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

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## February 2007

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#### 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.

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#### 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.

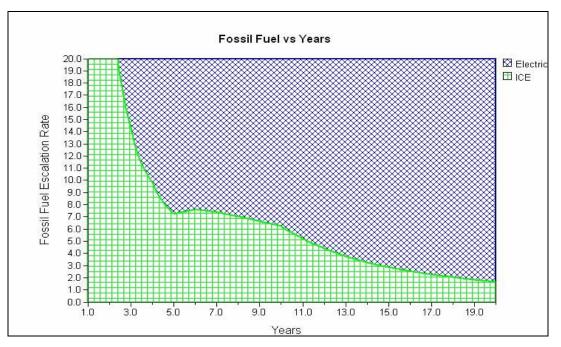


Figure 1-1. Airport "A" sensitivity analysis for all three ground support equipment types combined.

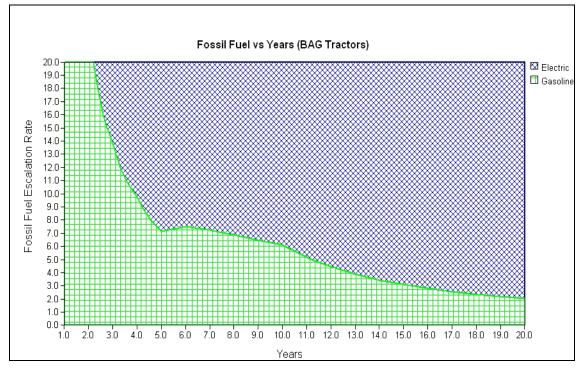


Figure 1-2. Airport "A" sensitivity analysis for baggage tractors.

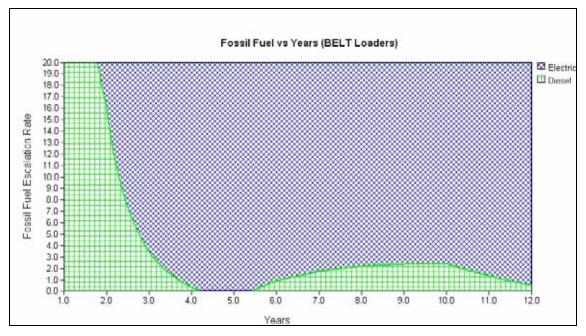


Figure 1-3. Airport "A" sensitivity analysis for belt loaders.

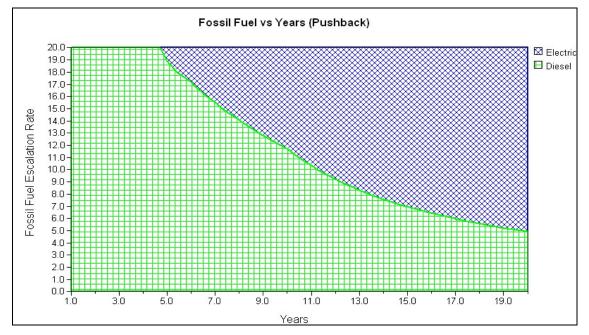


Figure 1-4. Airport "A" sensitivity analysis for pushback tractors.

#### 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.

Quality	Description	СО	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 n	CO = carbon monoxide, HC = total hydrocarbons, NOx = oxides of nitrogen, PM = particulate matter						

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

#### 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).

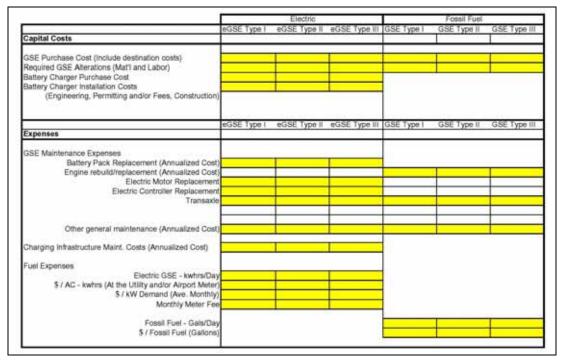


Figure 3-1. High-level data chart.

•

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.

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	Purchasing	inital	Ownership cost \$/vear	Operating Cost \$/yr	Total cort	Total for analysis	
All BagFrantor UC BagTonito Ender Benchender Einen Denz 2011 Februarie Even Control 2011 Februarie Even Control 2011 Februarie	\$255,000 \$142,000 \$271,600 \$364,000 \$225,400 \$250,000	\$60,000	123347 19.475 19.495 19.147 19.147 19.147 19.147	887,953 879,300 827,209 8152,129 857,238 827,341	\$1125.459 \$30,765 \$442,927, \$196,378 \$122,201 \$42,501	(12.3 (13.300) 13.775,300 1011(1320) 13.00(7.760) 11.440,500 1011(1320)	
GSE usage at airport	\$1,608,000	\$60.000	\$111,109	\$379.514	\$490.623	\$9.812,450	
	<b>Hereiter</b>	1.0	For	ITUITOR	work	15,253,340	
Low Median High			1	Electric Equip	herit	\$4,559,120	
the second second				Difference		\$654,220	
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Amortization rate     10     Ure of equipment for     amortization	New Analysis			Litinge #		379.104	
Update ownership costs							

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

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uciá seli %	increase per year	7	7	7	\$50.00	
		Gatoline Gallon/day	Diecel Gallorv/day	Electric W/hr/day	Hours per day	Total for
-	BiegTractor	a second s	3.375	22.2	1	(12)111,000
	Beltoader	27	2.43	3.48	5	6725.000
	Putback.	26	2.34	10.56	4	80118.029 87.1020-580 91.447,700 8049.520
	Pubback.	26		Reast Pa		801 8,020 16/3 302 5403 16/3 445 700
	Puhback.			Reast Pa	4	801 8,020 16/3 302 5403 16/3 445 700
	Pubback.			Reast Pa	4	171.029 52.025 560 171.44(7,760 8061.551 183.812.460 15.253.340
				Reast Pa	4	\$3,872,560 \$1,447,780 \$14,447,780 \$14,521 \$15,253,340 \$4,555,120
Low				Reast Pa	4	171.029 52.025 560 171.44(7,760 8061.551 183.812.460 15.253.340
	e Medan	- J Hgt		Reast Pa	4	1011.029 57.3025.580 51.44(7,780 59(1).251 53.812.460 55.253.340 54.595.120 5654.220

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

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igTractor agTractor ine ford 300 Br	Airport 1992					
Deutz 1011 B Deutz 2011 B		Estimate	ed emissions in tons per	real		
	Qty Equipment	C0	HC	Nos	PM	
Sateline ford 3 Secol Decide 10 Contra Route	40 Gascine tord 300 BagT actor 25 Dissel Deutz 1011 BeNoader 6 Tug MC PushBack	2306,896 5,473 1,721	84.199 1.310 .339	47 934 11.105 4.365	451 1.250 332	
	Total Emissions	2314.09	05.056	63.404	2.033	-
GSE urage			в	ack Pir		
Low Mec			Canalyza			
20 _	yearanalysis Run Analysis		DAILY I	Whe re		

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.

Equipment List	General	Energy/Fuel	Engne	Tianoniption/	Controller	Conta	Charger Repair	FeitChage
AC BagTactor DC BagTactor Electro Relificade Derei Deutz 2011 BagTactor Derei Deutz 2011 Bellbader Power Sharing cost per pot	Martmance \$10,407 \$63,640 \$40,890 \$59,280 \$39,500 \$16,000	\$30,004 \$56,008 \$7,316 \$150,042 \$108,001 \$108,001 \$108,001	\$4,520 \$12,524 \$5,564 \$18,758 \$3,549 \$000	Transade \$13,640 \$6,662 \$4,468 \$9,249 \$7,162 \$000	\$15,443 \$5,594 \$5,639 \$000 \$000 \$000	\$000 \$000 \$000 \$000 \$000 \$4,511	\$000 \$000 \$000 \$000 \$000 \$1,430	Interface \$1,200 \$1,200 \$1,200 \$1,200 \$000 \$000 \$000 \$000
Back		1						
			E	intro Equipment				
Low Medius High				Difference	\$8	94.220		
-	Tun Analysis			Difference DAILY KWhy unage estimate	11. 11. 11.	94.220		

Figure 3-5. Unit operating cost.

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t of available equip acoine ford 300 Bit evel Dexit 2011 B cBagTiractor acoine ford 300 Bit evel Dexit 2011 B evel Dexit 2011 B evel Dexit 2011 B	Vehicle Name Particulum Intel® COE Comment Granime Lond 300 Beg1 ractor Derent Devid 3001 Beg1 ractor AC Bag1 ractor D C Bag1 ractor D comment Devid 300 Beltoader D comment Devid 300 Beltoader D comment Devid 2011 Beltoader D comment Devid 2011 Beltoader D comment Devid 2011 Beltoader D comment Devid 2011 Beltoader	Trgine inplacement	Transmission Falsan Rate (6500 Nrs replacement cost (900 \$ Trate to isplace (16 hrs	
AL Registere DC Registere DC Registere Electric Delitos Denet Deda 2 Direct Deda 2	Pachase Pice	colt 1700 Time to replace in Nri 32 Preventive Maintenance Yeady cost of parts	Enimone Load factor 195 % Hotsepower 107 hp emissions in g/thp hout 00 1347 957	
GSE usage Low Med		1205 Yeady hours [25.7	HC 1227	
6 And 10 Life arro Updale owne	Back	]		

Figure 3-6. Vehicle edit table.

Charger list					
ke .					100
		Charger Cost			.1
Communicated Charges		4000			a de la compañía de l
Conventional Charger Single port Fast Diviger		Install Cost			
Power Shaving cost per port Coronadam former peaks	Charges Landering Property	Statute and statute and statute	-		
5	15	Part Parts			and the second sec
CONTRACTOR DATE		Preventive M			
cord replacement	charger part replacement	nt III (COLEMENT)			
[300	600	Yearly cost 200	of parts		
1000	1000	100			
Time to replace in	Time to repair in his	Yearly hours			Total for analyzis
hes		1	_		17.113.340
2	12				\$775,300 4018,500 \$3,807,560 \$1,445,780
1	T2				\$775.300 (818.520 (3.807.560)
1		\$60,000 \$111,109	\$379,514	\$450,623	\$775,300 4018,500 \$3,807,560 \$1,445,780
	Jack	Terraria Revenue	\$379.514 mil Fuel Eque		1775300 11112600 1112600 113407.940 11.445.760 19551.000
ESE usage of acout	Back.	Terraria Revenue	Transmore	neri	1777,300 11118,000 121407,940 131465,700 14551,000
	Back.	Terraria Revenue	Electric Equip	nent	1775.300 11118.000 13.907.900 13.465.700 153.912.460 155.253.340
ESE usinge of aicout	Back.	Terraria Revenue	mil Fuel Equip	nent	1775.300 11118.000 12147.540 11.455.700 14.555.000 15.253.340 14.555.100
ESE usage of acout	Back.	Terraria Revenue	Electric Equip Electric Equip Differenc DAILY	ment ment ra kwitu	1773 300 11967 560 11.465 780 1951 (00 155 200 155 200 155 200 155 200 155 200 155 200
ESE usinge of aicout	Back [\$1,608,000 h solgest Pour Analysis	Terraria Revenue	Electric Equip Electric Equip Differenc DAILY usage	ment ment ra	1775.300 11118.000 12147.540 11.455.700 14.555.000 15.253.340 14.555.100
ESE usage of accut Low Medium Hig 20 year or 6 Annotization rate	Back. [\$1.608,000 b wijette Pun Analysis New Analysis	Terraria Revenue	Electric Equip Electric Equip Differenc DAILY usage	seeral meral ra k/w/fw estimate	1773 300 11967 560 11.465 780 1951 (00 155 200 155 200 155 200 155 200 155 200 155 200
ESE usinge of airport Low Medium Hig 20 • year or 6 Annotization rate	Back. [\$1.608,000 b wijette Pun Analysis New Analysis	Terraria Revenue	Electric Equip Electric Equip Differenc DAILY usage	seeral meral ra k/w/fw estimate	1773 300 11967 560 11.465 780 1951 (00 155 200 155 200 155 200 155 200 155 200 155 200

Figure 3-7. Charger 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. Air	port "A" electric ground support	equipment included in study.	
GSE Type	Original GSE Equipment	Replacement GSE	Battery

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.

