PROPOSED

State of California
CALIFORNIA AIR RESOURCES BOARD

Hybridization and Full Electrification Potential in Off-Road Applications

RESEARCH PROPOSAL

Resolution 18-39

October 25, 2018

Agenda Item No.: 18-8-1

WHEREAS, the California Air Resources Board (CARB or Board) 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 2818-289, titled "Hybridization and Full Electrification Potential in Off-Road Applications," has been submitted by the University of California, Riverside for a total amount not to exceed $350,000;

WHEREAS, the Research Division staff has reviewed Proposal Number 2818-289 and finds that, in accordance with Health and Safety Code section 39701, the results of this study will provide CARB with a roadmap for future incentive programs that will help meet its air quality and climate goals by accelerating electrification of the off-road fleet; and

WHEREAS, in accordance with Health and Safety Code section 39705, the Research Screening Committee has reviewed and recommends funding the Research Proposal.

NOW, THEREFORE BE IT RESOLVED, that CARB, pursuant to the authority granted by Health and Safety Code section 39700 through 39705, hereby accepts the recommendations of the Research Screening Committee and staff and approves the Research Proposal.

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 Proposal as further described in Attachment A, in an amount not to exceed $350,000.

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Identification of Attachments to Board Resolution 18-39

Attachment A: "Hybridization and Full Electrification Potential in Off-Road Applications" Summary and Budget Summary

ATTACHMENT A

"Hybridization and Full Electrification Potential in Off-Road Applications"

Background

California has set ambitious goals to reduce greenhouse gas (GHG) emissions as defined in Assembly Bill (AB) 32 and to achieve air quality goals by meeting National Ambient Air Quality Standards. The goals will be achieved using a mixture of regulatory strategies and incentives. As a significant source of GHG and criteria pollutants, the off-road sector is an important target for emissions reductions. However, off-road equipment has a wide variety of applications, engine sizes and configurations, making it a challenge to characterize their operations, energy demands, and duty cycles. Additionally, engine and equipment manufacturers vary in their size and market share, and smaller businesses may be significantly impacted by new emissions regulations. In order to design incentive programs or regulations that will move this sector toward a cleaner and more sustainable future, a comprehensive study is needed to determine both the technological and economic feasibility of hybridizing or fully electrifying off-road equipment. For the technological considerations, the activity and load factors of typical off-road equipment need to be characterized and understood. Additionally, new infrastructure requirements and solutions should be considered in the feasibility analysis. This will help determine what GHG and criteria pollutant reductions could be achieved and whether currently available technology can be implemented to replace fossil fuel engines in the various equipment types and vocations. A cost-benefit analysis will need to examine the cost of new hybridized or electrified equipment, supporting infrastructure, and whether these new technologies incur additional or reduced operational expenses.

Objective

The objective of this study is to propose previously unexplored pathways for hybridization and electrification in off-road equipment that maximize climate and air quality benefits while remaining both technically and economically viable.

Methods

The contractor shall examine the current off-road equipment inventory and perform a market share analysis to determine which sectors emit a significant fraction of GHGs and criteria pollutants. The contractor will perform an electrification/hybridization feasibility analysis by identifying applications are well on their way toward electrification and determine what factors lead to electrification. The contractor will use extensive off-road activity and emissions data to determine the representativeness of standard duty cycles or create new duty cycles if needed. This information will help them parse the energy demands of different off-road applications. They will input the duty cycles and power demands into a powertrain model modified to consider the unique demands of off-road equipment to determine whether available battery technology could feasibly power these vehicles. They will create model solutions for three to five specific

applications and determine the feasibility of electrifying or hybridizing these applications. The applications chosen for the simulations should be those that represent sectors responsible for significant emissions in the state. They will perform a cost/benefit analysis and examine existing incentive and regulatory programs. They will examine the mechanics of these programs and their value for sustained fleet turnover and GHG as well as criteria pollutant emissions reductions. They will estimate the costs of electrifying the equipment recommended from the simulation portion and calculate the emissions benefits of both GHG and criteria pollutant emissions.

Expected Results
The current proposal prioritizes the technological feasibility of electrifying off-road applications while maximizing emissions reduction. It is expected that this will lead to the most effective incentive program with the most favorable cost/benefit in terms of reducing emissions within the state. The results of this project will provide CARB with a roadmap for future incentive programs to promote further electrification of off-road equipment that will help meet air quality and climate goals.

Significance to the Board
CARB has set ambitious goals to improve air quality and meet climate goals. The off-road sector is projected to be one of the largest sources of nitrogen oxides within the state in the future and a significant source of GHGs, thus incentivizing off-road electrification will help to achieve these climate goals and improve air quality.

Contractor:
University of California, Riverside

Contract Period:
24 months

Principal Investigators (PIs):
Kanok Boriboonsomsin, Ph.D., P.E. and Guoyuan Wu, Ph.D.

Contract Amount:
$350,000

Basis for Indirect Cost Rate:
The State and University of California, Riverside, have agreed to a twenty-five percent indirect cost rate.

Past Experience with this Principal Investigator:
Dr. Kanok Boriboomsomsin, is an associate research engineer at CE-CERT, University of California, Riverside. He has worked with CARB on two prior research contracts including the 90 Vocation Truck Study (13-301) and Tractor-Trailer Aero Study (14-302) with very satisfactory results. His work on both of these studies makes him highly qualified to work on this project, and he will utilize previously developed data analysis tools and activity data to create a high-quality final product. Dr. Boriboomsomsin holds

a Ph.D. in Transportation Engineering from the University of Mississippi. He has published a comprehensive body of work relating to activity data collection and analysis and emissions from light, heavy and off-road vehicles.

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

Year	2017	2016	2015
Funding	$ 450,818	$ 500,000	$ 0

B U D G E T S U M M A R Y

Contractor: University of California, Riverside

Hybridization and Full Electrification Potential in Off-Road Applications

DIRECT COSTS AND BENEFITS			
1.	Labor and Employee Fringe Benefits	$ 196,259	
2.	Subcontractors	$ 49,181	
3.	Equipment	$ 0	
4.	Travel and Subsistence	$ 850	
5.	Electronic Data Processing	$ 0	
6.	Reproduction/Publication	$ 0	
7.	Mail and Phone	$ 0	
8.	Supplies	$ 4,042	
9.	Analyses	$ 0	
10.	Miscellaneous	$ 50,811	
	Total Direct Costs		$ 301,143
INDIRECT COSTS			
1.	Indirect (F&A) Costs	$ 48,857	
	Total Indirect Costs		$ 48,857
TOTAL PROJECT COSTS			**$ 350,000**

ATTACHMENT 1

S U B C O N T R A C T O R ' S B U D G E T S U M M A R Y

Subcontractor: CalStart

Description of subcontractor's responsibility: The CALSTART team will identify currently available electrification technology, identify markets exploring hybridization/electrification, and identify influence of clean technology on market share for off-road equipment.

DIRECT COSTS AND BENEFITS				
1.	Labor and Employee Fringe Benefits	$	39,345	
2.	Subcontractors	$	0	
3.	Equipment	$	0	
4.	Travel and Subsistence	$	0	
5.	Electronic Data Processing	$	0	
6.	Reproduction/Publication	$	0	
7.	Mail and Phone	$	0	
8.	Supplies	$	0	
9.	Analyses	$	0	
10.	Miscellaneous	$	0	
	Total Direct Costs			$ 39,345
INDIRECT COSTS				
1.	Indirect (F&A) Costs	$	9,836	
	Total Indirect Costs			$ 9,836
TOTAL PROJECT COSTS				**$ 49,181**