

CONTRACT REQUESTS FORM (CRF)



New Contract _____ Amendment to Existing Contract: _____ Amendment Number: _____

Division	Contract Manager:	MS-	Phone	CM Training Date
Energy Research and Development	Marla Mueller	43	916-327-1716	8/19/2002

Contractor's Legal Name	Federal ID Number
DOE- Lawrence Livermore National Laboratory	94-6031193

Title of Project
Low-Cost High Sensitivity NOx Sensors

Term	Start Date	End Date	Amount
New/Original Contract	6/1/2012	3/31/2015	\$ 600,000

Line up the Amendment information as best as possible within the following table.

Amendment #	End Date (mm/dd/yy)	Amount

Business Meeting Information

Proposed Business Meeting Date	5/9/2012	<input type="checkbox"/> Consent	<input checked="" type="checkbox"/> Discussion
Business Meeting Presenter	Marla Mueller	Time Needed:	5 minutes

Agenda Item Subject and Description [This agenda item should be sent to the Research List Serve (Energy RD&D/PIER program)]
 Possible approval of Contract 500-11-022 for \$600,000 with Lawrence Livermore National Laboratory to develop a low-cost NOx sensor that is able to measure very low emission levels and that can be seamlessly integrated with NOx pollution control systems. This type of sensor is needed for small distributed generators that are having difficulties in achieving required control levels. The length of this agreement is 34 months. (PIER natural gas funding)
 Contact: Marla Mueller. (5 minutes)

- Business Meeting approval is not required for the following types of contracts:** *Executive Director's signature is required in all cases.*
- Contracts less than \$10k (*Policy Committee's signature is also required*)
 - Amendment for a no-cost time extension. Must be first extension, less than one year and original contract less than \$100k.
 - Contracts less than \$25k for Expert Witness in Energy Facility licensing cases and amendments.

Purpose of Contract or Purpose of Amendment, if applicable

The purpose of this contract is to develop a low-cost NOx sensor for small distributed generation (DG) units that are having difficulties controlling NOx emissions because current sensors are not accurate enough and are too slow for an efficient integration with NOx control systems. The researchers will use their successful experience developing NOx sensors for motor vehicles that could be customized to serve stationary DG units. The researchers will build and test prototype sensors in simulated DG environments in the laboratory prior to final testing in operating DG units.

California Environmental Quality Act (CEQA) Compliance

1. Is Contract considered a "Project" under CEQA?
 Yes: skip to question 2 No: complete the following (PRC 21065 and 14 CCR 15378):
 Explain why contract is not considered a "Project":
 Contract will not cause direct physical change in the environment or a reasonably foreseeable indirect physical change in the environment because This project is developing a NOx sensor and will not produce any change to the environment..
2. If contract is considered a "Project" under CEQA:
 a) Contract **IS** exempt. (Draft NOE required)
 Statutory Exemption. List PRC and/or CCR section number: _____
 Categorical Exemption. List CCR section number: _____
 Common Sense Exemption. 14 CCR 15061 (b) (3)
 Explain reason why contract is exempt under the above section:
 b) Contract **IS NOT** exempt. The Contract Manager needs to consult with the Energy Commission attorney assigned to their division and the Siting Office regarding a possible Initial Study.

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CEC-94 (Revised 5/11)

CALIFORNIA ENERGY COMMISSION



Budgets Information								
Contract Amount Funded		Breakdown by FY			Funding Sources			
Funding Source	Amount	FY	Amount	Approved?	Funding Source	FY	Budget List No.	Amount
ARFVTF	\$	11-12	\$600,000	Yes	NG Subaccount,	10-11	501.001E	\$600,000
ECAA	\$		\$					\$
State- ERPA	\$		\$					\$
Federal	\$		\$					\$
PIER - E	\$		\$					\$
PIER - NG	\$600,000		\$					\$
Reimbursement	\$		\$					\$
Other	\$		\$					\$
TOTAL:	\$600,000	TOTAL:	\$600,000		TOTAL:			\$600,000
Reimbursement Contract #:					Federal Agreement			

Contractor's Administrator/ Officer		Contractor's Project Manager	
Name:	Jeff Baker	Name:	Mark Javier
Address:	7000 EAST AVE # L-180	Address:	7000 EAST AVE # L-180
City, State, Zip:	LIVERMORE, CA 94550-9698	City, State, Zip:	LIVERMORE, CA 94550-9698
Phone/ Fax:	925-424-6774 / 925-423-5156	Phone/ Fax:	925 423-2135 / 925 423-5156
E-Mail:	baker44@llnl.gov	E-Mail:	javier1@llnl.gov

Contractor Is
<input type="checkbox"/> Private Company (including non-profits)
<input type="checkbox"/> CA State Agency (including UC and CSU)
<input checked="" type="checkbox"/> Government Entity (i.e. city, county, federal government, air/water/school district, joint power authorities, university from another state)

