STATE OF CALIFORNIA

GRANTS/CONTINGENT AWARD REQUEST

CEC-270 (Revised 02/10) CALIFORNIA ENERGY COMMISSION

To: Grants and Loans Office Date: 11/17/2011

Project Manager: Diana Mircheva Phone Number: 916-327-1322
Office: Energy Generation Research Office Division: Energy Research and Development MS- 437
Project Title: Lower Cost High Performance and High Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine

Type of Request: *(check one)*

☐ **New Agreement:** *(include items A-F from below)* Agreement Number: Assigned by G&L Office
Program: PIER NG / Transportation
Solicitation Name and/or Number:
Legal Name of Recipient: Westport Power, Inc.
Recipient's Full Mailing Address: 1750 75Th Ave W
Vancouver, BC V6P6G2
Recipient's Project Officer: Patric Ouellette Phone Number: 604-718-2079
Agreement Start Date: 6/30/2009 Agreement End Date: 3/30/2012

☒ **Amendment :** *(Check all that apply)* Agreement Number: PIR-08-045
☒ Term Extension – New End Date: 12/31/2012
☒ Work Statement Revision *(include Item A from below)*
☒ Budget Revision *(include Item B from below)*
☐ Change of Scope *(include Items A – F as applicable from below)*
☐ Other:

ITEMS TO ATTACH WITH REQUEST:

A. Work Statement
B. Budget
C. Recipient Resolution, if applicable. (Resolution may be requested in Special Conditions if not currently available.)
D. Special Conditions, if applicable.
E. CEQA Compliance Form
F. Other Documents as applicable
- Copy of Score Sheets
- Copy of Pre-Award Correspondence
- Copy of All Other Relevant Documents

California Environmental Quality Act (CEQA)

☐ CEC finds, based on recipient's documentation in compliance with CEQA:
☐ Project exempt: NOE filed:
☐ Environmental Document prepared: NOD filed:
☐ Other:
☒ CEC has made CEQA finding described in CEC-280, attached

Funding Information:

*Source #1: Amount: $ Statute: FY: Budget List #:
*Source #2: Amount: $ Statute: FY: Budget List #:
*Source #3: Amount: $ Statute: FY: Budget List #:

If federally funded, specify federal agreement number:

*** Source Examples include ERPA, PIER-E, PIER-NG, FED, GRDA, ARFVT, OTHER.**

Business Meeting Approval: *(refer to Business Meeting Schedule)*

Proposed Business Meeting Date: 1/11/2012 ☒ Consent ☐ Discussion
Business Meeting Participant: Diana Mircheva Time Needed: minutes

Agenda Notice Statement: *(state purpose in layperson terms)*

Possible approval of a ☒ Grant / ☐ Contingent Award to…
Possible approval of Amendment 1 to Agreement PIR-08-045 with Westport Power, Inc. to extend the contract term by 9 months and to reallocate the budget to extend engine testing to optimize performance and minimize emissions. The total grant amount of $998,844 remains unchanged. (PIER natural gas funding)
Contact: Diana Mircheva

Project Manager	Date	Office Manager	Date	Deputy Director	Date

Notice of Exemption **Form D**

To: Office of Planning and Research
PO Box 3044, 1400 Tenth Street, Room 222
Sacramento, CA 95812-3044

From: California Energy Commission
1516 Ninth Street, MS-48
Sacramento, CA 95814

Project Title: Lower Cost High Performance and High Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine

Project Location – Specific: 1691 West 75th Avenue, Vancouver, British Columbia, Canada V6P 6P2

Project Location – City: Vancouver, BC **Project Location – County:** British Columbia, Canada

Description of Project:

During the commercialization of the high pressure direct injection (HPDI) technology, new technologies have been advancing to improve the efficiency of comparable diesel engines. The project described in this proposal is aimed directly at further reducing the initial ownership and operating costs of HPDI technology, and at exploring selected efficiency improvements. Recognizing the situation that gas quality may be more variable as a result of new sources of natural gas entering the market, we also propose to improve the technology by exploring options for reducing sensitivity to fuel composition variance using one of our novel sensor technique recently developed under DOE sponsorship.

