State of California
AIR RESOURCES BOARD

Evaluation of the Feasibility, Cost-Effectiveness, and Necessity of Equipping Small Off-Road Diesel Engines with Advanced PM and/or NO_X Aftertreatment

RESEARCH PROPOSAL

Resolution 14-9

May 22, 2014

Agenda Item No.: 14-4-1

WHEREAS, the Air Resources Board (ARB) has been directed to carry out an effective research program in conjunction with its efforts to combat air pollution, pursuant to Health and Safety Code sections 39700 through 39705;

WHEREAS, a research proposal, number 2770-278, entitled: "Evaluation of the Feasibility, Cost-Effectiveness, and Necessity of Equipping Small Off-Road Diesel Engines with Advanced PM and/or NO_X Aftertreatment," has been submitted by the University of California, Riverside; and

WHEREAS, the Research Division staff has reviewed Proposal Number 2770-278 and finds that in accordance with Health and Safety Code section 39701, research is needed to improve ARB's understanding of small off-road diesel engine emissions. Results from this project will consist of nitrogen oxides (NO_X) and particulate matter (PM) emissions data for small (less than 37 kilowatts) off-road diesel engines, both with and without emission control technologies such as Diesel Particulate Filters and Selective Catalytic reduction. Results will include a detailed cost-benefit analysis of such controls, and predictions of their economic effects (i.e., consumer choices, manufacturer market share). Furthermore, results will inform ARB policy makers about the effectiveness of stricter emission standards and the advanced aftertreatment technologies that they would necessitate. Research Division staff recommends this proposal for approval.

WHEREAS, in accordance with Health and Safety Code section 39705, the Research Screening Committee recommends for funding:

> Proposal Number 2770-278 entitled "Evaluation of the Feasibility, Cost-Effectiveness, and Necessity of Equipping Small Off-Road Diesel Engines with Advanced PM and/or NO_X Aftertreatment," submitted by the University of California, Riverside, for a total amount not to exceed $800,000.

NOW, THEREFORE, BE IT RESOLVED that the Air Resources Board, pursuant to the authority granted by Health and Safety Code section 39703, hereby accepts the

recommendations of the Research Screening Committee and Research Division staff and approves the following:

> Proposal Number 2769-278 entitled: "Evaluation of the Feasibility, Cost-Effectiveness, and Necessity of Equipping Small Off-Road Diesel Engines with Advanced PM and/or NO_X Aftertreatment," submitted by the University of California, Riverside, for a total amount not to exceed $800,000.

BE IT FURTHER RESOLVED that the Executive Officer is hereby authorized to initiate administrative procedures and execute all necessary documents and contracts for the research effort proposed herein, and as described in Attachment A, in an amount not to exceed $800,000.

I hereby certify that the above is a true and correct copy of Resolution 14-9 as adopted by the Air Resources Board.

Tracy Jensen

Tracy Jensen, Clerk of the Board

Attachment A

"Evaluation of the Feasibility, Cost-Effectiveness, and Necessity of Equipping Small Off-Road Diesel Engines with Advanced PM and/or NO_X Aftertreatment"

Background

Off-road diesel engines are an important source of nitrogen oxides (NO_X) and particulate matter (PM), both nationally and within California. The development of emissions factors and inventories for off-road equipment has been more challenging than for on-road vehicles due largely to both the variability in the types of off-road diesel engines, and variability in operating conditions that are difficult to replicate during controlled dynamometer tests.

In California, the majority of mobile source off-road diesel engines sold as new after 2011 are subject to federal and State regulations that require compliance with stringent Tier 4 PM and NO_X exhaust standards. These standards generally require the use of advanced aftertreatment technologies, such as Diesel Particulate Filters (DPF) for PM removal and Selective Catalytic reduction (SCR) for control of NO_X. However, off-road diesel engines less than 37 kilowatts are allowed to certify with emissions at higher levels due to the belief that advanced aftertreatment could severely impact the cost of these smaller engines. A Regulatory Impact Analysis (RIA) estimated the costs of anticipated emission control technologies that were not in wide production when Tier 4 standards were implemented in 2004. However, some of the control technologies anticipated in the RIA are now common today in both the off- and on-road diesel sectors. This project will examine the potential for more stringent exhaust standards for the less than 37kW off-road engine sector, in light of the "economies of scale" of today's market, as well as the availability of additional exhaust control strategies and techniques that were not evaluated in the RIA.

Objectives

The goal of this study is to evaluate the potential effectiveness, feasibility, and cost effectiveness of implementing regulations to control emissions from mobile off-road diesel engines with rated powers of less than 37 kilowatts. Such regulations would essentially require the use of advanced emission control strategies such as DPFs and SCR. Specific objectives include: a comprehensive review of available aftertreatment and other technologies; a demonstration of selected aftertreatment technologies on actual engines; verification of the emissions performance of these devices through a series of emissions and durability tests; evaluation of the potential impacts on the emissions inventory; and evaluation of the impact of potential costs on the small engine marketplace and consumer choice.