Selection Process Used
<input type="checkbox"/> Solicitation <u>Select Type</u> Solicitation #: _____ # of Bids: _____ Low Bid? <input type="checkbox"/> No <input type="checkbox"/> Yes
<input type="checkbox"/> Non Competitive Bid (Attach CEC 96)
<input checked="" type="checkbox"/> Exempt Other Government Entity

Civil Service Considerations
<input type="checkbox"/> Not Applicable (Contract is with a CA State Entity or a membership/co-sponsorship)
<input checked="" type="checkbox"/> Public Resources Code 25620, et seq., authorizes the Commission to contract for the subject work. (PIER)
<input type="checkbox"/> The Services Contracted:
<input type="checkbox"/> are not available within civil service
<input type="checkbox"/> cannot be performed satisfactorily by civil service employees
<input type="checkbox"/> are of such a highly specialized or technical nature that the expert knowledge, expertise, and ability are not available through the civil service system.
<input type="checkbox"/> The Services are of such an:
<input type="checkbox"/> urgent
<input type="checkbox"/> temporary, or
<input type="checkbox"/> occasional nature
that the delay to implement under civil service would frustrate their very purpose.
Justification:
Public Resources Code 25620, et seq., authorizes the Commission to contract for the subject work. (PIER)

CONTRACT REQUESTS FORM (CRF)



Payment Method			
<input type="checkbox"/>	A. Reimbursement in arrears based on:		
<input type="checkbox"/>	Itemized Monthly	<input type="checkbox"/>	Itemized Quarterly
<input type="checkbox"/>		<input type="checkbox"/>	Flat Rate
<input type="checkbox"/>			One-time
<input checked="" type="checkbox"/>	B. Advanced Payment		
<input type="checkbox"/>	C. Other, explain:		

Retention			
1.	Is contract subject to retention?	<input checked="" type="checkbox"/>	No
		<input type="checkbox"/>	Yes
	If Yes, Do you plan to release retention prior to contract termination?	<input checked="" type="checkbox"/>	No
		<input type="checkbox"/>	Yes

Justification of Rates	
The contract price is reasonable, particularly considering the facility provided by the contract terms. The research will be conducted by a national laboratory; salaries and wages are in accordance with costing practice for all Department of Energy programs.	

Disabled Veteran Business Enterprise Program (DVBE)	
1.	<input checked="" type="checkbox"/> Not Applicable
2.	<input type="checkbox"/> Meets DVBE Requirements DVBE Amount:\$ _____ DVBE %: _____
	<input type="checkbox"/> Contractor is Certified DVBE
	<input type="checkbox"/> Contractor is Subcontracting with a DVBE: _____
3.	<input type="checkbox"/> Requesting DVBE Exemption (attach CEC 95)

Is Contractor a certified Small Business (SB), Micro Business (MB) or DVBE?		<input checked="" type="checkbox"/>	No	<input type="checkbox"/>	Yes
If yes, check appropriate box:		<input type="checkbox"/>	SB	<input type="checkbox"/>	MB
		<input type="checkbox"/>	DVBE		

Is Contractor subcontracting any services?		<input checked="" type="checkbox"/>	No	<input type="checkbox"/>	Yes
If yes, give company name and identify if they are a Small Business (SB), Micro Business (MB) and/or DVBE:					
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>
	<input type="checkbox"/>	No	<input type="checkbox"/>	SB	<input type="checkbox"/>

Miscellaneous Contract Information			
1.	Will there be Work Authorizations?	<input checked="" type="checkbox"/>	No
		<input type="checkbox"/>	Yes
2.	Is the Contractor providing confidential information?	<input type="checkbox"/>	No
		<input checked="" type="checkbox"/>	Yes
3.	Is the contractor going to purchase equipment?	<input checked="" type="checkbox"/>	No
		<input type="checkbox"/>	Yes
4.	Check frequency of progress reports		
	<input type="checkbox"/> Monthly <input checked="" type="checkbox"/> Quarterly <input type="checkbox"/> _____		
5.	Will a final report be required?	<input type="checkbox"/>	No
		<input checked="" type="checkbox"/>	Yes
6.	Is the contract, with amendments, longer than a year? If yes, why?	<input type="checkbox"/>	No
		<input checked="" type="checkbox"/>	Yes
The Department of General Services has agreed to give the Commission blanket authority to execute multi-year contracts to support the Commission's RD&D Programs.			