Gasoline Diesel D Diesel D AC BagT DC BagT Gasoline	ks Help A slable equipment ford 300 BogTractor futz 1011 BogTractor futz 1011 BogTractor futz 2011 BogTractor ford 000 Belthoader	G:	SE C	Cost	Mode	el V1	1.1	
	utz 1011 Beltioader utz 2011 Beltioader	Purchasing Price	Install	Ownership cost \$/www	Operating Cost \$/yr	Total cost	Total for analysis	
16 Die 7 GT1 12 DC 5 AC 16 Elec 7 350 8 Sin	oline ford 300 BegTractor eil Deutz 1011 Belloader 628/GT35 PushBack BagTractor tris Belloader E PushBack de pont Fast Charger er Sharing cost per port	\$442,000 \$515,200 \$403,400 \$425,000 \$177,500 \$620,800 \$551,000 \$140,000 \$190,000	\$24,000 \$12,000	\$22,100 \$25,760 \$30,170 \$21,300 \$8,875 \$31,040 \$32,550 \$8,200 \$8,200 \$8,100	\$175,649 \$114,907 \$59,222 \$66,290 \$27,946 \$46,638 \$40,764 \$40,764 \$4,388	\$197,749 \$140,667 \$88,392 \$07,590 \$36,821 \$77,878 \$73,314 \$16,976 \$12,488	\$3.954.300 \$2,813.340 \$1.751.560 \$736.420 \$1.456.200 \$1.456.200 \$249.760	L
	GSE usage at airport	\$3,725,900	\$36,000	\$188,095	\$543,788	\$731,883	\$14,637,680	
Lo	v Medium High				il Fuel Equipe lectric Equipe	nent	\$8,536,160 \$6,101,500 \$2,434,660	-
	Amortization rate	Pun Analysis New Analysis			Dillerence DAILY 8 utage e from util	ofimate	560.28	

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
% increase per year	7	7	2.5		:50.00
ve increase per year	1	1	1		
	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	
			Reset Para	meters to	
	OK		defa		

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.

a, Cost Break - Unit Operating Cost								
Equipment List	General Maintenance	Energy/Fuel	Engine	Transmission/ Transaxle	Controller	Cords	Charger Repar	Fast Charge Interface
Gasoline ford 300 BagTractor DieselDeutz 1011 Belkcader GT1628/GT35 PushBack DC BagTractor AC BegTractor Electric Belktloader 350E PushBack Single port Fast Charger Power Sharing cost per port	\$50,800 \$39,500 \$44,900 \$63,640 \$63,640 \$40,880 \$53,640 \$16,000 \$16,000	\$138,928 \$30,025 \$86,691 \$25,281 \$21,068 \$3,303 \$10,021 \$000 \$000	\$9,755 \$8,127 \$16,540 \$10,269 \$3,374 \$4,712 \$26,117 \$000 \$000	\$7,162 \$5,982 \$18,217 \$4,468 \$10,053 \$3,632 \$21,708 \$000 \$000	\$000 \$000 \$5,639 \$12,451 \$4,821 \$3,883 \$000 \$000	\$000 \$000 \$000 \$000 \$000 \$000 \$4,511 \$4,511	\$000 \$000 \$000 \$000 \$000 \$000 \$1,430 \$1,430	\$000 \$000 \$1,200 \$1,200 \$1,200 \$1,200 \$1,200 \$000 \$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.

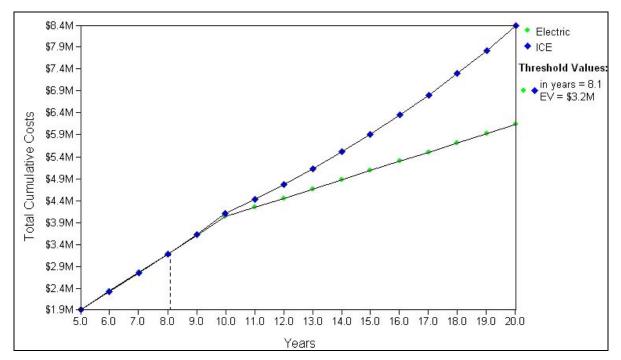


Figure 4-4. Airport "A" breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for all three types of ground support equipment.

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.

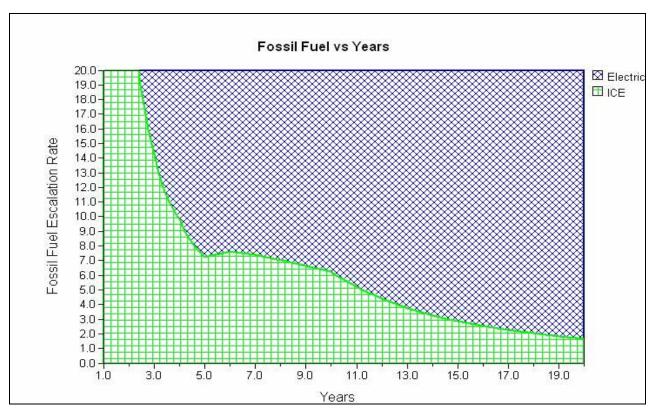


Figure 4-5. Airport "A" sensitivity analysis for all three ground support equipment types.

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.

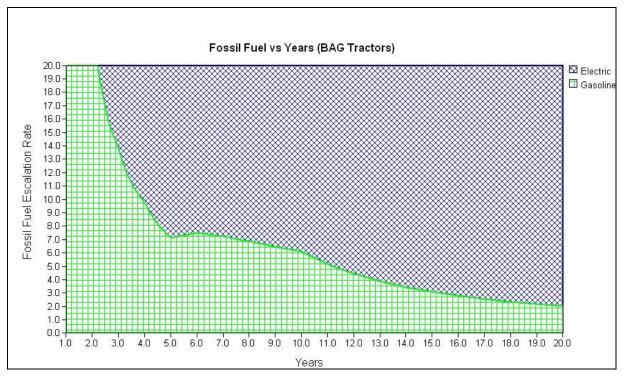


Figure 4-6. Airport "A" sensitivity analysis for baggage tractors.

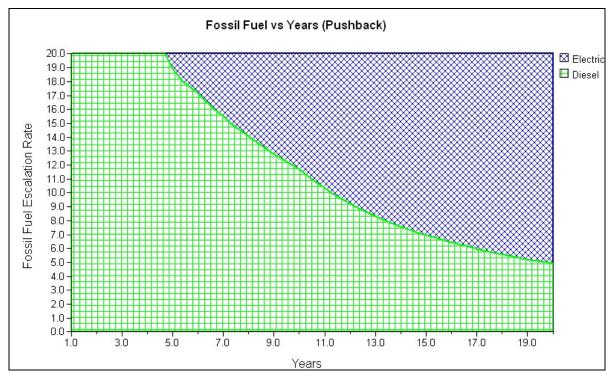


Figure 4-7. Airport "A" sensitivity analysis for pushback tractors.

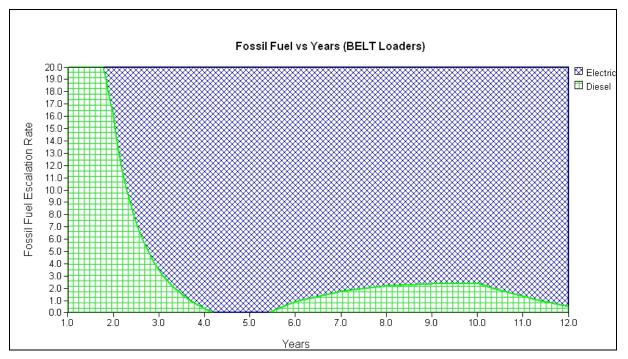


Figure 4-8. Airport "A" sensitivity analysis for belt loaders.

#### 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.

Quantity	Description	СО	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 1.11								
CO = carbon	CO = carbon monoxide, HC = total hydrocarbons, NOx = oxides of nitrogen, PM = particulate matter								

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

#### 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	Sealed—GEL	27
		Tractor—AC Drive Type		

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.

GSE Cost Software File Edit Tools Help	_	-					<u>_</u> ø×
Airport B	GSE	Cost	Mod	el V1	.1		
List of available equipment 1-750 PushBack Tog MC PushBack 300 PushBack 300 PushBack 611628/5135 PushBack Conventional Charger Brook post East Unkarger Prove Sharing cost per post			<b>R9</b>				
	Purchasing Insta Price	I Ownership cost \$/sear	Operating Cost \$/yr	Total cost \$/yr	Total for analysis		
27 Diesel Deutz 2011 BagTractor 27 AC BagTractor 10 Single port Fast Charger	\$702.000 \$158.500 \$175.000 \$30.0	\$35,100 \$47,925 \$10,250	\$320,396 \$197,476 \$10,970	\$355,496 \$245,401 \$21,220	\$7,109.920 \$4,308,020 \$424,400		
GSE usage at airport	\$1,835,500 \$30,0	00 \$93,275	\$528,842	\$622,117	\$12,442,340		
J		Foo	sil Fuel Equips	sent	\$7,109,920		
Low Medium High		E	Electric Equipr		\$5,332,420 \$1,777,500		
	Pun Analysis Vew Analysis		Differenci DAILY I usage e from util	(Whr	599.4		
List Analyzed						07/24/2006	16:20

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.

🐂 Params				
-	iasoline	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 Para defa	

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.

Cost Break - Unit Operating Cost								-
Equipment List	General Maintenance	Energy/Fuel	Engine	Transmission/ Transaxle	Controller	Cords		Fast Charge Interface
liesel Deutz 2011 BagTractor C BagTractor ingle port Fast Charger	\$59,200 \$90,407 \$16,000	\$21,068	\$19,750 \$4,520 \$000	\$9,249 \$13,640 \$000	\$000 \$15,443 \$000	\$000 \$000 \$4,511	\$000 \$000 \$1,430	\$000 \$1,200 \$000

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.

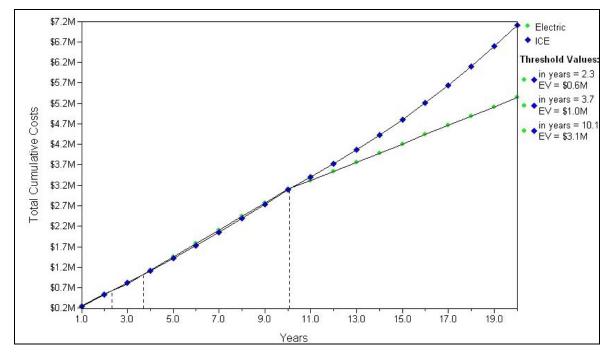


Figure 4-12. Airport "B" breakeven point for electric ground support equipment versus internal combustion engine ground support equipment.

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.

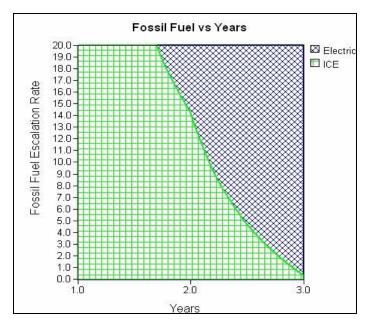


Figure 4-13. Airport "B" sensitivity analysis for baggage tractors years 0 through 3.

