
71 hp

emissions in g/(hp hour)  
CO  
1.7

HC  
0.72

Nox  
5.75

PM  
.835

Appendix C  
Airport “C” Input Data and Results Summary

**Appendix C - Airport “C” Input Data and Results Summary**



## Appendix C

### Airport "C" Input Data and Results Summary

V1.1.1 08/17/2006 Result of analysis for:

C page 1/2

		Purchasing Price	Install	Ownership cost \$/year	Operating Cost \$/yr	Total cost \$/yr	Total for analysis
16	Gasoline ford 300 BagTractor	\$416,000		\$20,800	\$165,317	\$186,117	\$3,722,340
7	Gasoline ford 300 Beltloader	\$199,500		\$9,975	\$50,364	\$60,339	\$1,206,780
7	Diesel Deutz 1011 Beltloader	\$225,400		\$11,270	\$50,272	\$61,542	\$1,230,840
6	GT1628/GT35 PushBack	\$517,200		\$25,860	\$49,904	\$75,764	\$1,515,280
16	DC BagTractor	\$568,000		\$28,400	\$88,398	\$116,798	\$2,335,960
14	Electric Beltloader	\$543,200		\$27,160	\$41,446	\$68,606	\$1,372,120
6	350E PushBack	\$558,000		\$27,900	\$35,542	\$63,442	\$1,268,840
8	Power Sharing cost per port	\$100,000	\$24,000	\$6,200	\$8,776	\$14,976	\$299,520
4	Power Sharing cost per port	\$150,000	\$12,000	\$8,100	\$4,308	\$12,408	\$249,760
		\$3,277,300	\$36,000	\$165,665	\$494,407	\$660,072	\$13,201,440

DAILY kWhr

usage estimate

from utility meter

560.736

Fossil Fuel Equipment

Electric Equipment

Difference

\$7,675,240

\$5,526,200

\$2,149,040

Estimated emissions in tons per year

		CO	HC	Nox	PM
16	Gasoline ford 300 BagTractor	659.113	24.057	13.695	.129
7	Gasoline ford 300 Beltloader	145.253	6.027	4.364	.041
7	Diesel Deutz 1011 Beltloader	1.226	.295	2.488	.280
6	GT1628/GT35 PushBack	1.501	.295	3.806	.290
16	DC BagTractor	.000	.000	.000	.000
14	Electric Beltloader	.000	.000	.000	.000
6	350E PushBack	.000	.000	.000	.000
8	Power Sharing cost per port	.000	.000	.000	.000
4	Power Sharing cost per port	.000	.000	.000	.000
Total Emissions		807.093	30.674	24.353	0.74

Energy cost and usage assumptions

	Gasoline	Diesel	Electric		Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	BagTractor	3.125	2.8125	18.5	5
% increase per year	7	7	2.5	Beltloader	2.25	2.025	2.9	4
				Pushback	3	1.95	8.8	3

Inputs

Number of years used for analysis	20	Labor Rate for Maintenance (\$/hr)	\$50.00
Amortization rate(%)	0		
Years of amortization	10		

## Appendix C

### Airport “C” Input Data and Results Summary

Result of analysis for C

Page 2/2

	Motor	Transmission	Controller	PM parts cost (\$/yr)	PM Labor hrs/yr	Battery Cost	Battery Life (yrs)	Sealed Batt	DC motor	Fast Charge
Gasoline ford 300 BagTractor	10000/1700/32	6500/900/16	0/0/0	\$1205	26.7 hrs					
Gasoline ford 300 Beltloader	15000/1700/32	6500/900/16	0/0/0	\$890	14.5 hrs					
Diesel Deutz 1011 Beltloader	15000/4000/16	6500/900/16	0/0/0	\$1250	14.5 hrs					
GT1628/GT35 PushBack	5000/4000/16	6500/5000/32	0/0/0	\$1520	14.5 hrs					
DC BagTractor	3250/975/10	20000/2000/16	3650/800/1.5	\$1047	24.7 hrs	\$6000	5 yrs	No	Yes	Yes
Electric Beltloader	7300/975/10	20000/2000/16	3650/800/1.5	\$669	15.5 hrs	\$4000	5 yrs	No	Yes	Yes
350E PushBack	4000/5300/20	5000/5500/16	3650/800/1.5	\$1082	14 hrs	\$6000	5 yrs	No	Yes	Yes

- XX/YY/ZZ represents failure rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement

	Load Factor (%)	Horse Power (hp)	CO (g/hp hr)	HC (g/hp hr)	Nox (g/hp hr)	PM (g/hp hr)	Fuel Type
Gasoline ford 300 BagTractor	55%	107	347.9577	12.7	7.23	.068	Gasoline
Gasoline ford 300 Beltloader	50%	107	241	10	7.24	.068	Gasoline
Diesel Deutz 1011 Beltloader	50%	71	3.06526	0.738	6.22	.7	Diesel
GT1628/GT35 PushBack	80%	100	2.59	0.51	6.57	.5	Diesel
DC BagTractor	55%	40	0	0	0	0	Electric
Electric Beltloader	50%	40	0	0	0	0	Electric
350E PushBack	80%	100	0	0	0	0	Electric

	Cord Failure	Charger Failure	PM parts cost (\$/yr)	PM Labor (hrs/yr)
Power Sharing cost per port	2/600/2	15/600/12	\$200	12 hrs
Power Sharing cost per port	2/600/2	15/600/12	\$200	12 hrs

- XX/YY/ZZ for chargers represents failure rate in years/cost of parts in \$ for replacement/ hrs of labor for replacement

