AIRPORT GROUND SUPPORT EQUIPMENT

This document presents the project criteria under the Carl Moyer Program for airport ground support equipment (GSE). It also contains a brief overview of the NOx emission inventory, current emission standards, available control technology, potential incentive projects eligible for funding, and emission reduction calculation and cost-effectiveness calculation methodologies.

A. Introduction

Airport vehicles and ground support equipment are used to transport passengers as well as baggage and freight, to support maintenance and repair functions, and to provide power to various service functions. Vehicles and equipment at airports fall into two broad categories. Land-side vehicles and equipment are used on the passenger/entry side of the airport. Air-side vehicles are used principally (at least half of the time) on the tarmac. For the purposes of the Carl Moyer Program, the GSE category is restricted to air-side equipment. Land-side vehicles and equipment are included in the on and off-road vehicles and equipment project criteria previously adopted by ARB.

Airport GSE includes aircraft pushback tugs, baggage and cargo tugs, carts, forklifts and lifts, ground power units, air conditioning units, belt loaders, and other equipment. It also includes vehicles such as light duty trucks that are used for airplane maintenance and fueling on the air-side of airport operations. Airport GSE does not include aircraft engines.

Most GSE in California have internal combustion engines (ICE). Electric GSE has zero exhaust emissions and thus can greatly reduce NOx emissions. Electric GSE is commercially available from a number of manufacturers, and interest in the use of electric equipment is increasing. Currently, there are no federal or California regulations that require the use of electric GSE. Less than 10% of the GSE used at airports in California is estimated to be electric. There are airports, however, with a very high percentage of electric GSE. For example, Denver International Airport was built within the last ten years, and was designed for all electric GSE. Also, Logan International Airport in Boston has made considerable progress in switching from ICE equipment to electric GSE equipment.

B. Ground Support Equipment and Emissions

GSE is used the moment an aircraft lands and until it takes off . GSE is used for tasks as diverse as towing, powering, and servicing. There is great diversity in the type of equipment used, as well as in the variety of engines that power GSE. The table below presents commonly used types of GSE and their estimated population in California. These estimates are from the ARB off-road emissions inventory. They do not include updated estimates for the South Coast Air Basin currently under development as part of the airport consultative process.

Table 1
Airport GSE Population in California
1995

Equipment Type	Diesel	Gasoline	LPG/CNG	Statewide Total
Baggage Tug	440	646	89	1,175
Belt Loader	172	304	19	495
Forklifts, lifts & cargo loaders	197	319	214	730
Ground Power Unit	228	71	0	299
Aircraft Tug (narrow & wide body)	214	60	0	274
Airstart Unit	70	0	0	70
Air Conditioner	22	0	0	22
Deicer	0	29	0	29
Cart & Lavatory Cart	0	22	0	22
Fuel Trucks	23	56	26	105
Utility Trucks (lavatory, maintenance, water & service)	20	356	31	407
Bobtail	0	92	2	94
Other	17	160	17	194
TOTAL	1,403	2,115	398	3,916

- ***Baggage Tugs*** (or Tractors) transport luggage or cargo between aircraft and terminals.

- ***Belt Loaders*** are a self-propelled conveyer belt that moves baggage and cargo between the ground and the airport.

- ***Forklifts, Lifts, and Cargo Loaders*** include equipment for lifting and loading cargo.

- ***Ground Power Units (GPUs)*** provide electricity to parked aircraft.

- ***Aircraft Tugs*** (pushback tractors) tow aircraft in areas where aircraft can not use their own engines for motion. These are generally the areas between the taxiway and the terminal and between the terminal and the maintenance base.

- ***Air Start Units*** are trailer or truck-mounted compressors that provide air for starting up the aircraft's main engines.

- ***Air Conditioning Units*** are trailer or truck mounted compressors that deliver air through a hose to parked aircraft for cabin ventilation and engine cooling.

- ***Deicers*** are trailers equipped with tank, pump, hose, and spray gun to transport and spray deicing fluid on aircraft (to ensure that no ice builds up on body of plane or in turbines).

- ***Lavatory carts*** are used to service aircraft lavatories. Other types of carts can be used to transport equipment and personnel.

- ***Fuel Trucks, Utility Trucks, Maintenance, Water and Service Trucks*** are used on the air-side of the airport for many diverse tasks.