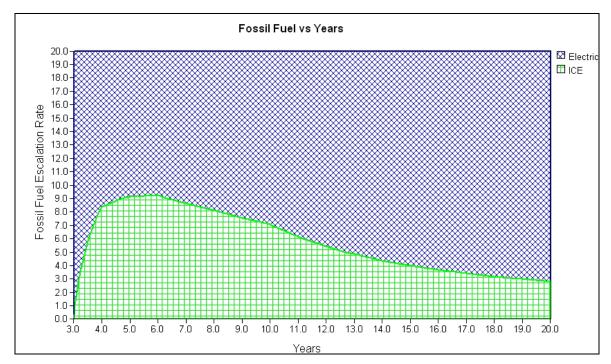


Figure 4-14. Airport "B" sensitivity analysis for baggage tractors years 3 through 20.

#### 4.2.1 Emissions

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

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

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

## 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.

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 4-7. Airport "C" ground support equipment included in the study.

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.

GSE Cost Software								X
Pile Edit Tools Help Alaport	GS	E Cos	st Mod	lel V1	1.1			
List of available equipment 1750 PurkBack Tog MC PurkBack 1860 PurkBack GT1523/GT35 PurkBack Convertional Charger Single port Fast Charger Revert Eherrop cost		7. N		k l		Î		
	Purchasing Price	Install Owner	rship Operating I/year Cost \$/ye	Total cost \$/yr	Total for analysis			
16 Gasoline ford 300 BagTinctor 7 Gasoline ford 300 Bellolader 7 Chereit Deutz 101 Bellolader 6 GT15226735 PurkBack. 16 DE BagTinston 4 Electric Bellolader 6 J30C PurkBack. 8 Power Sharing cost per polt 4 Elever Sharing cost per polt		\$20, \$3,3 \$11, \$25, \$28, \$27, \$27, \$27, \$27, \$24,000 \$5,20 \$12,000 \$12,000	75 \$50,364 270 \$50,272 860 \$49,904 400 \$88,398 160 \$41,446 900 \$35,542 00 \$80,776	\$186,117 \$60,339 \$61,542 \$75,764 \$116,798 \$60,606 \$63,442 \$14,976 \$168,000	\$3,722,340 \$1,266,780 \$1,20,840 \$1,55,260 \$2,305,560 \$1,372,120 \$1,380,040 \$2,205,520 \$2,205,200 \$2,205,200,200,200,200,200,200,200,200,20			
GSE usage at airport	\$3,277,300 1	\$165	,605 \$434,407	\$660,072	\$13,201,440			
			Fossil Fuel Equip	ment	\$7,675,240			
Low Medium High			Electric Equi		\$5.526.200			
Amotization vate	lun Analysis lew Analysis		usage	ce *k\whe estimate estimate nitity meter	\$2.143.040 560.738			
List Analyzed							08/17/2006	17.23

Figure 4-15. Results of Airport "C" main screen.

🖷 Params					_ D X
	Gasoline	Diesel	Electric	0.05	
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	3.125	2.8125	18.5	5	
Beltloader	2.25	2.025	2.9	4	·
Pushback	3	1.95	8.8	3	
	ОК		Reset Para		
			defa	ault	

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 Gasoline ford 300 Beltloader Diesel Deutz 1011 Beltloader GT1628/GT35 PushBack DC BagTractor Electric Beltloader 350E PushBack Power Sharing cost per port Power Sharing cost per port	\$50,800 \$32,300 \$44,900 \$63,640 \$40,880 \$53,640 \$16,000 \$16,000	\$138.928 \$100.028 \$90.025 \$86,691 \$25,281 \$3,963 \$12.026 \$000 \$000	\$9,755 \$5,587 \$8,127 \$16,540 \$10,269 \$4,712 \$26,017 \$000 \$000	\$7,162 \$5,982 \$5,982 \$18,217 \$4,468 \$3,632 \$21,708 \$000 \$000	\$000 \$000 \$000 \$5,639 \$4,821 \$3,883 \$000 \$000	\$000 \$000 \$000 \$000 \$000 \$000 \$000 \$4,511 \$4,511	\$000 \$000 \$000 \$000 \$000 \$000 \$1,430 \$1,430	\$000 \$000 \$000 \$1,200 \$1,200 \$1,200 \$1,200 \$000 \$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.

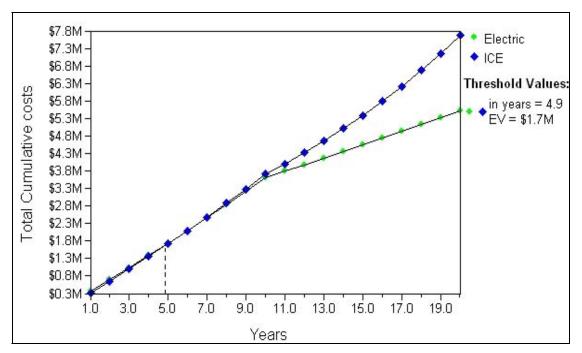


Figure 4-18. Airport "C" breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for all ground support equipment.

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.

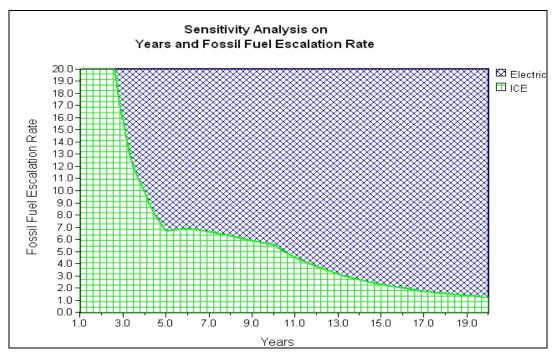


Figure 4-19. Airport "C" sensitivity analysis for all three ground support equipment types.

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.

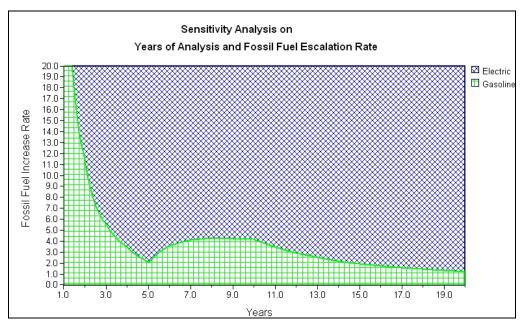


Figure 4-20. Airport "C" sensitivity analysis for baggage tractors.

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.

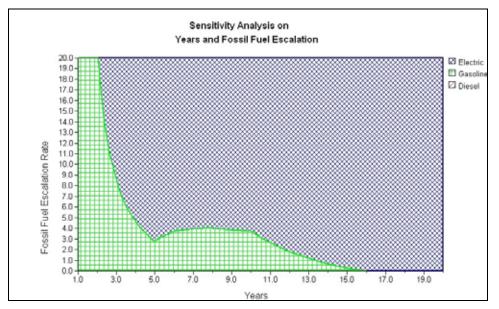


Figure 4-21. Airport "C" sensitivity analysis for belt loaders.

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.

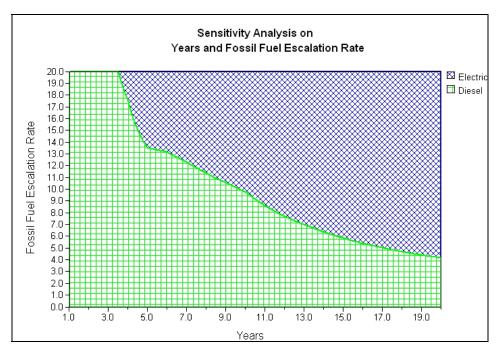


Figure 4-22. Airport "C" sensitivity analysis for pushback tractors.

#### 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.

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, $HC = total hydrocarbo$	ons, $NOx = oxides of n$	itrogen, PM = parti	culate matter	

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

#### 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).

	ist Software Tools Help	G	SE C	Cost	Mod	al VI	1			_16
		a.		2031	widd					
	I available equipment						_			
DCI	BagTractor BagTractor oline ford 300 Belticader		(1)	-la						
Dies	el Deutz 1011 Belticader sel Deutz 2011 Belticader		ET				- 'e i			
1.75	NC Bellowie 10 PushBack MC PushBack	-		and a	-			لملح لل		
1109		Purchasing	Install	Ownership cost \$/year	Operating Cost \$/yr	Total cost \$/yr	Total for analysis			
85 9 3	Gasoline ford 300 BagTractor Diesel Deutz 1011 BagTractor AC BagTractor Gasoline ford 300 Beltioader Diesel Deutz 1011 Beltioader Electric Beltioader	\$2,366,000 \$1,846,000 \$3,017,500 \$256,500 \$96,600 \$465,600		\$110,300 \$32,300 \$150,875 \$12,825 \$4,830 \$23,280	\$1.090.450 \$340.605 \$527.402 \$74.851 \$24.696 \$37.123	\$1,200,750 \$332,905 \$678,277 \$87,676 \$29,526 \$60,403	\$24,175,000 \$18,658,100 \$13,565,540 \$1,753,520 \$590,520 \$1,208,060	-		
72 77		\$1,260,000 \$1,000,000 \$2,733,500	\$216,000 \$231,000	\$23,200 \$73,000 \$26,950 \$136,675	\$37,123 \$70,904 \$29,674 \$447,250	\$50,403 \$152,704 \$56,624 \$500,900	\$1,205,600 \$1,055,600 \$1,132,400 \$11,670,660			
	GSE usage at airport	\$12,349,700	\$447,000	\$639,035	\$3,151,043	\$3,790,878	\$75,017,560			
	J				sil Fuel Equipe		\$45.177.140 \$30.640.420			
	Low Medium High			1	Diectric Equips Difference		\$14,536,720	-		
	20 year analysis	Run Analysis			DAILY I	ówhr	4365.792			
	0 Amortization rate	New Analysis			from util					
	10 Life of equipment for amortization									
ed									07/28/2006	16:44

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	
-	7	7	2.5	-	\$50.00	
% increase per year	J	l.	12.0			
	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		
	·		·			
	ſ	1	Reset Para			
	OK		neset hara defa			

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.

	Interrace
Diesel Deutz 1011 BagTractor \$58,740 \$150,042 \$18,758 \$9,249 \$000 \$0	0000 0000 0000
Gasoline ford 300 Beltloader         \$32,300         \$120,034         \$6,840         \$7,162         \$000         \$0           Diesel Deutz 1011 Beltloader         \$39,500         \$108,031         \$9,949         \$7,162         \$000         \$0           Electric Beltloader         \$40,880         \$4,021         \$5,664         \$4,468         \$5,639         \$0           Power Sharing cost per port         \$16,000         \$000         \$000         \$000         \$000         \$000         \$4           Conventional Charger         \$5,000         \$000         \$000         \$000         \$100         \$100         \$100	000         \$000         \$000           000         \$000         \$1,200           000         \$000         \$000           000         \$000         \$000           000         \$000         \$000           000         \$000         \$000           000         \$000         \$000           100         \$000         \$000           100         \$000         \$000           1,511         \$1,430         \$000           1,278         \$1,430         \$000           1000         \$000         \$1,200

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.

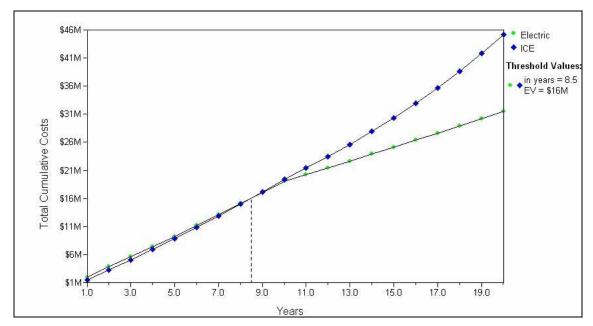


Figure 4-26. Airport "D" breakeven point for electric ground support equipment versus internal combustion engine ground support equipment for the bag tractor and belt loader.

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.