## Appendix C

### Airport “C” Input Data and Results Summary

File

Vehicle Name  
Gasoline ford 300 BagTractor

Vehicle Type  
BagTractor

Purchase Price  
26000 \$

Energy source  
Gasoline

Engine  
Motor  
Motor failure rate in hrs  
10000

Engine replacement cost  
1700

Time to replace in hrs  
32

Preventive Maintenance  
Yearly cost of parts  
1205

Yearly hours  
26.7

Transmission  
Failure Rate  
6500 hrs

replacement cost  
900 \$

Time to replace  
16 hrs

Emissions  
Load factor 55 %

Horsepower 107 hp

emissions in g/(hp hour)  
CO 347.957

HC 12.7

Nox 7.23

PM .068

File

Vehicle Name  
DC BagTractor

Vehicle Type  
BagTractor

Purchase Price  
35500 \$

Energy source  
Electric

Engine  
Motor  
Motor failure rate in hrs  
3250

Engine replacement cost  
975

Time to replace in hrs  
10

Preventive Maintenance  
Yearly cost of parts  
1047

Yearly hours  
24.7

Transaxle  
Failure Rate  
20000 hrs

replacement cost  
2000 \$

Time to replace  
16 hrs

Controller  
Failure Rate  
3650 hrs

replacement cost  
800 \$

Time to replace  
1.5 hrs

Emissions  
Load factor 55 %

Horsepower 40 hp

emissions in g/(hp hour)  
CO 0

HC 0

Nox 0

PM 0

## Appendix C

### Airport “C” Input Data and Results Summary

Vehicle Name Gasoline ford 300 Beltloader		Transmission Failure Rate 6500 hrs replacement cost 900 \$ Time to replace 16 hrs	
Vehicle Type Beltloader	Engine Motor Motor failure rate in hrs 15000 Engine replacement cost 1700 Time to replace in hrs 32	Emissions Load factor 50 % Horsepower 107 hp emissions in g/(hp hour) CO 241 HC 10 Nox 7.24 PM .068	
Purchase Price 28500 \$	Energy source Gasoline	Preventive Maintenance Yearly cost of parts 890 Yearly hours 14.5	

File		Transmission Failure Rate 6500 hrs replacement cost 900 \$ Time to replace 16 hrs	
Vehicle Name Diesel Deutz 1011 Beltloader		Emissions Load factor 50 % Horsepower 71 hp emissions in g/(hp hour) CO 3.06526 HC 0.738 Nox 6.22 PM .7	
Vehicle Type Beltloader	Engine Motor Motor failure rate in hrs 15000 Engine replacement cost 4000 Time to replace in hrs 16		
Purchase Price 32200 \$	Preventive Maintenance Yearly cost of parts 1250 Yearly hours 14.5		
Energy source Diesel			

## Appendix C

### Airport “C” Input Data and Results Summary

<p><b>File</b></p> <p>Vehicle Name  <input type="text" value="Electric Beltloader"/></p>		<p><b>Transaxle</b></p> <p>Failure Rate  <input type="text" value="20000"/> hrs</p> <p>replacement cost  <input type="text" value="2000"/> \$</p> <p>Time to replace  <input type="text" value="16"/> hrs</p>		<p><b>Controller</b></p> <p>Failure Rate  <input type="text" value="3650"/> hrs</p> <p>replacement cost  <input type="text" value="800"/> \$</p> <p>Time to replace  <input type="text" value="1.5"/> hrs</p>	
<p>Vehicle Type  <input type="text" value="Beltloader"/></p> <p>Purchase Price  <input type="text" value="38800"/> \$</p> <p>Energy source  <input type="text" value="Electric"/></p>		<p><b>Engine</b></p> <p>Motor            Motor failure rate in hrs  <input type="text" value="7300"/></p> <p>Engine replacement cost  <input type="text" value="975"/></p> <p>Time to replace in hrs  <input type="text" value="10"/></p>		<p><b>Emissions</b></p> <p>Load factor <input type="text" value="50"/> %</p> <p>Horsepower <input type="text" value="40"/> hp</p> <p>emissions in g/(hp hour)</p> <p>CO <input type="text" value="0"/></p> <p>HC <input type="text" value="0"/></p> <p>Nox <input type="text" value="0"/></p> <p>PM <input type="text" value="0"/></p>	
<p><b>Preventive Maintenance</b></p> <p>Yearly cost of parts  <input type="text" value="669"/></p> <p>Yearly hours  <input type="text" value="15.5"/></p>					

<p><b>File</b></p> <p>Vehicle Name  <input type="text" value="GT1628/GT35 PushBack"/></p>		<p><b>Transmission</b></p> <p>Failure Rate  <input type="text" value="6500"/> hrs</p> <p>replacement cost  <input type="text" value="5000"/> \$</p> <p>Time to replace  <input type="text" value="32"/> hrs</p>	
<p>Vehicle Type  <input type="text" value="Pushback"/></p> <p>Purchase Price  <input type="text" value="86200"/> \$</p> <p>Energy source  <input type="text" value="Diesel"/></p>		<p><b>Engine</b></p> <p>Motor            Motor failure rate in hrs  <input type="text" value="5000"/></p> <p>Engine replacement cost  <input type="text" value="4000"/></p> <p>Time to replace in hrs  <input type="text" value="16"/></p>	
<p><b>Preventive Maintenance</b></p> <p>Yearly cost of parts  <input type="text" value="1520"/></p> <p>Yearly hours  <input type="text" value="14.5"/></p>		<p><b>Emissions</b></p> <p>Load factor <input type="text" value="80"/> %</p> <p>Horsepower <input type="text" value="100"/> hp</p> <p>emissions in g/(hp hour)</p> <p>CO <input type="text" value="2.59"/></p> <p>HC <input type="text" value="0.51"/></p> <p>Nox <input type="text" value="6.57"/></p> <p>PM <input type="text" value=".5"/></p>	

## Appendix C

### Airport “C” Input Data and Results Summary

File

Vehicle Name  
350E PushBack

Vehicle Type  
Pushback

Purchase Price  
93000 \$

Energy source  
Electric

Engine  
Motor  
Motor failure rate in hrs  
4000

Engine replacement cost  
5300

Time to replace in hrs  
20

Preventive Maintenance  
Yearly cost of parts  
1082

Yearly hours  
14

Transaxle  
Failure Rate  
5000 hrs

replacement cost  
5500 \$

Time to replace  
16 hrs

Controller  
Failure Rate  
3650 hrs

replacement cost  
800 \$

Time to replace  
1.5 hrs

Emissions  
Load factor 80 %

Horsepower 100 hp

emissions in g/(hp hour)

CO 0

HC 0

Nox 0

PM 0

File

Power Sharing cost per port

Charger Cost  
37500

Install Cost  
3000

Cord  
Cord failure rate in years  
2

cord replacement cost  
600

Time to replace in hrs  
2

Charger Failure  
Charger failure rate in years  
15

charger part replacement cost  
600

Time to repair in hrs  
12

Preventive Maintenance  
Yearly cost of parts  
200

Yearly hours  
12



Appendix C  
Airport “C” Input Data and Results Summary

**Charger list**

File

Power Sharing cost per port

Charger Cost

Cord  
Cord failure rate in years

Charger Failure  
Charger failure rate in years

Install Cost

cord replacement cost

charger part replacement cost

Preventive Maintenance  
Yearly cost of parts

Time to replace in hrs

Time to repair in hrs

Yearly hours

Appendix D  
Airport “D” Input Data and Results Summary

**Appendix D - Airport “D” Input Data and Results Summary**

## Appendix D

### Airport "D" Input Data and Results Summary

V1.1.1.07/28/2006 Result of analysis for:

