Non-Road Electric Vehicle Emissions

Analysis and Recommendations

Technical Report

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Analysis and Recommendations

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PRODUCT DESCRIPTION

Energy security and quality of life in the United States and around the globe is dependent upon the reduction of air pollution, petroleum dependency, and developing a solution to global warming. Non-road transportation equipment offers an opportunity to support this quality of life objective with a reduction in emissions through electrification. Private sector initiatives and regulatory agencies have begun to focus on non-road vehicles and equipment.

This emission source category, which was largely unregulated until 1996, is now the subject of major emissions reduction initiatives by the federal Environmental Protection Agency (EPA) and the California Air Resources Board (ARB). The emission reductions from these initiatives are critically needed to assist non-attainment areas in meeting their 2010 goals under the Clean Air Act. Lack of compliance could have serious consequences for states, including the loss of federal transportation funding. Yet, despite the fact that many regions are still very far from meeting attainment goals, the proposed regulations fail to recognize the near-term emissions reduction opportunities provided by available zero emission non-road technologies.

Results & Findings

There is a tremendous amount of available information on the measurement of and control strategies for emissions from non-road mobile sources. The problem faced by analysts is a lack of consistency in how equipment is categorized and how emissions are measured and evaluated by various models and agencies. Despite this, the current data points to a number of opportunities and action items that could lead to increased market opportunities for electric technologies and improved air quality for the nation.

Challenges & Objectives

The purpose of this study is to review the current state of knowledge about non-road vehicle emissions, including what emissions models are currently used, how emissions are calculated, and how electric technologies are evaluated under the current modeling methodologies. The conclusions of this review will be used to help direct future EPRI efforts in this area.

Applications, Values & Use

Non-Road emissions regulations are currently being proposed and reviewed in many areas. Without accurate analysis and reporting of the emissions evaluation issues identified in this report, the resulting regulations will not provide an even playing field for non-road electric vehicles. Industry participation to correct some of these problems will have the dual benefit of increasing the market for electric drive technologies and achieving greater and more long-lasting emissions reductions.

EPRI Perspective

EPRI, which has had a Non-Road Transportation Program since 1994, is in the process of developing the information needed by EPRI members and stakeholders to participate in the debate on non-road emissions and promote electro-drive technologies as a major part of the solution. This study represents one task in this work effort.

Approach

The study team conducted a detailed literature review of emissions studies including prior EPRI work, presentations, work papers and current, as well as proposed, regulations. The literature review was supplemented by interviews with agency staff, utility staff and experts on emissions trading. A complete list of resources used for the study is provided in Appendix A.

There are two main sources of emissions models and regulatory standards: the federal EPA and the California ARB. Certain emission issues are under the complete jurisdiction of the federal government (for example regulation of fuel economy) and responsibility in other areas is shared (i.e., non-road engines). ARB is an active partner with EPA, sometimes initiating regulations or developing them jointly, and sometimes proposing more stringent regulations for California. As a result, we used ARB information extensively for this report, even though the study is national in scope.

The information from all these sources has been analyzed and compared, and forms the basis of our findings and recommendations.

Keywords

energy security
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non road transportation equipment

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Objective

The purpose of this study is to review the current state of knowledge about non-road vehicle emissions, including what emissions models are currently used, how emissions are calculated and how electric technologies are evaluated under the current modeling methodologies. The findings and recommendations from this review will be used to help direct future EPRI efforts in this area.

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The information from all these sources has been analyzed and compared, and forms the basis of our findings and recommendations.

Scope of the Study

The scope of this study generally required a detailed literature review of non-road vehicle/equipment emission inventories and models, regulations, rules, incentives, and other factors that could influence, positively or negatively, the increased penetration of electric vehicles into non-road markets. Some of the documents reviewed, such as the EPA and ARB models and proposed standards, categorize non-road engines by horsepower rather than function. Other documents, such as market studies and state and local air quality control measures, focus on equipment for specific end uses i.e., material handling, airports or lawn care. Many of the regulatory measures target a single pollutant. The disparity in the level of specificity and approach by stakeholders in evaluating non-road mobile source emissions makes it tricky to compare and analyze the available information.

Consequently, the team selected two major categories of equipment for closer examination based on the perceived opportunity for electric technologies. These include lift trucks (classes 1 through 8) and airport ground support equipment (GSE). General non-road vehicles (i.e., sweepers/scrubbers, lawn and garden equipment, other) are covered in Chapter Two discussion, which relates to all electric equipment categories. Not selected for further scrutiny are farm equipment, marine vessels, truck refrigeration units (TRUs), truck stop electrification (TSE) and auxiliary power units (APUs). We believe that several of these categories, particularly TRUs and TSE have significant potential for electric technologies, but are already being addressed in detail by other EPRI efforts. However, our findings and recommendations are generally transferable to these other important categories.

Organization of the Report

The Report begins with the major recommendation and findings. This chapter provides a discussion of conclusions and recommendations that resulted from this state-of-the-industry review relative to non-road electric vehicles/equipment and their associated air quality and energy security improvement benefits.

This is followed by an evaluation of existing non-road emission models and two chapters on specific types of equipment that are the focus of current or proposed regulations or incentive programs. This organization is necessitated by the diversity of approaches used in evaluating and regulating non-road emissions. As discussed above, emission standards are set by horsepower category, but adopted control measures are developed for specific types of equipment or end uses. Discussing either non-road as a category or individual end uses alone does not provide a total picture.

Summary of Findings and Recommendations

There is a tremendous amount of available information on the measurement of and control strategies for emissions from non-road mobile sources. The problem faced by analysts is a lack of consistency in how equipment is categorized and how emissions are measured and evaluated by various models and agencies. Despite this, the current data points to a number of opportunities and action items that could lead to increased market opportunities for electric technologies and improved air quality for the nation. These are summarized below.

1. Non-Road Emissions Inventories Do Not Include Electric Vehicles

Electric technologies are not represented in the non-road emissions inventory models used by the two major agencies, EPA and ARB, which develop emission reduction programs. The problem with this approach is that it does not accurately represent the total number of vehicles in service and the average emissions per vehicle, creates a baseline emission number (g/hp-hr) that is too high, and it ignores the incremental emissions reductions that could be achieved by non-road electric vehicles. For example, emissions could be reduced by increasing the implementation of the millions of existing units of zero-emission technologies or by cleaning up internal combustion engine technologies with increasingly stringent tailpipe standards. For non-road vehicle and equipment, EPA and ARB almost always follow the later strategy.

According to ARB, plans are already underway to include electric non-road technology in the upcoming revision of their non-road emission inventory model, OFFROAD. This revision is expected to be released in January 2004.

a) It is recommended that EPRI work cooperatively with ARB staff to provide accurate population and operational data for this effort.

b) Once the ARB effort is underway, EPRI should provide similar data to EPA to affect a similar revision in EPA's NONROAD2002a emissions model and its replacement, the MOVES[1] model.

[1] **M**ulti-scale m**O**tor **V**ehicles and equipment **E**mission **S**ystem (MOVES) is EPA's newest emission inventory model, currently in development.

2. Designation in Emission Reduction Regulations Addresses Engines, not Propulsion Systems

Regulation of mobile sources by EPA and ARB is based on a definition that the regulated vehicles, both on- and non-road, are equipped with "engines". As such, adopted and proposed emission standards focus on reducing tailpipe emissions from existing engine types rather than replacing these engines with inherently low or zero emission motors that have the same functionality.

c) It is recommended that EPRI provide technical support for other trade associations as they work to change the EPA and ARB reference to "engine" to the more general "propulsion system". This would not only aid pure electric technology, but hybrid drive systems, fuel cells and other non-internal combustion technologies.

3. Single Pollutant vs. Multi-Faceted or Holistic Approach

Non-road vehicles contribute to a broad range of environmental concerns, including air pollution, water pollution, recycling and disposal, indoor air pollution, global warming, petroleum importation, etc. These concerns today are typically addressed on a singular basis, with an emphasis on vehicle and equipment pollutant emissions. For air pollution, EPA, ARB and local air districts regulate seven "criteria" pollutants and numerous air toxics (such as formaldehyde, benzene, and 1, 3-butadiene). These include oxides of nitrogen (NOx) reactive organic gases (ROG[2]), carbon monoxide (CO) and particulate matter (PM10 and PM2.5[3]). Agencies also set standards for three other "criteria" pollutants: sulfur oxides (SOx), carbon dioxide (CO2) and lead. For global warming, U. S. Department of Energy (DOE), EPA and ARB also have programs to voluntarily reduce CO2; a combustion by-product that many believe contributes to global climate change. To address energy security concerns, DOE and State energy agencies implement programs that require petroleum consumption reductions. Often, programs are established to reduce only one pollutant, or address only one concern, which acts as a bias against solutions (such as non-road electrics) which deliver multiple pollutant reductions as well as reduce CO2 and petroleum consumption. These additional reductions are valuable to society, but are typically not monetized or incentivized.

Most emissions regulations are developed with the goal of reducing a particular pollutant that has proven negative health effects. For many years, NOx emissions were the target of most regulations since NOx is a precursor to ozone formation, a major component of smog. However, ROG emissions are also a precursor to ozone formation, and many air districts concentrate

[2] Generally quoted from Fact Sheet: Summary of EPA's Proposed Program for Low Emission Nonroad Diesel Engines and Fuel at http://www.epa.gov/nonroad/f03008.htmReactive organic gases (ROG) are also referred to as volatile organic compounds (VOCs) or reactive hydrocarbons (HC).

[3] Particulate matter less than 2.5 microns in diameter is sometimes called PM-fine. EPA will soon designate which air districts are in attainment or non-attainment for the new NAAQS for PM 2.5. PM-fine is cause by direct emissions, and secondarily by reactions in the atmosphere where NOx, SOx, ROG and other materials serve as pre-cursors for PM-fine.

equally in reducing ROG emissions. Recently, studies have been published documenting the increased risk of cancer due to exposure to diesel particulates. In fact, ARB has adopted a comprehensive multi-year strategy to promulgate many new regulations to reduce PM, and EPA is finalizing a determination for which air districts nationwide are out of compliance with a brand new national ambient air quality standard (NAAQS) for PM-fine.[4]

For the criteria pollutants, EPA and ARB do separate rulemakings for mobile and stationary sources. This complicates things because a vehicle's 'cradle to grave' pollution includes vehicle manufacturing (stationary), vehicle use (mobile), refueling (stationary) and fuel production (stationary such as a refinery or an electric power plant). When EPA or ARB conducts a mobile source rulemaking or issues grant funds, non-road EVs are considered to have zero-emissions, and the associated stationary source "upstream" emissions would be handled in separate rulemakings by local air districts (with EPA or ARB oversight only). However, as discussed above, EPA and, until very recently, ARB have not included non-road EVs as part of their mobile source rulemakings. For petroleum consumption and CO2 vehicle emissions, however, government agencies generally take a broader approach and examine vehicle use, refueling and fuel production (also known as "well-to-wheels").

Completion of fuel cycle emissions analyses are extremely complicated and expensive, since analysis must literally be conducted on a case-by-case basis for each region or locality. Fortunately, emission standards for criteria pollutants are currently developed based on analysis models that only consider the reductions achieved by the vehicle (tailpipe and on-board evaporative emissions from the fuel system). As such, electric drive technologies are assigned zero emissions, compared to conventionally-fueled technologies. In the context of emissions standards development, completion of a fuel cycle analysis for electric mobile sources is not necessary.

However, there are situations where a WTW analysis for non-road electric vehicles conducted by EPRI may be useful. For example, when power plant emissions are brought into the discussion by electric technology opponents, it would be helpful for the electric industry to have their own consistent WTW analysis to respond to potential criticisms of measures that reward zero emission technologies. Many regions already have very clean power plants and place a ceiling on power plant emissions. In addition, improvements in generation plant technologies should be incorporated into the models.

d) It is recommended that EPRI work with EPA and ARB to evaluate a holistic approach to emissions reductions. This approach should consider all criteria pollutants, GHGs and reduction in petroleum fuel consumption and should benefit electric technologies since they have zero emissions (with the exception of power plant emissions if those are included) and are very efficient.

e) It is recommended that EPRI to ensure that government funded studies (as well as other studies) that evaluate well-to-wheels emissions analyses not only examine power plant emissions for electric vehicles, but also the upstream emissions for production and

[4] See Footnote 2.

distribution of gasoline, diesel, natural gas, and other alternative fuels. It is surprising that many studies to date have not made this "apples-to-apples" evaluation.

4. In-Basin vs. Total Emissions

Our review found inconsistency in emissions analysis and reporting. While air quality agencies focus on in-basin emissions of criteria pollutants (NOx, ROG, PM10, PM2.5, CO, SOx, lead), some studies ignore this and instead focus on total emissions. Consideration of total emissions addresses concerns with the transport of emissions from other regions. The Clean Air Act focuses primarily on health-based population exposure to air pollution based on the above criteria pollutants, and secondarily on the damage air pollution causes to buildings, crops, etc., or to visibility (for example in national parks).

f) EPRI should follow the regulatory agency approach regarding analysis and reporting criteria pollutants, and work to ensure other studies follow suit. Specifically, the air agencies are concerned with "in-basin" emissions (recognizing that each air basin has a unique situation regarding transport emissions that should be included in the "in-basin" calculation.) Total emissions of criteria pollutants may be analyzed and reported, but are of significantly less concern because the Clean Air Act is primarily concerned with population exposure to criteria pollutants (a health-based concern).[5] For GHGs production, petroleum use, and energy / fuel use, a total perspective is the correct approach and in-basin values are not appropriate.

5. Power Plant Emission Models

Electric non-road vehicles and equipment are, by definition, zero emission. However, electricity consumed by electric non-road vehicles and equipment must be generated by power plants that often do emit pollution, the level of which depends on a number of factors including the air quality attainment status where the power plant is located, the age of the power generation technology, the fuel source (i.e., coal, natural gas, nuclear, hydro), technology design of the plant, and the peak vs. off-peak operational status. Further, fuel mixes for power plants vary from region to region and there is no consensus on how to allocate power sources to particular loads. A variety of modeling and analysis approaches are used to estimate the power plant emissions associated with electric vehicles. This analysis is often referred to as a fuel cycle analysis, or a well-to-wheels (or WTW) analysis. The selection of a specific approach depends on a number of issues, including the degree to which inputs are user-defined, the allocation of power loads on an "average" versus "marginal" basis, and the quality of the data utilized for the analysis.

A key concern with the various models used for fuel cycle analyses is the degree to which the model allows user-defined inputs. Many of the available models allow a large degree of input control by the user. This "user-friendliness" introduces a large degree of bias into the results of a

[5] While SOx is a Clean Air Act criteria pollutant, reporting in-basin and/or total upstream emissions for power plant SOx emissions is a special case. Due to the declining nationwide cap and trade program, SOx emissions from non-road EVs will not increase and are typically not analyzed for this reason.

particular analysis. For example, user-friendly models generally have a default value for power plant emissions, which is utilized if the modeler does not have a project-specific value. The problem here is this default value might be a national average value or regional average value that is completely inaccurate for the metropolitan area where the electric vehicle is used and charged. One specific model that is widely used is the Argonne National Laboratory's (ANL) GREET[6] model.

The alternative approach is a model design that is based on inputs developed by "expert consensus". These inputs are then fixed in the model as appropriate. A model that utilizes this more top-down approach, where the user is not able to alter basic inputs is preferred in the effort to establish consistent assumptions and data for these analyses. One of the more important inputs to a model is the characterization of the power plant emissions.

In an average emissions analysis, a local, state or national region's electricity power plant emissions would be determined from the complete mix of electricity sources for the entire year. This is a relatively straightforward calculation that requires large amounts of good data, but does not require a computer model. The problem with this approach is that it will overestimate emissions in regions with clean power, and underestimate emissions in regions with older, sometimes dirtier, power. Table 2-1 in Chapter 2, (see page 2-6) further addresses the pros and cons of an average emissions analysis approach.

Marginal emissions are defined as the emissions associated with the incremental, or marginal, load associated with the new electric technology's implementation. Marginal emission computer models apply to the purchased and generated electricity of a specific utility or metropolitan region. These marginal upstream emission models consider different scenarios for when the electric vehicles are charged, which is typically off-peak at night. In addition, they typically select the emissions resulting from the added electric vehicle load at power plants based on the least cost to operate (although in some areas local regulations require dispatch of power plants to the cleanest plants at certain times of day or year). The results are not applicable to the nation or large regions, or even large states such as California. While this seems like the preferred approach at first glance, there are a number of concerns with this approach. Please refer to Table 2-2 in Chapter 2 (see page 2-8) for a summary of the pros and cons of a marginal emissions analysis approach. It is noteworthy that average emission modeling conducted in the past has resulted in much larger upstream emissions for electric vehicles (on-road and non-road) than marginal emissions studies, for many areas of the country.

Table 2-4 in Chapter 2 (see page 2-14) provides a high level comparison of the relative usefulness of the key emission inventory and fuel cycle models and Table 2-3 in Chapter 2 (see page 2-12) provides a more detailed summary of the models' capabilities.

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[6] Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET)

New Approach

The EPRI Hybrid Electric Vehicle Working Group (HEVWG) developed a consensus approach that estimates for the first time a nationwide number for upstream emissions for on-road EVs and plug-in hybrid electric vehicles (HEVs) using the marginal emissions approach. This approach avoids having to complete expensive (least-cost-electricity dispatch) marginal emission studies for each metropolitan region in the nation. In addition, the HEVWG approach is already set up for application to non-road electric vehicles. It also has started to build a consensus among experts which might be able to be expanded.

Recommendations associated with power plant emissions analysis include:

g) It is recommended that EPRI work to investigate, refine, verify and improve the assumptions used by the HEVWG study. This should include a trend analysis to show the improvements in ten, twenty and thirty years for power plant fuel use and emissions. This preliminary WTW study should examine criteria pollutants as well as greenhouse gases and energy (total, fossil fuel, and petroleum).

h) It is recommended that EPRI work with ANL to incorporate the HEVWG compromise approach into future revisions to GREET. The marginal approach using expert-consensus inputs is affordable, and already has some support at ANL. The argument for this includes a brief reexamination of the older Electric Vehicle Total Energy Cycle (EVTEC) marginal emission analysis model[7], the more recent CEC Henwood marginal emission analysis model, and the average analysis done by for the electric airport ground support equipment (GSE) incentives in the ILEAV[8] program.

i) Upstream analysis of criteria pollutants, CO2, energy use, and petroleum use continues in many different forums. EPRI should participate in the key conferences and technical publishing opportunities (e.g. Transportation Research Board, Asilomar, etc) and scientific programs that conduct such modeling and establish associated protocols.

j) It is also recommended that efforts in this area be reviewed by stakeholders, since the results of these efforts are extremely important to the future of electric transportation markets.

6. Reward the Cleanest Technologies in Mandated or Voluntary Programs

Historically, emissions regulations are generally developed by setting a standard for the criteria pollutant(s) for a new engine's tailpipe and evaporative emissions and delineating a timeline for compliance with that standard by manufacturers. In addition, if additional reductions of emissions from in-use engines seem technologically feasible, EPA and ARB may issue

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[7] The EV TEC model by Argonne National Laboratory (ANL) and the National Renewable Energy Laboratory (NREL), which in 1995 included a custom-designed NREL-operated marginal emission model.

[8] Inherently Low Emission Airport Vehicle (ILEAV)

regulations, that, over time, require existing engines to reduce emissions by retrofitting engines with control devices, rebuilding or replacing the engine, retiring the vehicle, and/or using cleaner fuel. This approach with existing fleets is called a fleet rule or a “demand-side” rule. The tailpipe standard approach is called a “supply-side” rule. Both approaches can be used in traditional “command and control” regulations.

Incentive programs (grants, tax credits and various types of emission reduction credits) have been developed to reward both manufacturers and users that comply with new standards ahead of schedule or that exceed the tailpipe standard for emissions.

Another general problem with incentives is that they do not always give the cleanest technology the biggest reward and a reward in proportion to the vehicle’s ability to reduce criteria pollutants, air toxics, CO_2 and petroleum consumption.

k) It is recommended that EPRI participate in the review of existing regulations and incentive programs to determine if they can be restructured to give the rewards proportional to their ability to reduce criteria pollutants, air toxics, CO_2 and petroleum.

l) It is also recommended that life-cycle costs be incorporated in the cost-effectiveness evaluation conducted by some incentive programs.

7. Cost-Effectiveness Evaluations Should Include Life-Cycle Cost Considerations

Regulatory agencies are required to consider the economic impact of air pollution control strategies on stakeholders. A key tool for this analysis is determination of a proposed measure’s cost-effectiveness, usually estimated in dollars per ton of emissions reduced. Cost-effectiveness calculation methodologies, in some instances do not take into account various downstream factors that favor electric technologies such as longer useful life (without deterioration in emissions benefits), lower operating cost, and life-time reduced emissions.

For electric non-road equipment, cost-effectiveness is much more favorable if life-cycle cost is included in the analysis (compared to only using upfront, capital costs). EPA conducts life-cycle cost analyses as part of their standard cost-effectiveness calculation, while ARB considers life-cycle cost considerations to be optional in their analysis. ARB however, is required to calculate upfront, capital costs in their cost-effectiveness calculation.