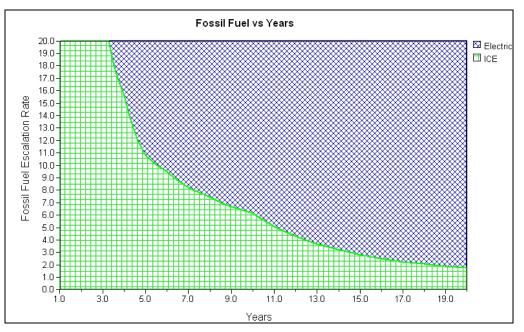


Figure 4-27. Airport "D" sensitivity analysis for baggage tractor and belt loader.

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.

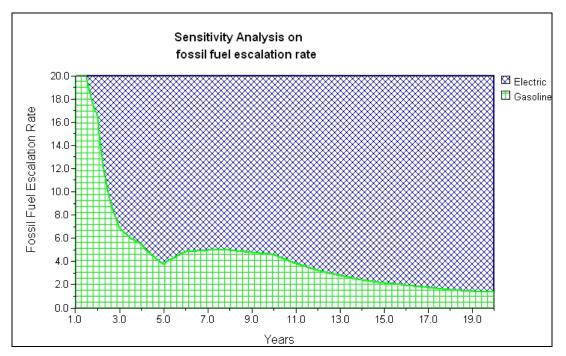


Figure 4-28. Airport "D" sensitivity analysis for baggage tractor.

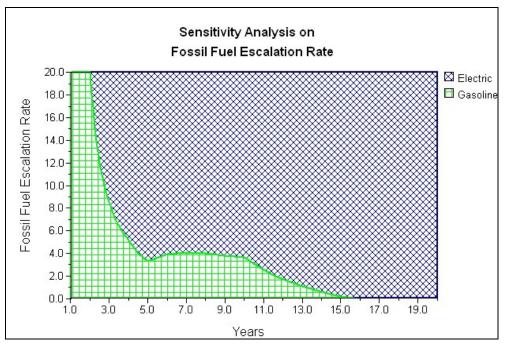


Figure 4-29. Airport "D" sensitivity analysis for belt loader.

#### 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.

10010 + 12.1	Alipoit D ethissions savings in	tons per year.			
Quantity	Description	CO	HC	NOx	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. $HC = total hydrocarbons$ . $NOx = oxides of nitrogen$ . $PM = particulate matter$					

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

## 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%.

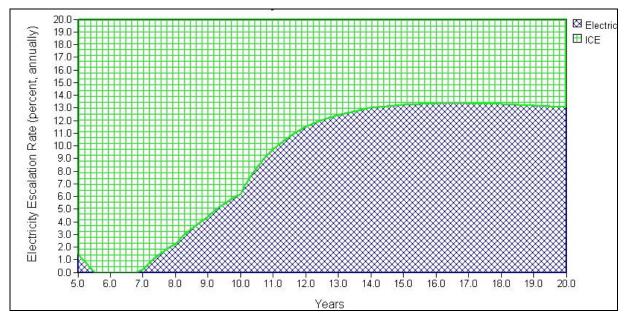


Figure 5-1. Electricity escalation rate versus years.

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.

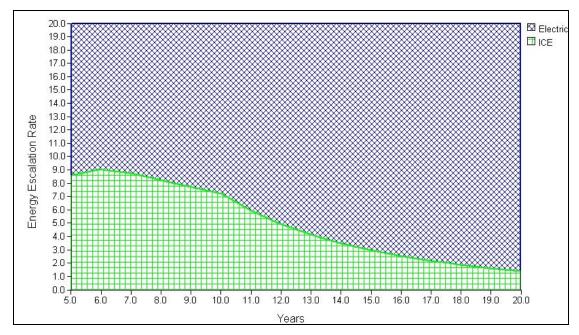


Figure 5-2. Energy escalation rates (annually) versus years.

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.

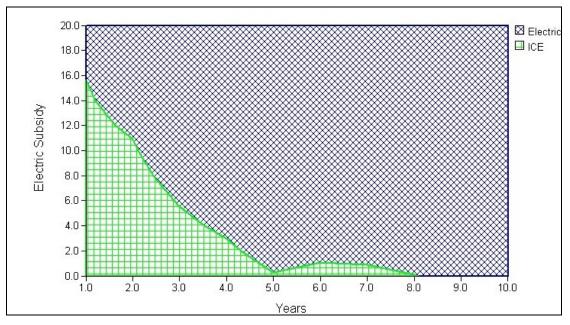


Figure 5-3. Electric ground support equipment capital cost subsidy (including charging infrastructure) versus years.

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.

page 1/2		Pu Pri	rchasing ce	Install	Owne cost \$		Operating Cost \$/yr	Total cos \$/yr	t Total analy:	
16 Diesel Deuts 7 GT1628/GT 12 DC BagTrac 5 AC BagTrac 16 Electric Belt 7 350E PushB 8 Single port F	tor loader lack	\$51 \$60 \$42 \$17 \$62 \$65 \$14	2,000 5,200 13,400 16,000 17,500 10,800 11,000 10,000 10,000	\$24,000 \$12,000	\$22, \$25, \$30, \$21, \$8,8; \$31, \$32, \$8,21 \$8,21 \$8,21	760 170 300 75 040 550 00	\$175,649 \$114,907 \$58,222 \$66,298 \$27,946 \$46,838 \$40,764 \$8,776 \$4,388	\$197,749 \$140,667 \$88,392 \$87,598 \$36,821 \$77,878 \$73,314 \$16,976 \$12,488		,340 ,840 ,960 ,20 ,560 ,280 ,20
		\$3,7	725,900	\$36,000	\$188	,095	\$543,788	\$731,883	\$14,63	7,660
DAILY kWhr usage estimate	560.28					Foss	sil Fuel Equip	ment	\$8,536	,160
from utility meter						E	lectric Equip	ment	\$6,101	,500
Estimated emissio	ons in tons per year					C	)ifference		\$2,434	,660
_aumored emisard	nia in tona per year	CO		HC			Nox		⊃M⊂	
16 Diesel Deu 7 GT1628/G 12 DC BagTri 5 AC BagTri 16 Electric Be 7 350E Push 8 Single port	actor eltloader	700.308 2.802 1.751 .000 .000 .000 .000 .000 .000	25.56 .675 .345 .000 .000 .000 .000 .000			14.9 5.60 4.44 .000 .000 .000 .000 .000	86 41 0 0 0 0 0		.137 .640 .338 .000 .000 .000 .000 .000	
	Total Emissions	704.861	26.58	3		24.6	378		1.115	
Energy cost and	Gasoline	Diesel	Electr		0	Gasolin Gallon <i>i</i> o	day Gall	on/day 🗸	ectric Vhr/day	Hours per day usage
/gallon or kWh		\$2.5	\$0.1		gTractor tloader		2.812		8.5	5
% increase per y	year 7	7	2.5			2.25	2.025		.9	4
				Fu	STUDGER	3	1.95	8	.8	3
- Inputs Number of years	s used for analysis	20	Labor Ra	ite for Main	tenance	(\$/hr)	\$50.00			
Amortization rate		0 10								

Result of analysis for xxx Page 2/2	Motor	Transmission	Controll	pr PM parts cost (\$/yr)	PM Labor jhrs/yr)	Battery Cost	Battery Life (yrs)	Sealed Batt	DC motor	Fast Charg
Gasoline ford 300 BagTractor Diesel Deutz 1011 Beltloader GT1628/GT35 PushBack DC BagTractor AC BagTractor Electric Beltloader 350E PushBack	10000/1700/32 15000/4000/16 5000/4000/16 3250/975/10 13697/1000/10 7300/975/10 4000/5300/20	6500/900/16 6500/900/16 6500/5000/32 20000/2000/ 20000/5500/1 5000/5500/16	2 0/0/0 3650/800/1 16 3650/1957/ 16 3650/800/1 5 3650/800/1	1.5 \$1047 .5 \$669 .5 \$1082	14 hrs	\$6000 \$4000 \$6000	5 улз 5 улз 5 улз 5 улз 5 улз	No No No	Yes No No No	Yes Yes Yes Yes
- XXYYY/ZZ represents failure n	Load Factor (%)	Horse Power (hp)	CO (g/hp hr)	HC (g/hp hr)	Nox (g/hp hr)		PM (g/hp hr)	Fue Typ		
Gasoline ford 300 BagTractor Diesel Deutz 1011 Beltloader GT1628/GT35 PushBack DC BagTractor AC BagTractor Electric Beltloader 350E PushBack	55% 50% 80% 55% 55% 55% 80%	107 71 100 40 40 40 100	347.9577 3.06526 2.59 0 0 0	12.7 0.738 0.51 0 0 0	7.23 6.22 6.57 0 0 0	.068 .7 .5 0 0 0	004	Gasolin Diesel Electric Electric Electric		
1	Cord Failure	Charger Failure	PM parts cost (\$/yr)	PM Labor (hrs/yr)		-				
Single port Fast Charger Power Sharing cost per port	2/600/2 2/600/2			12 hrs 12 hrs						
- XX/YY/ZZ for chargers repres	ents failure rate in	years/cost of p	arts in \$ for rep	acement/ hrs	of labor fo	r replace	ement			

File		
Vehicle Name Gasoline ford 300 BagTractor	•	Transmission Failure Rate 6500 hrs
Vehicle Type BagTractor	Engine Motor Motor failure rate in hrs 10000 Engine replacement	replacement cost 900 \$ Time to replace 16 hrs
Purchase Price	cost 1700 Time to replace in hrs 32	Emissions Load factor 55 % Horsepower 107 hp
Energy source Gasoline	Preventive Maintenance Yearly cost of parts 1205 Yearly hours 26.7	emissions in g/(hp hour) CO 347.957 HC 12.7 Nox 7.23 PM .068

File				
Vehicle Name		Transaxle Failure Rate	Controller Failure Rate	-
AC BagTractor	<b>•</b>	20000 hrs	3650 hrs	
		replacement cost	replacement cost	
	Engine Motor	5500 \$	1857 \$	
Vehicle Type	Motor failure rate in hrs	Time to replace	Time to replace	
BagTractor 💌	13687	16 hrs	1.5 hrs	
Purchase Price	Engine replacement cost			
35500 \$		- Emissions		
	Time to replace in hrs	Load factor 55 %		
	10	Horsepower 40 hp		
Energy source	Preventive Maintenance	emissions in g/(hp hour)		
Electric	Yearly cost of parts	CO 0		
	1047	HC 0		
	Yearly hours	Nox 0		
	24.7	РМ 0		

File			
Vehicle Name		Transaxle	Controller
DC BagTractor		Failure Rate	Failure Rate
		20000 hrs	3030
	Engine	replacement cost	replacement cost 800 \$
	Motor	12000	1000
Vehicle Type	Motor failure rate in hrs	Time to replace	Time to replace
BagTractor 🔽	3250	16 hrs	1.5 hrs
	Engine replacement		
Purchase Price	cost		
35500 \$	975		
	Time to contact in	Emissions	
	Time to replace in hrs	Load factor 55 %	
	10	Horsepower 40 hp	
Energy source		emissions in g/(hp hour)	
	Preventive Maintenance	C0 0	
Electric	Yearly cost of parts		
	1047	HC 0	
	Yearly hours	Nox 0	
	24.7	PM 0	
		PM Jo	

		<b>_</b>
Vehicle Name		Transmission Failure Rate
Diesel Deutz 1011 Beltloader	<u> </u>	6500 hrs
		replacement cost
	Engine	900 \$
	- Motor	1300 *
/ehicle Type	Motor failure rate in hrs	Time to replace
Beltloader 🔽	15000	
		16 hrs
	Engine replacement	
Purchase Price	cost	
32200 \$	4000	
	<b>-</b>	Emissions
	Time to replace in hrs	Load factor 50 %
	16	
		Horsepower 71 hp
Energy source		emissions in g/(hp hour)
	Preventive Maintenance	CO 3.06526
Diesel 🔽	Yearly cost of parts	
	1250	HC 0.738
		Nox 6.22
	Yearly hours	Nox 6.22
	14.5	PM 7
		<u> </u>

