State of California
AIR RESOURCES BOARD

The Development of Lifecycle Data for Hydrogen Fuel Production and Delivery

RESEARCH PROPOSAL

Resolution 14-23

July 24, 2014

Agenda Item No.: 14-6-1

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 2781-279, titled "The Development of Lifecycle Data for Hydrogen Fuel Production and Delivery," has been submitted by the University of California, Davis; and

WHEREAS, the Research Division staff has reviewed Proposal Number 2781-279 and finds that in accordance with Health and Safety Code section 39701, research is needed to provide essential data for the development of new hydrogen fuel pathways and strategies to expand the current hydrogen market, in order to support the successful implementation of the State's Low Carbon Fuel Standard;

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

> Proposal Number 2781-279 titled "The Development of Lifecycle Data for Hydrogen Fuel Production and Delivery," submitted by the University of California, Davis, for a total amount not to exceed $250,000.

NOW, THEREFORE BE IT RESOLVED, that the Air Resources Board, pursuant to the authority granted by Health and Safety Code section 39700 through 39705, hereby accepts the recommendations of the Research Screening Committee and Research Division staff and approves the following:

> Proposal Number 2781-279 titled "The Development of Lifecycle Data for Hydrogen Fuel Production and Delivery," submitted by the University of California, Davis, for a total amount not to exceed $250,000.

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 $250,000.

I hereby certify that the above is a true and correct copy of Resolution 14-23 as adopted by the Air Resources Board.

Tracy Jensen

Tracy Jensen, Clerk of the Board

ATTACHMENT A

"The Development of Lifecycle Data for Hydrogen Fuel Production and Delivery"

Background

The Low Carbon Fuel Standard (LCFS) regulation is designed to reduce lifecycle greenhouse gas emissions in the transportation sector. The regulation assesses a carbon intensity score for the full lifecycle of each fuel pathway. The regulation lowers overall greenhouse gas emissions by requiring each fuel provider to meet the annual carbon intensity target for a given year. As this carbon intensity target decreases over time, the greenhouse gas emissions from the transportation sector will also decrease with time. ARB has performed a lifecycle assessment of many transportation fuel pathways and assigned carbon intensity scores to these pathways, but additional pathways exist that have not yet been analyzed and do not yet have such scores. For example, there are currently no LCFS pathways for renewable hydrogen, although the technology for its production currently exists in California. While ARB staff working on the LCFS need lifecycle data on new pathways that include technology that is currently available, ARB staff working on the Vision Project will benefit from lifecycle data on potential pathways using technology that will become available over the next 10 to 20 years.

Objective

The objective of this project is to develop lifecycle analyses of criteria pollutant and greenhouse gas (GHG) emissions for the production and delivery of hydrogen transportation fuel in California. The project will also identify additional hydrogen markets outside of the transportation sector in order to ensure the viability of the hydrogen market in the near-term.

Methods

This project will analyze lifecycle greenhouse gas and criteria pollutant emissions for the production and delivery of hydrogen to light-and heavy-duty vehicles in California for processes not currently included in published LCFS pathways. This analysis will enable the ARB staff to develop new hydrogen pathways for the LCFS regulation. This study will review published literature to assess the fuels, infrastructure, and vehicle technology that can produce and utilize hydrogen in order to determine the most effective combinations not currently in the published LCFS to reduce greenhouse gas and criteria pollutants. The focus will be technologies and fuels related to renewable hydrogen. The production technologies will include thermal, electrolytic, and photolytic processes. The literature review will produce a set of hydrogen pathways for further analysis. The study will also examine the potential to use the current natural gas infrastructure for hydrogen distribution. The study will analyze the potential to leverage the current natural gas infrastructure to transport hydrogen by examining the percentage of hydrogen in the gas mixture that natural gas pipelines could support, the effect on natural gas quality from any potential contaminants in the hydrogen, and issues related to separating out the hydrogen from the natural gas at the destination. A lifecycle analysis will be performed to determine the hydrogen pathways with the lowest greenhouse gas and criteria

pollutant emissions. This analysis will include production, distribution, and storage of renewable hydrogen or hydrogen produced with technologies or fuels not currently in the LCFS. The study will assess which hydrogen production, distribution, and storage technologies will be available in the 5-year, 10-year, and 20-year timeframes. An economic assessment will be performed to estimate the hydrogen costs for each potential pathway. The economic assessment will be combined with the lifecycle emissions reductions estimates to determine the most cost-effective pathways for the production, distribution, and storage of hydrogen fuel. The market demand for hydrogen as a transportation fuel could be relatively low during the initial usage period. The potential low demand could act as a barrier to commercialization for hydrogen fuel. The study will identify potential non-transportation markets that could be served by hydrogen facilities during this early commercialization period. The study will also determine any potential barriers to growth in these non-transportation markets and attempt to find strategies or policies to overcome these barriers.