CONTRACT REQUESTS FORM (CRF)



The following items should be attached to this CRF		
1. Scope of Work, Attach as Exhibit A.	<input type="checkbox"/> N/A	<input type="checkbox"/> Attached
2. Budget Detail, Attach as Exhibit B.	<input type="checkbox"/> N/A	<input type="checkbox"/> Attached
3. CEC 96, NCB Request	<input type="checkbox"/> N/A	<input type="checkbox"/> Attached
4. CEC 30, Survey of Prior Work	<input type="checkbox"/> N/A	<input type="checkbox"/> Attached
5. CEC 95, DVBE Exemption Request	<input type="checkbox"/> N/A	<input type="checkbox"/> Attached
6. Draft CEQA Notice of Exemption (NOE)	<input type="checkbox"/> N/A	<input type="checkbox"/> Attached
7. Resumes	<input type="checkbox"/> N/A	<input type="checkbox"/> Attached
8. CEC 105, Questionnaire for Identifying Conflicts		<input type="checkbox"/> Attached
9. CEC 106, IT Component Reporting Form		<input type="checkbox"/> Attached

 Contract Manager Date Office Manager Date Deputy Director Date

The following signatures are only required when contract approval is delegated to the Executive Office and not approved at a Business Meeting. See Business Meeting Information Section.

 Presiding Policy Committee Date Associate Policy Committee Date Executive Director Date

Exhibit A – Statement of Work

Title of project

Low-Cost High Sensitivity NOx Sensor

Background

The U.S. Department of Energy has directed Lawrence Livermore National Security, LLC (LLNS) to perform the work described in this Appendix A for the California Energy Commission. Lawrence Livermore National Laboratory (LLNL), a laboratory owned by the Department of Energy, is located at 7000 East Avenue, Livermore, CA 94550. LLNS, a for profit corporation organized under the laws of the State of California with its principal place of business at 2300 First Street, Suite 204, Livermore, CA 94550, manages and operates LLNL under DOE Contract No. DE-AC52-07NA27344.

The California Energy Resources Conservation and Development Commission (Energy Commission) is an agency organized under the laws of the State of California with a principal place of business at 1516 Ninth Street, Sacramento, California 95814.

Project Goals and Objectives

Problem Statement

Between 2010 and 2018, electricity consumption in California is projected to grow at a rate of 1.2 percent annually, with peak demand projections at 1.3 percent.¹ Despite California's population projection of 53 million by 2030, electricity demand growth is projected lower than the U.S. average of 1.8 percent growth per year. This is due to California's history of demand management and energy conservation, as well as having an economy with low energy intensity.² Peak electricity demand in California is strongly related to rising temperatures. Extreme heat days in Los Angeles, or the 90 percent exceedance probability of the warmest summer days under the current climate, are projected to increase from 12 days per year to 96 days per year by 2100. The Los Angeles extreme heat temperature is currently 95°F and a statewide mean daily temperature above 86°F results in Stage II electricity emergency response.³

This increase in power will result in new electricity generation at central power plants and at distributed generation sites, potentially resulting in increased emissions of criteria air

¹ Kavalec, Chris and Tom Gorin, 2009. *California Energy Demand 2010-2020, Adopted Forecast*. California Energy Commission. CEC-200-2009-012-CMF.

² Budhreja, Vikram S., Fred Mobasher, Margaret Cheng. (Electric Power Group, LLC). 2004. *California's Electricity Generation and Transmission Interconnection Needs Under Alternating Scenarios*. California Energy Commission. 700-04-003.

³ Miller, Norman L., Jiming Jin, Katharine Hayhoe, and Maximilian Auffhammer. 2007. *Climate Change, Extreme Heat, and Energy Demand in California*. California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2007-023.

pollutants. However, most California residents live in areas that are classified as non-attainment for the Federal ozone standards. Eighteen of California's fifty counties that failed the ozone clean air test in the American Lung Association State of the Air 2011 report are ranked in the 25 worst counties for ozone in the United States. Twelve of California's fifty counties failed the Particulate Matter 2.5 (PM 2.5) 24-hour clean air test and four failed the PM2.5 annual test. Of the 25 worst counties in the United States for PM2.5, 15 are in California for 24-hour exposure and eight for annual exposure. The California Air Resources Board and air districts are spending considerable resources to find ways to reduce ozone and PM2.5 pollution. For example, to attain federal air quality standards, the South Coast Air Quality Management District (SCAQMD) will need to cut emissions by over 75%.⁴

Oxides of Nitrogen (NOx) prevention and control technology is a relatively complex issue, and increasingly stringent limits will require more advanced and less costly NOx measurement technology to cost-effectively reduce emissions. This will need to be accomplished using feedback control with integrated NOx measurement and pollution abatement systems (e.g., selective catalytic reduction) to improve energy efficiency.

Reciprocating engines are an example of where a low-cost NOx sensor is needed. Researchers for the PIER Renewables project "Ultra-Low Emission Integrated CHP Technology Development" (PIER Grant PIR-07-008) concluded that existing NOx sensors do not have the accuracy or precision required to provide actual values of NOx to use for control or monitoring of emissions from natural gas-fueled rich-burn engines⁵. Reciprocating engines have been the preferred prime mover for combined heat and power (CHP) applications less than three megawatts. Because they are relatively low cost and have high efficiency, reciprocating engines are projected to be the choice for a large majority of CHP applications through 2020. The inconsistent ability of engine emission control technology to comply with tightening emission requirements impedes the adoption of CHP in the state. Indeed, a major deterrent for new CHP implementation in California is the failure to cost-effectively achieve and sustain compliance with the California Air Resources Board's 2007 emission regulations and the amended the SCAQMD's Rule 1110.2 emission standard and real-time emission monitoring protocols.