File			
Vehicle Name		Transaxle	Controller
Electric Beltloader	•	Failure Rate	Failure Rate 3650 hrs
			13030
	Engine Motor	replacement cost 2000 \$	800 \$
Vehicle Type	Motor failure rate in hrs	Time to replace	Time to replace
Beltloader	7300	16 hrs	1.5 hrs
Purchase Price	Engine replacement cost		
\$	975		
	Time to replace in	Emissions	
	hrs	Load factor 50 %	
	10	Horsepower 40 hp	
Energy source		emissions in g/(hp hour)	
Electric	Preventive Maintenance	CO 0	
	Yearly cost of parts 669	нс о	
	663		
	Yearly hours	Nox 0	
	15.5	PM 0	

File		
Vehicle Name GT1628/GT35 PushBack	<b>•</b>	Transmission Failure Rate
,	Engine	Fe500 hrs replacement cost 5000 \$
Vehicle Type Pushback	Motor failure rate in hrs	Time to replace
Purchase Price	Engine replacement cost 4000	
	Time to replace in hrs	Emissions Load factor 80 %
Energy source	Preventive Maintenance	Horsepower 100 hp emissions in g/(hp hour) CO 2.59
Diesel	Yearly cost of parts 1520	HC 0.51
	Yearly hours 14.5	Nox 6.57 PM .5

File			
Vehicle Name		- Transaxle	Controller
350E PushBack	•	Failure Rate	Failure Rate
,		5000 hrs	3650 hrs
		replacement cost	replacement cost
	Engine Motor	5500 \$	800 \$
Vehicle Type	Motor failure rate in hrs	Time to replace	Time to replace
Pushback 💌	4000	16 hrs	1.5 hrs
Purchase Price	Engine replacement cost		
93000 \$	5300	Emissions	
	Time to replace in		
	hrs	Load factor 80 %	
	20	Horsepower 100 hp	
Energy source		emissions in g/(hp hour)	
Electric	Preventive Maintenance	C0 0	
	Yearly cost of parts 1082	HC 0	
	1002		
	Yearly hours	Nox 0	
	14	PM 0	

File		
Single port Fast Charger	•	Charger Cost 17500
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	Yearly hours 12

File		
		Charger Cost
Power Sharing cost per port	•	37500
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	Install Cost 3000 Preventive Maintenance Yearly cost of parts 200 Yearly hours 12

page	07/26/2006 Resu 1/2	It of analysis fo	c	Purchasi Price	ing	Install	Owner cost \$		Operating Cost \$/yr	Total o \$/yr	ost	Total f analys	
	Diesel Deutz 201 AC BagTractor Single port Fast C	_		\$702,000 \$958,500 \$175,000		\$30,000	\$35,1 \$47,9 \$10,2	325	\$320,396 \$197,476 \$10,970	\$355,4 \$245,4 \$21,22	01	\$7,109 \$4,908 \$424,4	,020
				\$1,835,50	00 1	30,000	\$93,2	75	\$528,842	\$622,11	17	\$12,44	2,340
	estimate 599	.4						Foss	il Fuel Equip	ment		\$7,109	,920
rom i	utility meter							E	lectric Equip	ment		\$5,332	,420
Estim	ated emissions in	tons per year						D	ifference			\$1,777	,500
				0		IC		17.0	Nox			⊃M 480	
27 27 10	Diesel Deutz 20 AC BagTractor Single port Fast		5.048 .000 .000		2.138 .000 .000			.000	)		.0	00	
	Tot	al Emissions	5.048		2.138			17.0	74		2.	48	
	r <b>gy cost an dusag</b> G ost at year 0	e assumptions asoline	Diesel		Electric		G	asoline		sel on/day	∃lec ∢Wh	tric r/day	Hours per da usage
	allon or kWhr	\$2.5	\$2.5	\$0.	1		ractor	3.75	3.37	5	22.2	2	7
% in	icrease per year	7	7	2.5	i	Beltic	ľ	2.7	2.43		3.48	3	5
						Push	back	3.6	2.34		10.5	56	4
- Inpu	its	d for analysis	20	Lab	or Rate	for Mainte	nance (	(\$/hr)	\$50.00				

Motor	Transmissio	n Contro	dier	cost	PM Labor (hrs/yr)	Battery Cost	Battery Life (yrs)	Sealed Batt	DC motor	Fast Charg
10000/4000/16 13687/1000/10			7/1.5 \$	1629 1047	26.7 hrs 24.7 hrs	\$7900	3 yrs	Yes	No	Yes
Load	Horse	00	н	ic	Nox		PM	Fue		
(%) 55% 55%	(hp) 71 40	hr)		r) 5	hr) 1.75		hr)	Diesel	_	
Cord Failure	Charger Failure	PM parts cost (\$/yr)								
2/600/2	15/600/12	\$200	12 hrs							
	10000/4000/16 13687/1000/10 Factor (%) 55% 55%	10000/4000/16         6500/900/16           13687/1000/10         20000/5500/           rate in hours of usage/cost of part Factor (%)         Horse Power (hp)           55%         71           55%         71           55%         71           55%         71           55%         71           55%         71           55%         71           55%         71           55%         71           60         Charger Failure	10000/4000/16         6500/900/16         0/0/0           13687/1000/10         20000/5500/16         0/0/0           rate in hours of usage/cost of parts in \$ for replay         Factor         CO           Load         Horse         CO           Factor         Power         (g/hp)           (%)         71         0           55%         71         0           55%         740         0           Cord         Charger         Cost           Failure         Charger         Cost           Stature         Cord         Charger           Failure         Charger         Cost           (\$Vr)         Stature         Cost	Motor         Transmission         Controller           10000/4000/16         6500/900/16         0/0/0         3650/1857/1.5         \$           13687/1000/10         20000/5500/16         3650/1857/1.5         \$         \$           rate in hours of usage/cost of parts in \$ for replacement/ Factor (%)         Horse         CO         H           Load         Horse         CO         (g/hp         (g/hp         (g/hp           55%         71         0         0         0         0           55%         740         0         0         0         0           Cord         Charger         Cost (\$/yy)         PM Lucost (\$/yy)         PM Lucost (\$/yy)         PM Lucost	Load         Horse (%)         COUL (%)         HC (%)         HC (%)         HC (%)         HC (%)	Motor         Transmission         Controller         cost (\$/yr)         Labor Ins/yr)           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           rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for reference Factor (%)         Horse Power (hp)         CO         HC (g/hp hr)         Nox (g/hp hr)           55%         71 40         1.7         0.72         5.75 0           55%         71 40         1.7         0.72         5.75 0           Cord Failure         Charger Failure         PM parts cost (\$/yr)         PM Labor (hrs/yr)	Motor         Transmission         Controller         cost (\$/yr)         Labor (hrs/yr)         Cost           10000/4000/16 13687/1000/10         6500/900/16 20000/9500/16         0/0/0 3650/1857/1.5         \$1629 \$1047         26.7 hrs 24.7 hrs         \$7900           rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement/ Factor (%)         Horse Power (hp)         CO         HC (g/hp hr)         Nox (g/hp hr)         Nox (g/hp hr)         9           55%         71 40         1.7 0         0.72 0         5.75 0         .835 0         0           Cord Failure         Charger Failure         PM parts (\$/yr)         PM Labor (hrs/yr)         PM Labor (hrs/yr)         PM Labor	Motor         Transmission         Controller         cost (\$/yr)         Labor (ns/yr)         Cost (yrs)         Life (yrs)           10000/4000/16 13687/1000/10         6500/900/16 20000/5500/16         0/0/0 3650/1857/1.5         \$1623 \$1047         26.7 hrs 24.7 hrs         \$7900         3 yrs           rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement         Nox (g/hp hr)         PM (g/hp hr)         \$1000         PM (g/hp hr)         \$1000           55%         71 40         1.7 0         0.72 0         5.75 0         .835 0         .835 0           55%         71 40         1.7 0         0.72 0         5.75 0         .835 0         .835 0           Cord Failure         Charger Failure         PM parts cost (\$/yr)         PM Labor (hrs/yr)	Motor         Transmission         Controller         cost (slyr)         Labor (rstyr)         Cost (yrs)         Life <sup>*</sup> (yrs)         Batt:           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           rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement         Power         (g/np hr)         HC (g/np hr)         Nox (g/np hr)         PM (g/np hr)         Fue Typ           553;         71 40         1.7 0         0.72 0         0.72 0         5.75 0         .835 0         Diesel Electric           Cord Failure         Charger Failure         PM parts (s/yr)         PM Labor (hrs/yr)         1.40         PM Labor         1.575         1.575	Motor         Transmission         Controller         cost (\$yr)         Labor hrs/yr)         Cost (yrs)         Life (yrs)         Batt         motor           10000/4000/16         6500/900/16         0/0/0 3650/1657/1.5         \$1629 \$1047         26.7 hrs 24.7 hrs         \$7900         3 yrs         Yes         No           rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement         Nox         PM (g/hp hr)         PM (g/hp hr)         Fuel Type           Load Factor (%)         Horse (hp)         CO (hr)         1.7 0         0.72         5.75 0         .835 0         Diesel Electric           55%         71 40         1.7 0         0.72 (\$fyr)         5.75 0         .835 0         Diesel Electric           Cord Failure         Charger Failure         PM parts cost (\$fyr)         PM Labor (hrs/yr)         PM Labor

File			
Vehicle Name		Transaxle	Controller
AC BagTractor	•	Failure Rate	Failure Rate
		20000 hrs	3650 hrs
	_ ·	replacement cost	replacement cost
	Engine Motor	5500 \$	1857 \$
Vehicle Type	Motor failure rate in hrs	Time to replace	Time to replace
BagTractor 🔽	13687		
		16 hrs	1.5 hrs
	Engine replacement cost		
Purchase Price			
35500 \$	1000		
	Time to replace in	Emissions	
	hrs	Load factor 55 %	
	10	Horsepower 40 hp	
		emissions in g/(hp hour)	
Energy source	- Preventive Maintenance		
Electric	Yearly cost of parts	CO 0	
,	1047	нс о	
	Yearly hours	Nox 0	
	24.7	PM 0	

Vehicle Name       Inansmission         Dresel Deutz 2011 BagTractor       Image: Constraint of the second se	, Edit Properties ile		
Vehicle Type       Motor failure rate in hrs         BagTractor       10000         Purchase Price       Engine replacement cost         26000       4000         Time to replace in hrs       Emissions         Time to replace in hrs       Load factor 55 %         Horsepower 71 hp emissions in g/(hp hour)       Preventive Maintenance         C0       1.7	Vehicle Name	Engine	Failure Rate 6500 hrs replacement cost
Image: Second	BagTractor	Motor failure rate in hrs 10000 Engine replacement cost	
Preventive Maintenance CO 1.7	\$	Time to replace in hrs	Load factor 55 % Horsepower 71 hp
1629         HC         0.72           Yearly hours         Nox         5.75           26.7         PM         .835		Yearly cost of parts 1629 Yearly hours	CO 1.7 HC 0.72 Nox 5.75