D page 1/2

		Purchasing Price	Install	Ownership cost \$/year	Operating Cost \$/yr	Total cost \$/yr	Total for analysis
91	Gasoline ford 300 BagTractor	\$2,366,000		\$118,300	\$1,090,450	\$1,208,750	\$24,175,000
71	Diesel Deutz 1011 BagTractor	\$1,846,000		\$92,300	\$840,605	\$932,905	\$18,658,100
85	AC BagTractor	\$3,017,500		\$150,875	\$527,402	\$678,277	\$13,565,540
9	Gasoline ford 300 Beltloader	\$256,500		\$12,825	\$74,851	\$87,676	\$1,753,520
3	Diesel Deutz 1011 Beltloader	\$96,600		\$4,830	\$24,696	\$29,526	\$590,520
12	Electric Beltloader	\$465,600		\$23,280	\$37,123	\$60,403	\$1,208,060
72	Power Sharing cost per port	\$1,260,000	\$216,000	\$73,800	\$78,987	\$152,787	\$3,055,740
77	Conventional Charger	\$308,000	\$231,000	\$26,950	\$29,674	\$56,624	\$1,132,480
77	DC BagTractor	\$2,733,500		\$136,675	\$447,258	\$583,933	\$11,678,660
		\$12,349,700	\$447,000	\$639,835	\$3,151,046	\$3,790,881	\$75,817,620

DAILY kWhr  
usage estimate  
from utility meter

4365.792

Fossil Fuel Equipment

\$45,177,140

Electric Equipment

\$30,640,480

Difference

\$14,536,660

Estimated emissions in tons per year

		CO	HC	Nox	PM
91	Gasoline ford 300 BagTractor	5248.189	191.552	109.049	1.026
71	Diesel Deutz 1011 BagTractor	35.139	5.622	44.900	6.520
85	AC BagTractor	.000	.000	.000	.000
9	Gasoline ford 300 Beltloader	233.443	9.686	7.013	.066
3	Diesel Deutz 1011 Beltloader	.657	.158	1.333	.150
12	Electric Beltloader	.000	.000	.000	.000
72	Power Sharing cost per port	.000	.000	.000	.000
77	Conventional Charger	.000	.000	.000	.000
77	DC BagTractor	.000	.000	.000	.000
Total Emissions		5517.428	207.018	162.295	7.762

Energy cost and usage assumptions

	Gasoline	Diesel	Electric		Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	BagTractor	3.75	3.375	22.2	7
% increase per year	7	7	2.5	Beltloader	2.7	2.43	3.48	5
				Pushback	3.6	2.34	10.56	4

Inputs

Number of years used for analysis	20	Labor Rate for Maintenance (\$/hr)	\$50.00
Amortization rate(%)	0		
Years of amortization	10		

## Appendix D

### Airport “D” Input Data and Results Summary

Result of analysis for D Page 2/2	Motor	Transmission	Controller	PM parts cost (\$/yr)	PM Labor (hrs/yr)	Battery Cost	Battery Life (yrs)	Sealed Batt	DC motor	Fast Charge
Gasoline ford 300 BagTractor	10000/1700/32	6500/900/16	0/0/0	\$1205	26.7 hrs					
Diesel Deutz 1011 BagTractor	10000/4000/16	6500/900/16	0/0/0	\$1602	26.7 hrs					
AC BagTractor	13687/1000/10	20000/5500/16	3650/1857/1.5	\$1047	24.7 hrs	\$6000	5 yrs	No	No	Yes
Gasoline ford 300 Beltloader	15000/1700/32	6500/900/16	0/0/0	\$890	14.5 hrs					
Diesel Deutz 1011 Beltloader	15000/4000/16	6500/900/16	0/0/0	\$1250	14.5 hrs					
Electric Beltloader	7300/975/10	20000/2000/16	3650/800/1.5	\$669	15.5 hrs	\$4000	5 yrs	No	No	Yes
DC BagTractor	3250/975/10	20000/2000/16	3650/800/1.5	\$1047	24.7 hrs	\$6000	5 yrs	No	No	Yes

- XX/YY/ZZ represents failure rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement

	Load Factor (%)	Horse Power (hp)	CO (g/hp hr)	HC (g/hp hr)	Nox (g/hp hr)	PM (g/hp hr)	Fuel Type
Gasoline ford 300 BagTractor	55%	107	347.9577	12.7	7.23	.068	Gasoline
Diesel Deutz 1011 BagTractor	55%	71	4.5	0.72	5.75	.835	Diesel
AC BagTractor	55%	40	0	0	0	0	Electric
Gasoline ford 300 Beltloader	50%	107	241	10	7.24	.068	Gasoline
Diesel Deutz 1011 Beltloader	50%	71	3.06526	0.738	6.22	.7	Diesel
Electric Beltloader	50%	40	0	0	0	0	Electric
DC BagTractor	55%	40	0	0	0	0	Electric

	Cord Failure	Charger Failure	PM parts cost (\$/yr)	PM Labor (hrs/yr)
Power Sharing cost per port	2/600/2	15/600/12	\$200	12 hrs
Conventional Charger	5/300/2	15/600/12	\$200	1 hrs

- XX/YY/ZZ for chargers represents failure rate in years/cost of parts in \$ for replacement/ hrs of labor for replacement