Since 1998, LLNL has focused on developing solid-state electrochemical NOx sensors for automotive application that employ a unique alternating current impedance-based (i.e., impedancemetric) measurement approach.^{6,7,8,9,10} This sensor strategy offers

⁴SCAQMD; Clean Air Connections – Federal Legislation, Technology Advancement.
http://www.aqmd.gov/ej/CAC/federal_legislation.htm.

⁵ Southern California Gas Company, *Task 4, Engine Air/Fuel Ratio Control and Software Design Report Final, Ultra-Low Emission Integrated CHP*, Contract PIR-07-008. In review.

⁶ L.P. Martin, L.Y. Woo, and R.S. Glass, *J. Electrochem. Soc.*, **154**, J97 (2007).

⁷ L.Y. Woo, L.P. Martin, R.S. Glass, and R.J. Gorte *J. Electrochem. Soc.*, **154**, J129 (2007).

potential advantages over more traditional direct current methods of operation, including a simple design, comparable responses (direction and magnitude) to both Nitric Oxide (NO) and Nitrogen Oxide (NO₂) (i.e., total-NO_x sensing capability), better stability, and lower-cost electronics compared to those required for amperometric operation.

LLNL's efforts to develop automotive NO_x sensors have led to improved prototypes with better performance. The automotive NO_x sensor has been licensed to private industry, EmiSense LLC, located in Salt Lake City, Utah.

The work proposed in this agreement will leverage the previous and ongoing work with automotive NO_x sensors at LLNL to address the unique issues and concerns of stationary applications. A NO_x sensor technology will be developed and demonstrated that will operate in relevant environments for measurement and feedback control to limit NO_x emissions. Anticipated issues include tailoring the technology to the stationary source and specific choice of primary and secondary combustion/emission controls. Based upon experience in developing NO_x sensors for automotive applications, specific conditions in the combustion exhaust including temperature, humidity, flow velocity, and chemical composition can influence ultimate sensor performance. Impedancemetric operation has the advantage of being flexible enough to allow a number of modifications to be made in order to specifically tailor sensor performance depending on the specific needs of the application.

Technical performance objectives

The technical goal of this project is to develop NO_x sensor technology that addresses the unique issues and concerns of stationary applications, including specific requirements that depend on the stationary source and the specific choice of primary and secondary combustion/emission controls.

The technical objectives upon which this project's success will be evaluated are:

- Selection of a high priority DG technology and definition of the operating environment and first generation sensor design
- Building prototype sensors and evaluating the response in a simulated DG environment in the laboratory
- Refining the initial sensor package to optimize the sensor for second generation testing
- Moving the second generation prototype sensors from laboratory testing to a "real world" testing environment
- Developing and testing a "final" third generation prototype.

⁸ L.Y. Woo, L.P. Martin, R.S. Glass, W. Wang, S. Jung, R.J. Gorte, E.P. Murray, R.F. Novak, and J.H. Visser. *J. Electrochem. Soc.*, **155**, J32 (2008).

⁹ L.Y. Woo, R.S. Glass, R.F. Novak, and J.H. Visser. *J. Electrochem. Soc.*, **157**, J81 (2010).

¹⁰ L.Y. Woo, R.S. Glass, R.F. Novak, and J.H. Visser. *Sensor Actuat. B-Chem.*, **157**, 115 (2011).

There are no economic/cost goals or objectives for this project.

Preliminary Activities

1.1 Attend Kick Off Meeting

The Facility Operator's Project Manager (Principal Investigator) shall attend a "kick off" meeting with the Commission Contract Manager to review the Energy Commission's expectations for: accomplishing tasks described in the work statement; administrative requirements in the terms and conditions of the contract (e.g., invoicing, statements vesting title, prior approvals, data disclosure limitations, monthly progress reporting format and content, etc.); and the Energy Commission's roles and responsibilities. The location of this meeting shall be designated by the Commission Contract Manager.

1.2 Describe Synergistic Projects

The work proposed in this agreement will leverage the previous and ongoing work with automotive NOx sensors at LLNL to address the unique issues and concerns of stationary applications.

1.3 Identify Required Permits

Prepare and submit to the Energy Commission Contract Manager a list of all permits required for construction and/or operation of equipment or the project facility, the name, address and telephone number of the permitting jurisdictions or lead agencies, and the schedule the Facility Operator will follow in applying for and obtaining these permits.

No permits are required to conduct this project.