The objectives of this project are summarized as following:

• Reduce the heavy-duty (HD) HPDI engine system component costs (fuel system, in particular injectors and fuel rail pressure control module, and exhaust after treatment) by 20%.
• Reduce HPDI fuel consumption by 5% from current levels over an ESC test which will lead to a 20% lower ESC averaged fuel consumption compared to today's SI engine.
• Improve HPDI power density by 10% (up to 21.5 bar) from current level which will lead to an engine power density that is approximately 25% higher compared to today's SI engines.
• Maintain emissions below 2010 EPA emissions targets (0.2 g/bhp-hr NOx, 0.01 g/bhp-hr PM, 0.14 NMHC g/bhp-hr) while improving on today's GHG emissions by approximately 20%.
• Improve engine operating robustness to natural gas quality and achieve satisfactory engine operation for a wider range of Wobbe index (45-55 MJ/std.m3 based on lower heating value of NG) and Methane number (50-100).

Name of Public Agency Approving Project: California Energy Commission

Name of Person or Agency Carrying Out Project: Westport Power, Inc.

Exempt Status: (*check one)*

- ☐ Ministerial (Sec. 21080(b)(1); 15268);
- ☐ Declared Emergency (Sec. 21080(b)(3); 15269(a));
- ☐ Emergency Project (Sec. 21080(b)(4); 15269(b)(c));
- ☐ Categorical Exemption. State type and section number _____
- ☐ Statutory Exemptions. State code number. _____
- ☒ Common Sense Exemption. 15061(b)(3)

Reasons why project is exempt:

The activity is covered by the general rule that CEQA applies only to projects which have the potential for causing a significant effect on the environment. Where it can be seen with certainty that there is no possibility

that the activity in question may have a significant effect on the environment, the activity is not subject to CEQA.

Lead Agency
Contact Person: **Diana Mircheva** **Area code/Telephone/Ext:** 916-327-1322

If filed by applicant:

1. Attach certified document of exemption finding.
2. Has a Notice of Exemption been filed by the public agency approving the project? ☐ Yes ☐ No

Signature: _____ **Date:** _____ **Title:** _____

☒ **Signed by Lead Agency**

☐ **Signed by Applicant** **Date received for filing at OPR:** _____

WORK STATEMENT

TECHNICAL TASK LIST

Task #	CPR	Task Name
1		Administration
2	X	Fuel system redesign modification and cost reduction
3	X	Engine combustion strategy and hardware selection
4	X	Test engine build and commissioning
5	X	Engine combustion, performance and emissions development
6		Engine optimization and final performance and emissions testing
7		Technology transfer activities
8		Production readiness plan

KEY NAME LIST

Task #	Key Personnel	Key Subcontractor(s)	Key Partner(s)
1	Patric Ouellette, Sandeep Munshi, Mihai Ursan	Not Applicable	Not Applicable
2	David Mumford, Mike Wickstone	Not Applicable	Not Applicable
3	Sandeep Munshi, Alan Welch, Philip Hill	Not Applicable	Not Applicable
4	Ken Mann, Mihai Ursan, Sandeep Munshi	Argonne National Laboratory	Not Applicable
5	Ken Mann, Jim Huang, Sandeep Munshi, Philip Hill	Not Applicable	Not Applicable
6	Ken Mann, Jim Huang, Sandeep Munshi, Philip Hill	Not Applicable	Not Applicable
7	Patric Ouellette, Sandeep Munshi	Not Applicable	Not Applicable
8	Patric Ouellette, David Mumford, Alan Welch, Sandeep Munshi	Not Applicable	Not Applicable

GLOSSARY

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

Acronym	Definition
BHP	Brake Horsepower

Acronym	Definition
BMEP	Brake Mean Effective Pressure
CFD	Computational Fluid Dynamics
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO2	Carbon Dioxide
CPR	Critical Project Review
DLC	Diamond Like Carbon
DOE	Department of Energy
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
ESC	European Stationary Cycle
ESC-13	13 mode European Steady State Test Cycle
g/bhp-hr	Grams per brake horse power-hour
HC	Hydrocarbon
HD	Heavy Duty
HCCI	Homogeneous Charge Compression Ignition
HCDI	Homogeneous Charge Direct Injection
HPDI	High Pressure Direct Injection
LNG	Liquefied Natural Gas
LTC	Low Temperature Combustion
NG	Natural Gas
NOx	Oxides of Nitrogen
PAC	Project Advisory Committee
PIER	Public Interest Energy Research
Pilot Diesel Ignition	Ignition with pilot diesel fuel
PM	Particulate Matter
SCAQMD	South Coast Air Quality Management District
SI	Spark ignited
SOC Sensor	Start Of Combustion Sensor
Summary Report	A report summarizing important findings relevant to a particular task or technical activity
UEGO Sensor	Universal Exhaust Gas Oxygen Sensor (also known as Lambda sensor)
VAVE	Value Analysis Value Engineering