## Appendix D

### Airport “D” Input Data and Results Summary

File

Vehicle Name  
Gasoline ford 300 BagTractor

Vehicle Type  
BagTractor

Purchase Price  
26000 \$

Energy source  
Gasoline

Engine  
Motor  
Motor failure rate in hrs  
10000

Engine replacement cost  
1700

Time to replace in hrs  
32

Preventive Maintenance  
Yearly cost of parts  
1205

Yearly hours  
26.7

Transmission  
Failure Rate  
6500 hrs

replacement cost  
900 \$

Time to replace  
16 hrs

Emissions  
Load factor 55 %

Horsepower 107 hp

emissions in g/(hp hour)  
CO 347.957

HC 12.7

Nox 7.23

PM .068

File

Vehicle Name  
DC BagTractor

Vehicle Type  
BagTractor

Purchase Price  
35500 \$

Energy source  
Electric

Engine  
Motor  
Motor failure rate in hrs  
3250

Engine replacement cost  
975

Time to replace in hrs  
10

Preventive Maintenance  
Yearly cost of parts  
1047

Yearly hours  
24.7

Transaxle  
Failure Rate  
20000 hrs

replacement cost  
2000 \$

Time to replace  
16 hrs

Controller  
Failure Rate  
3650 hrs

replacement cost  
800 \$

Time to replace  
1.5 hrs

Emissions  
Load factor 55 %

Horsepower 40 hp

emissions in g/(hp hour)  
CO 0

HC 0

Nox 0

PM 0

## Appendix D

### Airport “D” Input Data and Results Summary

File

Vehicle Name  
AC BagTractor

Vehicle Type  
BagTractor

Purchase Price  
35500 \$

Energy source  
Electric

Engine  
Motor  
Motor failure rate in hrs  
13687

Engine replacement cost  
1000

Time to replace in hrs  
10

Preventive Maintenance  
Yearly cost of parts  
1047

Yearly hours  
24.7

Transaxle  
Failure Rate  
20000 hrs

replacement cost  
5500 \$

Time to replace  
16 hrs

Controller  
Failure Rate  
3650 hrs

replacement cost  
1857 \$

Time to replace  
1.5 hrs

Emissions  
Load factor  
55 %

Horsepower  
40 hp

emissions in g/(hp hour)  
CO  
0

HC  
0

Nox  
0

PM  
0

Vehicle Name  
Gasoline ford 300 Beltloader

Vehicle Type  
Beltloader

Purchase Price  
28500 \$

Energy source  
Gasoline

Engine  
Motor  
Motor failure rate in hrs  
15000

Engine replacement cost  
1700

Time to replace in hrs  
32

Preventive Maintenance  
Yearly cost of parts  
890

Yearly hours  
14.5

Transmission  
Failure Rate  
6500 hrs

replacement cost  
900 \$

Time to replace  
16 hrs

Emissions  
Load factor  
50 %

Horsepower  
107 hp

emissions in g/(hp hour)  
CO  
241

HC  
10

Nox  
7.24

PM  
.068



## Appendix D

### Airport “D” Input Data and Results Summary

<b>File</b> Vehicle Name <input type="text" value="Diesel Deutz 1011 Beltloader"/>		<b>Transmission</b> Failure Rate <input type="text" value="6500"/> hrs replacement cost <input type="text" value="900"/> \$ Time to replace <input type="text" value="16"/> hrs	
Vehicle Type <input type="text" value="Beltloader"/>		<b>Engine</b> Motor Motor failure rate in hrs <input type="text" value="15000"/> Engine replacement cost <input type="text" value="4000"/> Time to replace in hrs <input type="text" value="16"/>	
Purchase Price <input type="text" value="32200"/> \$		<b>Emissions</b> Load factor <input type="text" value="50"/> % Horsepower <input type="text" value="71"/> hp emissions in g/(hp hour) CO <input type="text" value="3.06526"/> HC <input type="text" value="0.738"/> Nox <input type="text" value="6.22"/> PM <input type="text" value=".7"/>	
Energy source <input type="text" value="Diesel"/>		<b>Preventive Maintenance</b> Yearly cost of parts <input type="text" value="1250"/> Yearly hours <input type="text" value="14.5"/>	

<b>File</b> Vehicle Name <input type="text" value="Electric Beltloader"/>		<b>Transaxle</b> Failure Rate <input type="text" value="20000"/> hrs replacement cost <input type="text" value="2000"/> \$ Time to replace <input type="text" value="16"/> hrs		<b>Controller</b> Failure Rate <input type="text" value="3650"/> hrs replacement cost <input type="text" value="800"/> \$ Time to replace <input type="text" value="1.5"/> hrs	
Vehicle Type <input type="text" value="Beltloader"/>		<b>Engine</b> Motor Motor failure rate in hrs <input type="text" value="7300"/> Engine replacement cost <input type="text" value="975"/> Time to replace in hrs <input type="text" value="10"/>		<b>Emissions</b> Load factor <input type="text" value="50"/> % Horsepower <input type="text" value="40"/> hp emissions in g/(hp hour) CO <input type="text" value="0"/> HC <input type="text" value="0"/> Nox <input type="text" value="0"/> PM <input type="text" value="0"/>	
Purchase Price <input type="text" value="38800"/> \$		<b>Preventive Maintenance</b> Yearly cost of parts <input type="text" value="669"/> Yearly hours <input type="text" value="15.5"/>			
Energy source <input type="text" value="Electric"/>					

Appendix D  
Airport “D” Input Data and Results Summary

File

Conventional Charger

Charger Cost  
4000

Cord  
Cord failure rate in years  
5

Charger Failure  
Charger failure rate in years  
15

Install Cost  
3000

cord replacement cost  
300

charger part replacement cost  
600

Preventive Maintenance  
Yearly cost of parts  
200

Time to replace in hrs  
2

Time to repair in hrs  
12

Yearly hours  
1

File

Power Sharing cost per port

Charger Cost  
37500

Cord  
Cord failure rate in years  
2

Charger Failure  
Charger failure rate in years  
15

Install Cost  
3000

cord replacement cost  
600

charger part replacement cost  
600

Preventive Maintenance  
Yearly cost of parts  
200

Time to replace in hrs  
2

Time to repair in hrs  
12

Yearly hours  
12

## **Appendix E - High-Level Data Trees**

## Appendix E High Level Data Trees

### GSE Equipment Capital Purchase Price

<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px; width: 30%;">Do you have actual GSE Purchase Price?</div> <div style="width: 30%; text-align: center;">Yes.</div> <div style="border: 1px solid black; padding: 5px; width: 30%;">Enter Purchase Price</div> </div>		
No		
<div style="border: 1px solid black; padding: 5px;">What type of GSE Equipment will you purchase?</div>		
Bag Tractor - Electric, Diesel or Gasoline	Belt Loader - Electric, Diesel or Gasoline	PushBack - Electric, Diesel or Gasoline
Est Values Provided by Model		
BT - Electric \$29,500, BT Diesel - \$26,000, BT - Gasoline - \$26,000	BL-Electric \$34,800, BL Diesel \$32,200, BL Gasoline \$28,500	PB-Electric \$87,000, PB Diesel \$86,200
(Battery options - Sealed \$7900, Flooded \$6000)	(Battery options - Sealed \$6200, flooded \$4000)	(Battery Options - Sealed \$7900, flooded \$6000)
Notes: Sealed Battery - 440Amphr; Flooded 500Amphr	Notes: Sealed Battery - 300Amphr; Flooded - 300Amphr	Notes: Sealed Battery - 440Amphr; Flooded 500Amphr; Gasoline not an option