1.4 Obtain Required Permits

The Facility Operator will supply written certification that it has received all necessary and required permits to construct, operate, or test the proposed equipment or facility as soon as they are received. During this project, the Facility Operator shall comply with all applicable laws, ordinances, regulations, and standards. If the Facility Operator is required to obtain permits specifically for performance of this Agreement, such permit expenses shall be separately identified as a cost and shall be reimbursable by the Energy Commission.

No permits are required to conduct this project.

1.5 Prepare Production Readiness Plan

This task is not applicable for the proposed work.

TECHNICAL TASKS

GLOSSARY

Specific terms and acronyms used throughout this work statement are defined as follows:

Energy Commission	California Energy Commission
CHP	Combined Heat and Power
CPR	Critical Project Review
DG	distributed generation
DOE	Department of Energy
LLNL	Lawrence Livermore National Laboratory
LLNS	Lawrence Livermore National Security
LSM	strontium-doped lanthanum manganite
NFCRC	National Fuel Cell Research Center
NO	nitric oxide
NO ₂	nitrogen dioxide
NO _x	oxides of nitrogen
PIER	Public Interest Energy Research
S	sulfur
SCAQMD	South Coast Air Quality Management District
TAC	Technical Advisory Committee
M&O	Management and Operating

SCOPE OF WORK

This agreement includes a set of administrative tasks and technical tasks. The remainder of this work statement defines these technical tasks. Task descriptions include goals, Contractor activities, and deliverables. The deliverables (such as test plans, technical reports and other interim deliverables) for each task are defined to the extent possible, but are subject to change based on recommendations from the Project

Manager and the approval of the Commission Contract Manager. The Contractor shall submit a draft of each deliverable, unless described differently in the technical tasks, to the Commission Contract Manager for review and comment in accordance with the approved Schedule of Deliverables. Deliverables not requiring a draft version are indicated by marking “(no draft)” after the deliverable name.

The Commission Contract Manager will provide written comments to the Contractor on the draft deliverable within 10 working days of receipt. Once agreement has been reached on the draft, the Contractor shall submit the final deliverable to the Commission Contract Manager. The Commission Contract Manager shall provide written approval of the final deliverable within 5 working days of receipt. Key elements from this deliverable shall be included in the Final Report for this project.

When creating technical deliverables, the Facility Operator shall use and follow, unless otherwise instructed in writing by the Commission Contract Manager, the latest version of the PIER Style Manual published on the Energy Commission's web site: <http://www.energy.ca.gov/contracts/pier/contractors/index.html>.

Technical Task List

Task 2.1	Select DG Priority Target, Define Test Environment, and Initial Prototype Design
Task 2.2	Simulated Laboratory Environment Test
Task 2.3	Develop and Test 2 nd Generation Prototype
Task 2.4	“Real World” Testing and Initiate Technology Transfer
Task 2.5	Develop and Test 3rd Generation Prototype
Task 2.6	Technology Transfer Activities

Task 2.1 Select DG Priority Target, Define Test Environment, and Initial Prototype Design

The goal of this task is to select a high priority DG technology for sensor development and demonstration. Based upon this selection, LLNL will determine materials and designs for a first generation prototype sensor.

The Contractor shall:

- Select a Technical Advisory Committee (TAC) with input from the Commission Contract Manager.
- Meet with a TAC to obtain input on a high priority DG target (boilers, microturbines, and reciprocating engines) for sensor development. Among the factors to be considered in selecting a DG technology are:
 - The most prevalent DG problem to solve, i.e., the largest environmental impact problem.
 - Budget and timeframe.

- Ease of translating what needs to be accomplished in NOx sensor development for automotive to stationary applications.
- Availability of collaborators/facilities to work with LLNL on the DG.
- Market potential for the NOx sensor.
- Prepare a Technical Advisory Committee Meeting Summary that discusses the DG type selected and explains the reasons for its selection.
- Define the applicable environment for the DG target.
- Determine performance criteria and select a set of promising sensor materials and designs dictated by the environmental survey and test environment.
- Prepare a two-page Project Fact Sheet for posting on PIER website.

Deliverables:

- Technical Advisory Committee Meeting Summary
- Project Fact Sheet

Task 2.2 Simulated Laboratory Environment Test

The goal of this task is to build prototype sensors and evaluate the response in a simulated laboratory DG environment.

The Contractor shall:

- Prepare a Simulated Laboratory Test Plan that describes the laboratory testing of prototypes in simulated environments. The Test Plan shall include but not be limited to the following:
 - Test objectives and technical approach.
 - A description of a matrix of chemical and physical parameters to be investigated, including: flow rate; temperature; and concentrations of NOx, oxygen, water, sulfur, and other elements or substances as determined in Task 2.1.
 - A description of the facilities, equipment, and instrumentation required to conduct the tests.
 - A description of the data analysis procedures to be used.
- Obtain Commission Contract Manager approval of the Simulated Laboratory Test Plan.
- Procure test gases and make modifications to the existing testing system, if necessary.
- Obtain internal health and safety approval for the Simulated Laboratory Test Plan.
- Construct prototype sensors with integrated heater and temperature measurement capability to include for the testing phase.
- Complete the tests as outlined in the Simulated Laboratory Test Plan.
- Analyze microstructural and other physical and chemical changes that occurred to the sensor as a result of testing.
- Develop algorithms for interference correction or strategy to separately measure and correct for the presence of interferences.
- Prepare a Summary of Test Results and Conclusions and include it in the Quarterly Progress Report.