- ***Bobtail Tractors*** are on-road trucks modified to tow trailers and equipment

Airport GSE can be owned by airlines, airports, cargo handlers, mail and parcel companies or management companies. Most airlines own or maintain the GSE they use, or have full service leasing from equipment management companies. Airports usually own the buildings and other stationary infrastructure on site and lease them to the airlines. The installation and cost of improvements, including electric equipment and vehicle infrastructure, are usually subject to the approval of the airport's property management staff. Costs can either be borne by the airport or passed on to the airlines. There is also a growing trend for airports to own the ground power units and charge the airlines for the time of usage.

As indicated in Table 1, there were an estimated 3,916 pieces of GSE operating in California in 1995. Table 2 lists 1995 and 2010 estimated NOx emissions from airport GSE in the South Coast Air Basin and statewide.

Table 2
Baseline NOx Emissions
Airport GSE

Location	Population	NOx Emissions (tons/day)	
		1995	2010
South Coast Air Basin	2,064	2.7	1.8
Statewide	3,916	5.0	3.2

C. Emissions Standards

Currently, there are no regulations that require the use of electric GSE at airports. However, the United States Environmental Protection Agency (U.S EPA) and ARB have adopted emission standards which are phased in over time and applicable to new (off-road) GSE equipment powered by internal combustion engines. Emission standards for GSE are contained in ARB and U.S EPA's emission standards for off-road equipment. Internal combustion engine GSE can either be powered by diesel engines (compression ignition engines) or by spark-ignited engines (which use gasoline, compressed natural gas, or propane fuel). There are separate emission standards for large spark-ignited engines and compression ignition engines.

1. Large Spark-Ignited Off-Road Engine Standards

Current model year large spark-ignited engines are not subject to either ARB or U.S. EPA emission standards. ARB has approved standards for new large spark-ignited off road engines to be implemented beginning with the 2001 model year. These standards will apply to all new off-road spark-ignited engines greater than 25 horsepower, including off-road airport GSE.

The regulations include exhaust emission standards for hydrocarbons (HC) and oxides of nitrogen combined, and for carbon monoxide. They also establish emission test procedures, test cycles, test fuel specifications, and emissions compliance requirements. Table 3 contains the emission standards applicable to large spark-ignited engines that were approved by ARB.

Table 3
Exhaust Emission Standards
Large Spark-ignited Engines

Year	Engine Size	NMHC + NOx (g/bhp-hr)	CO (g/bhp-hr)	Durability Period
2002 & subsequent years	<1.0 liter	9.0	410	1000 hours or 2 years
2001-2003 (Phase-in)	>1.0 liter	3.0	37	N/A
2004-2006 *	>1.0 liter	3.0	37	3500 hours or 5 years
2007 & later	>1.0 liter	3.0	37	5000 hours or 7 years

* *The standard for in-use compliance for engine families certified to the standards noted above shall be 4.0 gbhp-hr (5.4 g/kW-hr) hydrocarbon plus oxides of nitrogen and 50.0 g/bhp-hr (67 g/kW-hr) carbon monoxide for a useful life of 5000 hours or 7 years.*

2. Diesel Off-Road Engine Standards

ARB has adopted emission standards for off-road diesel cycle engines equal to or greater than 175 horsepower. The U.S. EPA has adopted NOx emission standards for off-road diesel cycle engines at or above 50 horsepower. The combination of ARB and U.S. EPA emission standards means that all of today's new off-road diesel cycle engines, including GSE, 50 to 750 horsepower have to be certified to meet a NOx emission standard of 6.9 g/bhp-hr.

U.S. EPA, ARB, and off-road diesel engine manufacturers have signed a Statement of Principles (SOP) that sets forth comprehensive future emission standards for compression ignition (diesel) off-road engines. U.S. EPA has adopted regulations for off-road diesel equipment consistent with the emission levels contained in the SOP. The ARB intends to revise California's regulations for off-road equipment to harmonize with federal regulations. Table 4 contains the applicable U.S. EPA standards for off-road diesel engines.