Appendix E  
High Level Data Trees

**Equipment Alterations Required?**

All GSE Mods performed at factory?	Yes	Enter "O"		
No				
Need to install Fast Charge Interface?	Yes	Do you know the cost?	Yes	Enter Cost \$
		No		
		Estimated Cost \$1200		
Any other modifications?	Yes	Enter Cost		
No				
Enter "O"				

## Appendix E High Level Data Trees

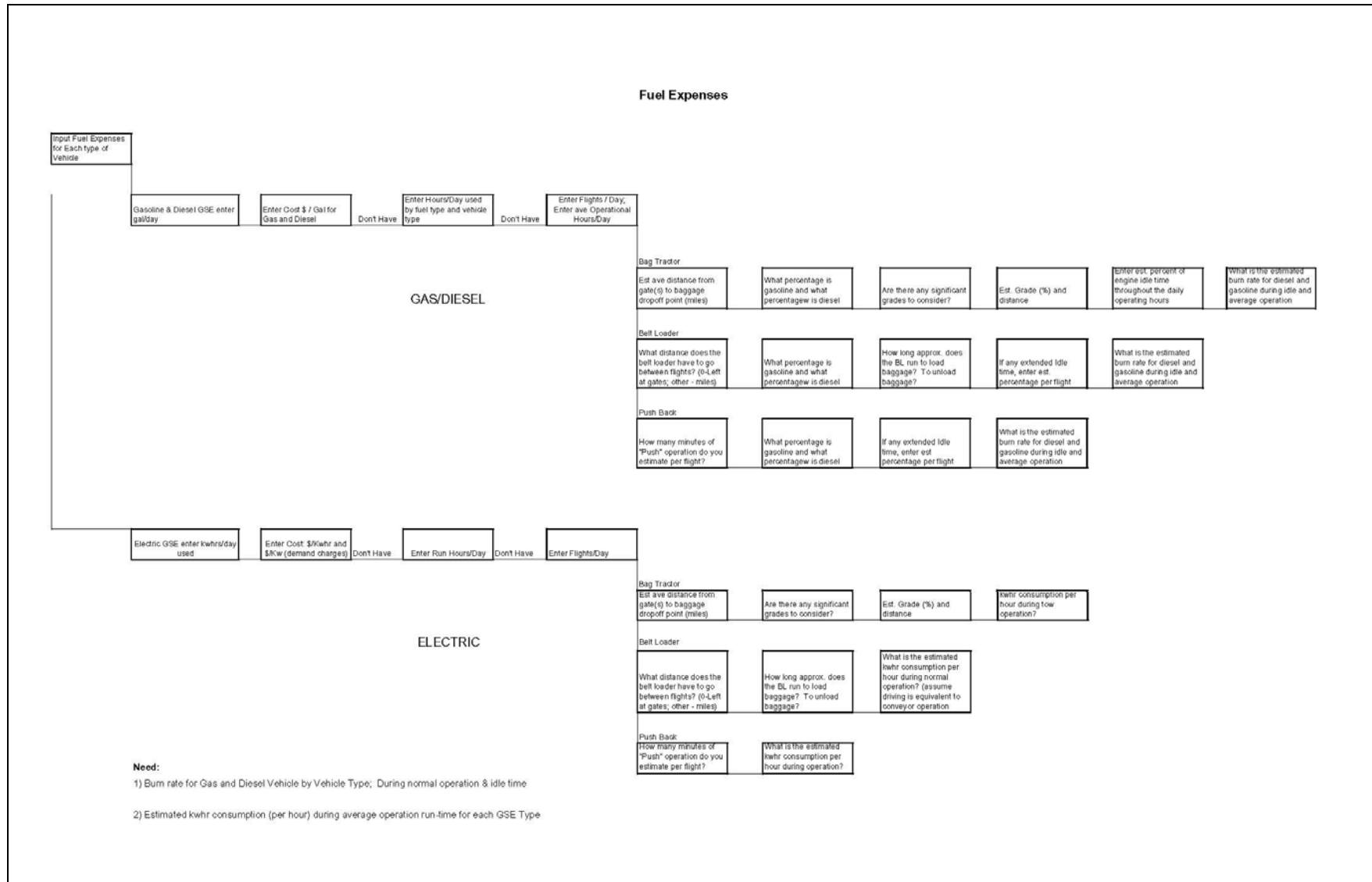
### Charging Infrastructure Maintenance

Input Annual Infrastructure Maintenance Costs for PM, Cords, General Maintenance	enter	Input Separately: PM, Cord, Chrgr Repair
Unknown		
General Charger PM - Filters, Cleaning Etc.	est	Enter actual PM costs or Est. 1 hr / Qtr per charger @ \$InHse Rate/hr
Replacement Rate		
Cord Replacement due to general wear and pull-out (includes labor and parts to change out)	est	<div style="display: flex; justify-content: space-between;"> <div>           First Year - 5%;            Second Yr - 5%;            Third Yr - 10%;            Fourth-plus - 15%         </div> <div style="border: 1px solid black; padding: 5px; width: 30%;">           Avg Replacement Cost: Enter or \$600 plus 2hrs InHse labor         </div> </div>
Other General Maintenance (Outside of Warranty)	est	<div style="display: flex; justify-content: space-between;"> <div>           First Year - n/a;            Second Yr - 5% (labor only);            Third Yr - 6%;            Fourth-plus - 7%         </div> <div style="border: 1px solid black; padding: 5px; width: 30%;">           Avg Repair Cost (assume Manufacture Rep): Enter or \$1,200         </div> </div>

Need:

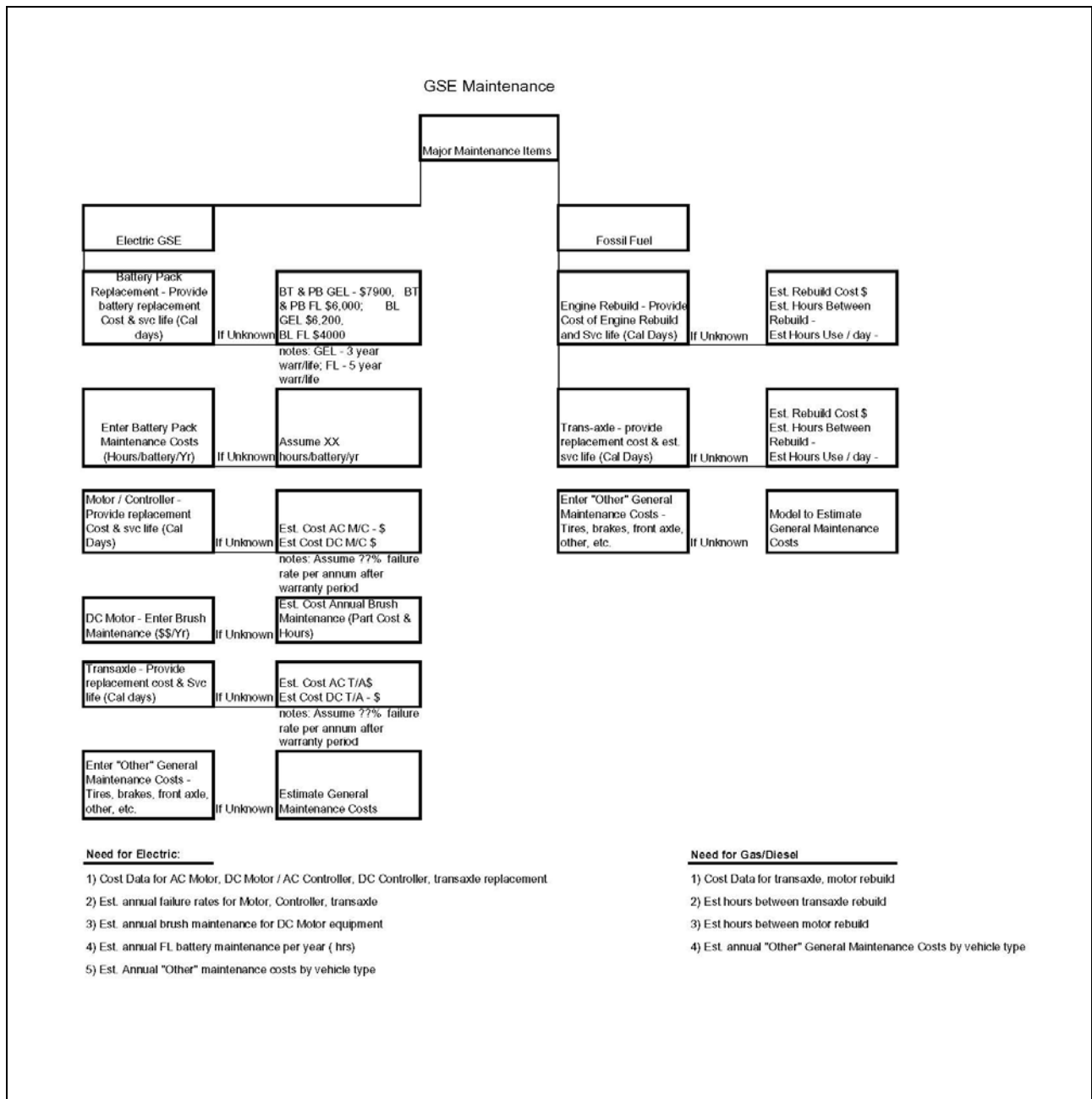
- 1) Review replacement rate assumptions
- 2) Replacement hours - Inhouse labor
- 3) Review Cord Replacement Cost
- 4) General PM estimate

## Appendix E High Level Data Trees





## Appendix E High Level Data Trees



## Appendix E High Level Data Trees

### Charger Installation

Do you have the actual Install costs or a contractor's estimate?	Yes	Enter the Amount
No		
Is the Charger a Power Server Design?	Yes	<div style="display: flex; justify-content: space-between;"> <div>Is adequate circuit available for multi-port system?</div> <div>Yes</div> <div>"D" Estimated Cost \$25k per System - install and setup DC Bus (e.g. 10-Port w/power server)</div> </div>
No	No	Go to "A" through "C" then add to "D"
Is 480V/3Ph Circuit Available in the general locale?	Yes	<div style="display: flex; justify-content: space-between;"> <div>How Many Feet from the Charger Location?</div> <div>Enter Feet to Charger</div> <div>Install Cost/Charger = \$500 + (\$150 x ft)</div> </div>
No		
"A"		
Is Bridge Power an Option?	Yes	<div style="display: flex; justify-content: space-between;"> <div>Utilize Bridge Power</div> <div>Enter Feet to Charger</div> <div>Install Cost/ charger = \$3.5k + (\$150x ft)</div> </div>
No		
"B"		
Is there available capacity in existing closest switchgear?	Yes	<div style="display: flex; justify-content: space-between;"> <div>How many Feet to Disconnect Location?</div> <div>Enter Feet to Disconnect</div> <div>Install Cost = (TBD)</div> </div>
No		
"C" Estimated Cost to Provide new switch gear = tbd		

Appendix E  
High Level Data Trees

**Battery Charging System**

Do you know the cost of the selected charge system?	Yes	Enter \$ Amount	
No			
Do you plan on utilizing Universal Fast Chargers?	Yes	How many vehicles per charge port?	One Estimated Cost \$12.5k/Vehicle
No			Two Estimated Cost \$7k/Vehicle
			Three Estimated Cost \$4k/vehicle
Estimated Cost \$4k/Vehicle			

**Assumptions:**

For Universal Fast Charge Systems; Either 15kW Dual Port Stand Alone Units or PowerServer Type 10-Port System  
Conventional Charger based on Ferro-Resonant Design (Outdoor rated cabinet) - Single Voltage and Amphour Rating, 1 per vehicle

# **Attachment A - Ground Support Equipment Cost Model Operating Guide**

## GSE Cost Model V1.1

List of available equipment

		Purchasing Price	Install	Ownership cost \$/year	Operating Cost \$/yr	Total cost \$/yr	Total for analysis
10	AC BagTractor	\$355,000		\$23,647	\$82,052	\$105,699	\$2,113,980
4	DC BagTractor	\$142,000		\$9,459	\$29,306	\$38,765	\$775,300
7	Electric Bellloader	\$271,600		\$18,092	\$22,809	\$40,901	\$818,020
14	Diesel Deutz 2011 BagTractor	\$364,000		\$24,247	\$166,131	\$190,378	\$3,807,560
7	Diesel Deutz 2011 Bellloader	\$225,400		\$15,014	\$57,275	\$72,289	\$1,445,780
20	Power Sharing cost per port	\$250,000	\$60,000	\$20,650	\$21,941	\$42,591	\$851,820