Another reason life-cycle cost analysis is important is that electricity continues to be less expensive overall than diesel, propane or natural gas. However, as electric utility pricing continues to move toward time-of-use rates, adding charging load for electric non-road vehicles could cause energy bills to skyrocket if charging at peak (i.e., expensive) times. Fortunately, time-of-use rates also offer attractive off-peak rates for those who can shift charging to night-time hours. Such peak load analysis and load shifting can be accomplished with a sophisticated energy management system or something as simple as a timer.

m) It is recommended that EPRI initiate a technical evaluation that provides information on the value of life-cycle costs as a component in the analysis of mobile source emission reduction measures by EPA and ARB.

n) It is recommended that EPRI help utilities develop the rate analysis tools to assist customers who are considering changing to electric non-road equipment.

8. Inclusion of Electric Drive Technologies in Credit Trading Programs Focusing on Those Credit Trading Programs That Have Highest Likelihood of Implementation.

The traditional approach with criteria pollutant reductions, i.e., the promulgation of emission standards, is called "command and control". In the last fifteen years there has been experimentation with a variety of more flexible regulatory approaches, which are generally known as "emissions credit trading". According to experts[9], "*the primary attraction of emissions trading is that a properly designed program provides a framework to meet emission reduction goals at the lowest possible cost. It does so by giving emission sources the flexibility to find and apply the lowest-cost methods for reducing pollution. Emission sources with low-cost compliance options have an incentive to reduce emissions more than they would under command and control regulation. By trading emission credits and allowances to high cost compliance sources, which can then reduce emissions less, cost-effective emission reductions are achieved by both parties. When inter-temporal trading is allowed, sources can also reduce emissions early, accumulating credits or allowances that can be used for compliance in future periods if this reduces cumulative compliance costs.*" This generally describes a cap-and-trade program, which can be for only stationary sources, for only mobile sources, or both. The general idea is to provide less expensive emission reductions "more than, or sooner than" required, and turn this into a commodity that displaces / prevents more expensive emission reductions by the same or different company. There can be no net emission reductions, or there can be a transaction factor or uncertainty factor that sets aside some percent of emission reductions for the good of air quality.

There are a number of issues associated with the success of emissions credit trading programs. In a broad sense, these issues are categorized into three main areas: threshold, design and implementation[10]. Threshold issues address emission goals, geographic area covered by the program (for example, some programs may only be allowed in non-attainment areas) and the specific commodity traded. Design issues consider initial allocation, geographic, sector and temporal factors, the trading parties and participating institutions (i.e., brokers, auctions, etc.). Implementation issues include certification, monitoring and reporting, compliance, maintenance and evaluation.

One of the most difficult issues is trading between mobile and stationary sources, i.e., inter-sector trading. Inter-sector trading is desired because stationary sources (power plants, refineries, factories) are regulated at a local level by air districts and generally need to buy emission credits to reduce their costs. However, the low cost emission credit generators are mobile sources, which generate "mobile source emission reduction credits" (MSERCs). After

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[9] Ellerman, A. Denny, and Joskow, Paul L., Massachusetts Institute of Technology, and David Harrison, Jr., National Economic Research Associates, Inc., "Emissions Trading in the U.S.: Experience, Lessons and Considerations for Greenhouse Gases", Prepared for the Pew Center on Global Climate Change, May 2003

[10] Forum for Economics and Environment, online at www.econ4env.co.za/archives/ATRIP/domestic2.pdf

eight years of effort, mobile-to-stationary trading is now allowed in only five rules in southern California. These rules are EPA-approved, but the approval process was lengthy and the programs are complicated. In light of the detailed requirements to generate and sell the credits, the rules are not even used very much. To repeat the complicated rulemakings in hundreds of air districts nationwide seems very unlikely given the amount of air district staff time it would take in each jurisdiction. In addition, there are long-standing objections from environmentalists regarding emission credit trading and its function as a "pay-to-pollute" program, and additional implementation concerns such as the long-term nature of stationary source credit requirements versus the shorter life of the vehicles that generate the credits.

While there are many other emission credit trading program approaches, two alternatives stand out[11]. The first is EPA's Averaging, Banking and Trading (AB&T) program, often referred to as a fleet average. In EPA's on-road and non-road rules, a fleet average approach is used to provide regulatory flexibility on top of their traditional command and control approach. A fleet average allows engine or vehicle manufacturers to make some products that are dirtier than required and some that are cleaner than required, as long as they meet their overall requirements on an average basis. In addition, the AB&T program allows trading between manufacturers. The AB&T facilitates mobile-to-mobile emissions trading. As mentioned under point 2, electric-drive vehicles such as battery electric, corded electric, fuel cell vehicles, plug-in HEVs are excluded from this type of program.

The other approach is a new mobile-to-stationary emission trading program that overcomes the problems of the established MSERC-to-stationary trading approach. In this new approach, EPA would select about ten top technologies that are targeted for commercialization (due to their clean air benefits) for a national credit trading program. These technologies (such as non-road EVs or truck stop electrification) would need to produce low cost emission reduction credits. Protocols and many other issues would be clearly defined by EPA to ensure that case-by-case certifications are not needed. Finally, EPA would develop this program into a national "model rule" for use by all interested air districts (saving significant staff time). With this approach, there would be many local stationary source buyers. A variation is to allow local stationary sources to contribute to an air quality investment fund, if their cost of compliance exceeds a certain threshold. EPA would then take this money and spend it only on the ten top pre-approved technologies.

One of the key issues when considering mobile source credit trading programs is whether to include the existing electric equipment already in service. Some argue that replacement of existing electric equipment, or even implementation of electric equipment in markets that are primarily serviced by EVs, should not be incentivized. On the other hand, makers of millions of non-road EVs have not been rewarded for going above and beyond the national emission standards, while makers of other clean equipment have been rewarded. Table 2-9 (see page 2-32) summarizes the relative merits of AB&T and MSERC programs.

[11] Forum for Economics and Environment, online at www.econ4env.co.za/archives/ATRIP/domestic2.pdf

Recommendations associated with emission credit trading programs include:

o) It is recommended that EPRI provide technical analysis for those working at the national level to include electric propulsion systems in credit trading programs.

p) Further, it is recommended to work with EPA to evaluate credit trading programs to allow inter-sector trading between on and non-road categories. This effort could take the form of developing a national program that is led by EPA that establishes a "model rule" that generates credits for the best electric technologies.

9. Who Pays? Taxpayer vs. Affected Industry

Manufacturers and industry resist command and control regulation for a number of reasons, the most important of which is they bear the cost of meeting the regulations. Incentives are preferred because they offer some sort of reward for voluntary participation in the effort to reduce emissions earlier-than or greater –than required. Traditional financial incentives (e.g. grants and tax breaks) help defray the costs of implementing the cleaner technology. However, financial incentives are usually dependent on the availability of government funding, and very significant budgets would be required if a complete replacement of all proposed command and control regulations were desired.

Another type of incentive is emission credit trading, which takes many different forms. Emission trading rules sometimes overlay or replace traditional command and control rules and because they are paid for /supported by industry rather than taxpayers, they are a particularly attractive type of incentive. Emission trading has the potential to provide manufacturers with the incentive to develop cleaner technologies in advance of requirements or to exceed requirements once they are in place, if the credit trading program adequately rewards them for this "sooner -than / more-than-required" effort.

10. Implementation / Quick Response Team

It is clear from the multitude of topics discussed in this report that there are a number of issues related to the implementation of electric technologies in the non-road transportation sector.

q) Development of an Implementation / Quick Response Team is recommended. This team would lead the implementation of the report's recommendations, as well as provide quick response for areas of concern regarding the industry.

11. Summary Document to Educate Outside Entities on These Issues.

A number of topics were addressed in this report that cross over a variety of interest areas. Many of the findings and recommendations, as supported by the report's discussion, provide an excellent summary of important issues that affect on-road and non-road mobile source emission reduction programs.

r) It is recommended that EPRI develop a summary document of this report for distribution to a wide audience that includes legislators, regulators, utility experts, and vehicle and equipment manufacturers.

12. Comprehensive Benefits Analysis is Needed

In the course of implementing the recommendations herein, a current analysis of the potential benefits of non-road electric technology implementation would be beneficial. This analysis would provide details regarding the emissions (all pollutants, including GHGs) and petroleum consumption reduction benefits, as well as other environmental impacts such as landfill, water resources, etc. Basically, the results of this analysis would provide a "big picture" review of electric technologies and their benefits. Table 2-5 in Chapter 2 (see page 2-21) provides an example of the type of information sought in this effort, though a more detailed and comprehensive effort is recommended.

s) It is recommended that EPRI determine the current and hypothetical market potential for non-road electric vehicles / equipment. For example, is the estimate of four million units in-service today, correct? How many more can be added in the future (i.e., what is the market growth potential)?

t) It is recommended that EPRI determine the benefits of this hypothetical increase and express it in an easy-to-comprehend, technically-correct way. For example, what is the national potential for petroleum, CO2, air toxics and criteria pollutant reduction? What are the cost savings and other customer benefits? These metrics should be applicable to both EPA and ARB jurisdictions.

13. New EPA Inventory Model

EPA is currently developing on a new modeling system called the **M**ulti-scale m**O**tor **V**ehicles and equipment **E**mission **S**ystem (MOVES). This model is in the conceptual design stage. This new system is designed to estimate emissions for on-road and non-road sources, cover a broad range of pollutants, and allow multiple scale analysis, from fine-scale analysis to national inventory estimation. When fully implemented, EPA intends that MOVES will replace both MOBILE6 (EPA's on-road emissions inventory model) and NONROAD. While this model does not include fuel cycle analysis, it is being designed with interface capabilities with other models, including GREET and other fuel cycle models. Further, MOVES is being designed with a significant increase in the amount of user inputs that are accepted; in other words, there is less of a "top-down" approach than existing EPA inventory models.

u) The first version of MOVES will include on-road GHG emissions modeling and is due by the end of 2004. Non-road capability will be added to the model in 2006. As such, it is reasonable that EPA will soon start their data gathering effort for this phase. It is recommended that EPRI provide EPA with technical information that supports the inclusion of electric non-road vehicles and equipment in MOVES (and any revisions to EPA's NONROAD2002a model prior to implementation of MOVES.

14. EPA Proposed Non-Road Engine Rule

EPA is proposing exhaust emission standards applicable to diesel engines (also called CI or combustion ignition engines) used in most kinds of construction, agricultural, and industrial equipment. These proposed standards are estimated to reduce emissions from these non-road vehicles by more than 90 percent. The proposed standards would take effect for new engines beginning in 2008 and be fully phased in by 2014, allowing adequate lead time for manufacturers and providers of the low-sulfur diesel fuel required for these engines. This long implementation schedule provides the electric non-road vehicle and equipment industry an excellent opportunity to market their products as meeting the rule far in advance of requirements. The ability of these products to “get credit” for early emission reductions is dependent on inclusion of electric propulsion systems in the rule, or the ability to generate tradable credits for these reductions.

v) It is recommended EPRI use this proposed rule as an opportunity to engage EPA in discussions regarding the role of electric equipment in meeting the rule’s goals. It is noteworthy that comments on the proposed rule will be accepted until August 20, 2004. This rulemaking deadline provides EPRI with the opportunity to engage EPA in regards to many of the recommendations in this report.

15. Electric Non-Road Vehicles / Equipment Categorization Issue

EPA and ARB models and proposed standards categorize non-road engines by horsepower rather than function. Other programs, such as market studies and state and local air quality control measures, focus on equipment for specific end uses i.e., material handling, airports, golf carts or lawn care. Many of the regulatory measures target a single pollutant. The disparity in the level of specificity and approach by stakeholders in evaluating non-road mobile source emissions makes it tricky to compare and analyze the available information.

w) It is suggested that EPRI develop a tool for its members that cross-references horsepower and equipment function classifications with applicable emission standards and regulations by EPA and ARB for all types and size of electric non-road equipment from lawn mowers to ships, from burden carriers to truck stop electrification.

x) It is recommended that EPRI consider developing a recommendation to revise the EPA equipment function classification approach to reflect the horsepower category approach used by agencies. EPA uses broad horsepower categories with only a few functional categories (e.g. pleasure boats). ARB historically has done the same, but seems to be transitioning to the use of functional categories (golf carts, forklifts, airport GSE, pleasure boats, etc).

Closing

Non-Road Mobile Source Emissions Reduction Opportunity Now!

Non-road vehicles and equipment present a significant opportunity for electric drive technologies. Even though the numbers of vehicles are small compared to light-duty on-road vehicles, the emissions reductions per vehicle are much larger.

Non-Road emissions regulations are currently being proposed and reviewed in many areas. Without accurate analysis and reporting of the emissions evaluation issues identified in this report the resulting regulations will not provide an even playing field for non-road electric vehicles. Industry participation to correct some of these problems will have the dual benefit of increasing the market for electric drive technologies and achieving greater and more long-lasting emissions reductions.

2
NON-ROAD ELECTRIC VEHICLE EMISSIONS REDUCTION CONSIDERATIONS

This chapter addresses general topics related to emission reduction calculation methodologies, emission inventory considerations and regulatory and policy drivers that encourage increased utilization of non-road electric vehicles and equipment. The important categories of forklifts and airport GSE are expanded in Chapter Three and Chapter Four, respectively.

Introduction

Non-road vehicles and equipment encompass a broad range of engine performance capabilities (i.e., horsepower) and applications. Categories generally include the following segments: construction and mining, industrial, lawn and garden, farm, commercial, logging, airport service, railway maintenance and recreational. Additional detail for categories emphasized in this study is provided below[12]:

- Industrial equipment - This category includes aerial lifts, forklifts, sweepers/scrubbers/varnishers, and other general industrial material-handling equipment.
- Airport Support Equipment and Vehicles - This category includes ground support equipment used in airport operations, including equipment for maintaining and fueling aircraft, transporting and loading cargo, transporting passengers, handling baggage, servicing lavatories, and serving food.
- Lawn and Garden Equipment – Includes lawnmowers, weed trimmers, brush cutters, leaf blowers/vacuums, rear-engine riding mowers, front mowers, chainsaws (under 6 horsepower), tillers (under 6 horsepower), shredders (under 6 horsepower), lawn and garden tractors, snowblowers, chippers/stump grinders, and commercial turf equipment.

Emissions from these vehicles and equipment include oxides of nitrogen (NOx), reactive organic gases (ROG), carbon monoxide (CO), particulate matter (PM), greenhouse gases (GHG[13]) and air toxics. Unfortunately, exhaust emissions from these vehicles are harmful to human health and

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[12] Complete List available from U.S. EPA at http://www.epa.gov/otaq/invntory/overview/examples.htm

[13] There are two aspects of greenhouse gas emissions modeling. The first is the evaluation of GHG emissions themselves and the second is the evaluation of the impact of the GHG emissions on global climate change. This study did not review the latter models, which are much more global in scope than the models discussed herein.

damaging to the environment[14]. According to EPA, the nearly 6 million non-road engines in the U.S. contribute 12 percent of the total NOx emissions and 44 percent of the total PM emissions. That is equivalent to the emissions from all of the trucks and buses in the nation. On an individual basis, many non-road vehicles are significantly dirtier than on-road vehicles. As a result, federal, state and local agencies are working diligently to mitigate the emissions of these pollutants and encourage the implementation of clean, low-polluting technologies. The most important aspect of this work effort is the promulgation of standards that limit the emissions allowed by mobile sources, such as non-road vehicles. This requires a thorough understanding of the technologies and their associated emissions characteristics, which are determined from emissions testing and modeling of those results.

Non-Road Mobile Source Emissions Modeling and Calculation Methodologies

Air quality regulators focus only on the tailpipe and evaporative emissions of a vehicle's fuel and propulsion system when setting emission standards for engines or equipment. As such, emission reduction calculations for non-road electric vehicle/equipment implementation require determination of the emissions from the conventional fueled vehicle/equipment (i.e., baseline) that is being replaced.

In order to evaluate the effectiveness of a proposed standard, rule or regulation, regulators use computer modeling to estimate the air quality impact of a specific proposal. For example, ARB's Motor Vehicle Emissions Inventory is "an accounting of those pollutants attributable to both on-road and off-road mobile sources."[15] In general, these inventories are the product of population, activity and emissions. Inventory models are then used to estimate the tons per day reduction of a specific program or control measure by determining the emissions reduced of the new measure against the baseline (do-nothing alternative).

Basic Principle of Emissions Inventory Modeling

Currently, there are two main emission models for non-road vehicle inventories, NONROAD2002a and OFFROAD, developed by EPA and ARB[16], respectively. These models are used to develop an emissions inventory that is a function of the equipment population, average horsepower, useful life, activity, certification and in-use emissions test results, deterioration and load factors[17]. These parameters are referred to as "input factors". These

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[14] Electric Off-Road Equipment in California Air Quality Incentive Programs, Arcadis Geraghty and Miller, December 17, 1998

[15] http://www.arb.ca.gov/msei/msei.htm

[16] ARB refers to non-road mobile sources as "off-road", but there is no difference in the definition.

[17] ARB Mail-Out #MSC 99-32. Notice of Public Meeting to Consider Approval of California's Emissions Inventory for Off-Road Large Compression-Ignited Engines (> 25 HP) Using the New OFFROAD Emissions Model. 1999.

models are used as the basis for all emission standards development and to evaluate the effectiveness of various regulatory control strategies. These models only consider vehicle emissions associated with a vehicle or engine fuel system (i.e., on-board evaporative emissions) and tailpipe emissions.

Interestingly, electric non-road vehicles and equipment are not included in the EPA and ARB emissions inventories, which are used to develop regulations. According to the agencies, this is for the obvious reason, they are zero emission. However, this excludes three to four million non-road electric vehicles in operation across the nation making the national average emissions per unit (also known as baseline emissions) inaccurate. An exception is EPA's model used to evaluate airport ground support equipment which they use for the FAA ILEAV incentive program, but not for regulation. This EPA airport model does include a fuel cycle analysis in order to assign power plant emissions to new electric equipment. Please refer to Chapter Three for a detailed discussion of the airport GSE models and associated emission reduction calculation methodologies.

Emission reduction calculation methodologies are well established for non-road vehicles and equipment. In general, emission reduction benefits represent the difference in the emission levels of the existing baseline engine or equipment relative to the newer, reduced-emission, replacement engine.

Emission levels are calculated by multiplying the engine emission factor (EF) in units of gm/bhp-hr by a conversion factor and an activity level, or

Pollutant Emissions = EF [g/bhp-hr] * Activity [per year] * Conversion Factor(s)

Equation 2-1

For off-road equipment, the activity level is either the annual hours of operation or annual fuel consumed. Both EPA and ARB models use hour-based activity factors for their inventory analyses.

Emission Factors

An emission factor is defined as an estimate of the average emission rate of a given pollutant for a given source, relative to units of activity. Emission factors can be determined from a number of sources, which provide varying levels of accuracy, depending on the source. The best source for an emission factor is actual emissions testing. Due to the high cost to conduct emissions tests on every non-road vehicle in the population, EPA and ARB rely on limited in-use testing data conducted by independent laboratories as well as certification test data provided by the manufacturers. These test data are supplemented were needed by standards that will come into effect in future years.

Load Factor

The engine load factor is an indicator of the nominal amount of work done by an engine for a particular application. It is given as a fraction of the rated horsepower of the engine, varies with engine application, and is sometimes provided by the manufacturer.

When a load factor is not available from the manufacturer, default values are determined by the agencies. Once a load factor has been established for a typical operating period, emissions performance over that period can be calculated from measured unit-work emissions rate. The results of this calculation are the overall emission estimates for the period of work.

Non-Road Vehicles/Equipment Emission Calculation Methodologies

Electric non-road vehicles and equipment emissions are zero, so determination of the baseline emissions of the equipment being replaced or converted (i.e., fossil fueled baseline equipment) is required to evaluate the net benefit of electric technologies. Accurately characterizing the emissions performance of a particular equipment category requires detailed knowledge in these specific areas: 1) the population of the equipment, 2) the rate of equipment emissions per unit of activity and 3) the amount of activity performed during the period of operation.

Hour-Based Calculation Methodology

When actual annual hours of equipment operation are the basis for determination of emission reductions, the conversion factor referenced above is the product of the engine's horsepower rating and the engine load factor. For example, a calculation of NOx emissions, based on hours, would utilize the formula:

Annual NOx emissions =

NOx[g/bhp-hr] * Activity[hrs/yr] * Engine Rating[hp] * Load Factor **Equation 2-2**

ARB's OFFROAD emission inventory model utilizes a large range of load factors for non-road vehicles and equipment. In addition, ARB has assigned a default load factor of 0.43 when better data are not available. Clearly, this is an area where additional research to improve load factor data in key electric target markets would be useful.

Fuel Consumption-Based Calculations[18]

Annual fuel consumption can also be used to determine emission reductions. In this case, the activity level is defined in terms of gallons consumed per year. In this approach, an energy consumption factor (ECF) must be determined to allow conversion of emissions given in g/bhp-hr to units of grams of emissions per gallon of fuel used (g/gal). The energy consumption factor

[18] California Air Resources Board, Carl Moyer Program Guidelines, April 2003 Draft

may be determined by: 1) dividing the horsepower rating of the engine by its fuel economy expressed in units of gallons per hour (gal/hr), or 2) dividing the energy density of the fuel (in units of BTU/gal) by the brake-specific fuel consumption of the engine. Note that ARB uses a default ECF for diesel engines of 18.5 bhp-hr/gal. While actual fuel consumption activity is used for the existing baseline engine, the annual fuel consumption of the replacement, reduced-emission engine may be estimated in proportion to the change in ECF whether the engine is diesel or alternative fuel.