Methods

The project will consist of the following major tasks: 1) Prescreening for cost-effective controls; Test method development; Testing of small off-road diesel engines; Cost/benefit analysis of advanced emission control strategies for small off-road diesel engines; 2) Determination of the impact of feasible emission control measures on the

emissions inventory and air quality; and 3) Determination of how new regulatory control measures could affect consumer choices and manufacturer market share.

The research team will review existing and emerging emission control technologies that could be employed on off-road diesel engines with power ratings of less than 37 kilowatts to significantly reduce PM and NO_X. They will then select at least seven new less than 37 kilowatts diesel engines that can be operated with either one or a combination of the emission control technologies (i.e., DPFs and SCR) previously identified by the contractor as effective and reasonable. Emissions from these engines will be measured at least three times over the course of at least 1,000 hours of actual operation. A cost-benefit analysis will be performed based on these results along with consultation with individual manufacturers.

The research team will then work with the ARB's diesel engine modeling staff and new engine certification staff to determine the environmental impact of the tested emission controls on small diesel engines. Specifically, ARB's Diesel Off-road On-line Reporting System will be used to estimate the population of relevant engines. Contractors will then use these populations and the measured emission rates as inputs to a dispersion model such as the United States Environmental Protection Agency's Community Multi-scale Air Quality (CMAQ) Model to produce air quality predictions.

Finally, the research team will gauge how the implementation of stricter PM and NO_X standards would influence the economic interests of small off-road diesel engine manufacturers. To accomplish this, the team will rely on existing relationships with these manufacturers and their trade associations, including the Outdoor Power Equipment Institute, the Association of Equipment Manufacturers, and the Engine Manufacturers Association. Based on input from these groups, the contractor will predict the influence of such standards on both consumer choice and manufacturer market share.

Expected Results

The results from this project will consist of NO_X and PM emissions data for small (less than 37 kilowatts) off-road diesel engines, both with and without emission control technologies such as DPFs and SCR. They will include a detailed cost-benefit analysis of such controls, and predictions of their economic effects (i.e., consumer choices, manufacturer market share).

Significance to the Board

Ambient PM is associated with adverse health effects. Elevated NO_X can lead to ozone production and can result in formation of secondary PM nitrate aerosol. Much progress has been made in recent years in reducing the PM and NO_X emissions for on-road diesel engines. Regulation of off-road engines has lagged slightly but is beginning to catch up. However, small off-road engines have been largely exempted from the strictest emissions standards. This project will provide both more accurate estimates of the contributions of small engines to ambient PM and NO_X, as well as the economic effects of Tier 4 (or similar) standards applied to these engines. Results from this

project will inform ARB policy makers about the effectiveness of applying new emission standards to small diesel engines.

Contractor:
University of California, Riverside

Contract Period:
36 months

Principal Investigator (PI):
Thomas Durbin, Ph.D.

Contract Amount:
$800,000

Basis for Indirect Cost Rate:
The State and the UC System have agreed to a ten percent indirect cost rate.

Past Experience with the Principal Investigator:
ARB staff have successfully managed several previous contracts with Dr. Thomas Durbin that have estimated emission rates from off-road diesel engines. This new project will build on these previous projects.

Prior Research Division Funding to the University of California, Riverside:

Year	2013	2012	2011
Funding	$ 777,062	$ 0	$ 390,004

BUDGET SUMMARY

University of California, Riverside

"Evaluation of the Feasibility, Cost-Effectiveness, and Necessity of Equipping Small Off-Road Diesel Engines with Advanced PM and/or NO_X Aftertreatment"

DIRECT COSTS AND BENEFITS			
1.	Labor and Employee Fringe Benefits	$ 261,402	
2.	Subcontractors	$ 0	
3.	Equipment	$ 55,615	
4.	Travel and Subsistence	$ 3,425	
5.	Electronic Data Processing	$ 0	
6.	Reproduction/Publication	$ 0	
7.	Mail and Phone	$ 0	
8.	Supplies	$ 8,050	
9.	Analyses	$ 278,184[1]	
10.	Miscellaneous	$ 139,623[2]	
	Total Direct Costs		$ 746,299
INDIRECT COSTS			
1.	Overhead	$ 53,701	
2.	General and Administrative Expenses	$ 0	
3.	Other Indirect Costs	$ 0	
4.	Fee or Profit	$ 0	
	Total Indirect Costs		$ 53,701
TOTAL PROJECT COSTS			**$ 800,000**

[1] The laboratory testing will be conducted in the Center for Environmental Research and Technology's (CE-CERT) Vehicle Emissions Research Laboratory, which has an hourly rate of $590. The in-use testing will be conducted with PEMS, which have daily rates for their use ($3000/day) and also for preparing to test ($1500/day).

[2] Miscellaneous costs are for rental of CE-CERT, which is an off-campus facility and therefore requires a rental fee of 26 percent of the modified total direct costs.