Problem Statement:

In 2007, Westport released the first commercial heavy-duty directly injected natural gas engine (the 15L GX). The high efficiency, high performance High Pressure Direct Injection (HPDI) technology has been integrated onto the Cummins ISX 15L engine. With peak brake thermal efficiency above 40%, maximum brake mean effective pressure (BMEP) of 19.5 bar, a power output of 450 hp and a peak torque of 1750 ft-lbs (all North American calibration), the Westport GX provides the highest natural gas engine performance on the market today. However, HPDI is currently more expensive that other competing natural gas engine technologies in part because volumes are still

low, in part because it is so novel, in part it requires more complex components, HPDI is currently more expensive than other competing natural gas engine technologies. During the commercialization of the HPDI technology, new technologies have been advancing to improve the efficiency of comparable diesel engines. The project described in this proposal is aimed directly at further reducing the initial ownership and operating costs of HPDI technology, and at exploring selected efficiency improvements. Recognizing the situation that gas quality may be more variable as a result of new sources of natural gas entering the market, we also propose to improve the technology by exploring options for reducing sensitivity to fuel composition variance using one of our smart sensor techniques recently developed under the Department of Energy (DOE) sponsorship.

Goals of the Agreement:

The goals of the agreement are:

- To further reduce the initial ownership and operating costs of HPDI technology, and to explore selected efficiency improvements.
- To improve engine performance (BMEP) and robustness to fuel quality variations.

Objectives of the Agreement:

The objectives of this agreement are:

- Reduce the heavy-duty HPDI engine system component costs (fuel system, in particular injectors and fuel rail pressure control module, and exhaust after treatment) by 20% compared to current design.
- Reduce HPDI fuel consumption by 5% from current levels over an European Stationary Cycle (ESC) test which will lead to an approximately 20% lower ESC averaged fuel consumption compared to today's spark ignited (SI) engine.
- Improve HPDI power density by 10% (up to 21.5 bar) from current levels which will lead to an engine power density that is approximately 25% higher compared to today's SI engines.
- Maintain emissions below 2010 Environmental Protection Agency (EPA) emissions targets (0.2 grams per brake horse power-hour [g/bhp-hr] Oxides of Nitrogen [NOx], 0.01 g/bhp-hr particulate matter [PM], 0.14 Non methane Hydrocarbon g/bhp-hr) while improving on greenhouse gas emissions by approximately 20% compared to today's SI engines.
- Improve engine operating robustness to natural gas quality and achieve satisfactory engine operation for a wider range of fuel quality.

Product Guidelines:

For complete product guidelines, refer to Section 5 in the Terms and Conditions.

TASK 1 ADMINISTRATION

Task 1.1 Attend Kick-off Meeting

The goal of this task is to establish the lines of communication and procedures for implementing this Agreement.

The Recipient shall:

- Attend a "Kick-Off" meeting with the Commission Project Manager, the Grants Officer, and a representative of the Accounting Office. The Recipient shall bring its Project Manager, Agreement Administrator, Accounting Officer, and others designated by the Commission Project Manager to this meeting. The administrative and technical aspects of this Agreement will be discussed at the meeting. Prior to the kick-off meeting, the Commission Project Manager will provide an agenda to all potential meeting participants.

  The administrative portion of the meeting shall include, but not be limited to, the following:
  - Discussion of the terms and conditions of the Agreement.
  - Discussion of Critical Project Review (Task 1.2).
  - Match fund documentation (Task 1.6).
  - Permit documentation (Task 1.7).