For example, a calculation of NOx emissions, based on fuel consumption, would utilize the formula:

Annual NOx emissions =

NOx[g/bhp-hr] * Activity[gal/yr] * ECF[hp-hr/gal] **Equation 2-3**

Improved Input Factor Data are Needed

As summarized above, emission inventory models rely upon a number of input factors and assumptions. It is obvious that the better the accuracy of the input factors, the better the result of the model analysis. It is recommended that EPRI work with agency staff to ensure that input factors related to electric non-road vehicles and equipment are the best available to the industry. According to ARB staff, the OFFROAD model relies on defaults and placeholders for many factors related to the estimation of non-road vehicles and equipment. Since EPRI's Non-Road Transportation Electrification Campaign is already planning to collect market data at the local, state and national level, it is recommended that these data be shared to enhance the population and equipment load data sets within ARB's OFFROAD model (and later with EPA).

Fuel Cycle versus Vehicle/Equipment-Only Emissions Analysis

The evaluation of emissions from electric non-road vehicles/equipment is a function of the universe being considered in the evaluation. Electric non-road vehicles and equipment are, by definition, zero emission. Since they have no tailpipe emissions, quantification of non-road electric vehicle emissions is quite simply, zero. Quantification of electric non-road vehicle and equipment emission reductions is simply the certified emission standards of the propane, gasoline, diesel or natural gas equipment (that the electric replaces) minus zero. For purposes of mobile source regulation of criteria pollutants, the upstream emissions (e.g. electric power plants or refineries) are not considered by EPA or ARB. Refinery, gasoline station, power plant and other upstream emissions are considered stationary source emissions and are regulated by EPA and, often, more stringently, by local air districts.

While mobile source regulations do not consider fuel cycle emissions when evaluating criteria pollutants, EPA, U.S. DOE, ARB and other agencies are now interested in fuel cycle use of petroleum and generation of greenhouse gases. They use this information for their voluntary CO2 reduction programs, and to give general policy advice for incentive programs. In addition for criteria pollutants, it is recognized by many, including electric vehicle industry competitors, that consideration of vehicle system emissions alone does not provide the complete picture of electric vehicle/equipment emission profiles. Electricity consumed by electric non-road vehicles/equipment must be generated by power plants that often do emit pollution, the level of which depends on a number of factors including the air quality attainment status where the power plant is located, the age of the power generation technology, the fuel source (i.e., coal, natural gas, nuclear, hydro), technology design of the plant, and the peak vs. off-peak operational status. Further, fuel mixes for power plants vary from region to region and there is no consensus on how to allocate power sources to particular loads.

This allocation of power loads is critical in the discussion of “average versus marginal” emissions. In an average emissions analysis, a local, state or national region’s electricity power plant emissions would be determined from the complete mix of electricity sources for the entire year. This is a relatively straightforward calculation that requires large amounts of good data, but does not require a computer model. The problem with this approach is that it will overestimate emissions in regions with clean power, and underestimate emissions in regions with older, sometimes dirtier, power. Table 2-1 further addresses the pros and cons of an average emissions analysis approach.

Table 2-1
Pros and Cons of Average Fuel Cycle Criteria Pollutants Analysis

Pros	Cons	Issues/Comments
Simple and low cost.	Areas with very low emissions for non-road EVs are inaccurately shown with much higher emissions. Areas with relatively high emissions for non-road EVs inaccurately shown with much lower emissions.	Average emission analysis has this problem because it doesn’t factor night time charging or in-basin emissions, and does factor in over 50% use of coal-fired electricity nationwide. Similar problems when applied to a region or metro area.
	Regulations and standards are not based on this analysis approach, so there is no applicability to emission standards	
	Has the potential to "arm" competitors with data to compete against EVs	More inaccuracy with nationwide average than with regionwide average. But in-basin and off-peak emissions can’t be shown.

Marginal emissions are defined as the emissions associated with the incremental, or marginal, load associated with the new electric technology’s implementation. In the past, marginal emissions for electric vehicles have been calculated using expensive, very sophisticated least-cost-dispatch computer models. Marginal emission computer models apply to the purchased and generated electricity of a specific utility or metropolitan region. These marginal upstream emission models consider different scenarios for when the electric vehicles are charged, which is typically off-peak at night. In addition, they typically select the emissions resulting from the added electric vehicle load at power plants based on the least cost to operate (although in some areas local regulations require dispatch of power plants to the cleanest plants at certain times of day or year). The results are not applicable to the nation or large regions, or even large states such as California.

While this seems like the preferred approach at first glance, there are a number of concerns with this approach. Please refer to Table 2-2 for a discussion of the pros and cons of a marginal emissions analysis approach. It is noteworthy that average emission modeling conducted in the past has resulted in much larger upstream emissions for electric vehicles (on-road and non-road) than marginal emissions studies, for many areas of the country. Also, while a marginal emission analysis provides very detailed information on emissions (up to 500 power plants might be examined for their load contributions to EVs), one weakness is to be relatively confident of accurate results the electric vehicles (on-road or non-road) must be about one percent of the total energy (kWh) from all electricity end-uses in the area or utility studied.

The incorporation of power plant emissions (for electric vehicle technology) and production, distribution and refueling emissions (for petroleum fuel vehicles) is referred to as full fuel cycle emissions (also called “well-to-wheels”, or WTW). Consideration of just tailpipe and evaporative emissions is sometimes referred to as “tailpipe-to-wheels” or TTW). Fuel cycle emissions for conventional fuels include feedstock recovery, fuel processing (refining), transportation, storage, and distribution of the fuel itself, as well as emissions associated with vehicle operation and fueling.

Clearly, completion of fuel cycle emissions analyses are extremely complicated and expensive, since analysis must literally be conducted on a case-by-case basis for each region or locality. Fortunately, emission standards are currently developed based on analysis models that <u>only</u> consider the reductions achieved by the vehicle (tailpipe and on-board evaporative emissions from the fuel system). As such, electric drive technologies are assigned zero emissions, compared to conventionally-fueled technologies. In the context of emissions standards development, completion of a fuel cycle analysis for electric mobile sources is not necessary. One exception is on the horizon. Preliminary indications are that ARB’s regulatory proceeding for GHG emission reductions in the light-duty passenger car and truck categories will include a WTW analysis of GHGs.

However, there are situations where a WTW analysis for non-road electric vehicles conducted by EPRI may be useful. For example, when power plant emissions are brought into the discussion by electric technology opponents, it would be helpful for the electric industry to have their own consistent WTW analysis to respond to potential criticisms of measures that reward zero emission technologies. Many regions already have very clean power plants and place a ceiling on power plant emissions. In addition, improvements in generation plant technologies should be incorporated into the models.

Table 2-2
Pros and Cons of Marginal Fuel Cycle Criteria Pollutants Analysis (except the HEVWG approach)

Pros	Cons	Issues/Comments
Analysis capability for each locality (e.g. metro region or utility service territory). Can show both in-basin and total emissions. Most accurate.	Requires expensive modeling. May require updates to models to handle deregulation. Models don't apply to large regions or nation. Model accuracy needs non-road EV kWh to be roughly 1% of total kWh in the metro / utility area.	Marginal increase in electricity consumption through electrification of non-road vehicles must be carefully analyzed based on the changing generation mix and emission control standards. The HEVWG compromise approach to marginal analysis does not use model, and the cons to left do not apply.
Provides a good understanding of the true real-life emissions of electric drive technology.	Regulations and standards are not based on this analysis approach, so there is no applicability to emission standards.	The conclusion of a comprehensive fuel cycle analysis may require regional marketing approaches (i.e., EVs are not targeted in areas where fuel cycle emissions do not favor EVs).
Good for defense against challenges (in certain cases).	Has the potential to "arm" competitors with data to compete against Evs.	Studies could be designed to provide useful data in the mitigation of the fuel cycle emissions (i.e., management of EV charging load, encouragement of cleaner power technologies, etc.)
A number of existing models that address fuel cycle emissions, though the degree of effectiveness varies from model to model.	A detailed comprehensive fuel cycle study would require significant financial and technical resources.	A study would have to look at a large number of localized areas to appropriately address the many factors affecting EV fuel cycle emissions (i.e., peak vs. off-peak charging, degree of plant emission controls, generation fuel mix, renewable sources of energy, etc.)
As clean power plant technologies are phased in over time, electric drive would also become cleaner.		

Caution is advised when considering a fuel cycle analysis, since the analysis may provide answers that support the electric industry's competitors' case. For example, the Gas Research Institute (GRI) commissioned a 1994 report prepared by Energy International, Inc. for the natural gas vehicle (NGV) industry[19]. The purpose of the study was to support an effort at the time to demonstrate that NGVs deserved so-called "equivalent ZEV" credit under ARB's zero emission vehicle (ZEV) regulation. The report conducted two WTW analyses, one for California and

[19] "Light Duty Vehicle Full Fuel Cycle Emissions Analysis", Topical Report Number GRI-93/0472, Prepared by Energy International, Inc. for the Gas Research Institute, April 1994.

another for the general U.S. case. Results of the WTW analyses concluded that for both California and the U.S., NGVs and other alternative fuels "provide equivalent fuel cycle emissions as EVs." (This report is cited only to illustrate how competitors use fuel cycle analyses to "fight" EV technology implementation, and not to argue its conclusions.)

If a large-scale WTW analysis is implemented by EPRI, it is recommended that a preliminary study based on the Inherently Low Emission Airport Vehicle (ILEAV) incentive program at the Federal Aviation Administration (FAA) be conducted. For ILEAV, airports across the country have already submitted applications that could be used to conduct a simple estimate of WTW electric vehicle emissions in those locations. This would provide a preliminary look at the variability based on region and fuel mix expected from ILEAV's use of the average emission analysis for each region. In addition, the EPRI Hybrid Electric Vehicle Working Group (HEVWG) developed a consensus approach that, for the first time, estimates nationwide upstream emissions for on-road EVs and plug-in HEVs using the marginal emissions approach. This approach avoids having to conduct expensive local least-cost-electricity dispatch marginal emission studies for each metropolitan region in the nation. In addition, the HEVWG approach is already capable of being applied to non-road electric vehicles. The results of this approach should be compared to the ILEAV approach. This preliminary study would provide EPRI a new, timely comparison of the marginal vs. average issue. In addition, new marginal models, such as the CEC Henwood model, could be examined, as well as the EV TEC[20] model which in 1995 included a custom-designed NREL operated marginal emission model. In the past, average emission models have resulted in much larger upstream emissions for electric vehicles (on-road and non-road) than marginal emissions studies for many areas of the country. A preliminary WTW study by EPRI should not just examine criteria pollutants, but also global warming gases and energy (total, fossil fuel, and petroleum).

Another important issue in upstream emission analysis is data resources. Several models mentioned in this analysis do not provide power plant emission data, but instead require such data be provided by the user. This can lead to serious problems, erroneous studies, and bad publicity for electric vehicles. Sometimes user-friendly models will have a default value for power plant emissions, if the user does not have a project-specific value. Reliance on this approach is problematic since this default value might be based on a national or regional average value that is completely inappropriate for the metropolitan area where the electric vehicle is used and charged.

Also, if there is success in the effort to "reward based on cleanliness", then as electric power plants in regions of the country where the cleanest power generation technologies are not yet implemented become cleaner and cleaner, the fuel cycle emissions for non-road electric vehicles in those regions will improve dramatically. In any case, the WTW analysis should represent an industry consensus so that there is a consistent approach across the county.

[20] The EV TEC model by Argonne National Laboratory (ANL) and the National Renewable Energy Laboratory (NREL), which in 1995 included a custom-designed NREL-operated marginal emission model.

Discussion of Existing Fuel Cycle Analysis Models

The goal of a full fuel-cycle analysis is to account for all of the emissions along the entire fuel-cycle process. This determines the total emissions (upstream and downstream) associated with the consumption of a given amount of fuel in the vehicle.

There are a number of models that are worth reviewing in consideration of fuel cycle emissions analysis. These include Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, the FAA/EPA models used in analysis of airport emissions (discussed below) and a new approach by the Hybrid Electric Vehicle Working Group (HEVWG) that looks at power plant emissions on a marginal basis (i.e., the incremental emissions resulting from power consumed by new implementation of electric equipment).

The two main emission models developed by the FAA for use by airports that facilitate assessment of GSE air quality impacts are Emission Dispersion Modeling System (EDMS) and the EPA GSE Model Version 1, used for the ILEAV program. It is important to note that there are also specialized spreadsheet models that are used to estimate emission levels of specific projects and policy strategies that are requested by airports, FAA, EPA, or regional air quality management districts. These models are usually customized by independent consultants or airport staff to fulfill specific tasks at a specific time. One interesting aspect of these airport models is that they include some degree of fuel cycle analysis using the average emission methodology (see Tables 2-1 and 2-2 for a discussion of the pros and cons of this approach).

EPA is currently working on a new modeling program called the **M**ulti-scale m**O**tor **V**ehicles and equipment **E**mission **S**ystem (MOVES). It is important to note that MOVES is still just a concept. This new program is designed to estimate emissions for on-road and non-road sources, cover a broad range of pollutants, and allow multiple scale analysis, from fine-scale analysis to national inventory estimation. When fully implemented, EPA intends that MOVES will replace both MOBILE6 (EPA's on-road emissions inventory model) and NONROAD. It is noteworthy that EPA has stated that a revision to NONROAD will be conducted prior to the implementation of the non-road portion of MOVES, but that the on-road model, MOBILE6 will not be revised, instead relying on MOVES for the update modeling.

While this model does not include fuel cycle analysis, it is being designed with interface capabilities with other models, including GREET and other fuel cycle models. Further, MOVES is being designed with a significant increase in the amount of user inputs that are accepted; in other words, there is less of a "top-down" approach than existing EPA inventory models.

For the development of MOVES, EPA literally started from "scratch", discarding over 25 years of accepted inventory modeling approaches for a new, "outside the box" approach. One fundamental design difference between MOVES and current inventory models is the use of second-by-second emissions data that were collected from vehicles during regular operation. This is compared to the standard practice of using emissions data collected over test cycles conducted in the lab. The advantage of laboratory data is the ability to establish a control, and then vary factors that affect emissions such as temperature, inspection and maintenance activities, humidity, etc. In other words, the lab allows simulation of a variety of controllable factors. The second-by –second data being collected by EPA is at best, a snap-shot in time of the specific vehicles instrumented for emissions measurement. EPA has collected over 100 gigabytes of second-by-second data for MOVES to date. While MOVES is meant to be highly integrateble with a number of other models, the user will need a comparable data set for meaningful results, for example second-by-second activity to match-up with the MOVES data set.

The first version of MOVES will include on-road GHG emissions modeling and is due by the end of 2004. Non-road capability will be added to the model in 2006. As such, it is reasonable that EPA will soon start their data gathering effort for this phase. EPRI should work to provide EPA with technical information that supports the inclusion of electric non-road vehicles and equipment in MOVES.

Table 2-3 provides a high level review of the key models and their capabilities. EPA's NONROAD2002a and ARB's OFFROAD inventory models were discussed previously. Table 2-4 provides a high level summary of the relative usefulness of each model.

Table 2-3 Capabilities of Emissions Models

Emission Model	Agency /Lead	Equipment Type	Tailpipe and Evaporative (Fuel System)	Fuel Cycle Capability	Power Plant Emissions Approach	Pollutants Modeled	Scale(s)	Source of Vehicle and Power Plant Data
OFFROAD	ARB	All Non-Road	yes	no	N/A	NOx, ROG, CO, PM	Macroscale Mesoscale	ARB staff for vehicles
NONROAD2a	EPA	All Non-Road	yes	no	N/A	NOx, HC, CO, SOx, PM10, CO2	Macroscale Mesoscale	EPA staff for vehicles
EDMS	FAA/EPA	Airport GSE	yes	yes	Average	SO2, CO, PM10, NO2, O3	Macroscale Mesoscale	Model users
ILEAV (EPA GSE Model Version 1)	FAA/EPA	Airport GSE	yes	yes	Average	CO, PM, SO2 and O3 precursors (NO3 and HC)	Macroscale Mesoscale	Model users
GREET v1.5 (beta 1.6 now available)	ANL	On-Road	yes	yes	Average or marginal	NOx, VOC, CO, SOx, PM10, GHGs (CO2, N2O, CH4), Air Toxics	Macroscale Mesoscale Microscale	Model users
HEVWG Approach	EPRI	On-Road (expandable to Non-road)	yes	yes	Marginal w/o modeling (Incremental emissions resulting from added Electricity use).	NOx, CO, SO2, PM, ROG, CO2	Macroscale Microscale	Consensus of study's experts at ARB, SCAQMD, TIAX, DOE, ANL, NREL, ERPI, utilities, & automakers

Table 2-3 Capabilities of Emissions Models (Continued)

Emission Model	Agency /Lead	Equipment Type	Tailpipe and Evaporative (Fuel System)	Fuel Cycle Capability	Power Plant Emissions Approach	Pollutants Modeled	Scale(s)	Source of Vehicle and Power Plant Data
MOVES	EPA	All On- and Non-Road	yes	No (but might be linked to GREET or others	N/A	NOx, HC, CO, SOx, PM, NH3, GHGs (CO2, N2O, CH4, A/C Refrigerants), Air Toxics	Macroscale Mesoscale Microscale	EPA staff for vehicles
Henwood	CEC	NA	Not available	yes	Marginal modeling	TBD	Microscale	TBD
EV TEC	ANL – NREL	On-road	yes	yes	Marginal modeling	TBD	Microscale	TBD
DeLucchi	ITS-UC Davis	On-road	yes	yes	Average Modeling	TBD	Macroscale Mesoscale	DeLucchi
Macroscale is Large-Scale Inventories (i.e., U.S. and County Level)								
Mesoscale is more refined – in general at a Regional Level								
Microscale is a detailed analysis for a specific intersection or group of links								

Table 2-4
Comparison of Major Emissions Models

Emission Model	PRO	CON	Comments
OFFROAD	Basic model for ARB emission regulations and standards. Users can't change basic input factors.	Does not include inventory for electric equipment. Does not incorporate Fuel Cycle emissions. No CO2 or fuel use.	
NONROAD (v2002a)	Basic model for EPA emission regulations and standards. Users can't change basic input factors.	Does not include inventory for electric equipment. Does not incorporate Fuel Cycle emissions. No CO2 or fuel use.	
EDMS	Analyzes airport-wide emissions and includes fuel cycle analysis. Also provides dispersion analyses to evaluate against NAAQS.	Fuel cycle aspect is based on many user-driven inputs. Uses less accurate, controversial average emission analysis	
ILEAV (EPA GSE Model Version 1)	Focus is on electric GSE and includes fuel cycle analysis. Also includes life-cycle cost analysis.	Fuel cycle aspect is based on many user-driven inputs. Uses less accurate, controversial average emission analysis	
GREET v1.5 (beta 1.6 now available)	Easy-Access and Ease of Use; Over 100 studies used this model. Includes fuel-cycle considerations. The more accurate marginal emission analysis may be used.	This User-Driven model can be influenced in that inputs are user-defined and not fixed. Most users put in less accurate, controversial average emission analysis.	
HEVWG Approach	Provides a marginal emissions analysis, though as an average for the country. Uses expert consensus. Low cost compared to most marginal. Includes CO2 and fuel use too. Includes refineries.	Need to build broader consensus.	
MOVES	Will replace EPA on- and off-road models. Designed to integrate with most existing models including fuel cycle models; also will allow extensive user-interface.	Won’t include non-road until 2006. Not clear which upstream emissions model will be linked to MOVES, or why to do this, or if it will for experts or non-experts	Currently in concept stage. GHG emissions first, followed by fully functional on-road.

Table 2-5 Comparison of Major Emissions Models (Continued)

Emission Model	PRO	CON	Comments
EV TEC	Uses sophisticated, marginal emissions computer model for upstream emissions analysis. Total energy use model including vehicle manufacture.	Has not been used since 1995 due to high cost and difficulty to modify for deregulated environment. Need to run for every metro area in nation. Hard to get data for model.	
Henwood	Uses sophisticated, marginal emissions computer model for upstream emissions analysis. Recent model.	Need to run for every metro area in nation. Hard to get data for model. High cost to do marginal study.	
Delucchi	Total energy use model including vehicle manufacture.	Uses less accurate, controversial average emission analysis for nation. Fair documentation. Harder to use. From 1993-1995.	Funded by USDOE

Model Update Status

According to ARB staff, the agency is updating its OFFROAD model to include electric vehicles and equipment. The need for this results from increasing activity in California to implement non-road measures that result in increased electric equipment, and ARB's desire to track growth in electric non-road vehicle and equipment implementation. This update is estimated to be finished in January 2004.

Other improvements expected in the update are improvements in activity and load data for all vehicle types, as well as implementation of various corrections. For example, the use of California's cleaner diesel fuel since 1993 would result in fewer NOx and PM emissions from diesel engines compared to the base emission rates used in the model. Thus, a fuel correction factor needs to be applied to the base emission rate, for both uncontrolled and emission-certified engines, to more accurately reflect the emissions from diesel engines when those engines are operated using cleaner California diesel fuel.

EPRI should engage in this update effort to ensure that ARB is able to collect real-life data regarding electric vehicle and equipment population, load and usage information and energy consumption. Once the OFFROAD model revision is well underway, then EPRI should work on getting EPA to follow suit.

Systems Approach is Needed

Currently, incentive programs, rules or regulations usually target a single pollutant or goal, instead of looking at the total overall benefits from a program or regulation. A systems approach is needed to appropriately allocate the full benefit of electric drive technology implementation.