GSE usage at airport

Low Medium High

20 year analysis

6	Amortization rate
10	Life of equipment for amortization

Update ownership costs

### Run Analysis

## New Analysis

### Fuel Equipment

### Electric Equipment

Difference

DAILY kW/hr  
usage estimate  
from utility meter

\$5,253,340

\$4,559,120

	\$694,220
--	-----------

279104

List Analyzed

7/20/2006

# Ground Support Equipment Cost Model Operating Guide

## Table of Contents

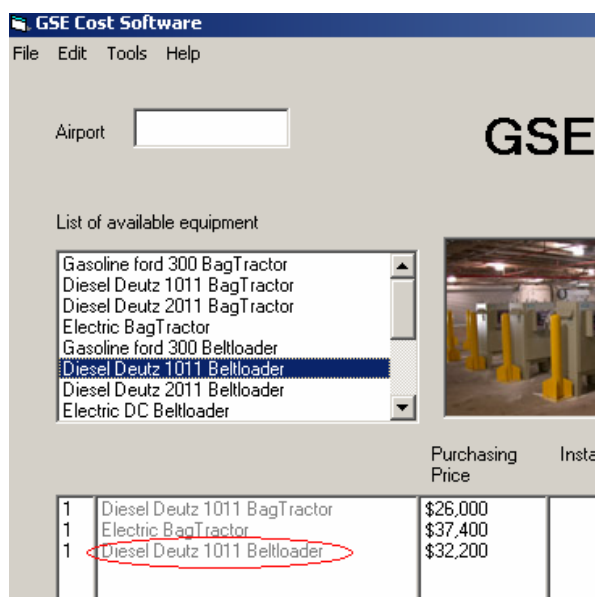
1	Quick Start Guide .....	4
1.1	Selecting Your Equipment .....	4
1.2	Selecting Equipment Quantity .....	4
1.3	Purchase Price .....	5
1.4	Install Cost .....	5
1.5	Ownership Cost.....	5
1.6	Selecting Usage and Number of Years .....	5
1.7	Run Analysis Button .....	6
1.8	Unit Operating Cost .....	7
2	How Operating Vehicle Cost is Calculated .....	7
2.1	Energy Cost per Vehicle .....	7
2.2	Vehicle Maintenance Cost .....	7
2.3	Adding a New Vehicle .....	9
3	How Operating Cost is Calculated for Chargers.....	9
3.1	Charger Maintenance Cost.....	9
3.2	Adding a New Charger to the List of Available Equipment .....	10
4	Viewing Emissions .....	10
5	Comparing Two Models .....	10

**NOTE:** This software is intended to predict the costs of different airline GSE options and their associated vehicle emissions. The model provides default values for three major pieces of equipment—baggage tractors, belt loaders, and pushback tractors. This cost model utilizes actual cost data based on GSE operations by two major airlines at two airports on the west coast, one airport in the mid-west, and one airport in the northeastern United States.

## 1. Quick Start Guide

### 1.1 Selecting Your Equipment

Begin by naming the airport you desire to study. Select your equipment by double clicking on each type of equipment you wish to analyze on the top left list box. Your selection appears below for analysis. (Note: You can save this file at any time by selecting “File” at the top, then “Save.”)



### 1.2 Selecting Equipment Quantity

Once you have selected your equipment, you can change your quantity by double clicking on the number on the left of the table for each corresponding piece of equipment.

		Purchasing Price
1	Diesel Deutz 1011 BagTractor	\$26,000
1	Electric BagTractor	\$37,400
1	Diesel Deutz 1011 Beltloader	\$32,200

If you need to delete an item, just highlight the quantity of the equipment and hit “delete”. If you want to delete all your selections or start a new analysis, click “New Analysis” or select “File” then “New.” (**Caution:** If you have not saved the current file before performing this action, any previous data will be deleted.)



## 1.3 Purchase Price

Default numbers are provided by the model for all GSE equipment and charger types listed. Purchasing price can be modified by double clicking on it. The price you will need to enter is the unitary price for that specific equipment.

## 1.4 Install Cost

Install cost applies to chargers; double clicking on that value can modify the default value. This is a unitary cost and applies only for one charger or one port in the case of multi-port systems. The default values assume that available power is within reasonable vicinity, and no major switchgear or utility feeds are required. These numbers are only defaults and can be modified by the user as necessary.

## 1.5 Ownership Cost

Ownership cost is a calculated number based on interest rate, life of equipment, purchasing cost, and install cost (if applicable).

Ownership cost spreads the cost of the equipment and installation over the life of the equipment at a given interest rate.

Default value is 6% and a 10-year amortization. These parameters can be changed in the boxes below the usage selector.

## 1.6 Selecting Usage and Number of Years

Usage of the equipment can be selected by clicking on the desired level of usage under the title called “GSE Usage at Airport.” This will set some default values that were used for the analysis (see the parameters table below for details).

The 'Params' window contains the following data:

	Gasoline	Diesel	Electric	
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	GSE Hourly labor cost \$50.00
% increase per year	12	12	7	

	Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/day	Hours per day usage
BagTractor	3.125	2.8125	18.5	5
Beltloader	2.25	2.025	2.9	4
Pushback	3	1.95	8.8	3

Buttons: OK, Reset Parameters to default

The “Year Analysis” combo box is also located under “GSE Usage at Airport.” The “Year Analysis” affects your operating cost per year and your total cost for analysis.

## 1.7 Run Analysis Button

After you have selected the usage and the number of years for the analysis, click on the “Run Analysis” button. A new window pops up displaying parameters that are used for this analysis. If the default parameters are acceptable, click the “OK” button to get the operating cost, total cost, and total results.

If you desire to input your own values for your location, you can change any of the parameters in this window before you hit the “OK” button.

The tables below display the default parameters used depending on what GSE usage is selected on the main input screen.

Low GSE usage at airport default parameters

	Gasoline Gallon/day	Diesel Gallon/day	Electric kW/hr/day	Hours per day usage
BagTractor	2.5	2.25	14.8	3
Beltloader	1.8	1.62	2.32	3
Pushback	2.4	1.56	7.04	2

Medium GSE usage at airport default parameters

	Gasoline Gallon/day	Diesel Gallon/day	Electric kW/hr/day	Hours per day usage
BagTractor	3.125	2.8125	18.5	5
Beltloader	2.25	2.025	2.9	4
Pushback	3	1.95	8.8	3

High GSE usage at airport default parameters

	Gasoline Gallon/day	Diesel Gallon/day	Electric kW/hr/day	Hours per day usage
BagTractor	3.75	3.375	22.2	7
Beltloader	2.7	2.43	3.48	5
Pushback	3.6	2.34	10.56	4

## 1.8 Unit Operating Cost

The model provides a summary of unit operating costs for each piece of GSE and charging equipment for the entire period of the analysis. For example, if you select a 20-year analysis, this would provide unitary cumulative costs over the period for each piece of equipment selected in the scenario. The following table is found under the “Tools” section.