Deliverables:

- Simulated Laboratory Test Plan (no draft)
- Summary of Test Results and Conclusions (to be included in the Quarterly Progress Report)

Task 2.3 Develop and Test Second Generation Prototype

The goal of this task is to refine the sensor package used in Task 2 to optimize the sensor for second generation testing. This may involve the specification of different materials and a redesign for greater effectiveness. Barrier coatings to prevent sensor surface contamination (e.g., sulfur or silicon, may be needed. The Contractor may work with external collaborators for expediency.

The Contractor shall:

- Redesign the prototype sensor as necessary, and adjust experimental procedures to improve performance.
- Determine if barrier coatings are necessary to improve performance, and collaborate with industrial partners as necessary (e.g., Ford Research Laboratory and EmiSense) to efficiently proceed to third generation devices (following “real world” preliminary testing in Task 2.4).
- Identify and collaborate with industrial partners and potential commercialization entities to develop a packaging strategy needed for Task 2.4 “real world” testing.
- Construct a second generation prototype sensor
- Repeat the battery of laboratory tests conducted in Task 2.2, making adjustments where necessary.
- Prepare Critical Project Review Report #1. Submit it to the Commission Contract Manger at least 15 days before the Critical Project Review. The Report will include the following:
 - the second generation prototype sensor design and rationale for the design;
 - test results;
 - analysis;
 - conclusions;
 - plans for “real world” testing in Task 2.4;
 - recommendations for adjustments in the work plan going forward; and
 - photographs as appropriate.
- Participate in Critical Project Review #1.
- Adjust any future development and test plan based on comments received during the Critical Project Review. Clarify/add discussion where appropriate in Critical Project Review Report #1. The final version of this report shall be submitted to the Commission Contract Manager within 10 working days of the Critical Project Review. The Commission Contract Manager shall send written notification of approval to the Contractor within 5 working days of receipt. Key elements from the report shall be included in the Final Report for this project.

Deliverables:

- Critical Project Review Report #1

Task 2.4 “Real World” Testing and Initiate Technology Transfer

The goals of this task are to move the second generation prototype sensors from laboratory testing to a “real world” testing environment and to initiate the technology transfer process. This phase of development will verify performance, design, and durability.

The Contractor shall:

- Secure a test site and prepare a Field Test Plan that details field test procedures at the test site. The Test Plan shall include but not be limited to the following:
 - an evaluation of the suitability of the University of California, Irvine National Fuel Cell Research Center (NCFRC) site (or another field site if the NCFRC site is not available) for “real world” testing;
 - a description of facilities, equipment, and instrumentation required to conduct the tests;
 - a description of test procedures, including parameters to be controlled and how they will be controlled;
 - a description of side-by-side testing with commercial NO_x sensors and analytical equipment.
- Obtain Commission Contract Manager approval of the Field Test Plan.
- Make minor modifications to the second generation prototype sensor and packaging based on Task 2.3 results prior to “real world” testing.
- Conduct testing as outlined in the Field Test Plan.
- Prepare Critical Project Review Report #2 based on the results of sensor performance in field tests. Submit the report at least 15 days before the Critical Project Review. The Report shall include but not be limited to the following:
 - the goal of the test;
 - a description of the methodology used;
 - a summary of results;
 - considerations for modification of the prototype for final third generation devices;
 - a discussion of the data set needs of commercial entities for “hand off” for future development; and
 - data and photographs as appropriate.
- Participate in the Critical Project Review #2.
- Adjust any future developments and test plans based on comments received during the Critical Project Review. Clarify/add discussion where appropriate in Critical Project Review Report #2. Submit the final version of this report to the Commission Contract Manager within 10 working days after the Critical Project Review. The Commission Contract Manager shall send written notification of approval to the Contractor within 5 working days of receipt. Key elements from this report shall be included in the Final Report for this project.
- Communicate with commercialization entity(ies) and acquire tentative agreement for their involvement pending outcome of Task 2.5 test results.

Deliverables:

- Field Test Plan
- 2nd Critical Project Review Report

Task 2.5 Develop and Test 3rd Generation Prototype

The goal of this task is to develop and test a “final” third generation prototype based upon the results obtained in Task 4 testing. In this task the Contractor may work with collaborators for expediency in implementing more advanced test protocols and to facilitate technology transfer activities.