Table 4
U.S. EPA Exhaust Emission Standards for Off-Road Diesel Engines

Rated Power (horsepower)	NOx and PM Emission Standards (g/bhp-hr)							
	1997/8		2003/2004		2007		2008	
	NOx	PM	NMHC +NOx	PM	NMHC + NOx	PM	NOx	PM
50 ≤ hp < 100	6.9	--	5.6	0.30	5.6	0.30	3.5	0.30
100≤ hp < 175	6.9	--	4.9	0.30	3.0	0.22	3.0	0.22

3. Electric GSE Equipment

As discussed earlier there are no regulations requiring the use of electric GSE at airports. Measure M15 in the 1994 State Implementation Plan (SIP) called for U.S. EPA to set new standards for aircraft engines. The SIP superceded U.S. EPA's Federal Implementation Plan (FIP) which did call for electric GSE at airports. As an outgrowth of SIP/FIP activities, ARB, U.S. EPA, the South Coast Air Quality Management District (SCAQMD), the Air Transport Association, and other stakeholders in the South Coast Air Basin have been participating in a Public Consultative Process that include negotiations to develop approaches (besides aircraft emission standards) for reducing emissions from airport activities. The use of electric GSE is currently being considered for a MOU currently under negotiation for the five major airports in the South Coast Air Basin.

The outcome of these negotiations is expected to result in a Memorandum of Understanding signed by the stakeholders, agreeing to reduce emissions from airport GSE. The MOU will cover five airports in the South Coast: LAX, Ontario, Orange County, Burbank, and Long Beach. Because those five airports are covered under the current MOU negotiation process, they would not be eligible for funding under the Carl Moyer Program

D. Control Strategies

A cost-effective way to reduce emissions is to replace GSE powered by an internal combustion engine with electric equipment. Electric equipment has no exhaust emissions and replacing equipment powered by ICE engines with electric equipment will reduce NOx emissions. Electric GSE is commercially available for a number of equipment types, including belt loaders, baggage tractors, aircraft tugs, lifts, and GPU's. Several airlines and airports have conducted electric GSE demonstration programs and fleet conversion programs. Much of the experience to date with electric equipment has been quite positive. In addition to air quality benefits, users have found that electric equipment is more "task specific" than ICE equipment. Electric equipment often includes more ergonomic features and users find that it "rides better" than equivalent diesel equipment. However, the higher capital cost of electric equipment has prevented its widespread use to date. A detailed discussion of control strategies is included in the report: "*Assessment of Airport Ground Support Equipment Using Electric Power or Low-*

Emitting Fuels (Final Report)," prepared for the Air Resources Board by Arcadis Geraghty & Miller, July 20, 1999.

The Carl Moyer Program will fund the replacement of ICE GSE with comparable electric equipment. The most promising categories are those where electric equipment has been used and demonstrated, and is readily available from commercial vendors. This includes electric baggage tugs, belt loaders, and aircraft tugs. These equipment categories also represent a significant portion of the statewide GSE population, and also have some of the highest average annual hours of usage. Replacing these ICE equipment types with comparable electric equipment would reduce NOx emissions. Therefore, the Carl Moyer Program guidelines have been designed to target these categories. Other promising projects include lifts and cargo loaders. Deciers, carts, lavatory carts and airstart units each represent a much smaller part of the GSE equipment inventory (less than 100 units each statewide). Fuel, utility, water, and service trucks are not covered under the airport GSE guidelines, but can qualify under the on-road category, provided they meet on-road vehicle project criteria.

E. General Project Criteria

The primary focus of the Carl Moyer Program is to achieve emission reductions from off-road engines and equipment operating in California as early and as cost-effectively as possible. The project criteria are designed to ensure that the emission reductions expected through the deployment of electric GSE funded under the program are real and quantifiable. A project must meet a cost-effectiveness criterion of $12,000 per ton of NOx reduced, must operate for at least five years from the time it is first put into operation, and at least 75 percent of the hours of operation must occur in California.

F. Airport GSE Project Criteria

Airport GSE projects must meet the general project criteria, and the specific airport GSE project criteria given below:

- ICE equipment must be replaced with new electric equipment.

- Eligible equipment includes the following types of equipment: belt loaders, baggage tugs or tractors, forklifts, lifts, cargo loaders, ground power units, or aircraft tugs. Other GSE equipment will be evaluated on a case-by-case basis.

- Equipment must be purchased for use at a commercial (passenger) airport in California.

- Equipment purchased for use at a military airport will be considered on a case by case basis. The equipment must not be covered by any existing regulations or permit requirements, and the emission reductions must be surplus to any credit banking programs.

- Equipment must be purchased by the business or organization that will be operating the equipment. This includes airports as well as passenger airline companies.

- Purchases by airline service companies or ground handlers are eligible if they provide documentation (such as written contracts or other binding agreements) specifying that they will operate the equipment at a passenger airport not excluded under the Carl Moyer Program for a minimum five year period.