For example, the ARB's diesel emission risk reduction plan has an extensive set of measures to reduce diesel particulate in California. Other than an effort to ensure that a strategy does not significantly increase another pollutant, this plan does not evaluate the commensurate NOx emission reductions that will be achieved by the plan. Further, there is no consideration of potential fuel savings by various technology options. If these other benefits (i.e., reduced NOx or increased fuel economy) were considered as part of the evaluation process, it is possible that electric technologies could possible compete with inexpensive diesel retrofit technologies.

One problem with focusing on only one or two pollutants at a time is that there may be unintended consequences where an improvement in one area results in a negative consequence somewhere else. An example of the potential consequences of this approach is the gasoline additive MBTE which was added to gasoline to reduce hydrocarbon emissions but has now been removed because MTBE, a known carcinogen, was found in groundwater (from fuel leakage).

The MBTE issue is an example of how well-intended efforts can have unintended harmful consequences. More work is needed to identify if there are in fact tradeoffs among the various pollutants and between greenhouse gas emissions and other emission control efforts. The ideal would be a weighted formula that quantifies all emissions impacts of a proposed strategy. While such an effort is probably not on the near-term horizon, there is clearly much that can be done to move toward a better understanding of the consequences of focusing on one pollutant at a time.

There is good news. Two recent actions in California have laid the groundwork, and hopefully are setting precedent for other states as well as the nation to follow a more holistic approach to environmental and energy improvement policy.

Specifically, the California Energy Action Plan's principle goal is to "Ensure that adequate, reliable, and reasonably-priced electrical power and natural gas supplies, including prudent reserves, are achieved and provided through policies, strategies, and actions that are **cost-effective and environmentally sound** for California's consumers and taxpayers."[21] [Emphasis added]

[21] Energy Action Plan, jointly adopted on May 8, 2003 by the California Public Utilities Commission, Consumer Power and Conservation Financing Authority and California Energy Commission.

Also, Assembly Bill 2076 directed the California Energy Commission and the ARB to develop and adopt recommendations on a strategy to reduce petroleum dependence[22]. This coordinated effort established the first formal effort to consider the nexus between the environment, fuel supply and economy of California.

It is important to recognize a systems approach has some challenges. A key challenge is addressing concerns about double counting emissions and even other, unrelated benefits. For example, some air quality incentive programs will not allow funding for vehicles that are being purchased to meet Energy Policy Act fleet purchase requirements.

Of course, it makes sense to ensure that a "ton" of pollutant reductions is not counted twice. But if a program only incentivizes NOx emission reductions, but also obtains PM reductions, or petroleum use reduction, these additional reductions should be rewarded to the project implementer since they have a current or potential monetary value, and were not requested from or paid for by the government agency. This is difficult since regulatory agencies consider these to be "anyway emissions reductions"; emission reductions that they know will be achieved as a result of a specific program which should not be given multiple credits. Ideally, these extra benefits should accrue to the vehicle or equipment owner, to sell, save or trade. The bottom line is that accounting across unrelated project benefits (i.e., energy security vs. air quality) should not prohibit multiple incentives.

It is recommended that EPRI help re-define the issue of double counting. If a technology applies for incentives under two programs, one that focuses on NOx reduction and another which focuses on PM, they should get funding under both. Although the "anyway" emissions will occur regardless of which incentive is received, the applicant did have a choice <u>not</u> to go above and beyond the standard and should be rewarded for doing the "right thing".

Consideration of Greenhouse Gas Emission Reduction Efforts

In light of the previous discussion advocating a systems approach, an overview of efforts to address climate change concerns is timely. It is generally believed that GHG emissions contribute to adverse global climate change. While the U.S. is not currently a signatory to the international agreement to reduce GHGs, there are a number of voluntary GHG reduction efforts ongoing throughout the country.

A systems approach that evaluates all the benefits associated with electric drive technology implementation would also consider GHG emission reductions. It is instructive to relate one key GHG, carbon dioxide (CO2) to another strategic goal, that of energy security.

[22] Draft Joint Agency Report entitled "Reducing California's Petroleum Dependence", July 2003

As an example, ARB[23] uses the following calculation to estimate the fuel economy of a diesel engine over a specific test cycle:

$$\mathbf{MPG_{diesel} = 2778 / (0.866\ HC\ (g/mi) + 0.429\ CO\ (g/mi) + 0.273\ CO2\ (g/mi))} \qquad \textbf{Equation 2-4}$$

It is recognized for internal combustion engine vehicles that CO2 is inversely proportional to efficiency, as illustrated by the above equation. This means that as CO2 emissions decrease, fuel economy increases. Thus, programs that reduce GHG emissions provide additional benefits in terms of increased fuel efficiency. However, CO2 reduction for electric non-road equipment must also calculate the power plant emissions which can range from zero (e.g., nuclear, wind, solar, etc) to large values (e.g., coal).

United States

The U.S. Climate Change Action Plan[24] documents the policy commitments and programs being implemented by the federal government today. The plan includes a large number of voluntary programs that target efficiency improvements in residential, commercial and industrial energy market segments (i.e., Energy Star), as well as GHG emission reduction programs in agriculture, waste management, forestry and transportation segments, to name just a few.

While significant activity in the transportation arena is underway (FreedomCar, Hydrogen Research Program, Clean Automotive Technology development, etc.), there are no specific mandates at the national level to reduce GHG emissions. Furthermore, there are no voluntary or research programs that target non-road mobile sources of GHG emissions (although is some cases, the technology improvement achieved in the on-road vehicles may occasionally transfer to non-road vehicles/equipment). This may be an area worth pursuing at the federal level when seeking federal funding for additional research or demonstrations for non-road electric vehicles and equipment. After all, a number of electric vehicle studies have estimated the CO2 emission reduction potential to be between 50 and 70 percent[25].

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[23] Chassis Dynamometer Emissions Testing Results for Diesel and Alternative-Fueled Transit Buses, Pellegrin et. al, SAE Paper No. 931783, August, 1993.

[24] US Climate Action Report: The United States of America's Third National Communication Under the United Nations Framework Convention on Climate Change (U.S. Department of State, May 2002) (see **http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsUSClimateActionReport.html**)

[25] SIP 2003 Seven Possible Mobile Source Control Measures, EPRI, Palo Alto, CA: 2002. 1007455

State and Local GHG Emission Reduction Initiatives

A number of states (over nineteen) have specific climate change action plans including the New England states, Massachusetts, New York, Maryland, New Jersey, Wisconsin, and Texas. These states and other have also developed voluntary registries for GHG emissions, and GHG emission inventories have been completed in 37 states. According to the Climate Change Action Plan report of 2002, 110 U.S. cities and counties participate in the Council for Local Environmental Initiatives' Cities for Climate Protection Campaign.

California GHG Emission Activity

ARB is now required to develop and adopt regulations that reduce greenhouse gases emitted by passenger vehicles and light-duty trucks. While this effort does not include non-road mobile sources, it is instructive to review the framework in which greenhouse gas emission reductions are first being addressed, since it is possible that non-road regulations for GHG emission reductions may follow.

Specifically, ARB is required to adopt these light-duty GHG regulations by January 1, 2005, though they may not take effect prior to January 1, 2006. The regulations will apply to 2009 and later model year vehicles[26].

The bill requires ARB to carefully consider technical feasibility and the impact of the proposal on the economy of the state. Interestingly, the bill clearly <u>prohibits</u>:

- New fees or taxes on vehicles, fuel or miles traveled
- A ban on the sale of any vehicle category
- A required reduction in vehicle weight
- A limitation or reduction in the speed limit or
- A limitation or reduction in vehicle miles traveled

[26] http://www.arb.ca.gov/cc/factsheets/ccfactsheet.pdf

Recommendation Regarding GHG Emissions

It is clear that while significant effort is being conducted at all levels of government, specific focus on the non-road vehicle and equipment category is lacking. Since electric non-road technologies provide excellent GHG emission reduction benefits, it is recommended that EPRI pursue voluntary GHG emission reduction programs for the non-road mobile source category. Such programs could provide research and/or demonstration funding, or simply incentive funds to implement electric non-road equipment.

Benefits of Non-Road Electric Vehicles/Equipment

The findings and recommendations resulting from this study lead to an increase in the implementation of electric transportation technologies. As such, it is useful to review the air quality and energy security benefits of electric technologies. Table 2-5 below provides the potential emissions reductions and fuel displacement achieved by future on-road and non-road EV products, given population increases in non-road equipment due to factors such as government regulation[27].

[27] Jackson, Michael D., Arthur D. Little, Inc., "Report on the Electric Vehicle Markets, Education, RD&D and the California Utilities' LEV Programs", Final Report, March 22, 2002.

Table 2-6
Future Gasoline and Emissions Displacement by EVs in California

Technology	2011 Estimated Population (1000s)	2011 Gasoline Displaced (million gallons)	2011 NO_x + ROG Reduced in CA Non-attainment Areas (tons/day)
On-road EVs			
Light-duty EVs, NEVs, CEVs	75 – 123	3.7 – 16.3	1.3 – 2.1
Plug-in HEVs	0 – 50	0 – 7.1	a
Shuttles (Transit, School, Hotel, etc)	0.1 – 10	0 – 14.2	Up to 10.5
Non-road EVs and Other Electro-drive Equipment			
Airport Bag Tugs & Belt Loaders	0.7 – 2.8	0.1 – 1.2	1 – 5[b]
Class 1 Forklifts	20 – 29	4.6 – 13.3	6.3 – 17[c]
Class 2 Forklifts	17 – 25	3.9 – 11.5	c
Class 3 Forklifts	35 – 43	1.9 – 4.7	c
Golf Carts	68 – 94	1.8 – 5.1	a
Sweepers, Scrubbers, and Varnishers	128	5.8 – 11.6	Up to 4
Industrial Tow Tractors	8.8 – 12	0.6 – 1.6	b
Burden and Personnel Carriers, Turf Trucks	34 – 45	0.9 – 2.4	0.05 – 0.1
Electrified Truck Stops / Refrigerated Warehouses	Up to 2,000 spaces	0 – 17.5	Up to 6.8[d]
Walk-behind Lawn Equipment	Up to 800,000	0.02 – 0.3	0.5 – 6
Total	387 – 561	24 – 107	9 – 51

[a] Not estimated.

[b] Industrial Tow Tractors' emissions displacement included with Airport Equipment.

[c] Class 2 and 3 Forklifts' emission displacement included with Class 1 Forklifts. As much as 17 tons/day could be displaced electric forklifts if aggressive penetration requirements are adopted.

[d] Emissions could reach as high as 35 tons/day if aggressive penetration requirements are enacted for electrified refrigeration units and truck stop / port-side idling.

While the focus of this study is non-road electric technology emissions reductions analysis and quantification, the systems approach advocated above requires a brief reminder of the energy security benefits of electric drive technology.

Per unit fuel consumption was analyzed in EPRI Report 1007455[28] and is summarized below in Table 2-6 for a number of key non-road vehicle/equipment categories.

Table 2-7
Summary of Petroleum Gallons Displaced by Electric Technologies on an Annual Basis.

Vehicle/Equipment Type	Fuel Type	Annual Gallons Displaced Per Unit (gal/yr)
Forklift	Gasoline	15,840
	Diesel	9,566
Sweeper/Scrubber	Gasoline	3,010
	Diesel	8,104
Burden and Personnel Carrier	Gasoline	1,953
Turf Care Equipment	Gasoline (2-cylce)	1,034
	Gasoline (4-cycle)	10,599
	Diesel	4,217
Residential Walk-	Gasoline (2-cylce)	48
Behind Lawnmowers	Gasoline (4-cycle)	26

Cost-Effectiveness Calculation Methodologies

Regulatory agencies are required to consider the economic impact of air pollution control strategies on stakeholders. A key tool for this analysis is determination of a proposed measure's cost-effectiveness, usually estimated in dollars per ton of emissions reduced. There are two issues related to cost-effectiveness evaluations that should be considered.

First, cost-effectiveness evaluations are usually conducted for the specific pollutant targeted by a regulation. This single focus approach fails to recognize other emission reductions that may be very cost-effective relative to other reduction approaches. Cost-effectiveness should be conducted for the total environmental benefit of a proposed emissions reduction strategy.

The second issue relates to the need for total life-cycle cost consideration. Unfortunately, some agency cost-effectiveness calculation methodologies do not consider various downstream factors that favor electric technologies. For example, while electric technologies tend to have higher up

[28] SIP 2003 Seven Possible Mobile Source Control Measures, EPRI, Palo Alto, CA: 2002. 1007455.

front capital costs, they have other life-cycle benefits, including longer useful life, continuous emissions performance (i.e., no degradation), and lower operating costs (especially with respect to fuel cost savings), that more than compensate for higher initial capital costs. Of specific concern is ARB, which by statute, must consider in their analysis costs from the manufacturer's point of view not the consumers point of view. Thus, ARB's cost-effectiveness only includes up-front capital costs. ARB staff sometimes includes life-cycle costs in their rulemaking documents, but only as a point of information, not because the are required to do so. It is noteworthy that EPA does conduct life-cycle cost analyses for their rules, and the FAA's airport GSE model used for GSE also includes life-cycle costing factors when analyzing the benefit of proposed projects.

It is recommended that EPRI initiate a technical evaluation that provides information on the value of life-cycle costs as a component in the analysis of mobile source emission reduction measures, and that cost-effectiveness analyses include all the benefits of a specified approach.

Command and Control Regulations vs. Incentives

Overview

Historically, emissions regulations are generally developed by setting a standard for the criteria pollutant(s) for new engine's tailpipe and evaporative emissions and delineating a timeline for compliance with that standard by manufacturers. In addition, if additional reductions of emissions from in-use engines seem technologically feasible, EPA and ARB may issue regulations, that, over time, require existing engines to reduce emissions by retrofitting engines with control devices, rebuilding or replacing the engine, retiring the vehicle, and/or using cleaner fuel. This approach with existing fleets is called a fleet rule or a "demand-side" rule. The tailpipe standard approach is called a "supply-side" rule. Both types of approaches can be used in traditional "command and control" regulations.

Incentive programs (grants, tax credits and various types of emission reduction credits) have been developed to reward both manufacturers and users that comply with new standards ahead of schedule or that exceed the tailpipe standard for emissions. Again the problem of a piecemeal approach is common. For example, a tax credit may be provided for a vehicle's petroleum reduction, but the associated reduction of criteria pollutants and CO2 is not rewarded for this vehicle.

The other general problem with the incentives is they do not always give the cleanest technology the biggest reward and a reward in proportion to the vehicle's ability to reduce criteria pollutants, air toxics, CO2 and petroleum consumption.

Policy makers continue to debate whether supply-side or demand-side approaches work best in reducing emissions and whether command and control regulations or incentives provide the most cost-effective solutions.

Command and control regulations can be effective for obtaining a rapid reduction in emissions. For example, in the case of the conversion from internal combustion engine (ICE) to electric golf carts, an ARB mandate was successful in completely converting the fleet within a few years. Relative to the eight to ten year horizons for some mandates (i.e., EPA's proposed non-road standards), this is relatively fast. Relative to incentives this is also very fast, unless there is significant financial investment in the incentive programs.

Manufacturers and industry, on the other hand, tend to argue against command and control regulation if they believe the regulation is not technologically feasible in the time allowed, or if there is only one technology available that can meet the regulation. If there is only one technology, then industry tends to argue that requiring suppliers to produce new technologies without a mandate that requires consumers to buy the new products will always fail. This is because the new technologies are initially more expensive and sometimes less convenient or reliable. This was the argument made during the debate over California's ZEV mandate. In addition, when regulators try to create a consumer mandate by requiring that only clean technologies be produced, such as the recent ARB proposal to require electric forklifts for all lift capacities under 8,000 pounds, there is a backlash from the manufacturers who will lose market share.

Incentives are often preferred because they offer some sort of reward for voluntary participation in the effort to reduce emissions earlier-than or greater –than required. Traditional financial incentives help defray the costs of implementing the cleaner technology. One benefit of incentives is that they usually do not go through the lengthy regulatory adoption process. On the other hand, financial incentives are usually dependent on the availability of government funding, which is limited at best in today's economic climate. For example, California spends about $4 per car (fee on registration) to fund air quality grants by local cities and air districts. In the South Coast Air Basin, roughly $40 million per year is collected and spent on incentives. Contrast this to the cost of command and control rules which are much more expensive. For example, the latest round of proposed rules for mobile sources in California have direct costs on manufacturers of $770 million per year in 2010, indirect costs of $1.5 billion per year in reduced economic output and $1.3 billion per year in reduced personal income[29]. In other words it is not feasible to raise over $1 billion per year worth of incentives so that grants and tax breaks replace command and control rules that are designed to help a region meet the federal air quality attainment deadlines. Taxpayers are probably not willing to pay this much, and typically expect the polluters to pay instead. Industry, rather than taxpayers, funds command and control rules or their alternative, emission trading programs.

Another type of incentive is emission credit trading, which takes many different forms. Emission trading rules sometimes overlay or replace traditional command and control rules and because they are funded by industry rather than taxpayers, they are a particularly attractive type of incentive. Emission trading (see later discussion) has the potential to provide the manufacturers the incentive to develop cleaner technologies in advance of requirements or to exceed requirements once they are in place, if the credit trading program adequately rewards them for this "sooner -than / more-than-required" effort.

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[29] Source: ARB's Proposed 2003 State and Federal Strategies for the California State Implementation Plan – Section 5, Potential Impacts. ARB also notes that the benefits to society are roughly three times these costs.

A regulatory approach (command and control or their regulatory alternatives – emission trading programs) can gain market share much faster than grants or tax breaks. On the other hand, incentives reduce the risk of trying a much cleaner technology while allowing market forces to determine the success of the technology. One successful combination of incentive and requirement is the Carl Moyer Program in California, which provides incentives for earlier-than-required or greater-than-required emissions reductions. ARB has statewide Moyer program guidelines, but these can be superceded by more restrictive local air district Moyer program requirements. For example, the South Coast Air Quality Management District, does not allow clean diesel projects to qualify for on-road vehicles.

Regulators typically include both command and control and incentives in their programs. The tough job is matching each approach to the best opportunities for success. Requiring electric golf carts was likely a success because the electric technology was already in the market and widely accepted. Well-structured emission credit trading programs would significantly benefit electric drive technology. The best approach will differ by type of equipment and the availability of cleaner alternatives.

EPRI should continue to evaluate the pros and cons of various command and control and voluntary approaches to try to establish the criteria that would lead to the earliest possible adoption of the most favorable emissions reduction technologies, including electric.

Existing and Pending Command and Control Regulations for Non-Road Mobile Sources

Under the 1990 Clean Air Act Amendments, areas in violation of national ambient air quality standards (NAAQS) must develop state implementation plans (SIPs) detailing those strategies that will be implemented to comply with the NAAQS. State and local air quality management agencies must achieve specified reductions by deadlines that are based upon the severity of their violations. It is within this framework that emissions standards and air pollution improvement strategies are implemented throughout the country. There are a number of well documented rules and regulations at the national, state and local levels that affect implementation of mobile sources emissions reduction strategies. The impetus for these programs goes beyond emission reductions and includes health, safety and energy security improvement goals.

A list of some of the major programs that require emission reductions is provided below:

- U.S. EPA and ARB Emission Standards/Regulations
- ARB Off-Road Vehicle Emission Standards, including all compression ignition and large and small spark ignited engines.
- Occupational Health and Safety (OSHA)
- ARB Diesel Risk Reduction Plan
- EPA memorandum of agreement with the Air Transport Association for five Southern California Airports.
- ARB regulation requiring electric golf carts

There are also a variety of voluntary programs that provide incentives for the early adoption of clean technologies in the mobile source sector. Unfortunately, a number of these programs do not include incentives for non-road vehicles and equipment. For example, Congress is currently considering the CLEAR ACT. This proposed legislation would accelerate the implementation of advanced automotive technologies, with the multiple goals of enhanced national energy security and diversity by reduction in petroleum consumption and improved air quality through the use of clean technologies and fuels. It does not appear that non-road vehicles and equipment are currently included in this proposed legislation.

Other examples:

- Voluntary Efforts to Reduce Greenhouse Gas Emissions
- FAA Inherently Low Emission Airport Vehicle (ILEAV) Incentive Program
- Energy Policy Act
- Federal Highway Administration (FHWA) Congestion Mitigation and Air Quality Improvement Program (CMAQ). Non-road is not eligible, but truck stop electrification and electric-standby for truck refrigeration units are eligible.
- Local, State and Federal Tax incentives, which need to be reviewed to ensure that non-road technologies are eligible to participate.
- California's Carl Moyer Incentive program – provides incentives to reduce diesel engine emissions – forklifts are eligible in certain cases.
- Mobile Source Air Pollution Reduction Review Committee grant program
- State Energy Program (DOE)
- South Coast AQMD's five pilot rules allowing emission credit trading between mobile and stationary sources. Non-road is not eligible, but truck stop electrification and electric-standby for truck refrigeration units are eligible.
- Air Quality Investment Programs (AQIP)
- Local and State Funding for research and development
- A number of funding programs pending in state legislatures, but do not expect those to go far in light of the budget crisis.