Equipment List	General Maintenance	Energy/Fuel	Engine	Transmission/Transaxle	Controller	Cords	Charger Repair	Fast Charge Interface
AC BagTractor	\$30,407	\$38,894	\$4,520	\$13,640	\$15,443	\$000	\$000	\$1,200
DC BagTractor	\$63,640	\$56,008	\$12,624	\$5,062	\$6,994	\$000	\$000	\$1,200
Electric Belloader	\$40,880	\$7,316	\$5,864	\$4,468	\$5,639	\$000	\$000	\$1,200
Diesel Deutz 2011 BagTractor	\$59,280	\$150,042	\$18,758	\$9,249	\$000	\$000	\$000	\$000
Diesel Deutz 2011 Belloader	\$38,500	\$108,031	\$9,949	\$7,162	\$000	\$000	\$000	\$000
Power Sharing cost per port	\$16,000	\$000	\$000	\$000	\$000	\$4,511	\$1,430	\$000

Back

Low Medium High

20 year analysis

Run Analysis

New Analysis

6 Amortization rate

10 Life of equipment for amortization

Update ownership costs

Electric Equipment Difference \$694,220

DAILY kWhr usage estimate from utility meter 379.104

List Analyzed 7/20/2006

## 2. How Operating Vehicle Cost is Calculated

Operating cost consists of the sum of the energy cost, preventive maintenance cost, and repair/replacement cost for the equipment.

### 2.1 Energy Cost per Vehicle

Vehicle energy cost per year equals energy use per day times the average energy cost over the analysis period times 365. This cost is the main cost among operating costs, especially with ICE vehicles.

### 2.2 Vehicle Maintenance Cost

Vehicle maintenance costs are divided into two major categories: preventative maintenance and repair maintenance. Preventative maintenance includes most service items typically found with GSE, including oil changes, service checks, tire replacement, brake jobs, front-end rebuild, starter repair, and motor brush replacement, when applicable.

**Edit Properties**

File

**Vehicle Selection:** Diesel Deutz 2011 BagTractor

**Description:** Diesel Deutz 2011 BagTractor

**Vehicle Type:** BagTractor

**Purchase Price:** 26000 \$

**Energy source:** Diesel

**typical energy per day moderate usage of the equipment:** 2.8125

**Motor:**

- Motor failure rate in hrs: 10000
- Engine replacement cost: 4000
- Time to replace in hrs: 16

**Preventive Maintenance (Circled):**

- Yearly cost of parts: 1629
- Yearly hours: 26.7

**Transmission:**

- Failure Rate: 29000 hrs
- replacement cost: 5500 \$
- Time to replace: 16 hrs

**Controller:**

- Failure Rate: 0 hrs
- replacement cost: 0 \$
- Time to replace: 0 hrs

**Emissions:**

- Load factor: 55 %
- Horsepower: 71 hp
- emissions in g/(hp hour):
  - CO: 1.7
  - HC: 0.72
  - Nox: 5.75
  - PM: .835

Maintenance cost is the cost of parts plus the number of hours times the labor rate that can be modified in the parameters window (default is \$50 per hour).

For example, the preventative maintenance cost for the vehicle above is  $\$1,629 + 26.7 \times \$50 = \$2,964$ .

Repair maintenance is calculated based on failure rates for engines, transmissions, and controllers (if applicable). Battery replacement cost is also added to the repair maintenance cost and includes replacement cost and the period between replacements.

To view the vehicle maintenance cost parameters, select “Edit Vehicles” under the “Edit” header at the top of the screen. (Note: You cannot make changes to these pre-set parameters—see Section 2.3.)

**Edit Properties**

File

Gasoline ford 300 BagTractor

Description: Gasoline ford 300 BagTractor

Vehicle Type: BagTractor

Purchase Price: 26000 \$

Energy source: Gasoline

typical energy per day moderate usage of the equipment: 3.125

**Motor**

Motor failure rate in hrs: 10000

Engine replacement cost: 1700

Time to replace in hrs: 32

**Preventive Maintenance**

Yearly cost of parts: 1205

Yearly hours: 26.7

**Transmission**

Failure Rate: 29000 hrs

replacement cost: 5500 \$

Time to replace: 16 hrs

**Controller**

Failure Rate: 0 hrs

replacement cost: 0 \$

Time to replace: 0 hrs

**Emissions**

Load factor: 55 %

Horsepower: 107 hp

emissions in g/(hp hour)

CO: 347.957

HC: 12.7

Nox: 7.23

PM: .068

## 2.3 Adding a New Vehicle

To change the parameters, select “Add New Vehicle” under the “File” header and change the desired parameters. Click the “Save” box at the bottom of the screen to save this new item to the master list. Start with the file that closely resembles the new equipment you wish to create because the defaults for the current vehicle set on the screen will remain when you select “Add New Vehicle.”

## 3. How Operating Cost is Calculated for Chargers

### 3.1 Charger Maintenance Cost

The charger operating costs are divided into two major categories: preventive maintenance and repair maintenance. Preventative maintenance includes items such as filters, general cleaning, and inspections that are recommended annually. They are shown as labor and materials in the preventative maintenance window. The preventative maintenance window under “Edit Charger” displays a part cost and number of hours per year that is replaced as part of the preventative maintenance.

Repair maintenance includes all major repairs required during the year, including a separate category for the DC output cords. (Note: Charger repair cost is linked only to the number of years and not the daily usage selected.)

### **3.2 Adding a New Charger to the List of Available Equipment**

To change the parameters, select “Add New Charger” under the “File” header, and change the desired parameters. Click the “Save” box at the bottom of the screen to save this new item to the master list. The defaults for the current charger set on the screen will remain when you select “Add New Charger;” therefore, you should begin with the file that closely resembles the new equipment you wish to create.

## **4. Viewing Emissions**

After you have selected your equipment, you can view the yearly estimated emissions. Remember, this is based on your “GSE usage at airport” input that will affect the vehicle usage per day input. Results are based on emissions numbers, usage per day, load factor, and horsepower of the vehicle. The eGSE are considered to have zero tailpipe emissions.

## **5. Comparing Two Models**

Different model scenarios can be compared with the GSE Cost Model software. Before running a comparison, have a least one model saved on your hard drive.

- First load (Select File and Open) a file you wish to compare with another one or create a list of equipment, run the analysis, and save the file (see Section 1 of this Quick Start Guide for more details).
- Select Tools and Compare with files. The software now prompts you to open a file that it will compare with the one currently loaded.
- A new window will display the costs of both scenarios and the differences between the two.