  The technical portion of the meeting shall include, but not be limited to, the following:
  - The Commission Project Manager's expectations for accomplishing tasks described in the Scope of Work.
  - An updated Schedule of Products.
  - Discussion of Progress Reports (Task 1.4).
  - Discussion of Technical Products (Product Guidelines located in Section 5 of the Terms and Conditions).
  - Discussion of the Final Report (Task 1.5).

The Commission Project Manager shall:

- Designate the date and location of this meeting.

Recipient Products:

- Updated Schedule of Products
- Updated List of Match Funds
- Updated List of Permits

Commission Project Manager Product:

- Kick-Off Meeting Agenda

Task 1.2 Critical Project Review (CPR) Meetings

The goal of this task is to determine if the project should continue to receive Energy Commission funding to complete this Agreement and to identify any needed modifications to the tasks, products, schedule or budget.

CPRs provide the opportunity for frank discussions between the Energy Commission and the Recipient. CPRs generally take place at key, predetermined points in the Agreement, as determined by the Commission Project Manager and as shown in the Technical Task List above. However, the Commission Project Manager may schedule additional CPRs as necessary, and any additional costs will be borne by the Recipient.

Participants include the Commission Project Manager and the Recipient and may include the Commission Grants Officer, the Public Interest Energy Research (PIER) Program Team Lead, other Energy Commission staff and Management as well as other individuals selected by the Commission Project Manager to provide support to the Energy Commission.

The Commission Project Manager shall:

- Determine the location, date, and time of each CPR meeting with the Recipient. These meetings generally take place at the Energy Commission, but they may take place at another location.
- Send the Recipient the agenda and a list of expected participants in advance of each CPR. If applicable, the agenda shall include a discussion on both match funding and permits.
- Conduct and make a record of each CPR meeting. One of the outcomes of this meeting will be a schedule for providing the written determination described below.
- Determine whether to continue the project, and if continuing, whether or not modifications are needed to the tasks, schedule, products, and/or budget for the remainder of the Agreement. Modifications to the Agreement may require a formal amendment (please see the Terms and Conditions). If the Commission Project Manager concludes that satisfactory progress is not being made, this conclusion will be referred to the Energy Commission's Research, Development and Demonstration (RD&D) Policy Committee for its concurrence.
- Provide the Recipient with a written determination in accordance with the schedule. The written response may include a requirement for the Recipient to revise one or more product(s) that were included in the CPR.

The Recipient shall:

- Prepare a CPR Report for each CPR that discusses the progress of the Agreement toward achieving its goals and objectives. This report shall include recommendations and conclusions regarding continued work of the projects. This report shall be submitted along with any other products identified in this scope of work. The Recipient shall submit these

documents to the Commission Project Manager and any other designated reviewers at least 15 working days in advance of each CPR meeting.

- Present the required information at each CPR meeting and participate in a discussion about the Agreement.

Commission Project Manager Products:

- Agenda and a list of expected participants
- Schedule for written determination
- Written determination

Recipient Product:

- CPR Report(s)

Task 1.3 Final Meeting

The goal of this task is to closeout this Agreement.

The Recipient shall:

- Meet with Energy Commission staff to present the findings, conclusions, and recommendations. The final meeting must be completed during the closeout of this Agreement.

  This meeting will be attended by, at a minimum, the Recipient, the Commission Grants Office Officer, and the Commission Project Manager. The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be two separate meetings at the discretion of the Commission Project Manager.

  The technical portion of the meeting shall present an assessment of the degree to which project and task goals and objectives were achieved, findings, conclusions, recommended next steps (if any) for the Agreement, and recommendations for improvements. The Commission Project Manager will determine the appropriate meeting participants.

  The administrative portion of the meeting shall be a discussion with the Commission Project Manager and the Grants Officer about the following Agreement closeout items:
  - What to do with any equipment purchased with Energy Commission funds (Options).
  - Energy Commission's request for specific "generated" data (not already provided in Agreement products).
  - Need to document Recipient's disclosure of "subject inventions" developed under the Agreement.
  - "Surviving" Agreement provisions, such as repayment provisions and confidential Products.
  - Final invoicing and release of retention.

- o Prepare a schedule for completing the closeout activities for this Agreement.

Products:

- Written documentation of meeting agreements
- Schedule for completing closeout activities

Task 1.4 Quarterly Progress Reports

The goal of this task is to periodically verify that satisfactory and continued progress is made towards achieving the research objectives of this Agreement on time and within budget.