Overview of EPA Proposed Non-Road Engine Rule

One pending action worth discussion is EPA's proposal for new emission standards applicable to non-road diesel engines[30]. EPA estimates that non-road diesel engines affected by the proposed rule currently account for about 44 percent of national mobile source diesel PM emissions and about 12 percent of national NOx emissions. The proposed exhaust emission standards apply to diesel engines used in most kinds of construction, agricultural, and industrial equipment, and are expected to reduce emissions by more than 90 percent. The proposed standards would take effect for new engines beginning in 2008 and be fully phased in by 2014, allowing adequate lead time for manufacturers and providers of the low-sulfur diesel fuel required for these engines.

This long implementation schedule provides the electric non-road vehicle and equipment industry an excellent opportunity to market their products as meeting the rule far in advance of requirements. The ability of these products to "get credit" for early emission reductions is dependent on inclusion of electric propulsion systems in the rule, or the ability to generate tradable credits for these reductions.

Table 2-7 provides a summary of the proposed EPA standards and implementation timeline for different engine sizes.

Table 2-8
Summary of EPA's Proposed Rule on Diesel Engines

Rated Power	First Years that Standards Apply	PM
less than 25 hp	2008	0.3
equal to or more than 25, but less than 75	2013	0.02
equal to or more than 75, but less than 175	2012-2014	0.02
equal to or more than 175, but less than 750	2011-2013	0.01
greater than or equal to 750	2011-2014	0.01

* The 3.5 g/hp-hr standard includes both NOx and non-methane hydrocarbons.

Source: Fact Sheet: Summary of EPA's Proposed Program for Low Emission Non-road Diesel Engines and Fuel

[30] Generally quoted from Fact Sheet: Summary of EPA's Proposed Program for Low Emission Nonroad Diesel Engines and Fuel at http://www.epa.gov/nonroad/f03008.htm

Emissions Trading Programs

The traditional approach with criteria pollutant reductions, i.e., the promulgation of emission standards, is called “command and control”. In the last fifteen years there has been experimentation with a variety of more flexible regulatory approaches, which are generally known as “emissions credit trading”. According to experts[31], “*the primary attraction of emissions trading is that a properly designed program provides a framework to meet emission reduction goals at the lowest possible cost. It does so by giving emission sources the flexibility to find and apply the lowest-cost methods for reducing pollution. Emission sources with low-cost compliance options have an incentive to reduce emissions more than they would under command and control regulation. By trading emission credits and allowances to high cost compliance sources, which can then reduce emissions less, cost-effective emission reductions are achieved by both parties. When inter-temporal trading is allowed, sources can also reduce emissions early, accumulating credits or allowances that can be used for compliance in future periods if this reduces cumulative compliance costs.*” This generally describes a cap-and-trade program, which can be for only stationary sources, for only mobile sources, or both. The general idea is to provide less expensive emission reductions “more than, or sooner than” required, and turn this into a commodity that displaces / prevents more expensive emission reductions by the same or different company. There can be no net emission reductions, or there can be a transaction factor or uncertainty factor that sets aside some percent of emission reductions for the good of air quality.

There are a number of issues associated with the success of emissions credit trading programs. In a broad sense, these issues are categorized into three main areas: threshold, design and implementation[32]. Threshold issues address emission goals, geographic area covered by the program (for example, some programs may only be allowed in non-attainment areas) and the specific commodity traded. Design issues consider initial allocation, geographic, sector and temporal factors, the trading parties and participating institutions (i.e., brokers, auctions, etc.). Implementation issues include certification, monitoring and reporting, compliance, maintenance and evaluation.

One of the most difficult issues is trading between mobile and stationary sources, i.e., inter-sector trading. Inter-sector trading is desired because stationary sources (power plants, refineries, factories) are regulated at a local level by air districts and generally need to buy emission credits to reduce their costs. However, the low cost emission credit generators are mobile sources, which generate “mobile source emission reduction credits” (MSERCs). After eight years of effort, mobile-to-stationary trading is now allowed in only five rules in southern California. These rules are EPA-approved, but the approval process was lengthy and the programs are complicated. In light of the detailed requirements to generate and sell the credits,

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[31] Ellerman, A. Denny, and Joskow, Paul L., Massachusetts Institute of Technology, and David Harrison, Jr., National Economic Research Associates, Inc., “Emissions Trading in the U.S.: Experience, Lessons and Considerations for Greenhouse Gases”, Prepared for the Pew Center on Global Climate Change, May 2003

[32] Forum for Economics and Environment, online at www.econ4env.co.za/archives/ATRIP/domestic2.pdf

the rules are not even used very much. To repeat the complicated rulemakings in hundreds of air districts nationwide seems very unlikely given the amount of air district staff time it would take in each jurisdiction. In addition, there are long-standing objections from environmentalists regarding emission credit trading and its function as a “pay-to-pollute” program, and additional implementation concerns such as the long-term nature of stationary source credit requirements versus the shorter life of the vehicles that generate the credits.

While there are many emission credit trading program approaches, two alternatives standout[33]. The first is EPA’s Averaging, Banking and Trading (AB&T) program. In EPA’s on-road and non-road rules, a fleet average approach is used to provide regulatory flexibility on top of their traditional command and control approach. A fleet average allows engine or vehicle manufacturers to make some products that are dirtier than required and some that are cleaner than required, as long as they meet their overall requirements on an average basis. In addition, the AB&T program allows trading between manufacturers. The AB&T facilitates mobile-to-mobile emissions trading. As mentioned previously, electric-drive vehicles such as battery electric, corded electric, fuel cell vehicles, plug-in HEVs are excluded from this type of program; a rough estimate is that about four million existing non-road EVs are excluded.

The other approach is a new mobile-to-stationary emission trading program that overcomes the problems of the established MSERC-to-stationary trading approach. In this new approach, EPA would select about ten top technologies that are targeted for commercialization (due to their clean air benefits) for a national credit trading program. These technologies (such as non-road EVs or truck stop electrification) would need to produce low cost emission reduction credits. Protocols and many other issues would be clearly defined by EPA to ensure that case-by-case certifications are not needed. Finally, EPA would develop this program into a national “model rule” for use by all interested air districts (saving significant staff time). With this approach, there would be many local stationary source buyers. A variation is to allow local stationary sources to contribute to an air quality investment fund, if their cost of compliance exceeds a certain threshold. EPA would then take this money and spend it only on the top ten pre-approved technologies.

Further Discussion Regarding Mobile Source Emission Reduction Credits (MSERCs) and Trading with Stationary Sources

MSERC trading programs are based on the concept that opportunities exist to reduce emissions from mobile sources beyond what is being achieved by regulatory/mandated programs. Mobile source emission reduction credits are created when reductions in emissions from cars, buses, or other mobile sources exceed the required reductions. The basic concept is to use MSERCs to offset increases in emissions associated with economic growth, instead of requiring emission reductions from industrial sources, and also use reductions to improve California's air quality.

MSERC trading programs are designed to provide flexibility to the stationary source regulated community. ARB has published guidelines that reflect general consensus regarding current

[33] See Footnote 32.

design of MSERC trading programs. The key objectives, according to ARB[34], of MSERC trading are (directly quoted):

- The reductions must not be required by law or regulation, or otherwise assumed to occur as part of a regional air quality plan.
- The reductions must be real, and quantified to an acceptable degree of certainty.
- To be used as stationary source offsets or to replace other emission reduction requirements, the mechanism used to obtain mobile source emission reduction credits must be enforceable and legally binding.
- The life of the reduction must be reasonably established, and commensurate with the proposed use of the credit.

On the surface, MSERC trading appears to be a good concept. The problem is that in the last eight years, only five specific credit trading programs have received SIP approval from EPA. Further, the approval process for those five programs took a considerable time, and significant resources and commitments are required for implementation. The amount of air district staff time required to design the rules makes it infeasible for individual air districts across the nation to implement these types of MSERC-to-stationary source trading programs. Finally, some environmental advocacy groups oppose MSERC trading programs because they are perceived as a form of "pay-to-pollute". In reality, the MSERC trading mechanisms approved in their current form are overwhelming and not practicable. For MSERC trading to be effective, a national, top-down, effort to address problem areas is needed. This top-down approach was proposed earlier in this section.

Further Discussion Regarding Fleet Averages for Mobile Source Rules or Averaging, Banking and Trading (AB&T) Programs

EPA and ARB have used fleet averages (AB&T programs) as a tool to provide production flexibility to manufacturers. According to one expert we talked to, AB&T programs have been "tacked onto" existing mobile source rules, rather than developed as a comprehensive or intentional strategy. An example of this is that gasoline, propane and natural gas fueled equipment (spark-ignited engines) can not trade emissions (i.e. use AB&T flexibility) with diesel engines (compression ignition engines). Historically, EPA and ARB have kept these two technology categories separate, but could increase flexibility by allowing these two major categories to conduct inter-source mobile-to-mobile emissions trading.

Typically, AB&T is used to accelerate rule implementation (i.e., earlier than when all categories can realistically comply). For example, EPA might require a specific standard earlier than some technologies can achieve, but provide manufacturers with an AB&T program as a way for manufacturers to phase-in compliant products over a longer time. ABT programs can also reward greater than emission reductions.

[34] Guidelines for the Generation and Use of Mobile Source Emission Reduction Credits, ARB, February 1996.

Essentially, the emission benefits from an engine certified to a lower Family Emission Limit (FEL) are used to offset the emissions from engines certified to a higher FEL level within a specific engine family. AB&T credits are usually averaged into the manufacturer's engine family limit (FEL), cut could also be "banked" for later use, or "traded". Note that while manufacturers can trade AB&T credits with other manufacturers, it is not likely to occur since they are competitors.

Since electric technologies are not currently a target in non-road engine rulemakings, they are not eligible to generate AB&T credits. They are not engines, and they do not meet the Clean Air Act definition of non-road vehicle, non-road equipment, or engines. If there were no battery electric, corded electric, plug-in hybrid electric or fuel cell electric equipment in the rule category / inventory, it would be easy to add electrics to the AB&T program. A definition change is all that is needed. However, when a category already has large numbers of electric equipment in service, more than a definition change is needed. To be in the AB&T program, this electric equipment would need to be added to the inventory, which would change the fleet average baseline (average emissions per unit). Similarly, combining the separate AB&T programs for diesel and gasoline powered equipment (discussed above) would change the fleet average baseline.

Inclusion of electric forklifts in a fleet average AB&T program is an illustrative example. Some forklift manufacturers produce engine-equipped forklifts, some manufacture electrics, and some do both. The baseline emissions target would be set lower in order to factor in the large market share for electrics. All-electric manufacturers could sell emission reduction credits to engine manufacturers. Or internal trading of emission reduction credits could occur for those manufacturers who make both electric and engine forklifts. Banking of credits, for use at a later date would also be an option. Manufacturers who only make engine forklifts could buy credits or reduce the emissions of their product.

AB&T versus MSERCs

The relative merit of MSERC programs versus AB&T programs depends on many factors. As MSERC programs are currently designed, it is not practical to expect significant opportunity for electric technologies in these programs. Until AB&T programs allow credit for electric technologies, AB&T is not a meaningful incentive to the electric vehicle industry.

It is recommended that EPRI provide technical analysis for those working at the national level to ensure electric propulsion systems are included in credit trading programs (both MSERC and AB&T). Further, it is recommended to work with EPA to evaluate credit trading programs to allow inter-sector trading between on- and non-road categories. This effort could take the form of developing a national program that is led by EPA that establishes a "model rule" that generates credits for the best electric technologies. Finally, EPRI should provide technical support to ensure that electric propulsion systems are included in the AB&T programs in order to take advantage of this program. Table 2-8 discusses the relative merits of MSERC versus AB&T credit trading approaches.

Table 2-9
Relative Merits of AB&T versus MSERC Credit Programs

Emissions Trading Concept	Pros	Cons	Comments/Notes
AB&T	Provides mobile source vehicle/ equipment manufacturers production flexibility.	Does not currently allow inter-sector trading (i.e., between on- and off-road) or trading between engine types (spark vs. compression ignition)	
	Would be even better if CI, SI and electric categories could be combined.	Can trade between manufacturers, but don't due to competitive issues.	This may change as rules get stricter, and if electric, SI and CI are combined as manufacturers often make all three.
		Requires change in baseline fleet average emissions in many cases.	
		Electric must be added to inventory.	ARB is doing this by Jan 2004. EPA has no plans.
MSERCs Sold to Stationary Sources	Good concept.	Procedures and methodologies to get programs approved are overwhelming and time consuming and must be done separately for each air district in the nation.	Need to have a standard "model rule" at EPA that addresses the best (e.g. top ten) technologies that automatically assigns ERCs to specific types of stationary sources. See text for details.
	Allows (and rewards) voluntary soon-than or more-than required reductions.	Jurisdictional issues.	
		Resource constraints at the agencies.	
	In theory, allows (and rewards) voluntary early reductions.	In practice, difficult for end-user to receive and utilize credits.	

3
FORKLIFT

Introduction

Among non-road vehicles, battery-powered forklifts have the largest market share of any electric technology. At the end of 2001, nearly 60 percent of forklifts in Classes 1 through 5 were electric.[35] This proportion has been steadily growing for the last 25 years. The drivers for this growth include health and safety regulations for indoor work environments, technological improvements and favorable life-cycle costs. In some industries, such as cold storage and retail food markets, electric forklifts currently have nearly 100% market share[36].

Despite this success, there is still room for market growth, especially in less traditional industries such as construction, lumber, cargo handling and metalwork. Forklifts are also an attractive non-road application for electro-drive advocates to focus on because the technology has been well-established for many years, but has experienced recent advances in battery and charging technology as well as equipment functionality. Many of the innovations first tested on on-road electric vehicles, such as regenerative braking, are now being transferred to non-road electric vehicles.

The timing is right for a major focus on this industry by electro-technology advocates. EPA and ARB have recently proposed regulations to clean up existing as well as new internal combustion (ICE) forklift engines. ARB proposal, in particular, initially included a mandate that all new forklifts under 8,000 pounds lift capacity be electric. Not surprisingly, the propane industry, which stands to be the most severely impacted by this regulation, is fighting back and has succeeded in getting ARB to back down from its mandate position.

Current State of Information About Emissions

Forklift Classifications

Forklifts (also known in the industry as lift trucks) are one of the major types of equipment within the larger category of non-road vehicles. Forklifts are defined as mobile vehicles powered by electric motors or internal combustion engines and used to carry, push, pull, lift,

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[35] EPRI, "Lift Trucks and Market Potential. December 2002 Report 70007518.

[36] Wood, Brett (Toyota Material Handling, USA). Presentation to EPRI, Birmingham, Alabama, May 20, 2003).

stack, or tier materials controlled by a rider or pedestrian operator, indoors or outdoors [ASME/OSHA]. [37] The Industrial Truck Association (ITA) has defined seven classes of forklifts. These classes are characterized by the type of engine, work environment (indoors, outdoors, narrow aisle, smooth or rough surfaces), operator positions (sit down or standing), and equipment characteristics (type of tire, maximum grade, etc.) Several classes are further divided by operating characteristics. Table 3-1 lists the forklift classifications as well as available information from various sources on typical fuels, characteristics, horsepower and lift capacity.

Table 3-1
Forklift Classes

Class	Lift Code	Engine Type	Type/Use	Typical Lift Capacity	Typical hp	Tire Type
1	1	Electric	Counterbalanced rider, stand up			Cushion or pneumatic (air filled)
1	4		Three-wheel, sit down			
1	5		Counterbalanced rider, sit down	3,000-6,000 lbs.	•50	
1	6		Counterbalanced rider, sit down	3,000-6,000 lbs.	•50	
2			Narrow aisle truck	3,000-6,000 lbs.	•50	Solid
3			Hand or hand/rider truck	3,000-6,000 lbs.	•50	
4		ICE—gasoline, CNG, propane, diesel	Rider, sit down, generally suitable for indoor use on hard surfaces	3000-16,000 lbs.	50-120	Cushion
5			Rider, sit down, typically used outdoors, on rough surfaces or steep inclines		50-120	Pneumatic
6		ICE—gasoline, CNG, propane, diesel; Electric	Ride on unit with the ability to tow at least 1,000 pounds; designed to tow cargo rather than lift it (e.g. an airport tug)		>750	
7		ICE (primarily diesel)	Rough terrain forklift truck for outdoor use; almost exclusively powered by diesel engines	6,000 -40,000 lbs.	>750	

Source: California Air Resources Board, Carl Moyer Program Guidelines, 2003

[37] American Society of Mechanical Engineers (ASME) and Occupational Safety and Health Administration (OSHA)

For the purpose of emissions measurement by EPA and ARB, forklifts are defined by horsepower, ignition system and cylinder displacement. Horsepower rating can be confusing because there is not always a direct relationship between horsepower and lift capacity. In general, horsepower for a given lift capacity has been decreasing as engines and motors become more efficient. For example a 5,000 pound lift capacity with two motors of approximately ten hp each can replace a comparable propane forklift with a 48 hp engine.

Internal combustion forklifts can be powered by compression ignition (CI) or spark ignition (SI) technology. Compression ignition engines are diesel powered and tend to be for heavy-duty applications--typically over 6,000 pounds lift capacity. Spark ignition is typical of smaller gasoline, propane and natural gas powered forklifts that are usually used indoors and range from 3,000 to 16,000 pounds lift capacity. Propane is the most commonly used fuel in spark-ignited engines. Spark ignition engines over 25 horsepower are referred to as Large Spark Ignition engines (LSI).

Forklift Population and Emissions Inventory

The best available source on forklift inventories is the 1997 EPRI report on Forklifts and its 2002 update.[38] The 2002 Update uses data purchased from the ITA in 1996 and updated by applying each state's proportion of the total market to annual shipments of new forklifts between 1996 and 2001. Forklift retirements were also estimated based on historical useful life and removed from the inventory. The report estimates a total forklift inventory in the U.S. of 1.4 million units with 58% of those being electric. Several states such as Illinois and New York have even higher proportions of electric forklifts. Table 3-2 provides the equipment summary both nationally and for the states with the largest market share.

Table 3-2
Forklift Inventories by Combined Class Total U.S. and Selected States

Area	Electric Rider	Motorized Hand	ICE	Total	Area Market Share
Total U.S.	435,914	378,215	598,074	1,412,203	100%
California	45,177	40,250	65,544	150,972	10.7%
Illinois	29,148	22,202	28,733	80,183	5.7%
New York	19,301	22,750	18,594	60,645	4.3%
Texas	27,956	23,309	47,166	98,431	7.0%

Data reviewed by ARB staff and cited in the 2003 Carl Moyer Program Guidelines indicate that there were about 70,000 electric forklifts in California and 31,000 ICE forklifts in California in 1998. The EPRI data show an inventory of 85,000 electric forklifts and 66,000 ICE forklifts for

[38] EPRI, Electric Lift Trucks. Market Description and Business Opportunities." November 1997. TR-109789 Final Report; "Lift Trucks and Market Potential. December 2002 Report 70007518.

a total of 151,000 lift trucks in California in 2001. (Note that since the ITA data are based on forklift classification and ARB data are based on horsepower category, direct comparisons are not possible.)

Table 3-3 shows ARB's 1998 estimated daily NOx emissions in California for internal combustion forklifts.

Table 3-3
1998 Population and NOx Emission Estimates For Industrial Forklifts with Internal Combustion Engines in California and South Coast Air Basin Data

Horsepower Range	Fuel	State Population	State NOx Emissions (tons per day)
50≤ hp <120	Gasoline	9,318	13.1
50≤ hp <120	CNG, Propane	17,638	22.0
50≤ hp <120	Diesel	3,303	6.0
120≤ hp <175	Gasoline	340	1.1
120≤ hp <175	CNG, Propane	645	1.7
120≤ hp <175	Diesel	337	0.9
>175 hp	Diesel	136	0.6
Total		31,717	45.1

Source: California Air Resources Board, Carl Moyer Program Guidelines, 2003

Twenty-eight of the 45 tons of NOx emissions per day (or 62%) comes from forklifts under 120 horsepower. ARB has indicated their intent to add electric forklifts to the OFFROAD emissions inventory revision, providing a more accurate total picture.

While there are more than 30 forklift manufacturers selling product in the U.S., eighteen manufacture both electric and ICE equipment and nine are electric only. The majority of manufacturers who make electric forklifts offer them in the 3,000 to 6,000 lift capacity although there are some as high as 12,000 lbs or more.

Market share for ICE forklifts is dominated by Clark, Hyster, Komatsu and Caterpillar. While no single Japanese manufacturer has a large market share, the Japanese manufacturers in total have about 50% of the forklift market. (note data is from 1990).

Electric forklifts dominate in the lower lift capacity portion of the market and in indoor applications. They have been less accepted for outdoor and heavy-duty applications. The perceived limitations of electric forklifts have been:

- Battery range and performance
- Water-proofing for outdoor applications
- Speed
- Gradeability
- Performance at higher lift capacities

As evidence of the real or perceived limitations of electric forklifts, multiple shift forklift users lean toward forklifts with ICE engines. For example, while sixty-nine percent of class 1 and 2 (electric) forklifts operate one shift a day, and only 16% operate two shifts, 59% of ICE forklifts operate one shift, and almost 40% operate two shifts. The average propane tank is replaced or refilled after 15 hours while the average battery is charged after 11 hours (Gas Research Institute Report, 1995 and ARB 2003 Moyer Guidelines).