The Contractor shall:

- Make any necessary adjustments or redesigns of the second generation prototype sensor.
- Fabricate third generation prototypes.
- Conduct a test of sensors in a laboratory, followed by “real world” environments. The tests will follow protocols established in Tasks 2.3 and 2.4.
- Develop and evaluate strategies for mass production and manufacturing, which may include microfabrication using thin film processing (MEMs type) and substrates with integrated heaters. Finalize strategies for interference mitigation, which may include using a multiple frequency technique or independent measurements of environmental factors (e.g., temperature and oxygen concentration).
- Prepare a Summary of Test Results and Conclusions and include it in the Quarterly Progress Report.

Deliverables:

- Summary of Test Results and Conclusions (to be included in the Quarterly Progress Report)

Task 2.6 Technology Transfer Activities

The goal of this task is to develop a plan to make the knowledge gained, experimental results, and lessons learned available to key decision-makers.

The Contractor shall:

- Prepare a Technology Transfer Plan that explains how the knowledge gained in this project will be made available to the public. The level of detail expected is least for research-related projects and highest for demonstration projects. Key elements from this report shall be included in the Final Report for this project.
- Conduct technology transfer activities in accordance with the Technology Transfer Plan. These activities shall be reported in the Quarterly Progress Reports.

Deliverables:

- Technology Transfer Plan

Task 3.0 Reporting Tasks

All reports shall be delivered to:

Accounting Office, MS-2
California Energy Commission
1516 9th Street, 1st Floor
Sacramento, CA 95814

Task 3.1 Quarterly Progress Reports

The Contractor shall prepare *written* Quarterly Progress Reports to the Commission Contract Manager by the 30th of the following month, starting after the Department of General Service's contract approval date and shall continue each quarter until the Final Report has been accepted by the Commission Contract Manager. Attachment A-1 provides a recommended format and content requirements for the Quarterly Progress Report.

Task 3.2 Final Report

The Final Report shall be a public document. If the Contractor will be preparing a confidential version of the final report as well, the Contractor shall perform the following tasks for both the public and confidential versions of the Final Report. When creating the Final Report, the Facility Operator shall use and follow, unless otherwise instructed in writing by the Commission Contract Manager, the latest version of the PIER Style Manual published on the Energy Commission's web site:

<http://www.energy.ca.gov/contracts/pier/contractors/index.html>

Subtask 3.2.1 Final Report Outline

- Contractor shall prepare and submit to the Commission Contract Manager for review an outline of the Final Report describing the original purpose, approach and results of the project.
- The outline shall be submitted to the Commission Contract Manager for review. The Commission Contract Manager shall determine if the outline is satisfactory. If the Commission Contract Manager determines that the outline is unsatisfactory, he or she will, in a timely manner, provide to the Contractor written comments, which indicate how the outline can be improved. The Contractor shall revise the outline to meet the Commission Contract Manager's requirements. Upon finding the final report outline satisfactory, the Commission Contract Manager shall provide to the Contractor written approval of it.

Subtask 3.2.2 Draft Final Report for Comment

- The Contractor shall prepare and submit to the Commission Contract Manager a draft Final Report on the project. The format of the report shall follow the approved outline.

- The draft final report shall be submitted to the Commission Contract Manager for review and to determine, in a timely manner, if it is satisfactory. If the Commission Contract Manager determines that it is unsatisfactory, he or she will, provide to the Contractor written comments, which indicate how it can be improved. The Contractor shall revise the draft final report incorporating the Commission Contract Manager's corrections and required changes. Upon finding the revised draft to be satisfactory, the Commission Contract Manager shall provide to the Contractor written approval of it.

Subtask 3.2.3 Final Report

- The Contractor shall prepare a Final Report and submit it to the Commission Contract Manager after receiving the Commission Contract Manager's written approval of the draft Final Report. This task shall be deemed complete and accepted by the Commission only when the Commission Contract Manager approves the Final Report in writing. Upon approval, the Contractor shall submit two unbound copies of the Final Report to the Commission Contract Manager.

Task 3.3 Final Meeting

Contractor shall meet with the Commission Contract Manager to present findings, conclusions, and recommended next steps (if any) for the project.

Contractor will also discuss with the Commission Contract Manager the following contract close-out items:

- What to do with any state-owned equipment (Options), if applicable
- Commission's request for specific "generated" data (not already provided in contract deliverables)
- Need to document Contractor's disclosure of "subject inventions" developed under the contract
- Need to file UCC-1 form re: Commission's interest in patented technology
- Other "surviving" contracts provisions.

Critical Project Reviews

The Energy Commission will conduct critical project reviews at the conclusion of the following tasks:

- Task 2.3, Develop and Test 2nd Generation Prototype
- Task 2.4, "Real World" Testing and Initiate Technology Transfer

Critical project reviews are meetings between the Facility Operator, the Energy Commission Contract Manager, and other individuals selected by the Commission Contract Manager to provide objective, technical support to the Energy Commission. The purpose of these meetings is to discuss with the Facility Operator the status of the project and its progress toward achieving its goals and objectives. These meetings may take place at the Energy Commission in Sacramento, or at another reasonable location determined by the Commission Contract Manager.