The objectives of this task are to summarize activities performed during the reporting period, to identify activities planned for the next reporting period, to identify issues that may affect performance and expenditures, and to form the basis for determining whether invoices are consistent with work performed.

The Recipient shall:

- Prepare a Quarterly Progress Report which summarizes all Agreement activities conducted by the Recipient for the reporting period, including an assessment of the ability to complete the Agreement within the current budget and any anticipated cost overruns. Each progress report is due to the Commission Project Manager within 15 working days of the end of the reporting period. The recommended specifications for each progress report are contained in the terms and conditions of this Agreement.

Product:

- Quarterly Progress Reports

Task 1.5 Final Report

The goal of the Final Report is to assess the project's success in achieving its goals and objectives, advancing science and technology, and providing energy-related and other benefits to California.

The objectives of the Final Report are to clearly and completely describe the project's purpose, approach, activities performed, results, and advancements in science and technology; to present a public assessment of the success of the project as measured by the degree to which goals and objectives were achieved; to make insightful observations based on results obtained; to draw conclusions; and to make recommendations for further RD&D projects and improvements to the PIER project management processes.

The Final Report shall be a public document. If the Contractor has obtained confidential status from the Energy Commission and will be preparing a confidential version of the Final Report as well, the Contractor shall perform the following subtasks for both the public and confidential versions of the Final Report.

The Recipient shall:

- Prepare an Outline of the Final Report.
- Prepare a Final Report following the approved outline and the latest version of the PIER Final Report guidelines published on the Energy Commission's website at http://www.energy.ca.gov/contracts/pier/contractors/index.html at the time the Recipient begins performing this task, unless otherwise instructed in writing by the Commission Project Manager. Instead of the timeframe listed in the Product Guidelines located in Section 5 of the Terms and Conditions, the Commission Project Manager shall provide written comments on the Draft Final Report within fifteen (15) working days of receipt. The Final Report must be completed on or before the end of the Agreement Term.
- Submit one bound copy of the Final Report with the final invoice.

Products:

- Draft Outline of the Final Report
- Final Outline of the Final Report
- Draft Final Report
- Final Report

Task 1.6 Identify and Obtain Matching Funds

The goal of this task is to ensure that the match funds planned for this Agreement are obtained for and applied to this Agreement during the term of this Agreement.

The costs to obtain and document match fund commitments are not reimbursable through this Agreement. Although the PIER budget for this task will be zero dollars, the Recipient may utilize match funds for this task. Match funds shall be spent concurrently or in advance of PIER funds for each task during the term of this Agreement. Match funds must be identified in writing and the associated commitments obtained before the Recipient can incur any costs for which the Recipient will request reimbursement.

The Recipient shall:

- Prepare a letter documenting the match funding committed to this Agreement and submit it to the Commission Project Manager at least 2 working days prior to the kick-off meeting. If no match funds were part of the proposal that led to the Energy Commission awarding this Agreement and none have been identified at the time this Agreement starts, then state such in the letter. If match funds were a part of the proposal that led to the Energy Commission awarding this Agreement, then provide in the letter a list of the match funds that identifies the:
    - Amount of each cash match fund, its source, including a contact name, address and telephone number and the task(s) to which the match funds will be applied.

- o Amount of each in-kind contribution, a description, documented market or book value, and its source, including a contact name, address and telephone number and the task(s) to which the match funds will be applied. If the in-kind contribution is equipment or other tangible or real property, the Recipient shall identify its owner and provide a contact name, address and telephone number, and the address where the property is located.
- Provide a copy of the letter of commitment from an authorized representative of each source of cash match funding or in-kind contributions that these funds or contributions have been secured.
- Discuss match funds and the implications to the Agreement if they are reduced or not obtained as committed, at the kick-off meeting. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide the appropriate information to the Commission Project Manager if during the course of the Agreement additional match funds are received.
- Notify the Commission Project Manager within 10 days if during the course of the Agreement existing match funds are reduced. Reduction in match funds must be approved through a formal amendment to the Agreement and may trigger an additional CPR.