- The ICE equipment which is being replaced must have an engine rated at 50 horsepower or greater (which is equivalent to an electric motor 37 kilowatts or greater).

- NOx reductions obtained through this program must not be required by any regulation, memoranda of understanding/agreement, air quality permit requirement, California Environmental Quality Act (CEQA) or other offset agreement, or any other legally binding agreement.

- Equipment purchased for use at LAX, Ontario, Orange County, Burbank, or Long Beach is excluded from the Carl Moyer Program.

- Leased or rented equipment is excluded from the Carl Moyer Program, as is used equipment.

G. Sample Application

In order to qualify for incentive funds, districts will make applications available and solicit bids for reduced-emission projects from GSE equipment operators. A sample application form is included in Attachment A. The applicant must provide at least the following information, as listed in Table 5 below:

Table 5
Minimum Application Information

1. Company name	11. Project Life
2. Project name	12. Model & Manufacturer of ICE equipment being replaced (if an existing fleet)
3. Air district	13. Type of engine (model & serial number)
4. Equipment type purchased	14. Type of fuel used
5. Type of business: Commercial airport or Passenger airline or Airline service company	15. Engine horsepower
5. Airport at which equipment will be operated	16. Estimated annual hours of operations
6. Manufacturer & model number for new equipment	17. Cost of new ICE equipment
7. Number of equipment purchased	18. Incentive amount requested
8. Cost of equipment (including battery pack)	19. Match funds
9. Is this equipment: replacing existing equipment? For fleet expansion? Other?	20. New reduced-NOx emissions
10. Who will operate equipment? (airport, airline, equipment management company, other)	

H. Emission Reduction and Cost-Effectiveness

1. Emission Reduction Calculation

The emission reduction benefit will be calculated for NOx emissions only and will be determined using the annual hours of operation. Annual NOx emission reductions are determined by multiplying the difference in the NOx emission levels of electric and ICE equipment, the engine load factor, and the hours the engine is expected to operate per year.

The load factor is an indication of the amount of work done, on average, by an engine in a particular application, given as a fraction of the rated horsepower of that engine. If the actual load factor is known for an engine it should be used in calculating emission reductions. If the actual load factor is not known, the default value contained in Table 6 will be used.

Another variable in determining emission reductions is the number of hours the equipment operates. If actual hours of equipment operation are not available, the default values given in Table 6 should be used to calculate emission reductions. Baseline NOx emissions for ICE equipment are provided in Table 7. All information in Table 6 is taken from ARB's off-road emission inventory.

Table 6
Default Load Factors and Annual Operating Hours

Equipment	Horsepower	Load Factor	Annual Hours
Belt Loader	51-120 (*60*)*	0.50	810
Baggage Tug	130-175 (*100*)	0.55	876
Cargo Loaders	51-120 *(70)*	0.50	719
A/C Tugs wide body	250-500 *(500)*	0.80	515
A/C Tugs narrow body	121-175 *(130)*	0.80	551
Lifts	51-120 *(100)*	0.50	376
Ground Power Units	120-175 (*150*)	0.75	796

** horsepower in parenthesis is the average horsepower for the type of equipment listed*

Table 7
Default Baseline Emission Factors for GSE Equipment

Horsepower Range	Fuel Type	Baseline NOx Emission Rate (grams/bhp-hr)
>50	Propane	10.5
51-120	Gasoline	11.8
121-175	Gasoline	12.9
51-300	Diesel	6.9

2. Cost-Effectiveness Calculation

The portion of the cost for a GSE project to be funded through the Carl Moyer Program is the difference between the total cost of purchasing new electric equipment and the cost of buying "conventional" replacement equipment. Only the amount of money provided by the Carl Moyer program and any local district match funds can be used in the cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, when multiplied with the initial capital cost, gives the annual cost of a project over its expected lifetime.

Capital Recovery Factor (CRF) $= [(1 + i)^n (i)] / [(1 + i)^n - 1]$

Where, i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. Example calculations for GSE projects are provided below.

3. Examples

For the purposes of explaining the emission reduction and the cost effectiveness calculations from a particular GSE project, two examples are presented below. The first example describes the calculations based on replacing four diesel baggage tugs with four electric baggage tugs, and the second example shows calculation for the replacement of a gasoline belt loader with an electric belt loader.

Example 1 – Calculations for replacement of a diesel baggage tug based on hours of operation.