A recent presentation by the National Product Development, Strategic Planning and Marketing Services Manager for Toyota Material Handling, USA, details how recent technological developments are overcoming these barriers to the expansion of electric forklifts into nontraditional markets. Recent performance improvements include:

- Increased travel speeds and acceleration rates that now rival IC forklifts
- Increased ramp speed and gradeabilty due to addition of AC motors
- Pneumatic tire designs for outdoor operation
- Rust proof designs for operation in temperature controlled and marine environments
- Sealed spark-proof and explosion proof designs for operation in combustible environments
- Increased battery performance (25% more watt hours per pound)
- Sealed maintenance free batteries
- Regenerative braking that increases run time and prolongs brake life

These improvements plus other advances such as more comfortable seating and more joystick type gears, provide an opportunity for electric forklifts to penetrate new markets. As indicated in Section 3 below, increases in the number and proportion of electric forklifts could have a significant effect on emissions and cost.

Federal and State Regulatory Measures and or Incentive Programs

Current and Proposed Emission Standards for New Forklift Engines

Currently, Both EPA and ARB regulate a portion of the non-road engine inventory that includes forklifts. Table 3-4 summarizes the division of responsibility between the EPA and ARB.

Table 3-4
Division of Responsibility Between EPA and ARB for Non-Road Engines

Horsepower	Pre-empted Equipment (Farm or Construction)	Non-pre-empted Equipment
< 175 hp	EPA	ARB
• 175 hp	ARB	ARB

Source: California Air Resources Board, Carl Moyer Program Guidelines, 2003

Large Spark Ignited Engines (LSI)

EPA and ARB have both adopted standards for new LSI ignited engines. Table 3-5 compares the EPA and ARB standards by year. In 1998, ARB adopted standards for non-road LSI engines to be phased in beginning in 2001. The EPA standards adopted in 2002 align with the ARB standards in 2004 but beginning in 2007, become more stringent than the ARB regulations. In 2004 and 2005 ARB is planning to adopt rules that conform to the more stringent EPA 2007 standard. Table 3-6 provides the ARB baseline emissions for Forklift engines by model year.

Table 3-5
Exhaustive Emission Standards New Large Spark-Ignited Engines[39]

Year	Engine Size	ARB[40] NMHC + NOx (g/bhp-hr)	ARB NOx Only (g/bhp-hr)	EPA NMHC + NOx (g/bhp-hr)	EPA NOx Only (g/bhp-hr)	ARB CO (g/bhp-hr)	EPA CO (g/bhp-hr)	Durability Period
2002 & later	<1.0 liter	9.0	7.2			410		1000 hours or 2 years
2001-2003 (Phase-in)	>1.0 liter	3.0	2.4			37		N/A
2004-2006	>1.0 liter	3.0	2.4	3.0	2.4	37	37	3500 hours or 5 years
2007 & later	>1.0 liter	3.0	2.4	2.0	1.6	37	3.3	5000 hours or 7 years

Source: California Air Resources Board, Carl Moyer Program Guidelines, 2003[41]

[39] Note: Both EPA and ARB use the convention of naming successively more stringent emissions standards by Tiers. The first requirements in a given category are called Tier 1, and they are following by Tiers 2, 3 etc. For engines that have had a series of regulations, the current standards may be Tier 3; for others the standards may still be Tier 1.

[40] Beginning in 2001, new engines are certified to a NOx and NMHC standard. To compare the new NOx standards to the old, a factor of 0.95 is applied to diesel engines or 0.80 to alternative fuel engines. This has already been included in Table 2.5 and is indicated in the shaded area.

[41] Tables 2.5 and 2.6 illustrate part of the problem in trying to compare EPA and ARB emissions standards. Table 2.5 categorizes LSI emission standards by liters displaced and Table 2.6 categorizes the same standards by horsepower.

Table 3-6
ARB Baseline Emission Rates for Forklift Engines by Model Year

Rated Power (horsepower)	Type of Engine	Model Year	Emission Standards/Rates (g/bhp-hr)[42]	
			NOx	NMHC +NOx
25 ≤ hp < 50	Compression ignition (diesel)	2000-2003	6.4	7.1
		2004 +	5.0	5.6
50 ≤ hp < 100	Compression ignition (diesel)	Pre-2000	8.75[43]	--
		2000-2003	6.9	--
		2004 +	5.0	5.6
		2008 +	3.2	3.5
100 ≤ hp < 175	Compression ignition (diesel)	Pre-2000	8.17[44]	--
		2000-2002	6.9	--
		2003 +	4.4	4.9
		2007 +	2.7	3.0
25 < hp ≤ 50	Large Spark-ignited (propane) Uncontrolled	Pre-2002	13.0[45]	--
		2002 +	7.2	9.0[46]

[42] Beginning in 2001, new engines are certified to a NOx and NMHC standard. To compare the new NOx standards to the old, a factor of .95 is applied to diesel engines or .80 to alternative fuel engines. This has already been included in Table 2.5.

[43] Emission rate for uncontrolled off-road heavy-duty diesel engines of 50 to 120 horsepower.

[44] Emission rate for uncontrolled off-road heavy-duty diesel engines of 120 or more horsepower.

[45] Emission rate for uncontrolled off-road heavy-duty propane engines of 25 to 50 horsepower.

[46] This emission standard is for propane or gasoline LSI engines with a displacement of 1.0 liter or less.

Table 3-6 ARB Baseline Emission Rates for Forklift Engines by Model Year (Continued)

Rated Power (horsepower)	Type of Engine	Model Year	Emission Standards/Rates (g/bhp-hr)[47]	
			NOx	NOx
> 50 hp	Large Spark-ignited (propane) Uncontrolled	Pre-2001	Pre-2001	10.5[48]
		2001-2006	2001-2006	2.4
		2007 +	2007 +	1.6
25 < hp ≤ 50	Large Spark-ignited (gasoline) Uncontrolled	Pre-2002	8.0[49]	--
25 ≤ hp < 50	Compression ignition (diesel)	2000-2003	6.4	7.1
		2004 +	5.0	5.6
50 ≤ hp < 100	Compression ignition (diesel)	Pre-2000	8.75[50]	--
		2000-2003	6.9	--
		2004 +	5.0	5.6
		2008 +	3.2	3.5
100 ≤ hp < 175	Compression ignition (diesel)	Pre-2000	8.17[51]	--
		2000-2002	6.9	--
		2003 +	4.4	4.9
		2007 +	2.7	3.0

[47] Beginning in 2001, new engines are certified to a NOx and NMHC standard. To compare the new NOx standards to the old, a factor of .95 is applied to diesel engines or .80 to alternative fuel engines. This has already been included in Table 2.5.

[48] Emission rate for uncontrolled off-road heavy-duty propane engines of 50 or more horsepower.

[49] Emission rate for uncontrolled off-road heavy-duty gasoline engines of 25 to 50 horsepower.

[50] Emission rate for uncontrolled off-road heavy-duty diesel engines of 50 to 120 horsepower.

[51] Emission rate for uncontrolled off-road heavy-duty diesel engines of 120 or more horsepower.

Table 3-6 ARB Baseline Emission Rates for Forklift Engines by Model Year (Continued)

Rated Power (horsepower)	Type of Engine	Model Year	Emission Standards/Rates (g/bhp-hr)[52]	
			NOx	NOx
25 < hp ≤ 50	Large Spark-ignited (propane) Uncontrolled	Pre-2002	13.0[53]	--
		2002 +	7.2	9.0[54]
> 50 hp	Large Spark-ignited (propane) Uncontrolled	Pre-2001	10.5[55]	--
		2001-2006	2.4	3.0[56]
		2007 +	1.6	2.0[9]
25 < hp ≤ 50	Large Spark-ignited (gasoline) Uncontrolled	Pre-2002	8.0[57]	--
		2002 +	7.2	9.0[58]
50 < hp < 120	Large Spark-ignited (gasoline) Uncontrolled	Pre-2001	11.8[59]	--
		2001-2006	2.4	3.0[9]
		2007 +	1.6	2.0[9]
> 120 hp	Large Spark-ignited (gasoline) Uncontrolled	Pre-2001	12.9[60]	--
		2001-2006	2.4	3.0[9]
		2007 +	1.6	2.0[9]

Source: California Off-Road Large Spark-Ignited Engine Emissions Inventory (October 1998)

[52] Beginning in 2001, new engines are certified to a NOx and NMHC standard. To compare the new NOx standards to the old, a factor of .95 is applied to diesel engines or .80 to alternative fuel engines. This has already been included in Table 2.5.

[53] Emission rate for uncontrolled off-road heavy-duty propane engines of 25 to 50 horsepower.

[54] This emission standard is for propane or gasoline LSI engines with a displacement of 1.0 liter or less.

[55] Emission rate for uncontrolled off-road heavy-duty propane engines of 50 or more horsepower.

[56] This emission standard is for propane or gasoline LSI engines with a displacement of more than 1.0 liter.

[57] Emission rate for uncontrolled off-road heavy-duty gasoline engines of 25 to 50 horsepower.

[58] This emission standard is for propane or gasoline LSI engines with a displacement of 1.0 liter or less.

[59] Emission rate for uncontrolled off-road heavy-duty gasoline engines of 50 to 120 horsepower.

[60] Emission rate for uncontrolled off-road heavy-duty gasoline engines of 120 or more horsepower.

Compression Ignition Engines

The regulation of compression ignition engines (CI) follows the same division of responsibility as the LSI engines (Table 3-4). Table 3-4 shows the current and proposed standards for new CI engines. As with LSI engines, recently proposed regulations would ultimately cover existing engines and require that they be retrofit to meet very low NOx and PM emissions standards (Tier 4). The new standards will not specify the technology required for compliance but it is known that the NOx adsorbers and diesel particulate filters currently being developed will require very low sulfur diesel to operate properly (less than 15 parts per million (ppm)). The proposed EPA regulations give equipment manufacturers until 2014 to meet the new standards in part due to industry claims that sufficient low sulfur diesel will not be available until that time. The new regulations will reduce reactive organic gas emissions as well as NOx, ROG and PM.

Proposed Forklift Measure in State Implementation Plan

In addition to the standards for new equipment, ARB recently proposed adopting two new control measures as part of the new State Implementation Plan (SIP) that would affect both new forklifts and existing forklifts. It was initially proposed as two measures—one to retrofit existing forklifts and one to require that new forklifts under 8,000 pounds be electric. The retrofit proposal applies to existing forklifts greater than 25 hp and manufactured prior to 2001. Tests have shown that with the addition of a catalyst-based emission system, pre-2001 forklifts can match the lower emissions of new engines designed with catalysts.

Due to intensive lobbying by a broad coalition organized by the propane industry, the proposal was amended at the June 26, 2003 ARB Board hearing. A great deal of manufacturer and user testimony was presented regarding the negative effects of an electric purchase mandate including information on the unsuitability of electrics for certain applications and job losses that would occur as internal combustion engine forklift maintenance and repair jobs were phased out.

As a result of the testimony, the two proposed control measures were combined into one that includes new purchases and retrofits and may permit compliance tradeoffs between the sections of the measure. The actual measure will be developed in the next year or so.

Results of ARB's Proposed SIP Measures

Tables 3-7 to 3-10 shows the anticipated emission reductions from the ARB SIP forklift control measures as originally proposed by ARB staff. The draft SIP shows the South Coast and San Joaquin Valley areas separately since they are the two severe non-attainment areas in California. [61]

[61] Proposed 2003 State and Federal Strategy for California SIP, Section II

Table 3-7
OFF-RD LSI-2: Clean Up Existing Off-Road Gas Equipment Through Retrofit Controls [Spark-Ignition Engines 25 hp and Greater] Estimated Emission Reductions (South Coast, Summer Planning, tpd)

Pollutant	2005	2006 (Annual Average)	2008	2010	2020
ROG	Not Applicable	1	0.4-1.0	0.5-1.4	0-0.1
NOx	Not Applicable	2.5	1.5-3.0	1.5-3.5	0.2-0.4
PM10	Not Applicable	Not Quantified	Not Quantified	Not Quantified	Not Quantified

Table 3-8
OFF-RD LSI-2: Clean Up Existing Off-Road Gas Equipment Through Retrofit Controls [Spark-Ignition Engines 25 hp and Greater] Estimated Emission Reductions (San Joaquin Valley, Winter Planning, tpd)

Pollutant	2010
ROG	0.1
NOx	0.1
PM10	0

Table 3-9
OFF-RD LSI-2: Clean Up Existing Off-Road Gas Equipment Through Retrofit Controls [Spark-Ignition Engines 25 hp and Greater] Estimated Emission Reductions (South Coast, Summer Planning, tpd)

Pollutant	2005	2006 (Annual Average)	2008	2010	2020
ROG	Not Applicable	1	0.4-1.0	0.5-1.4	0-0.1
NOx	Not Applicable	2.5	1.5-3.0	1.5-3.5	0.2-0.4
PM10	Not Applicable	Not Quantified	Not Quantified	Not Quantified	Not Quantified

Table 3-10
OFF-RD LSI-2: Clean Up Existing Off-Road Gas Equipment Through Retrofit Controls [Spark-Ignition Engines 25 hp and Greater] Estimated Emission Reductions (San Joaquin Valley, Winter Planning, tpd)

Pollutant	2010
ROG	0.1
NOx	0.1
PM10	0

Emissions Calculations

Current emissions inventory for forklifts is based on tailpipe and evaporative emissions measurements of existing engines. As discussed in Chapter One, EPA uses the NONROAD2002a model to measure emissions, whereas ARB uses the OFFROAD model to measure emissions. Electric forklifts are not currently included in the inventory although ARB has indicated that they plan to add electric forklifts in the near future.

One of the problems with the current emissions modeling for forklifts (as well as other off-road vehicles) is that the many of the longer range benefits of electrics are not considered. Table 3-11 lists the qualitative pros and cons of electric forklifts when compared to ICE forklifts. There is presently no model that quantifies these factors to fully compare the cost-effectiveness of emission reductions from electric and ICE forklifts. On the other hand, the models also do not include upstream power plant emissions which would reduce the total emissions benefit.

Table 3-11
Qualitative Comparison of Electric and ICE Forklifts

	Electric Forklift	ICE Forklift
Initial cost	Higher	Lower
Fuel Costs	About $4 per shift. Electricity prices previous considered more stable than other fuels but customers need to understand load management options	Higher--$9-14 per shift
Operating Costs	Lower—Per study by National Services, Inc. difference in cost between electric and propane forklift is $1 per hour of operation. Per Yuasa, electric operating cost is 60% of ICE	Higher
Battery Capacity	Historically 6.5 hours; improved batteries are showing up to 29% increase in watt hours/lb	n/a
Noise	Quiet	Up to 85 dB

Table 3-12 Qualitative Comparison of Electric and ICE Forklifts (Continued)

	Electric Forklift	ICE Forklift
Maintenance Cost	Battery Replacement (5 Years)	Engine rebuilds (5-10 years)
Indoor Use	Zero emissions—no exhaust	Some exhaust
Outdoor Use	Viewed as not as effective for slopes, rough terrain or heavy duty applications although technology improvements may have changed this	SI viewed as best for slopes, rough terrain or heavy duty applications (diesel)
Facility Issues	May need battery room, additional batteries and battery changeout equipment	Fuel tank storage issues; higher A/C and ventilation costs
Emissions Reduction	Clean for life	Catalyst requires maintenance; emissions could worsen over life
Multiple Shifts	Requires battery changeout or fast charger—about 11 hours	Refueling approximately every 15 hours (propane)
Usable Life	11-15 years—need at least 1 new set of batteries	9 years but often used well beyond—rebuild after 5-10 years

Sources: EPRI Report, Toyota presentation; 2003 Carl Moyer Guidelines

Table 3-12 attempts to show the difference in lifetime NOx emissions and cost-effectiveness between electric and non electric forklifts. The example is based on replacing an existing forklift with a 3,000 pound electric forklift instead of a new propane forklift, The example uses a 5% year capital recovery factor and several variations on expected life and hours of operation. As shown in the Table, the project life of 5 years is the least cost-effective. A longer project life cuts the cost per ton of NOx reduced in half. In addition, the example indicates how much better a two-shift operation is, both in terms of NOx reduction and cost-effectiveness.

Table 3-13
Examples of Forklift Emissions Reduction and Cost-Effectiveness

Option	Annual operating hours per forklift	Project Life (5 years max)	Annual NOx Tons Reduced per Lift	Capital Recovery Factor	Incremental Cost per Forklift	Annualized Cost-Effectiveness per Forklift
5 year life per Moyer	1700	5	0.26	0.23	$5,307	$4,720
9 year life	1900	9	0.29	0.14	$5,307	$2,560
11 year life	1900	11	0.29	0.12	$5,307	$2,194
11 year life and 2 shifts	3400	11	0.52	0.12	$5,307	$1,226

Although it is clearly much more cost-effective to switch a forklift that operates for two shifts to electric than one that operates a single shift, many industries have been slow to adopt electric forklifts for multi-shift operations. The reasons include the cost of additional battery packs and battery swapout equipment, concerns about down time for swapouts and battery maintenance and replacement costs. Many of these concerns are being addressed by new developments in the industry such as sealed batteries and fast charging that also protects the batteries from overcharging. It is still a difficult task to convince a customer to change technologies without a regulatory requirement.

Public Policy Impacts

Because electric forklifts have not been included in either EPA's or ARB's emissions inventory, they have not be eligible to participate in a number of the opportunities and incentives available to engines. These are discussed in detail in Chapter One.

Inclusion of electric forklifts in AB&T or credit trading programs could add flexibility for manufacturers and reduce the costs of compliance. For example perhaps overcompliance with electrics by one manufacturer could be used against undercompliance on ICE engines by the same manufacturer. Or perhaps the electric manufacturer could generate credits that could be sold to another manufacturer for use in lieu of more costly compliance options. Perhaps these credits could have a limited life span so that noncompliant manufacturers must eventually comply. Another example is a manufacturer that chooses to make more electric forklifts, reducing the number of non-electrics that would need to meet the new ICE emissions standard.

Findings and Recommendations

Health and Safety

The Health and Safety benefits of electric forklifts could be promoted more vigorously. Electric forklift technologies are available today and are widely accepted. In fact, various worker health and safety rules (OSHA) now require that forklifts in certain enclosed environments be electric. It would be a logical extension of these studies to conclude that there would also be substantial health and safety benefits to electric forklifts for workers in less restrictive environments. Other studies have documented the health effects of prolonged exposure to diesel emissions even in outdoor environments. Studies of railroad, dock, trucking and bus garage workers exposed to high levels of diesel exhaust over many years demonstrated a 20 to 50% increase in risk of lung cancer or premature death.[62] Such studies could lead to a demand side mandate for electric forklifts based on health and safety considerations as well as emissions reductions. Such a requirement could be take the form of non-road fleet rules (similar to the on-road fleet rules adopted by AQMD) currently under consideration by ARB. Unlike the 1190 rules, any forklift fleet requirement would need to include private sector fleets in order to be effective.

It is recommended that EPRI review studies of health impacts of ICE forklifts or other ICE non-road vehicles in various indoor and outdoor environments to determine if additional health-related benefits for such equipment are quantifiable and may be used to market electric technologies.

Lower Life-Cycle Costs and Greater Life-Cycle Emission Benefits of Electric Forklifts

Current emissions models account for tailpipe emissions only and do not take into consideration the lower life-cycle costs and longer emissions benefits of electric forklifts. Even with the lack of full fuel cycle or life-cycle data, ARB technical staff typically finds electric forklifts to be the cleanest technology.

It is recommended that EPRI test the impact of including various life-cycle cost factors on emission reductions modeling and cost-effectiveness.

Case Study: California Incentive Program (Moyer)

The Carl Moyer Program (CMP) provides an incentive to buydown the higher initial cost of electric forklifts. The guidelines for the CMP adopted in 2000 initially <u>excluded</u> forklifts under 6,000 pounds. Thanks to a lobbying effort by SCE and others, ARB permitted a demonstration program for electric 3-6,000 pound forklifts but at a reduced cost-effectiveness limit ($3,000 dollars per ton of NOx vs. $13,600 for over 6,000 pound lift capacity) and with many restrictions. There was a significant marketing effort by utilities to forklift dealers and customers

[62] Information from Union of Concerned Scientists website, www.ucsusa.org.

during the first year of the CMP and many businesses applied for funding. Unfortunately, the program was oversubscribed and many of the applicants did not have a positive experience with the program. Among the complaints were:

- Too short lead time—did not take business budgeting cycles into account
- Lack of certainty regarding future funding since forklifts have a long life-cycle
- Delays in funding announcements
- Complexity of application form
- Failure to qualify for full funding of differential cost for single shift operation
- Confusion over 50 hp requirement since most if not all 3-6,000 pound forklifts are less than 50 hp

This case study illustrates the complexity of implementing effective incentive programs.

It is recommended that EPRI provide information to policymakers regarding the impact of removing the more stringent cost-effectiveness restrictions on electric forklifts in the CMP so that there is a level playing field.

Federal Regulations

The new federal tax deduction for equipment purchases by small businesses could be used to encourage forklift replacements.

The Energy Policy Act currently requires federal and state governments and fuel providers to convert their on-road fleets to alternative fuels. Actual results under EPACT lag far behind the targeted goals of the legislation due largely to cost and limited vehicle availability. Since EPACT does not count emissions reductions from non-road vehicles perhaps, EPACT could be amended to include allow emissions credit trading between on-road and non-road vehicles.

Congestion Management and Air Quality Mitigation (CMAQ) funds under TEA-21 could not be used for non-road vehicles since they were not classified as mobile sources. A project was rejected by FHWA as noncompliant with CMAQ because forklifts were not considered a mobile source. This classification is in conflict with EPA's regulations which count forklifts and many other types of equipment as non-road mobile sources. If the EPA definition were adopted by FHWA, forklifts and other clean non-road technologies could be eligible for CMAQ funding.