Products:

- A letter regarding match funds or stating that no match funds are provided
- Copy(ies) of each match fund commitment letter(s) (if applicable)
- Letter(s) for new match funds (if applicable)
- Letter that match funds were reduced (if applicable)

Task 1.7 Identify and Obtain Required Permits

The goal of this task is to obtain all permits required for work completed under this Agreement in advance of the date they are needed to keep the Agreement schedule on track.

Permit costs and the expenses associated with obtaining permits are not reimbursable under this Agreement. Although the PIER budget for this task will be zero dollars, the Recipient shall budget match funds for any expected expenditures associated with obtaining permits. Permits must be identified in writing and obtained before the Recipient can make any expenditures for which a permit is required.

The Recipient shall:

- Prepare a letter documenting the permits required to conduct this Agreement and submit it to the Commission Project Manager at least 2 working days prior to the kick-off meeting. If there are no permits required at the start of this Agreement, then state such in the letter. If it is known at the beginning of the Agreement that permits will be required during the course of the Agreement, provide in the letter:
  - o A list of the permits that identifies the:

    - Type of permit.
    - Name, address and telephone number of the permitting jurisdictions or lead agencies.
- The schedule the Recipient will follow in applying for and obtaining these permits.
- Discuss the list of permits and the schedule for obtaining them at the kick-off meeting and develop a timetable for submitting the updated list, schedule and the copies of the permits. The implications to the Agreement if the permits are not obtained in a timely fashion or are denied will also be discussed. If applicable, permits will be included as a line item in the Progress Reports and will be a topic at CPR meetings.
- If during the course of the Agreement additional permits become necessary, provide the appropriate information on each permit and an updated schedule to the Commission Project Manager.
- As permits are obtained, send a copy of each approved permit to the Commission Project Manager.
- If during the course of the Agreement permits are not obtained on time or are denied, notify the Commission Project Manager within 10 days. Either of these events may trigger an additional CPR.

Products:

- Letter documenting the permits or stating that no permits are required
- A copy of each approved permit (if applicable)
- Updated list of permits as they change during the term of the Agreement (if applicable)
- Updated schedule for acquiring permits as changes occur during the term of the Agreement (if applicable)

TECHNICAL TASKS

TASK 2 FUEL SYSTEM REDESIGN MODIFICATION AND COST REDUCTION

The goal of this task is to improve the design of the HPDI fuel system (injectors and fuel rail pressure control module) and lower the costs by reducing system complexity and number of components.

Task 2.1 Mechanical Design Modification of the HPDI Injector and Fuel Rail Pressure Control Module

The Recipient shall:

- Evaluate design and manufacturing improvements identified in the Oct/Nov 2008 Value Analysis Value Engineering (VAVE) exercise that was carried out at Westport for reducing the injector and associated fuel system complexity and cost. The VAVE analysis identified improvements

to the injector and associated fuel system, such as a reduction in number of machining operations, reduction in number of parts, design simplifications, and reduction in costs achievable through volume procurement and supply chain improvements. A simpler compressed natural gas (CNG) fuel pressure regulation system with fewer set points was also evaluated as part of the VAVE analysis. These improvements and any other potentially new concepts will be evaluated in light of the current project.

- Rank and select design and manufacturing improvements from VAVE analysis to achieve project cost reduction targets and estimate impact on cost reduction.
- Perform engineering calculations and drawings for fabricating injector and associated fuel system components.

Product:

- A summary report on ranking and selection of various cost reductions strategies, description of engineering activities for fabricating the injector and associated fuel system parts, and estimates of costs before and after change

Task 2.2 Procure Parts, Build and Test Simplified HPDI Injector and Fuel Rail Pressure Control System

The Recipient shall:

- Acquire, assemble and test prototype parts of the HPDI injectors and associated fuel system.
- Characterize flow behavior of the injectors and optimize operation.

Products:

- A summary report on the prototype injector and associated fuel system build and testing and its comparison to incumbent system
- A summary report on approximate percentage cost reduction achieved

Task 2.3 Test Durability of Modified Components - Injectors, Fuel Rail Pressure Control Module

The Recipient shall:

- Use parts to run limited durability tests up to 300 hours with CNG on a test rig or an engine at Westport.
- Characterize changes in the injectors (CNG and diesel flow verses pulse width) and the fuel rail pressure control module.
- Document changes in the fuel rail pressure control module performance.
- Analyze impact of durability testing on injectors and other parts.
- Prepare report on the durability test data and of the characterization data, recommendations for the designs revisions, and viability of injector design for future production.