Expected Results
The study will provide lifecycle emissions data for novel hydrogen pathways that are not currently included in the Low Carbon Fuels Standard. The study will also provide background information on potential hydrogen markets that could expand the market for hydrogen in the near-term.

Significance to the Board
Results will provide essential data for the development of new hydrogen fuel pathways, and strategies to expand the current hydrogen market. This information will support the successful implementation of the State's Low Carbon Fuel Standard program.

Contractor:
University of California, Davis

Contract Period:
24 months

Principal Investigator (PI):
Marshall Miller, Ph.D.

Contract Amount:
$250,000

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

Past Experience with this Principal Investigator:
ARB staff has worked with a number of staff at the University of California, Davis (UCD) Institute for Transportation Studies (ITS) in the past. ARB has not worked with Marshall Miller as a principal investigator before but ARB is confident that he will perform his intended duties diligently given his 20 years of expertise working at hydrogen systems

at UCD. We have worked with the other UCD researchers on the project before, including Chris Yang, and have been impressed with their work.

The literature review, life-cycle analysis, and hydrogen market assessment will be completed by the UCD team. The technology and economic assessments will be completed by the University of California, Riverside (UCR) team. This division of labor leverages UC Davis's expertise in hydrogen lifecycle analysis and UCR's connections with industry for practical assessments of hydrogen technology and economic potential.

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

Year	2013	2012	2011
Funding	$1,131,716	$4,949,363	$1,394,560

BUDGET SUMMARY

University of California, Davis

"The Development of Lifecycle Data for Hydrogen Fuel Production and Delivery"

DIRECT COSTS AND BENEFITS			
1.	Labor and Employee Fringe Benefits	$ 112,941	
2.	Subcontractors	$ 124,994[1]	
3.	Equipment	$ 0	
4.	Travel and Subsistence	$ 0	
5.	Electronic Data Processing	$ 0	
6.	Reproduction/Publication	$ 200	
7.	Mail and Phone	$ 0	
8.	Supplies	$ 200	
9.	Analyses	$ 0	
10.	Miscellaneous	$ 300	
	Total Direct Costs		$ 238,635
INDIRECT COSTS			
1.	Overhead	$ 11,364	
2.	General and Administrative Expenses	$ 0	
3.	Other Indirect Costs	$ 0	
4.	Fee or Profit	$ 0	
	Total Indirect Costs		$ 11,364
TOTAL PROJECT COSTS			**$ 250,000**

[1] Note: The subcontract with UC Riverside was included to utilize their expertise in hydrogen technology, economics and connections with industry stakeholders.

ATTACHMENT 1

SUBCONTRACTORS' BUDGET SUMMARY

Subcontractor: University of California, Riverside

Description of subcontractor's responsibility: The technology and economic assessments for this research project will be completed by the UC Riverside team, leveraging UC Riverside's connections with industry for practical assessments of hydrogen technology and economic potential.

DIRECT COSTS AND BENEFITS				
1.	Labor and Employee Fringe Benefits	$	86,521	
2.	Subcontractors	$	0	
3.	Equipment	$	0	
4.	Travel and Subsistence	$	5,386	
5.	Electronic Data Processing	$	0	
6.	Reproduction/Publication	$	0	
7.	Mail and Phone	$	0	
8.	Supplies	$	0	
9.	Analyses	$	0	
10.	Miscellaneous	$	23,896	
	Total Direct Costs			$ 115,803
INDIRECT COSTS				
1.	Overhead	$	9,191	
2.	General and Administrative Expenses	$	0	
3.	Other Indirect Costs	$	0	
4.	Fee or Profit	$	0	
	Total Indirect Costs			$ 9,191
TOTAL PROJECT COSTS				**$ 124,994**