	08/17/2006 Results 1/2	t of analysis fo	P	urchasing rice	Install		ership \$/year	Operating Cost \$/yr	Total cos \$/yr	st Total analys	
16 7 6 16 14 6 8 4	Gasoline ford 300 Gasoline ford 300 Diesel Deutz 1011 GT1628/GT35 Pi DC BagTractor Electric Beltloade 350E PushBack Power Sharing co	Beltloader 1 Beltloader ushBack. r ist per port	\$1 \$2 \$5 \$5 \$5 \$5 \$5 \$5 \$5 \$5	16,000 99,500 (25,400 (17,200 (68,000 (43,200 (58,000 (00,000 (50,000	\$24,000 \$12,000	\$9,9 \$11, \$25, \$28, \$27, \$6,2	270 860 400 160 900	\$165,317 \$50,364 \$50,272 \$49,904 \$88,338 \$41,446 \$35,542 \$8,776 \$4,388	\$186,117 \$60,339 \$61,542 \$75,764 \$116,798 \$68,606 \$63,442 \$14,976 \$12,488	\$1,206 \$1,230 \$1,515	5,780 5,280 5,280 2,120 8,840 520
			\$3	,277,300	\$36,000	\$165	5,665	\$494,407	\$660,072	\$13,20	1,440
	Y kWhr e estimate 560.	736					Fos	sil Fuel Equip	ment	\$7,675	,240
	utility meter						E	Electric Equip	ment	\$5,526	,200
ctin	nated emissions in	tone ner veer					C	Xifferen ce		\$2,149	0,040
,5011	Idrea ethissions in	tons per year	CO		HC			Nox		PM	
16 7 6 16 14 6 8 4	Gasoline ford 30 Gasoline ford 30 Diesel Deutz 10 GT1628/GT35 DC BagTractor Electric Beltoad 350E PushBack Power Sharing o Power Sharing o	00 Beltloader 11 Beltloader PushBack ler cost per port	659.113 145.253 1.226 1.501 .000 .000 .000 .000 .000	24.0 6.02 .295 .295 .000 .000 .000 .000	27 5 5 1 1		4.3 2.4 3.8 .00 .00 .00 .00	88 06 0 0 0 0		.129 .041 .280 .000 .000 .000 .000	
	Tot	al Emissions	807.093	30.6	74		24.3	353		0.74	
C	ost at year 0	e assumptions asoline	Diesel	Elect			Gasolin Gallon/	day Gall	on/day A	ectric Vhr/day 8.5	Hours per day usage
	allon or kWhr		\$2.5	\$0.1			3.125	2.812		9	4
% 11	ncrease per year	7	ľ	2.5		ishback		1.95	-	8	3
							×	1.55	0		2
- Inp	uts mber of years use	d for analysis	20	Labor R	ate for Mai	ntenance	(\$/hr)	\$50.00			
	ortization rate(%)		0		and the ships		(a)				
	ars of amortization		10	-							

Result of analysis for C Page 2/2	Motor	Transmission	n Contro	ller	PM parts cost (\$/yr)	PM Labor hrs/yr)	Battery Cost	Battery Life (yrs)	Sealed Batt	DC motor	Fast Charge
Gasoline ford 300 BagTractor Gasoline ford 300 Beltloader Diesel Deutz 1011 Beltloader GT1628/GT35 PushBack DC BagTractor Electric Beltloader 350E PushBack	10000/1700/32 15000/1700/32 15000/4000/16 5000/4000/16 3250/975/10 7300/975/10 4000/5300/20	6500/900/16 6500/900/16 6500/900/16 6500/5000/3 20000/2000/ 5000/2000/ 5000/5500/10	0/0/0 0/0/0 2 0/0/0 16 3650/800/ 16 3650/800/ 6 3650/800/	1.5 1.5 1.5	\$1205 \$890 \$1250 \$1520 \$1520 \$1047 \$669 \$1082	26.7 hrs 14.5 hrs 14.5 hrs 14.5 hrs 24.7 hrs 24.7 hrs 15.5 hrs 14 hrs	\$4000 \$6000	5 угз 5 угз 5 угз 5 угз	No No No	Yes Yes Yes	Yes Yes Yes
	Load Factor (%)	Horse Power (hp)	CO (g/hp hr)	0	HC g/hp hr)	Nox (g/hp hr)		PM (g/hp hr)	Fue Typ		
Gasoline ford 300 BagTractor Gasoline ford 300 Beltloader Diesel Deutz 1011 Beltloader GT1628/GT35 PushBack DC BagTractor Electric Beltloader 350E PushBack	55% 50% 50% 50% 55% 50% 80%	107 107 71 100 40 40 100	347.9577 241 3.06526 2.59 0 0 0	12.7 10 0.73 0.51 0 0	8	7.23 7.24 6.22 6.57 0 0	.068 .068 .7 .5 0 0		Gasolin Gasolin Diesel Diesel Electric Electric	e	
	Cord Failure	Charger Failure	PM parts cost (\$/yr)		Labor s/yr)						
Power Sharing cost per port Power Sharing cost per port	2/600/2 2/600/2		\$200 \$200	12 h 12 h							

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

File		
Vehicle Name Gasoline ford 300 BagTractor	<u> </u>	Transmission Failure Rate   6500   hrs
Vehicle Type BagTractor	Engine Motor Motor failure rate in hrs 10000 Engine replacement cost 1700	replacement cost 900 \$ Time to replace 16 hrs Emissions
Energy source Gasoline	Time to replace in hrs 32 Preventive Maintenance Yearly cost of parts 1205 Yearly hours 26.7	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		Transaxle	Controller
DC BagTractor	•	Failure Rate	Failure Rate
,		20000 hrs	3650 hrs
		replacement cost	replacement cost
	Engine	2000 \$	800 \$
	Motor		
Vehicle Type	Motor failure rate in hrs	Time to replace	Time to replace
BagTractor 💌	3250	16 hrs	1.5 hrs
			1.5
Purchase Price	Engine replacement cost		
	975		
35500 \$	3/3	<b>F</b> : :	
	Time to replace in	Emissions	
	hrs	Load factor 55 %	
	10	lleven les	
		Horsepower 40 hp	
Energy source		emissions in g/(hp hour)	
	Preventive Maintenance	CO O	
Electric	Yearly cost of parts		
	1047	HC 0	
		Nox 0	
	Yearly hours	Nox 0	
	24.7	PM 0	
	· · · · · · · · · · · · · · · · · · ·	10	

Engine       Engine         Wotor       Motor         Motor       Motor failure rate in hrs         Beltloader       15000         Purchase Price       Engine replacement cost         28500       \$         1700       Emissions         Time to replace in hrs       1200         image: series       Time to replace in hrs         32       Energy source         Preventive Maintenance       C0         Yearly cost of parts       HC         830       HC	Vehicle Name Gasoline ford 300 Beltloader	<b></b>	Transmission Failure Rate
Purchase Price 28500 S Energy source Gasoline Engine replacement 1700 Time to replace in hrs 32 Preventive Maintenance Yearly cost of parts Engine replacement CO 241 CO CO 241 CO CO CO CO CO CO CO C	Vehicle Type	Motor Motor failure rate in hrs	900 \$ Time to replace
Energy source Preventive Maintenance C0 241 Gasoline Yearly cost of parts		Cost 1700 Time to replace in	Emissions
890 HC 10		Preventive Maintenance	emissions in g/(hp hour)
Yearly hours         Nox         7.24           14.5         PM         .068		890 Yearly hours	Nox 7.24

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

File			
Vehicle Name Electric Beltloader	•	Transaxle Failure Rate 20000 hrs	Controller Failure Rate 3650 hrs
	Engine Motor	replacement cost	replacement cost 800 \$
Vehicle Type Beltloader	Motor failure rate in hrs 7300	Time to replace	Time to replace
Purchase Price	Engine replacement cost 975		
	Time to replace in hrs	Emissions Load factor 50 %	
Energy source	Preventive Maintenance	Horsepower 40 hp emissions in g/(hp hour)	
Electric	Yearly cost of parts 669	C0 0 HC 0	
	Yearly hours 15.5	Nox 0 PM 0	

File		
Vehicle Name		Transmission
GT1628/GT35 PushBack	•	Failure Rate
		6500 hrs
	Engine	replacement cost 5000 \$
	Motor	10000
Vehicle Type	Motor failure rate in hrs	Time to replace
Pushback 🔽	5000	32 hrs
Purchase Price	Engine replacement cost	
86200 \$	4000	
	Time to replace in	- Emissions
	hrs	Load factor 80 %
	16	Horsepower 100 hp
Energy source		emissions in g/(hp hour)
Diesel	Preventive Maintenance	CO 2.59
Diesei	Yearly cost of parts 1520	HC 0.51
	1320	10.01
	Yearly hours	Nox 6.57
	14.5	PM .5

File			
Vehicle Name		Transaxle	Controller
350E PushBack	•	Failure Rate	Failure Rate
	_	5000 hrs	3650 hrs
		replacement cost	replacement cost
	Engine Motor	5500 \$	800 \$
Vehicle Type	Motor failure rate in hrs	Time to replace	Time to replace
	4000		
Pushback 🔽	I	16 hrs	1.5 hrs
	Engine replacement		
Purchase Price	cost		
93000 \$	5300		
	<b>.</b>	Emissions	
	Time to replace in hrs	Load factor 80 %	
	20		
		Horsepower 100 hp	
Energy source	- Preventive Maintenance	emissions in g/(hp hour)	
Electric		CO 0	
	Yearly cost of parts		
	1082	HC 0	
	Yearly hours	Nox 0	
	14		
		PM 0	

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	Time to repair in hrs	Yearly hours

🐂 Charger list		
File		
Power Sharing cost per port	<b>_</b>	Charger Cost 12500
Cord Cord failure rate in years 2 cord replacement cost 600 Time to replace in	Charger Failure Charger failure rate in years 15 charger part replacement cost 600 Time to repair in hrs	Install Cost 3000 Preventive Maintenance Yearly cost of parts 200 Yearly hours
hrs 2	12	12

50 \$24,175,000 \$18,658,100 \$13,565,540 \$1,753,520 \$590,520 \$1,208,060 \$3,055,740 \$1,132,480 \$11,678,660 <b>\$45,177,140</b> <b>\$30,640,480</b> <b>\$14,536,660</b>
\$45,177,140 \$30,640,480 \$14,536,660
\$30,640,480 \$14,536,660
\$14,536,660
PM
6.520 .000 .066 .150 .000 .000 .000
7.762
ectric Hours per day Whr/day usage 2.2 7
.48 5
0.56 4