EPRI should consider providing information to the public policy makers in the following areas

- New small business capital investment provision of tax code amendments to provide greater incentives (i.e., in the form of accelerated depreciation) or partial tax credits for buying the cleanest equipment.
- Amendments to the EPACT legislation to allow non-road emissions reductions to be credited toward EPACT compliance goals.
- Justification for the inclusion of non-road vehicles in the new T-3 legislation.

Technological Advances

Electric forklifts are not currently viewed as viable replacements for outdoor or rough terrain forklifts or for lift capacities over 6,000 lbs. As the testimony at the June 26th ARB Board hearing indicated, electric forklifts are not currently accepted for all applications under 8,000 pounds and this view is prevalent among both manufacturers and users. In addition requiring manufacturers to sell only electric forklifts in the under 8,000 pounds lift capacity as recommended in the original ARB SIP measure shifts the balance of power among forklift manufacturers and raises many competitive issues that will be heavily contested by impacted propane and diesel forklift manufacturers

It is recommended that EPRI develop case studies that inform consumer about value proposition of Electric Drive Vehicle in the outdoor or rough terrain applications

4
AIRPORT GROUND SUPPORT EQUIPMENT

Introduction

This chapter addresses additional detail related to emission reduction calculation methodologies, emission inventory considerations and the regulatory framework that are specific to the airport ground support equipment (GSE) category. A special chapter is provided for GSE for two main reasons: (1) the emissions modeling and inventory methodologies vary significantly from the rest of the non-road market segment, and (2) GSE are an excellent target for electric technology implementation in light of increasing concern about airport generated pollution.

Background

Air pollution emissions from airports continue to increase as airports expand to meet the increasing demand for air travel in the United States (U.S.). As a result, airports are under increasing pressure to adopt more aggressive and stringent emission reduction strategies and programs. This is particularly true for the airports that are located within U.S. non-attainment areas.

Airport GSE represents one of the three major groups of mobile emission sources at large commercial airports. The other two sources include aircraft and ground access vehicles (GAVs). GSE contribute a small, but significant, share of hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NOx) and particulate matter (PM) emissions at many major airports. According to EPA[63], about two to three percent of total manmade emissions in a typical metropolitan area come from these three sources at airports. This share is expected to increase as air travel continues to grow, while emissions from other non-airport sources are subject to increasing stringent controls.

Airport GSE generally consists of a diverse range of vehicles and equipment that are used to service aircraft during passenger and cargo loading and unloading, maintenance, and other ground based operations. The wide range of activities associated with aircraft ground operations generally requires a mix of GSE in a fleet, each of which has its own emission performance and activity characteristics. For example, a typical activity undertaken to service an aircraft at the gate includes: cargo loading and unloading, passenger loading and unloading, aircraft refueling, food and beverage catering, engine and fuselage examination and maintenance, portable water

[63] EPA GSE Emission Studies, December 1998

storage, lavatory waste tank drainage etc. In addition, electrical power and conditioned air is generally required throughout the gate operational period for both passenger comfort and safety.

Types of GSE

There are 23 categories of GSE that operate on five different fuel/energy types: conventional fuels (diesel and gasoline), compressed natural gas (CNG), liquefied petroleum gas (LPG/propane) and electricity. A typical GSE fleet includes pushback tugs, baggage and cargo tugs, carts and lavatory carts, forklifts and lifts, ground power units, air condition units, belt loaders, fuel trucks, utility trucks, bobtail, de-icers, airstart units, and other equipment. Table 4-1 summarizes these GSE and highlights the most common electric models.

Table 4-1
GSE Categories

GSE Category	Electric	Gasoline	Diesel	CNG	LPG
Aircraft Pushback tractor	Yes	Yes	Yes	Yes	Yes
Air conditioning unit	Yes	Yes	Yes	Yes	Yes
Air start unit	Yes	Yes	Yes	Yes	
Baggage tug	Yes	Yes	Yes	Yes	Yes
Belt Loader	Yes	Yes	Yes	Yes	Yes
Bobtail	Yes	Yes		Yes	Yes
Cargo loader		Yes	Yes	Yes	Yes
Cargo tractor		Yes	Yes	Yes	Yes
Cart	Yes	Yes		Yes	Yes
Catering truck		Yes	Yes		
Deicer		Yes	Yes	Yes	
Forklift	Yes	Yes	Yes	Yes	Yes
Fuel truck		Yes	Yes	Yes	Yes
Generator			Yes		
Ground power unit	Yes	Yes	Yes	Yes	
Hydrant truck			Yes		
Lavatory truck		Yes	Yes	Yes	
Lift	Yes	Yes		Yes	Yes

Table 4-2 GSE Categories (Continued)

GSE Category	Electric	Gasoline	Diesel	CNG	LPG
Other GSE		Yes	Yes	Yes	Yes
Passenger stand	Yes				
Service truck		Yes	Yes	Yes	Yes
Sweeper			Yes		

Source; Technical data support, FAA Advisory circular, on Reducing Emissions on Commercial Aviation, September 29, 1995

GSE is generally owned by airlines, airports, cargo handlers, mail and parcel companies or management companies. A significant number of the GSE fleet is dedicated for airport use only, and therefore are not permitted to operate on public roads. However, some of the service vehicles are permitted to operate both on and off the airport airfield areas. These vehicles generally bring supplies from outside of the airport such as food, catering, fuel, and lavatory trucks.

Electric GSE is commercially available for a number of equipment types, including belt loaders, baggage tractors, aircraft tugs, lifts, and ground power units. Electrically powered versions of baggage tugs and belt loaders generally account for over a third of all GSE in use. Additionally, electric versions of the aircraft pushback tractors, air start units; conditioned air units, general-purpose vehicles, and other specialty GSE are currently available in the marketplace. Electric carts are already fulfilling about half of overall GSE cart market demand, according to EPA[64]. Several airports (including Denver, Sacramento, and Boston) have conducted electric GSE demonstration programs and fleet conversion programs during the last few years. Much of their experience to date with electric equipment has been positive.

Fixed Gate Infrastructure Support

While the majority of conventionally powered GSE can be either converted or replaced by alternative fuels or electricity, a significant fraction of GSE can be eliminated entirely by incorporating fixed-point-use support equipment into aircraft gate design. Such design not only eliminates all energy demands associated with moving displaced mobile GSE between aircraft gates and maintenance/storage facilities, but it also facilitates the use of hard-wired electrical power connections, thereby eliminating the need for recharging infrastructure. With electric GSE, there is increased demand for electrical power. However, fixed equipment is estimated to consume less power than equivalent mobile GSE.

[64] Technical Support for development of GSE Emission reductions, Sierra Research, December 31, 1998

The use of fixed gate-based power and conditioned air services is common at many airports. Many airports have gone through extensive upgrading of their gates to incorporate 400 hertz outlets to replace the use of APUs and starters.

Gate-based electrical connections eliminate not only the emissions associated with ground power units, but the majority of aircraft based auxiliary unit emissions as well. Other GSE that can be eliminated or curtailed through the use of fixed-based equipment include lavatory, fuel, water, food, and air start service equipment. In some cases, baggage tugs and belt loaders can be eliminated through the installation of centralized conveyor belt-driven baggage distribution and delivery system that moves baggage directly from the check-in counters to the gate area. These systems are expensive and cannot generally be retrofitted to existing terminal designs. However, they can, and should be incorporated into new terminal designs.

Implementation Barriers

The major disadvantage for electric GSE compared to the conventional fueled GSE is the initial up-front capital cost, which together with power infrastructure upgrades and terminal space constraints continues to prevent its widespread use at airports. One strategy to address this issue is to implement life-cycle cost analysis when evaluating electric GSE projects.

Further, the efficient use of electric GSE must be well documented. Specifically, electric GSE must show reliability that is equivalent to conventional GSE. The good news is that several demonstration programs have, or are in the process of establishing electric GSE reliability (discussed below).

Finally, additional recharging equipment and electrical facility upgrades will be required at airports to support significant electric GSE use in the future.

OEM Perspective

Many manufacturers state that environmental regulations and the need to reduce emissions at airports are the main drivers pushing their customers to consider electric and alternative fuel GSE. Other factors include adverse health effects of diesel and gasoline fumes, the improved performance of electric equipment and the promise of reduced fuel costs and lower maintenance expenses. The availability of various incentives and credits for reducing GSE emissions is also an important consideration as many of the GSE conversion projects have been co-funded by air quality districts and other airport financing programs. With an increased interest in electric GSE, some OEMs have begun to develop a growing selection of products. For other OEMs, it is still not economically viable to develop and produce electric GSE. However, over time, this trend is expected to change as the technology improves and demand increases throughout the country.

Review of Emissions Information Related to GSE

GSE emissions are not the dominant source of airport emissions. However, emissions from GSE are easier to control than the other sources of airport emissions and the conversion of GSE can provide significant reductions in the total emission levels at an airport. GSE emission estimates are generally based on airport specific GSE populations, vehicle emission rates, and the overall time (duty-cycle) of airport equipment. Equipment use varies substantially by aircraft type and size. For example, less GSE is required to service a smaller aircraft (Boeing 737, Airbus 320), compared to the number of GSE necessary to support a jumbo aircraft (Boeing 747 or Airbus 340). Equipment emissions are also influenced by time of day and seasonal operations, considering that airline schedules vary during peak and non-peak periods, and seasons of the year where weather plays a significant role. These variations in GSE activity are critical in the estimation of GSE emission impacts at major commercial airports.

Power Plants and GSE Emissions

The emissions associated with electric GSE also vary with local power generating characteristics. While electric GSE emit no pollutants in the conventional sense (i.e., tailpipe or on-board evaporative emissions), electric GSE do place an additional demand on local power generating stations as a direct result of marginal (incremental to base load) GSE electricity use. This additional demand translates to incremental power plant emissions. In spite of this, the emission reduction potential associated with the use of electric GSE is *dramatic* compared with all four internal combustion (ICE) fuels, according to the EPA[65]. This study concluded that, under any scenario, HC and CO are entirely eliminated when electric GSE is used. The same is typically true for NOx and PM relative to diesel GSE. The variation in potential NOx reductions relative to gasoline, LPG, and CNG GSE is a bit wider, but typical reductions approached 90 percent for all three fuels. The study determined that electric GSE PM reductions are typically smaller than HC, CO, and NOx reductions, but still significant.

Regulatory and Policy Framework for GSE

A review of regulatory and policy programs that drive (or have the potential to drive) electric GSE implementation are summarized below.

[65] Approaches to Controlling Emissions from GSE, K.G Duleep and Meszeler, GSE Today, April 1999.

Clean Air Act

Air travel is the fastest growing segment of the transportation industry, with the FAA forecasting a 50 percent increase in airline passengers by 2010. This growth has placed unprecedented pressure on airport capacity with almost two-thirds of the nation's 100 largest airports making plans to expand. The vast majority of these airports are located in highly polluted metropolitan areas where the approval of new growth hinges upon their ability to devise and implement innovative measures to offset adverse air quality impacts.

The expanded use of alternative fueled GSE and landside vehicle fleets presents one of the most significant and cost-effective strategies available that can help enable airports to mitigate the environmental impacts of expansion. Airports are a major source of air pollution and projected by the year 2010 to be responsible for more than ten percent of total pollution in some urban areas. This has focused increasing regulatory attention on methods for reducing airport pollution. On average, approximately 45 percent of air pollution at commercial airports is caused by landside vehicles traveling to and from the airport site; about 40 percent is generated by aircraft; 10 percent by GSE; and 5 percent by miscellaneous sources. In some cases, the contribution to air pollution by GSE is even greater. For example, in Texas it is estimated that over one-third of the total air pollution generated by Dallas- Fort Worth International Airport (DFW) comes from GSE.

Due to complications associated with international standard setting for new or existing aircraft engines, increasing attention on strategies that help reduce GSE emissions, which is can be regulated on a local or regional level, has been seen in recent years. Occupational Health and Safety (OSHA)

Airports and their tenants can also be motivated to use alternative fuels as a way of meeting the "permissible exposure limits" (PELS) established under the Occupational Health and Safety Administration for indoor air pollution.

Alternative fuel GSE can help to dramatically reduce air pollution in enclosed areas. At Denver International Airport (DIA), vehicles now convey baggage through tunnels originally designed for automated baggage conveyance systems. To keep emissions low and protect workers, DIA now requires that all vehicles operating in the tunnel be fueled either by natural gas or electricity. Vehicles are checked at regular intervals by an on-site dynamometer, which ensures that vehicles are operating at peak efficiency.

At JFK International Airport, British Cargo and Nippon Cargo Airlines converted their material handling vehicle fleets to electric GSE in order to improve indoor air quality and worker safety.

EPA and ARB Emission Standards/Regulations

Currently, there are no specific regulations or mandates that require the use of electric GSE at airports. However, EPA and ARB have adopted increasingly stringent emission standards for non-road engines including GSE. These standards will affect GSE manufacturers, who may turn to electric technologies to meet the upcoming requirements (See Chapter One for a review of these standards). The standards, which are being phased in over time, are applicable to new non-road GSE equipment powered by internal combustion engines (ICE). ICE GSE can either be powered by diesel engines (compression ignition (CI) engines) or by sparked ignited (SI) engines (which use gasoline, CNG, or propane).

As a result of EPA and ARB emissions standards means that all of today's new off-road diesel engines, including GSE engines, 50 hp and greater, have to be certified to meet NOx+NMHC emission standards of 5.6 g/bhp-hr or lower depending on the hp rating.

FAA Incentive Program (ILEAV)

The Wendell H. Ford Aviation Investment Reform Act for the 21st Century (AIR 21) (March 2000) instructed the U.S. Department of Transportation to implement the Inherently Low Emission Airport Vehicle (ILEAV) pilot program as part of the more general Airport Improvement Program (AIP). Accordingly, the FAA solicited proposals from major public use airports for ILEAV grants to support the acquisition of low emission vehicles and fuels service facilities.

Eligible airports were required to be located within an EPA-designated non-attainment area[66] for at least one of the six criteria pollutants. The most relevant to the airport emissions are ozone precursors (NOx and VOC), CO, and PM10. Non-road vehicles and equipment (i.e., GSE) vehicles were eligible under this program.

Ten airports were selected by the FAA to demonstrate the emission benefits and economic feasibility of deploying low emission vehicles certified by the EPA in place of ICE based vehicles or engines used for the same purpose at the airport. The following airports were awarded up to $2 million each for their projects: Sacramento, San Francisco, Denver, Chicago, New York Kennedy, New York LaGuardia, Baton Rouge, Dallas, Baltimore, and Atlanta. The FAA funding will be used to procure alternative fuel vehicles, including electric GSE, and also to construct alternative fuel and electric charging infrastructure. This pilot program is scheduled to conclude March 2005.

The selected airports are required to report to the FAA semi-annually to document the emission reduction benefits relative to the replaced conventional ICE vehicles. Based on the reporting up to date, the electric GSE fleet analyzed in the GSE model has been shown to generate zero tail pipe emissions.

[66] Determined National Ambient Air Quality Standards (NAAQS)

Extension of ILEAV Program/Emission Credits

Since the funding for this national program has already been awarded, there is limited opportunity to generate new emission reduction opportunities under this program. However, Congress is currently considering legislation to reauthorize the airport program. The proposed "Centennial of Flight Aviation Authorization Act" (Flight-100) would, among other safety and environmental initiatives, make permanent the ILEAV program. The Flight-100 legislation is discussed in detail below.

State and Local GSE Emission Reduction Mandates

Texas

In June of 2000, the Texas Natural Resource Conservation Commission (TNRCC) negotiated settlement agreements with Houston International and Dallas-Fort Worth International Airports, requiring that 90 percent of all GSE be alternatively fueled by 2005, as a condition of approval for airport expansion. The TNRCC estimates that the replacement of internal combustion engines with electric-powered GSE at the airports will eliminate over twenty tons per day of NOx. Strategies are also being explored to accelerate the conversion of landside vehicle fleets to alternative fuels

California - Air Quality Certificates

One way ARB has attempted to address airport related emissions is through its authority to issue state air quality certification for certain types of airport related projects. For example, ARB can make award of an airport an Air Quality Certificate (AQC) for constructing a runway contingent upon an airport establishing an emission reduction program to reduce airport-wide emissions. These emission strategies generally include the conversion of ICE GSE to electric GSE.

California - ARB and Airlines MOU

In order to achieve emissions reductions at airports located within the South Coast Air Basin, ARB, EPA, and Federal Aviation Administration (FAA) have concluded a cooperative public/private agreement with the airlines serving the five major airports in the region . This Memorandum of Understanding (MOU)67 was also signed by the airports as their cooperation is necessary for implementation of the agreement. The MOU implements emission reduction measures that are designed to achieve cleaner air in the South Coast Basin through the reduction of emissions from GSE. Under the agreement, all major airlines operating at the five major airports in the South Coast Air Basin (LAX, Ontario, Burbank, John Wayne, and Long Beach) would begin to incorporate lower emission GSE into their fleet. Section III-C of the MOU stipulates that the participating airlines will, in aggregate, have zero emission vehicles or

[67] South Coast Ground Service Equipment Memorandum of Understanding, An Innovative Agreement to Achieve Clean Air, November 27, 2002.

equipment represent at least 45 percent of new GSE purchases by December 31, 2010. Sections III-A and III-B of this MOU have also set goals for the 1997 GSE fleet to meet emission rate goals and ZEV goals by December 31, 2010. This MOU serves as an example of a program that has transferability elsewhere in the U.S.

State and Federal Tax Incentives

New York, California, and Arizona have tax incentive programs that are applicable to electric GSE. New York's program offers a 60 percent state credit to help offset the incremental cost of purchasing an AFV (capped at $5,000 for light-duty vehicles and $10,000 for heavy-duty vehicles). It also offers a 50% unlimited tax credit for the development of alternative fueling infrastructure.

Los Angeles Region

As noted above, many airports have plans to expand to meet project growth in air travel. The need for approval of Master Plans and expansion plans at many airports provide ARB, EPA and FAA an opportunity to require emissions reduction programs to mitigate the increased pollution created by expansion. Los Angeles World Airports, for example, is working aggressively with its tenants to expand the use of AFVs as criteria for proposed airport expansion and offsetting the projected air quality pacts of future growth. In the LAX Master Plan, emission reduction measures included the total replacement of conventional GSE by electric GSE. This action would result in significant emission reductions, as a result working to the benefit of the airport in its conformity analysis that is required for the Master Plan to be approved by the U.S. Department of Transportation**.**

Economic Incentives

The potential to reduce costs is the single most important factor in an airport fleet's decision to make a commitment to alternative fuels, since airlines operate in a highly competitive market. Fuel is typically one of an airline's largest ongoing operating expenses. Fleet operators are much more likely to switch to alternative fuels when the change will result in quantifiable savings that will offset incremental costs and result in increased profits. This can be accomplished through savings accrued from the fuel price differential, and by the lower maintenance costs and extended engine life attributable to the use of cleaner alternative fuels.

Fuel Cost Savings

Fuel cost for electricity is still cheaper than diesel or other gaseous fuels. In addition, in the past, the cost of electricity has been perceived to be more stable than other fuels.

Life-Cycle Cost Analysis

The initial purchase costs of electric GSE are high relative to gasoline, diesel, CNG, and LPG GSE. However, the total *net present value of lifetime cost* of electric GSE is generally lower than the conventional fueled GSE vehicles. The cost premium is almost entirely associated with the required battery pack and recharging system. The cost premium ranges from $8,000 for a diesel-powered tractor to about $13,000 for a gasoline powered tractor. The initial price premium is compounded by periodic battery replacement requirements (usually every five years) that are twice as expensive as the alternative engine replacement or rebuild requirements associated with conventionally fueled GSE.

However, these cost premiums are balanced by a substantial reduction in fuel cost over the life of the equipment. Electric GSE uses no fuel during idle periods, which can comprise as much as 50 percent of the typical GSE operation. Based on an average fuel cost of $0.45 per kilowatt-hour, the overall fuel savings associated with high-use GSE operations such as a baggage tractor can range from $2,500 per year for diesel GSE (average use would save about $1,000 per year) to over $6,000 per year for gasoline and CNG equipment.

Maintenance requirements of electric GSE are also improving, especially with the latest generation of electric GSE technologies. Maintenance costs are estimated to be reduced by as much as two-thirds relative to gasoline and diesel powered GSE. First generation electric GSE were prone to high maintenance. Users of second-generation electric GSE have reported significant improvements in all three areas of long-term maintenance cost reduction[68]. Electric GSE batteries require frequent maintenance to ensure long battery life. In the 2001 San Francisco International Airport (SFO) ILEAV study, electric GSE showed the lowest life-cycle costs. For highly trafficked airports, electric GSE is the lowest cost option according the ILEAV study.

Airport GSE Emission Modeling and Calculation Methodologies

Below is a detailed discussion of GSE emission calculation methodologies and the two major GSE models used to measure the impact of emission reduction programs at airports.

Currently, there are two main emission models developed by the Federal Aviation Administration (FAA) for use by airports that facilitate assessment of GSE air quality impacts. These include the Emission Dispersion Modeling System (EDMS) and the EPA GSE Model Version 1. It is important to note that there are also specialized spreadsheet models that are used to estimate emission levels of specific projects and policy strategies that are requested by airports, FAA, EPA, or regional air quality management districts. These models are usually customized by independent consultants or airport staff to fulfill specific tasks at a specific time.