A passenger airline in Sacramento applies for a Carl Moyer Program grant for the purchase of four new electric baggage tugs to replace four diesel baggage tugs currently in the fleet. The airline has decided to purchase the electric baggage tugs instead of purchasing new diesel baggage tugs certified to a 6.9 g/bhp-hr NOX standard. The cost of a new electric baggage tug is $24,000 (each), or whereas the cost to buy a new diesel baggage tug is $19,000 (each). The new baggage tugs each will operate 876 hours annually (each) and will operate 100 percent of the time in California.

<u>Emission Reduction Calculation</u>

Annual NOx Reductions (tons/year) =
[(Baseline NOx) - (Reduced NOx)] * (Horsepower Rating) * (Annual Operating Hours) * (Load Factor) * (% Op. in CA) * (ton / 907,200 grams)

Where,

Baseline NOx Emissions	= Emission level from a new diesel baggage tug: 6.9 g/bhp-hr
Reduced NOx Emissions	= New electric baggage tug: 0 g/bhp-hr
Rated Horsepower	= 100 hp
Annual Operating Hours	= 876 hours
Load Factor	= 0.55
% Operated in CA	= 1.0 (i.e., 100%)
(ton/907,200 g)	Converts grams to tons

Hence, estimated annual NOx reductions (for four baggage tug) are:

((6.9 – 0) g/bhp-hr) (100 hp)(4 baggage tugs) (876 hours/year) (0.55) (1.0) * (ton / 907,200 g) = **1.46 tons/year**

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Total cost of new electric baggage tug	= $24,000 x 4=$96,000
Cost of new diesel baggage tug	= $19,000 x 4=$76,000
Incremental Capital Cost	= $96,000-$76,000=$20,000
Max. Amount Funded	= $20,000
Capital Recovery	= $[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
Annualized cost	= (0.23)($20,000) = $ 4,600/year
Cost-Effectiveness	= ($4,600/year)/(1.46 tons/year) **= $3,151/ton**

The project meets the cost-effectiveness limit of $12,000/ton NOx reduced and is eligible for an incentive amount of $20,000.

Example 2– Calculations for replacement of a gasoline belt loader with an electric belt loader.

An airline company which operates at the Fresno airport applies for a Carl Moyer Program grant for the purchase of a new electric belt loader to replace a gasoline belt loader in their existing fleet. The new electric belt loader will be used for five years at the Fresno airport. The airport has decided to purchase a new electric belt loader instead of purchasing a new gasoline belt loader with uncontrolled emissions of 10.5 g/bhp-hr. The cost of the new electric belt loader is $30,000, whereas the cost to buy a new gasoline belt loader is $27,000. The new belt loader will operate 810 hours annually and will operate 100 percent of the time in California.

Emission Reduction Calculation

Annual NOx Reductions (tons/year) =
[(Baseline NOx) - (Reduced NOx)] * (Horsepower Rating) * (Annual Operating Hours) * (Load Factor) * (% Op. in CA) * (ton / 907,200 grams)

Where,

Baseline NOx Emissions	= Uncontolled emission level from a new gasoline belt loader: 11.4 g/bhp-hr
Reduced NOx Emissions	= New electric belt loader: 0 g/bhp-hr
Rated Horsepower	= 60 hp
Annual Operating Hours	= 810 hours
Load Factor	= 0.55
% Operated in CA	= 1.0 (i.e., 100%)
(ton/907,200 g)	Converts grams to tons

Hence, estimated annual NOx reductions are:

(11.4 – 0) g/bhp-hr) (60 hp) (810 hours/year) (0.55) (1.0) * (ton / 907,200 g) = **0.34 tons/year**

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Total cost of new electric belt loader	= $30,000
Incremental Capital Cost	= $30,000 - $27,000 =$3,000
Max. Amount Funded	= $3,000
Capital Recovery	**=** $[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
Annualized cost	= (0.23)($3,000) = $690/year
Cost-Effectiveness	= ($690/year)/(0.34 tons/year) **= $2,029/ton**

The project meets the cost-effectiveness limit of $12,000/ton NOx reduced and is eligible for an incentive amount of $3,000

I. Reporting and Monitoring

During the project life, a district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer funds for new electric GSE projects. This is to ensure that the equipment is operated as stated in the GSE program application. Those participating in the Carl Moyer Program are required to keep appropriate records during the life of the project funded. Records must contain, at a minimum, total hours operated, amount of electricity used, and maintenance and repair information. Records must be retained and updated throughout the project life and made available at the request of the district.