Motor	Transmissio	n Contro	ller	PM parts cost (\$/yr)	PM Labor [hrs/yr)	Battery Cost	Battery Life (yrs)	Sealed Batt	DC motor	Fast Charg
10000/4000/16 13687/1000/10 15000/1700/32	6500/900/16 20000/5500/ 6500/900/16 6500/900/16 20000/2000/	6 0/0/0 716 3650/1857 6 0/0/0 6 0/0/0 716 3650/800	7/1.5	\$1205 \$1602 \$1047 \$890 \$1250 \$669 \$1047	14.5 hrs 14.5 hrs 15.5 hrs	\$4000	5 yrs 5 yrs 5 yrs	No No No	No No No	Yes Yes Yes
rate in hours of us	age/cost of par	ts in \$ for repla	cemen	nt/hrs of I	abor for re	placem	ent			
Load Factor (%)	Horse Power (hp)	CO (g/hp hr)	(	HC g/hp hr)	Nox (g/hp hr)		PM (g/hp hr)			
55% 55% 50% 50% 50% 50% 55%	107 71 40 107 71 40 40	347.9577 4.5 0 241 3.06526 0 0	0	8	5.75 ) 7.24 5.22 )	.835	5	Diesel Electric Gasolin Diesel Electric	e	
Cord Failure	Charger Failure	PM parts cost (\$/yr)								
2/600/2 5/300/2	15/600/12 15/600/12	\$200 \$200								
	10000/1700/32 10000/4000/16 13687/1000/10 15000/1700/32 15000/4000/16 7300/975/10 3250/975/10 3250/975/10 Load Factor (%) 55% 55% 55% 55% 55% 55% 55% 55% 55% 5	10000/1700/32 10000/4000/16 13687/1000/10 15000/100/12 15000/4000/16 7300/975/10 3250/975/10 3250/975/10 3250/975/10         6500/900/16 6500/900/16 20000/2000/ 55% 71 55% 71 50% 40 50% 107 50% 40           Cord Failure         Charger Failure           Cord Failure         Charger Failure           2/600/2         15/600/12	10000/1700/32 10000/4000/16 13687/1000/10 15000/1700/32 15000/4000/16 7300/975/10 3250/975/10 3250/975/10         5500/900/16 20000/2000/16 20000/2000/16 20000/2000/16 20000/2000/16 3650/800 300/800 30	10000/1700/32 10000/4000/16 13687/100/10 15000/1700/32 15000/1700/32 15000/1700/32 15000/4000/16 7300/975/10 3250/975/10 20000/2000/16 3250/975/10 20000/2000/16 3650/800/1.5 365	Motor         Transmission         Controller         cost (\$/yr)           10000/1700/32 10000/4000/16 13687/1000/10 15000/1700/32 15000/4000/16 5500/900/16 20000/2000/16 3250/975/10 3250/975/10         6500/900/16 20000/2000/16 3650/800/1.5         0/0/0 3650/800/1.5         \$1047           7300/975/10 3250/975/10         20000/2000/16 20000/2000/16 3650/800/1.5         3650/800/1.5         \$669           rate in hours of usage/cost of parts in \$ for replacement/ hrs of I         Horse Power (%)         CO         HC (g/hp hr)         HC (g/hp hr)           55%         71 4.5         0         0         0         0           55%         71 4.5         0.722 50%         0         0         0         0           50%         107 50%         71 4.5         3.06526 0.738 0         0	Motor         Transmission         Controller         cost (\$/yr)         Labor hrs/yr)           10000/1700/32 10000/4000/16 13687/1000/10 19000/1700/32 15000/4000/16 19000/1700/32 15000/900/16 19000/4000/16 3250/975/10         6500/900/16 6500/900/16 6500/900/16 20000/2000/16 3650/800/1.5         0/0/0 \$1250 \$15.5 hrs 3650/800/1.5         \$1047 \$889 \$1250 \$15.5 hrs 14.5 hrs 15.5 hrs 14.7 hrs           Load         Horse         CO         HC         Nox (g/hp           Load         Horse         CO         HC         Nox (g/hp           55%         107         347.9577 1.2.7         12.7         7.23 5.75           55%         71         4.5         0.72         5.75 5.75           50%         107         241         10         7.24           50%         107         241         10         7.24           50%         107         241         0         0         0           50%         40         0         0         0         0         0           50%         40         0         0         0         0         0         0           55%         40         0         0         0         0	Motor         Transmission         Controller         cost (\$/yr)         Labor hrs/yr)         Cost (\$/yr)           10000/1700/32 10000/4000/16 13687/100/10 15000/1700/32 15000/1700/32 15000/1700/32 15000/100/16 3500/900/16 3500/900/16 3250/9075/10 3250/975/10 3250/975/10 3250/975/10         6500/900/16 20000/2000/16 3650/800/1.5         67 hrs \$1047         28.7 hrs 28.90 \$1250         \$6000 \$1250           10000/1700/32 550/9075/10 3250/975/10         20000/2000/16 20000/2000/16 3650/800/1.5         3650/800/1.5         \$659 \$1047         24.7 hrs \$4000         \$6000           12000/2000/16 3250/975/10         20000/2000/16 20000/2000/16         3650/800/1.5         \$659 \$1047         24.7 hrs \$4000         \$6000           12000/2000/16 3250/975/10         20000/2000/16 20000/2000/16         3650/800/1.5         \$1047         24.7 hrs \$6000         \$6000           12000/2000/16 3250/975/10         20000/2000/16 20000/2000/16         3650/800/1.5         \$1047         24.7 hrs \$6000         \$6000           120000/2000/16 (%)         107         347.9577         12.7         7.23         .0685           55%         107         347.9577         12.7         7.24         .068           50%         107         241         10         7.24         .068           50%         40         0         0         0         0	Motor         Transmission         Controller         cost (\$/yr)         Labor hrs/yr)         Cost (yrs)         Life (yrs)           10000/1700/32 13887/1000/10 13887/1000/10 20000/5000/16 33850/800/15 20000/2000/16 33500/800/15 3250/975/10         6500/900/16 20000/2000/16 20000/2000/16 20000/2000/16 20000/2000/16 20000/2000/16         0/0/0 3650/800/1.5 3650/800/1.5         \$1047 \$1047         24.7 hrs 24.7 hrs \$4000         \$4000 5 yrs           rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement         Cost 10.72         Nox 24.7 hrs         \$6000         5 yrs           Load Factor (%)         Horse (hp)         CO 10         HC 00         Nox 0         PM (g/hp hr)         Nox 0         PM (g/hp hr)           55% 55%         107 50%         347.9577 10         12.7 2.7 5.75         3.835 0.0835         0 0         0         0           55% 55%         107 50%         347.9577 10         12.7 0.72         5.75 0.835         0.838 0         0 0         0         0         0         0           50%         107 50%         241 00         0	Motor         Transmission         Controller         cost (st/yr)         Labor hrs/yr)         Cost (yrs)         Life (yrs)         Batt.           10000/1700/32 13687/1000/16 15000/4000/16 15000/4000/16 5500/900/16 15000/4000/16 3650/900/16 00/0/0         0/0/0 3850/1857/1.5 \$1047         \$1205 \$1602 \$2.7 hrs \$2.7 hrs \$14.5 hrs \$14.5 hrs \$4000         5 yrs \$6000         No           15000/1700/32 5500/900/16 3650/800/1.5         6500/900/16 3650/800/1.5         0/0/0 \$1250         \$14.5 hrs \$4.5 hrs \$5.7 hrs \$6000         5 yrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$5.7 hrs \$6000         5 yrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$4.5 hrs \$5.7 hrs \$6.2 hrs	Motor         Transmission         Controller         cost (\$iyr)         Labor hrs/yr)         Cost (yrs)         Life (yrs)         Batt Batt         motor           10000/100/16 10000/100/16 15000/100/16 15000/100/16 15000/2000/16 20000/5900/16 20000/2000/16 3250/975/10 3250/975/10 3250/975/10 3250/975/10 3250/975/10 3250/975/10 3250/975/10 3250/975/10 3250/975/10 3250/975/10 3250/975/10         Controller 0/0/0 3650/800/1.5 3650/800/1.5 3650/800/1.5 3650/800/1.5         Labor 1602 \$1602 \$1622 14.5 hre 15.5 hre \$4000         Syre yre \$4000         No         No         No           rate in hours of usage/cost of parts in \$ for replacement/ hrs of labor for replacement         No         No         No         No         No         No           Load Factor (%)         Horse Power (hp)         CO hp)         CO hp)         HC (g/hp)         Nox (g/hp)         PM (g/hp)         Fuel Type           55% 55% 50%         107 107         347.9577 12.7 5.75         12.7 5.75         .068 0         Gasoline Diesel Electric           50% 50%         107 241         10 0         0 <t< td=""></t<>

File		
Vehicle Name Gasoline ford 300 BagTractor		Transmission Failure Rate 6500 hrs
Vehicle Type	Engine Motor Motor failure rate in hrs	replacement cost 900 \$ Time to replace
BagTractor	Engine replacement cost	16 hrs
120000	Time to replace in hrs 32	Emissions Load factor 55 % Horsepower 107 hp
Energy source Gasoline	Preventive Maintenance Yearly cost of parts 1205 Yearly hours 26.7	emissions in g/(hp hour) CO 347.957 HC 12.7 Nox 7.23 PM .068

File			
Vehicle Name		Transaxle	Controller
DC BagTractor	•	Failure Rate	Failure Rate 3650 hrs
		replacement cost	replacement cost
	Engine	2000 \$	800 \$
Vehicle Type	Motor Motor failure rate in hrs	Time to replace	Time to replace
	3250	Time to replace	
BagTractor		16 hrs	1.5 hrs
Purchase Price	Engine replacement cost		
	975		
\$		- Emissions	
	Time to replace in hrs	Load factor 55 %	
	10		
		Horsepower 40 hp	
Energy source	Preventive Maintenance	emissions in g/(hp hou	ll)
Electric	Yearly cost of parts	CO O	
	1047	HC 0	
		Nox 0	
	Yearly hours 24.7	1°	
	<b>E</b> T. (	PM 0	

File			
Vehicle Name		Transaxle	Controller
AC BagTractor		Failure Rate	Failure Rate
		20000 hrs	3650 hrs
	Engine	replacement cost	replacement cost
	Motor	\$5500	1857 \$
Vehicle Type	Motor failure rate in hrs	Time to replace	Time to replace
BagTractor	13687	16 hrs	1.5 hrs
	Engine replacement		I
Purchase Price	cost		
35500 \$	1000		
	Time to replace in	Emissions	
	hrs	Load factor 55 %	
	10	Horsepower 40 hp	
Energy source		emissions in g/(hp hour)	
Electric	Preventive Maintenance	CO 0	
	Yearly cost of parts	HC 0	
	1047	нс јо	
	Yearly hours	Nox 0	
	24.7	PM 0	

Vehicle Name		Transmission
Gasoline ford 300 Beltloader		Failure Rate 6500 hrs
	Engine	replacement cost 900 \$
Weblete Torre	Motor Motor failure rate in hrs	Time to colore
Vehicle Type		Time to replace
Beltloader	15000	16 hrs
Purchase Price	Engine replacement cost	
28500 \$	1700	
120300	1	Emissions
	Time to replace in hrs	Load factor 50 %
	32	Horsepower 107 hp
Energy source		emissions in g/(hp hour)
Gasoline	Preventive Maintenance Yearly cost of parts	C0 241
	890	HC 10
	Yearly hours	Nox 7.24
	14.5	PM .068

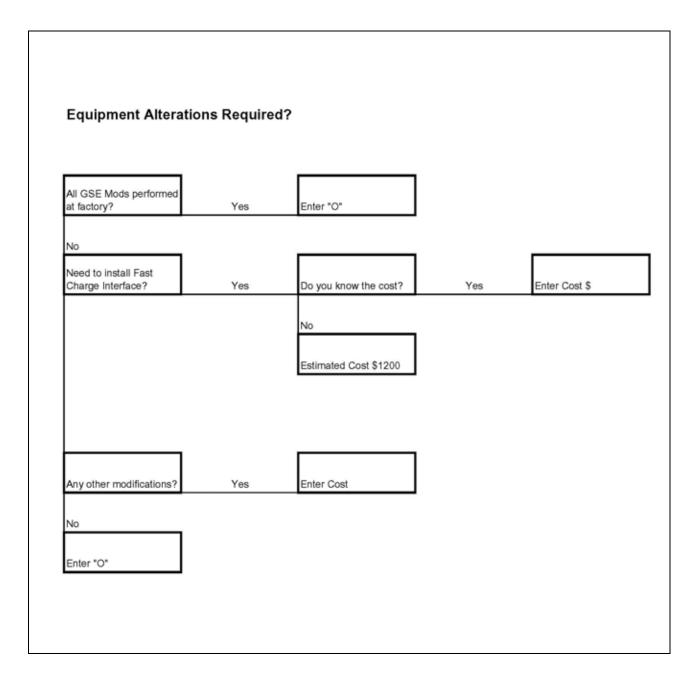
File		
Vehicle Name		Transmission
Diesel Deutz 1011 Beltloader	▼	Failure Rate
		6500 hrs
	Engine	replacement cost
	Motor	\$
Vehicle Type	Motor failure rate in hrs	Time to replace
Beltloader	15000	hrs
		16 hrs
Purchase Price	Engine replacement cost	
	4000	
32200 \$		Emissions
	Time to replace in hrs	Load factor 50 %
	16	
		Horsepower 71 hp
Energy source		emissions in g/(hp hour)
Diesel	Preventive Maintenance	CO 3.06526
Diesei	Yearly cost of parts	
	1250	HC 0.738
	Yearly hours	Nox 6.22
	14.5	PM 7
		PM <u>1.7</u>