The wide range of activities associated with aircraft ground operations lead to an equally diverse fleet of GSE, where each individual equipment or vehicle has its own activity characteristics and

[68] Southwest Airlines, Sacramento Airport, and July 2003

emissions performance. To calculate emissions from GSE operations at airports, a number of factors are used to determine what method of calculation should be used and what assumptions should be considered. These are primarily based on the type of GSE and fuel type.

Fossil Fueled GSE (Baseline) Emission Vehicle System Calculation Methodologies

For conventional fuel GSE (which is needed as the baseline for calculating reductions), the factors that determine the quantity of pollutants emitted are the emission factors, average rated brake horsepower, load factor, and usage (i.e., activity). Accurately characterizing the emissions performance of a particular GSE requires detailed knowledge in two specific areas: 1) the rate of equipment emissions per unit of activity and 2) the amount of activity performed during the period of operations.

The unit activity emissions rate can be either measured directly or estimated from previous measurements taken for similar equipment engines. In other words, emissions measurements for GSE are usually measured in terms of grams of emissions per brake horsepower-hour of work performed (load factor). See Chapter 2 for additional discussion of load factors.

The following equation is typically used to calculate the pollutant emissions from an individual unit of equipment[69]:

$$E\,t = (BHPt \times LF\,t \times U\,t \times EI\,t) \times CF \qquad \textbf{Equation 4-1}$$

Where: **E t** is emission per year of pollutant, in pounds, produced by GSE type t

BHPt is the average rated brake horsepower of the engine of the equipment type t

LFt is the load factor utilize in GSE operations for equipment type t

U t is the annual hours of use for equipment type t

EI t is the emission index (or emission factor) for pollutant i in grams per BHP which is specific to a given engine size (and engine vintage for diesel engines) and fuel type.

i is the pollutant type (HC, CO, NOx, PM, SO2)

t is the equipment type (e.g. Diesel baggage tug)

CF is 0.0022046 unit conversion factor from grams to pounds

[69] Technical data to support the FAA's Advisory Circular in reducing emission from commercial aviation, Energy and Environmental Analysis, September 29, 1995). This report was prepared for the EPA Motor Vehicle Fuel Emission Lab in cooperation with the FAA.

Electric GSE Emission Vehicle System Calculation Methodologies

In the case of electric GSE, overall emission reductions are evaluated based on two key factors: 1) the emission performance of the equipment being replaced or converted, and 2) the specific power generating characteristics of a region in which the airport is located since the tailpipe emissions of the GSE are zero. For electric GSE, the quantity of emissions due to the generation of electricity to recharge GSE is determined by the emission factor(s) of the electric power plant(s) and the overall amount of electricity from each plant that is consumed by the GSE.

The electricity used at the airport comes from a mix of local and regional power supplies. The emissions generated at the power plant depend on the power generation technologies, fuel used, and emission controls. These factors vary from region to region in the U.S. Airports served by relatively low emitting power generation facilities will produce larger emission reduction benefits from electric GSE than will be achieved in areas served by older, higher emitting power plants. While HC and CO emission reduction are significant (almost 100 percent) regardless of local power generating facilities, NOx, PM, and CO2 reductions can vary considerably as a function of power generation technology.

The best case scenario in the model assumes potential GSE electrical demand is satisfied by a natural gas generating station that employs maximum air quality controls. Conversely, the worst case scenario assumes GSE electrical demand comes from a coal generating facility under essentially uncontrolled conditions. The average case represents a more typical level of utility emissions based on actual rates for a geographically diverse sample of utilities.

The emission reduction benefits of electric GSE rely solely on the assumptions and factors related to power generation emissions. Any improvements in the methodology should focus effort in this area.

To calculate total displaced emissions, the emission rate per unit time (e.g. pounds per year) is aggregated over the total time such emission would have accrued.

The following equation is used to calculate electric GSE emissions:

$$Eg = Ut \times Eig \qquad \textbf{Equation 4-2}$$

Where,

Eg – emission of pollutant **i**, in pounds, attributable to the use of GSE type **t** **(**e.g. electric baggage) for a given time period

Ut – megawatt hours of electricity used by equipment type **t**

Eig – emission index (or emission factor) for pollutant **i** in pounds per megawatt hour or electricity consumed. These factors are built-in for coal and natural gas power plants and take into account the types of controls established at those plants.

i – pollutant type (HC, CO, NOx CO2)

t – equipment type (e.g. electric baggage tug)

FAA EDMS Model

The EDMS is the most widely used emission model for airport air quality analysis. This model is used to estimate airport-wide emission levels for master plan projects and programs, as well as airport site-specific projects. The EDMS was developed by the FAA in cooperation with the U.S. Air Force (USAF) in the mid-1980s as a complex microcomputer model to assess the air quality impacts of proposed airport development projects. It has since been the FAA preferred model for airport air quality analysis. In 1993, the EPA formalized the EDMS as EPA's preferred Guideline model for use in civil airport and military base assessments. In response to the growing needs of the air quality analysis community and changes in regulations, the FAA in cooperation with the USAF, re-engineered and enhanced EDMS in 1997 to create EDMS Version 3.0[70]. This version was built under the guidance of a government and industry advisory board composed of experts from the scientific, environmental policy, and analysis fields. Since then, EDMS Version 3.2 was developed and used in the preparation of the LAX Master Plan Environmental Impact Statement and Environmental Impact Report[71].

The EDMS assesses the air quality impacts of airport emission sources, particularly aviation sources, which consist of aircraft, auxiliary power units, and GSE. EDMS also offers the capability to model other airport emissions sources that are not aviation-specific, such as power plants, fuel storage tanks, and ground access. EDMS analysis is conducted to satisfy the National Environmental Protection Act (NEPA) and general conformity requirements under the Clean Air Act of 1990.

The EDMS is not currently designed to perform air toxics analyses for aviation sources and must be supplemented with other air toxic evaluation methodologies and models in consultation with the appropriate FAA regional program office.

Emissions from GSE are measured using the FAA and EPA accepted test procedures. Assignment of GSE to an aircraft and associated usage times are made based on site-specific data developed for a project at an airport. For example, a master plan project would require data for existing GSE for all aircraft using gates at the terminal and remote locations. Default values used by the EDMS model are normally used to supplement the site-specific data as needed.

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[70] Emission and Dispersion Modeling System Policy for Airport Air Quality Analysis, Interim Guide to the FAA Orders 1050.1D and 5050.4A, April 13, 1998.

[71] LAX Mast Plan EIS/EIR, Camp Dresser McKee, July 2003.

Basic EDMS Methodology

Emission factors for gasoline and diesel powered GSE are obtained from the EDMS. The penetration or future use and electric GSE are usually provided by the airport or from independent studies. In addition to emission factors identified by state agencies such as ARB, literature searches are conducted to identify other appropriate emissions factors for alternative fuel GSE. Emissions are based on the alternative fuel type, brake horsepower, and time-in-mode. Zero emission is assumed for electric powered GSE.

A central system replacing ground power units (GPU – ground units with portable generators that can be used to provide power to aircraft parked at the gate) as well as most aircraft Auxiliary Power Units (APUs) usage at the terminal gates are generally assumed for project alternatives being compared to the preferred project. Gate electrification is also assumed if the airport is proposing to implement future electrification programs.

Pollutant emissions are calculated using a methodology accepted by the EPA and the FAA for emergency generators, air starts units (ASU-ground units used to start aircraft turbofan engines), and air conditioning (AC) units. Emissions are calculated based on the generator or engine/turbine power rating, usage rate, and pollutant emission indices based on power output and fuel type. Any air pollution control equipment in use at the airport, or required in the future as identified in the regional air quality district, state air resources agency (e.g. ARB), or EPA rules and regulations are incorporated into the model.

The equipment capacities, typical operating hours, and pollution controls are based on the existing condition survey of GSE at the airport. Future condition emissions are also based on the number of aircraft operations for each alternative project at the airport. The uncontrolled emissions factors are obtained from EPA's Compilation of Air pollutant Emission Factors. Cargo and general aviation gates are generally assumed to have power connections and can run on-board AC units.

The EDMS model measures five criteria pollutants, including SO2, CO, PM10, NO2 and O3. The evaluation of O3 is conducted using the standard practice of evaluating volatile organic compounds (VOC) and NOx, which are key components of the formation of ozone. Fuel consumption is not a major emphasis of the model; though it can be calculated with the models input factors and equipment's brake specific fuel consumption.

The emissions estimates are categorized for each alternative in terms of on-airport operational emissions, off-airport operations emissions, and construction related emissions. The on-airport operational emissions include GSE activity. All equipment activity is quantified in hours. In addition, dispersion analyses are conducted to estimate the resultant concentrations of pollutants, once emitted into the atmosphere, and these concentrations are compared to the State and National Ambient Air Quality Standards.

FAA ILEAV GSE Model

A more specific emission model used for GSE projects at major airports is the EPA ILEAV GSE Model. The ILEAV GSE model is required in the FAA ILEAV Grant Program. This model was used specifically to estimate GSE emissions resulting from the replacement of conventional fuel with alternative fuel GSE including CNG, LNG, LPG, and electric[72]. This analysis produces results that are specific to the equipment being replaced, converted or added to the GSE fleet.

The ILEAV GSE Model was developed by Sierra Research for the EPA Office of Transportation and Air Quality to be used as a planning tool by metropolitan planning organizations. The model is a Microsoft Excel Spreadsheet Model that includes emission factors, equipment activity, and population profiles from the EPA's NONROAD Emission Inventory Model. GSE emissions factors are standardized in grams/hour (g/hr). Annual load factors and mileage accumulation data are used to obtain total annual emissions. The model includes 23 categories of GSE and compares five different fuel/energy types: gasoline, diesel, LPG, CNG, and electric. The model has two options for the gasoline fueled GSE: two-stroke and four-stroke engines. Vehicles covered are typically equipped with an odometer and not driven on-road or regulated as on-road vehicles.

The model assesses four criteria pollutants including hydrocarbons (VOC), NOx, CO, and PM. The model does not calculate SO2. Instead, FAA requires a detailed set of worksheets to be completed to estimate the SO2 emission reductions associated with GSE vehicles. These worksheet factors are based on the sulfur content in the fuel. The model calculates emissions based on several input parameters describing the existing and replacement equipment, which include electric technology and the expected life of the battery. The model applies a load factor for the engine and horsepower of the engine where the hours of vehicle operation are generally known. This methodology is utilized because a significant number of GSE operations take place while the vehicles are stationary, resulting in less mileage accumulation. In fact most GSE equipment is equipped with an hour-meter instead of an odometer.

The results of each analysis, for each pollutant, are grouped in either Level One or Level Two categories, depending on whether the pollutant is responsible for non-attainment status of the region. Level One includes emission reductions due to the project for the criteria pollutants associated with nonattainment status. These pollutants represent the area's most serious emissions. Level Two includes reductions from the project for the remaining criteria pollutants (i.e., pollutants not associated with non-attainment status). The ILEAV model then evaluates the Level One and Level Two emissions separately, and for the total overall program benefits.

One of the unique and beneficial differences in the ILEAV model is the inclusion of life-cycle cost analyses, which also include an estimate of the upstream emissions of the power generation facilities that supply the electric power to the project vehicles (i.e., well-to-wheels, or WTW). This approach recognizes that electric motors do not produce emissions at their activity center, but combustion emissions are generated at electric power generation stations which produce the electricity used by the electric GSE.

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[72] Methodology for Calculation of Emission Benefits and Project Costs, FAA, November 2000

Still, it is important to realize that the full fuel cycle analysis is not conducted for petroleum or other alternative fuels (CNG, LNG or LPG). As such, the model is not conducting an "apples-to-apples" comparison. Luckily, electric GSE continue to fare well in the analysis in spite of this inconsistency.

The economic analysis determines the total amount of emission reductions with the ILEAV funding (i.e., the differential replacement cost of low emission vehicles versus conventional fueled vehicles). The model also analyses the economic sustainability of the project (i.e., life-cycle costs) as determined by calculation of capital cost recovery and an annual net operating costs or income. The input for the cost analysis includes purchase price, replacement/rebuild cost, unit fuel cost, unit maintenance cost, discount rate, electricity use, and unit of electricity cost.

The ILEAV model analyzes CO, PM, SO2 and O3 precursors (NO3 and HC) emissions. Of these criteria pollutants, O3, CO, and PM are generally of greatest concern at airports.

ILEAV Model Results

In the San Francisco Airport ILEAV GSE emission analysis, the model showed 100 percent emission reductions for electric GSE that would be used as a replacement for diesel fueled GSE[73]. For example, the replacement of nine diesel belt loaders by nine electric GSE in Table 4-2 showed a significant reduction in tons per year by pollutant type: HC 0.44 tons, CO 1.63 tons, NOx 3.57 tons, and PM 0.50 tons. Four 4-stroke gasoline baggage tugs replaced by four electric GSE in Table 4-3 showed a significant decrease in emission tons per year: HC 6.65 tons; CO 140.75 tons; NOx 3.03 tons; and PM 0.05 tons.

Table 4-3
Nine Diesel Fueled Belt Loaders Replaced by Nine Electric Belt Loaders

Pollutant	Emission reduction (tons/yr)	Costs	NPV Lifetime Costs ($)-Diesel	NPV Lifetime Costs ($)-Electric
HC	0.44	Purchase	252,000	284,904
CO	1.63	Replacement	28024	20,990
NOx	3.57	Fuel	131,608	6
PM	0.50	Maintenance	278,943	200
		Total	690,575	270,099

Source: SFO ILEAV Grant Application Proposal GSE Model, February 2001

[73] San Francisco International Airport ILEAV Study, Calstart, February 2001

Table 4-4
Four 4-Stroke Gasoline Baggage Tugs Engine Replace by Four Electric Baggage Tugs

Pollutant	Emission reduction (tons/yr)	Costs	NPV Lifetime Costs ($)-Diesel	NPV Lifetime Costs ($)-Electric
HC	6.65	Purchase	100,000	102,527
CO	140.75	Replacement	5,231	15,545
NOx	3.03	Fuel	229,385	3
PM	0.05	Maintenance	428,035	94
		Total	816,650	118,213

Source: SFO ILEAV Grant Application Proposal GSE Model, February 2001

As expected, the total *net present value of lifetime cost* of electric GSE is generally lower than the conventional fueled GSE vehicles as shown in the Tables 4-3 and 4-4. Even though electric technologies have higher up front purchase (capital) and replacement costs compared to diesel and gasoline vehicles, the fuel and maintenance costs are generally much lower for electric GSE, if considered over the lifetime of the vehicles.

Fuel Cycle GSE Emission Calculation Considerations

The GSE calculation methodologies are among the only emissions models to include “upstream” and “downstream” emissions. (See Chapter One for discussion of other emission models). As discussed above, the EDMS and ILEAV models do consider the WTW emissions of electric GSE, in order to assign emissions to electric vehicles. It is noteworthy that these models do not implement a similar analysis for the fossil fuel baseline or alternative fuel cases.

Emission Credit Trading Relative to GSE

As indicated earlier, Congress is currently considering legislation to reauthorize the airport program. Specifically, the "Centennial of Flight Aviation Authorization Act" (Flight-100) would, among other safety and environmental initiatives, make permanent the ILEAV program.

In its current form, Flight-100 includes a program that allows airports to receive EPA emission credits for the voluntary emission reductions achieved with the FAA funds.

This concept is unique, since it is traditional for funding agencies to retain the emission reductions (or credits) generated from a project their funding helps implement.

It is recommended that EPRI participate in the analysis of emission credits and provide information to public policy makers on the potential value to airports to retain the emission credits. An airport emission credit program will have three significant benefits to electric GSE markets:

- Government funding to support the implementation of electric GSE (and other alternative fuels).
- The ability to generate emission reduction credits for use by airports, perhaps to be sold to other interested parties (depending on the terms of the agreement).
- It will act as a precedent for the idea that technology implementers retain emission reduction credits, in spite of the use of government co-funding to implement the project.

Recent Airport Success Case

In 2002**,** Sacramento County Airport System (SCAS) together with ARB, Electric Transportation Engineering Corporation (ETEC), Southwest Airlines (SWA), Defense Advanced Research Projects Agency (DARPA), and Sacramento Municipal Utility District (SMUD) funded an electric GSE demonstration project at Sacramento Airport (SMF). The purpose of the project was to demonstrate the reduction of airport emissions from GSE. The project established a fleet of twelve electric baggage tractors that utilized the fast charge Energy Delivery System (EDS) developed by ETEC. The project was designed to fully integrate the electric GSE with SWA management system, human resources, and operating strategies. During the project, an additional thirteen electric bag tractors were added, in addition to laboratory and field testing of sealed lead-acid battery modules. The EDS is equipped with four charge ports to which GSE vehicles can be connected for battery charging.[74]

The project successfully demonstrated that electric GSE can successfully replace fossil-fueled GSE in normal operations at SMF. While the charger was seen by SMF as a large electric load, its effects on the supply grid's power quality was found to be minimal. Furthermore, additional cost of electric energy required for the project was more than offset by the fossil fuel cost savings, which resulted in a net savings of about $1,277 per year per bag tractor. The optimized battery pack demonstrated excellent performance, and cycle life during the project was projected to result in 40 percent savings in initial battery cost. The emission savings for the 25-unit fleet were estimated to be about 343 tons for CO, 16 tons for HC, and 7.4 tons for NOx.

As a result of this success, SWA has increased the number of electric GSE at SMF and has installed an EDS at Ontario. ETEC is now offering the EDS as a commercial product to the airline industry.

[74] Demonstration of the use of Fast Charged Electric GSE as a means of reducing airport emissions, Electric Transportation Engineering Corporation, January 31, 2002

Airport GSE Recommendations

Opportunities for GSE Aftermarket Conversion to Electric

Virtually all GSE, regardless of current fueling options are candidates for conversion to electric power or replacement with electric powered equipment. GSE manufacturers currently offer an electric power option on a wide range of equipment types while several firms offer after-market conversions to electric power[75].

GSE conversion generally requires the removal of the internal combustion engine and fuel storage tanks to obtain sufficient room to install the necessary electric motor, motor controller, and battery pack. Some equipment types and configurations may not be able to store sufficient battery capacity to fulfill required service demands within existing space limitation. As a result of these constraints, the ability to convert specific GSE to electric power would require a detail review of the candidate equipment. Replacing or converting GSE should be based on the use of the equipment. Equipment that is continuously in service will require quick turnaround battery replacement facilities, quick recharge capability, or the availability of fully charged backup equipment. Most GSE will require between one and five charging cycles a day, thereby, requiring charging facilities in close proximity to the operators, in some cases requiring fast-charging capability.

GSE Modeling

Considering the extensive peer review that each of the GSE models has undergone over the years and the fact that airport activity involves many assumptions relating to traffic, airfield, airspace, air quality, noise etc., no specific recommendations are made for model algorithm improvement. Further, major changes for the EDMS and GSE Models are initiated by the FAA and EPA; model revisions have historically been conducted every two to four years.

However, as with all models, there is always room for improvement of input factors. Specific to GSE, improvements in load factors is desirable, though an extensive data collection effort at all the airports and power plants would be required to accurately establish factors under various operational scenarios. EPRI should evaluate the cost-benefit of such a data collection effort.

Direct Financial Subsidy

Direct financial subsidies (or incentives) could be used to assist airlines in the procurement of electric GSE through financial assistance from the airport or air quality districts. Airports can also support with infrastructure development costs, for example paying for upgrading of power supplies to facilities and buildings to accommodate recharging facilities.

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[75] Technical Support for Development of Airport GSE, EPA Contract No 68-C7-0051, Sierra Research Inc. December 31, 1998

Tax Credits/Incentives for Purchasing Non-Road Electric Vehicles

Government entities can provide tax credits for price differences between buying electric GSE and buying a similar gasoline or diesel GSE. This would encourage airlines and ground operators to accelerate the deployment of electric GSE at many of their airport facilities throughout the country.

Provide Free Chargers and Infrastructure Upgrades

Airports can procure chargers and enter into an agreement with the airlines to operate the chargers as long as the chargers remain at the airport. Power upgrades at terminals and other ancillary facilities at airports provide an opportunity for ground crews to operate more efficiently. For example, ground crews can perform opportunity charging of one to four electric GSE using fast chargers. To support this effort, airports would have to work with their tenants to evaluate the costs and resources required to upgrade power supplies at their facilities. These efforts would also include gate electrification (400 hertz) to provide conditioned air units, air start units, and ground power units to service the aircraft.

Recommended EPRI Actions

EPRI should develop an alliance with FAA to perform a review of the ten approved ILEAV projects in the context of evaluating the ILEAV model as a useful WTW analysis tool. Special emphasis should be placed on those ILEAV-program airports which have applied to deploy significant number of electric GSE. This review would look at the assumption and methodologies applied in calculating and allocating electric GSE emissions to power generating facilities.

EPRI should also work with the airports and airline trade groups such as the Airline Transport Association (ATA), Airport Council International (ACI), and the association of American Airport Executives (AAAE) to review aviation related emissions reductions opportunities in the airport environment.

EPRI should conduct a review of case studies in other parts of the world such as Zurich, Switzerland, Frankfurt, Germany, and London, UK to assess what those airports are doing to reduce GSE emission impacts by using electric GSE. These airports have taken the initiative to reduce both landside and airside emissions by applying a mix of strategies including electric vehicles use at their airports.

A
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