Prior to the critical project review meeting, the Facility Operator will provide the task deliverable(s) to the Commission Contract Manager sufficiently in advance to allow the Contract Manager's review of the deliverable document(s) before the review meeting. If not already defined in the Work Statement, the Commission Contract Manager shall specify the contents of the deliverable document(s).

At the project review meeting, the Facility Operator shall present the required technical information and participate in a discussion about the project with the Commission Contract Manager and other meeting attendees, if any.

Following the project review meeting, the Energy Commission will determine whether the Facility Operator is complying satisfactorily with the Work Statement and whether the project is demonstrating sufficient progress toward achieving its goals and objectives to warrant continued PIER financial support for the project.

Sponsor's Key Personnel and Agreement Management

- A. The name and area code/phone number of the California Energy Commission's Contract Manager is listed on Exhibit F and is the official technical contact for the Energy Commission.

The Sponsor's Contract Manager is responsible for the day-to-day project status, decisions and communications with the Facility Operator Project Manager (Principal Investigator). The Commission Contract Manager will review and approve all project deliverables, reports, and invoices.

The Sponsor may change the Contract Manager by notice given to the Facility Operator at any time signed by the Contract Officer of the Energy Commission.

- B. The name and area code/phone number of the California Energy Commission's Contract Officer is listed on Exhibit F and will be the Contract Officer for the Agreement and is the official administrative contact for the Energy Commission.

Facility Operator's Key Personnel and Agreement Administration

The Facility Operator is obligated to comply with the terms and conditions of its Management and Operating (M&O) Contract with the DOE when performing work under this agreement. The DOE may require substitution of the named "key personnel" under this agreement should the DOE determine that the services of the Project Manager (Principal Investigator) or other named key personnel are necessary to meet the Facility Operator's M&O Contract obligations to the DOE. Should the DOE direct the Facility Operator to substitute the named key personnel under this agreement, the Facility Operator shall inform the Energy Commission of the directed substitution in accordance with paragraphs A and B below. In the event that the Energy Commission does not concur with the substitution of named key personnel as directed by the DOE, this agreement shall be terminated in accordance with the Termination provision of the terms and conditions.

- A. The name and area code/phone number of the National Laboratory's Project Manager (Principal Investigator) is on Exhibit F and will be the Project Manager (Principal Investigator) for this project and is the official technical contact for Lawrence Livermore National Laboratory.

The Facility Operator's Project Manager (Principal Investigator) is responsible for the day-to-day project status, decisions, and communications with the Sponsor's Contract Manager. The Facility Operator's Project Manager (Principal Investigator) will review and approve all project deliverables and reports.

The Facility Operator's Project Manager (Principal Investigator) is designated as "key personnel" under the Agreement. The Energy Commission reserves the right to prior written concurrence of any substitution of the Project Manager (Principal Investigator).

- B. The key personnel are listed on Exhibit F in this agreement.

Facility Operator's key personnel may not be substituted without the Commission Contract Manager's prior written concurrence. Such concurrence shall not be unreasonably withheld. All other personnel may be substituted by Facility Operator, with written notification made to the Commission Contract Manager.

- C. The name and area code/phone number of National Laboratory Agreement Administrator is on Exhibit F and will be the Agreement Administrator for this Agreement and is the official administrative contact for Lawrence Livermore National Laboratory.

Facility Operator's key subcontractors

The Facility Operator's key subcontractors are listed on Exhibit F in this agreement.

Facility Operator's key subcontractors may not be substituted without the Commission Contract Manager's prior written concurrence. Such concurrence shall be timely provided and not unreasonably withheld. Delay in written concurrence may result in a work stoppage of subcontract work. All other subcontractors may be substituted by Facility Operator, with written notification made to the Commission Contract Manager.

Report standards

- A. The report outline and format will be provided by the Sponsor's Contract Manager to the Facility Operator's Project Manager (Principal Investigator).
- B. All reports shall be delivered to the Accounting address shown on Exhibit F.
- C. Progress Reports. The Facility Operator shall prepare a Progress Report that summarizes all Agreement activities conducted by the Facility Operator to date, with

an assessment of ability to complete the project within the current budget and any anticipated cost overruns. Each Progress Report is due to the Commission Contract Manager within 30 days after the end of the reporting period. The Commission Contract Manager will specify the report format and contents and the number of copies to be submitted.

- D. Final Report and Final Meeting. At the conclusion of the Agreement's technical work as provided for this Statement and revised project plan, Facility Operator shall prepare a comprehensive written Final Report, including an Executive Summary. The Commission Contract Manager will review and approve the Final Report.