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

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	Time to repair in hrs	Yearly hours

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	Time to repair in hrs	Yearly hours 12

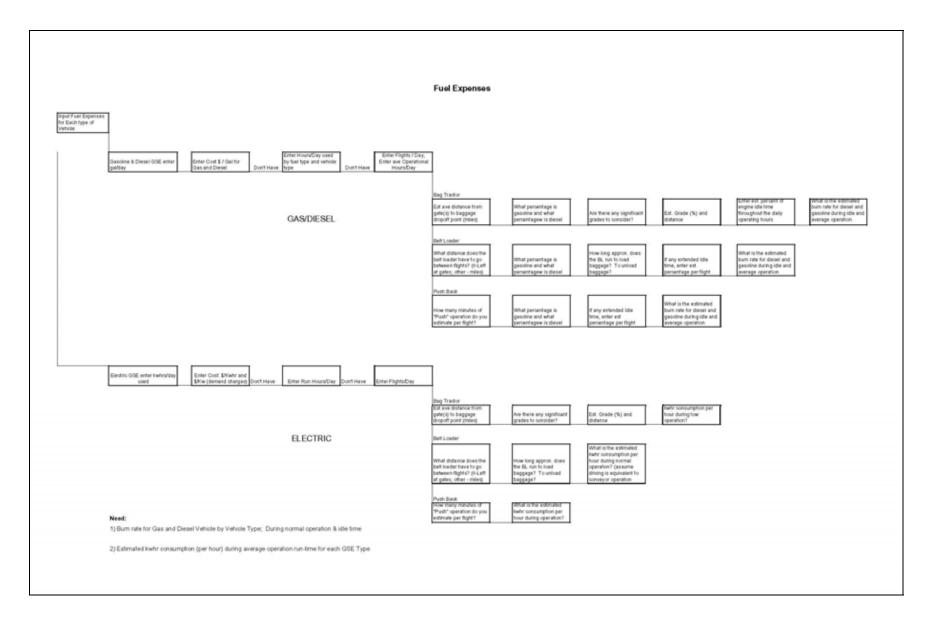
	GSE Equip	oment Capital Purch	nase Price	
		Do you have actual GSE Purchase Price? No What type of GSE Equipment will you	Yes.	Enter Purchase Price
Bag Tractor - Electric, Diesel or Gasoline	Belt Loader - Electric, Diesel or Gasoline	purchase? PushBack - Electric, Diesel or Gasoline		
Est Values Provided 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		

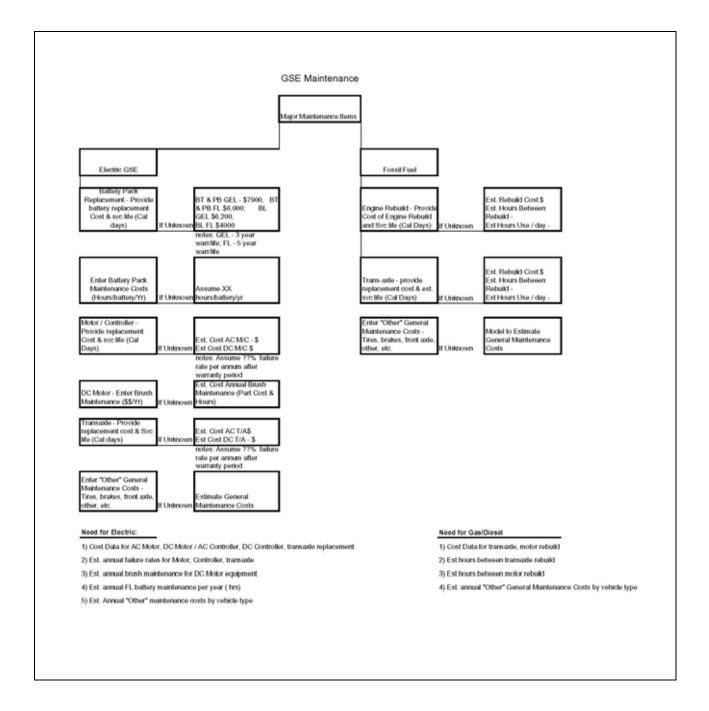


	Charging	Infractructure N	laintar	
	Charging	Infrastructure N	lainter	hance
			_	
Input Annual Infrastructure Maintenance Costs for PM,		Input Separately: PM, Cord, Chrgr	]	
Cords, General Maintenance	enter	Repair		
Unknown			-	
		Enter actual PM	1	
General Charger PM - Filters,		costs or Est. 1 hr / Qtr per charger @		
Cleaning Etc.	est	\$InHse Rate/hr		
		Replacement Rate	-	
Cord Replacement due to	í .	First Year - 5%;	1	
general wear and pull-out		Second Yr - 5%;		
(includes labor and parts to change out)	est	Third Yr - 10%; Fourth-plus - 15%		Avg Replacement Cost: Ente or \$600 plus 2hrs InHse labo
onango oaty		rounn pluo - 1070		
		First Year - n/a;	1	
		Second Yr - 5% (labor only);		Avg Repair Cost (assume
Other General Maintenance		Third Yr - 6%;		Manufacture Rep): Enter or
(Outside of Warranty)	est	Fourth-plus - 7%		\$1,200
Need:				
1) Review replacement rate as	sumptions			
2) Replacement hours - Inhous	e labor			
2) Review Cord Replecement (				

3) Review Cord Replacement Cost

4) General PM estimate





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

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 \$4k/Vehicle			Estimated Cost \$7k/Vehicle	
			Three	
Assumptions:		W Dual Port Stand Alone Unit	Estimated Cost \$4k/vehicle	an 10 Part Surfam

Attachment A - Ground Support Equipment Cost Model Operating Guide

t Tools Help							
post Sample Asport	G	SE (	Cost	Mod	el V1	.1	
t of available equipment			-				
encieve food 300 BegTractor ierel Deutz 1011 BegTractor eseal Deutz 2011 BegTractor C BegTractor C BegTractor C BegTractor croime ford 300 Beltloader ierel Deutz 1011 Beltloader ierel Deutz 2011 Beltloader				P	0		
	Purchasing Price	Install	Ownership cost \$/year	Operating Cost \$/yr	Total cost \$/y	Total for analysis	
AC Bag Familie     DC Bag Familie     DC Bag Familie     Electric Belfonder     Dissel Omaz 2011 Rog Trainer     Dissel Omaz 2011 Rog Trainer     Dissel Omaz 2011 Rog Trainer     Dissel Shifther cont per post	\$355,000 \$142,000 \$271,600 \$364,000 \$225,400 \$250,000	\$50,000	\$73,647 (1),419 (1),052 (24,247 (1),014 (20,050	882.052 825.055 822.005 8166.130 957.275 821.341	\$105,599 \$38,765 \$40,901 \$140,376 \$72,289 \$42,591	42,111,980 8776,200 81307,500 81307,560 11,445,709 9951,820	
GSE usage at airport	\$1,600,000	\$60,000	\$111.109	\$379.514	\$490.623	\$9.012.460	
use usage a arpor	Transferre	Ter des se	Foo	al Fuel Equips	nent :	\$5,253,340	
Low Medium High		Electric Equipment				\$4.559,120	
and the second second				Differenc	•	\$694,220	
20 💌 year analysis	Run Analysis			DAILY usage (		379 104	
S Amortization rate	New Acalysis				ly motor		
10 Life of equipment for amortization Update ownership costs							

# Ground Support Equipment Cost Model Operating Guide Table of Contents

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**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.")

🖣, G	SE Cost Software		
File	Edit Tools Help Airport	GS	ε
	List of available equipment		
	Gasoline ford 300 BagTractor Diesel Deutz 1011 BagTractor Diesel Deutz 2011 BagTractor Electric BagTractor Gasoline ford 300 Beltloader Diesel Deutz 1011 Beltloader Diesel Deutz 2011 Beltloader Electric DC Beltloader		
		Purchasing Price	Insta
	1 Diesel Deutz 1011 BagTractor 1 Electric BagTractor 1 Diesel Deutz 1011 Beltloader	\$26,000 \$37,400 \$32,200	

# 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 Electric BagTractor Diesel Deutz 1011 Beltloader	\$26,000 \$37,400 \$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).

💐 Params				<u>_</u> _×
	àasoline	Diesel	Electric	
Cost at year 0 /gallon or kWhr	\$2.5	\$2.5	\$0.1	- GSE Hourly labor cost
% increase per year	12	12	7	\$50.00
	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
		,	,	
		1	Reset Para	meters to
	OK		defa	

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.

	Gasoline Gallon/day	Diesel Gallon/day	Electric kWhr/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
		*		-

Low GSE usage at airport default parameters

Medium GSE usage at airport default parameters

	Gasoline 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

High GSE usage at airport default parameters

	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

## 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 Mantenance	Energy/Fuel	Engne	Transmission Transpode	Controller	Cords	Charger Repar	Fast Charge Interface
AC BagTractor DC BagTractor Electric Belkoader Diniel Deutz 2011 Balkoader Diniel Deutz 2011 Belkoader Power Sharing cost per port	\$90,407 \$63,640 \$40,880 \$52,280 \$38,500 \$16,000	\$30,094 \$56,008 \$7,316 \$150,042 \$108,001 \$000	\$4,520 \$12,624 \$5,664 \$16,758 \$9,949 \$000	\$13,640 \$6,062 \$4,468 \$9,249 \$7,162 \$000	\$15,443 \$5,994 \$5,639 \$000 \$000 \$000	\$000 \$000 \$000 \$000 \$000 \$4.511	\$000 \$000 \$000 \$000 \$000 \$1,430	\$1,200 \$1,200 \$1,200 \$000 \$000 \$000 \$000
Back Low Medium High				Difference	and the second sec	34.220		
	Run Analysis			CRC Ligapher Difference DAILY KW	16	94,220		

#### 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.

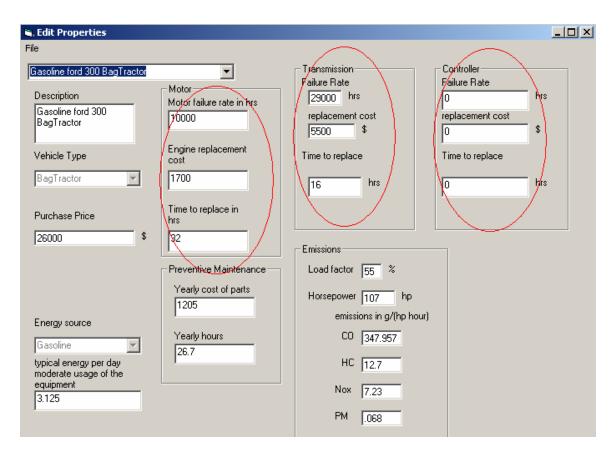
କ, Edit Properties		<u>×</u>
File		
Diesel Deutz 2011 BagTractor	- Transmission	Controller Failure Rate
Description Motor	20000 brs	
Diesel Deutz 2011 BagTractor 10000	replacement cost	replacement cost
	5500 \$	0 \$
Vehicle Type Engine replaceme cost	nt Time to replace	Time to replace
BagTractor 4000	16 hrs	0 hrs
Purchase Price Time to replace in hrs		
26000 \$ 16	- Emissions	
Preventive Mainte	hance Load factor 55 %	
Yearly cost of pa	Horsepower 71 hp	
Energy source	emissions in g/(hp h	iour)
Diesel	CO [1.7	
typical energy per day moderate usage of the	HC 0.72	
equipment	Nox 5.75	
2.8125		
	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.)



## 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.