Products:

- A summary report on the durability test data and of the characterization data, recommendations for designs revisions, and viability of injector design for future production
- CPR Meeting

TASK 3 ENGINE COMBUSTION STRATEGY AND HARDWARE SELECTION

The goal of this task is to evaluate various combustion and engine operation strategies for improving engine efficiency and power density, reducing operating cost and identifying test engine hardware requirements. As part of the combustion studies the engine may be operated with higher Exhaust Gas Recirculation (EGR) levels than current and may require more accurate control of bulk air/fuel ratio. Schemes for extracting additional energy from the exhaust will also be studied to improve engine efficiency. Westport recently completed development of the start of combustion (SOC) sensor technology for real time combustion control as part of a DOE funded project. Recently, new ideas have been proposed at Westport to integrate input from the SOC sensor with an universal exhaust gas oxygen (UEGO) sensor as well as any other sensors (as necessary) to create an integrated Virtual Sensor to improve engine combustion and operating robustness as well as account for variation in natural gas fuel composition. In this task it is proposed to extend these concepts on virtual sensing through analysis, modeling and engine testing.

Task 3.1 Engine Cycle Modeling and Analysis for Power Density and Efficiency, Specify Hardware Modifications

The Recipient shall:

- Develop, validate and run the engine cycle model using existing commercial software (Engine cycle modeling software from Gamma Technologies or its equivalent).
- Evaluate in-cylinder strategies such as Miller cycle to reduce airflow at light /medium loads without pumping penalties seen with a throttle.
- Evaluate various exhaust energy extraction schemes (e.g. two-stage turbocharging, turbocompounding, Rankine bottoming cycle, etc.) and predict engine performance and efficiency improvements.
- Evaluate strategies such as skip firing for improving part load operation efficiency.
- Identify current engine hardware constraints.
- Evaluate engine hardware modifications required to operate the engine with higher intake boost pressure, drive higher levels of EGR and achieve desired air/fuel ratio control.
- Prepare a report on a set of recommendations and quantitative prediction of performance characteristics and efficiency trade-offs for various exhaust energy recovery schemes, a set of recommendations and predictions of engine performance and efficiency improvement trade-offs,

and identify current engine hardware constraints, and specific engine hardware modifications necessary to implement exhaust energy recovery scheme and achieve desired boost pressure, EGR levels and air/fuel ratio control.

Product:

- Provide a report on a set of recommendations and quantitative prediction of performance characteristics and efficiency trade-offs for various exhaust energy recovery schemes, a set of recommendations and predictions of engine performance and efficiency improvement trade-offs, and identify current engine hardware constraints, and specific engine hardware modifications necessary to implement exhaust energy recovery scheme and achieve desired boost pressure, EGR levels and air/fuel ratio control

Task 3.2 Engine Computational Fluid Dynamics (CFD) Modeling (With Chemical Kinetics) and Evaluation of Various In-Cylinder Advanced Combustion Strategies

The Recipient shall:

- Develop, validate and run the engine CFD (computational fluid dynamics) model to simulate in-cylinder combustion, chemical reactions and flow processes using in-house existing software (e.g. Generic Open-Foam Low Dimension or its equivalent).
- Investigate various low temperature combustion (LTC) regimes (e.g. homogeneous charge compression ignition (HCCI) and combination of HCCI and HPDI-homogeneous charge direct injection) to mitigate in-cylinder generation of pollutants such as NOx and PM in order to reduce exhaust after-treatment requirements. This effort will focus on certain speed/load regimes (lower loads) where LTC can be implemented in theory and would be beneficial to a real driving cycle.
- Investigate effect of engine parameters (e.g. injection timing, injection pressure, multiple fuel injections, swirl ratio, intake charge temperature, EGR level and cylinder/piston surface temperature) on combustion and emissions.
- Investigate effect of piston bowl and fuel injector nozzle geometry changes in order to enable various low temperature combustion regimes.
- Prepare report on a set of predictions of engine performance, efficiency and emissions trade-offs to evaluate various advanced combustion strategies. Identify preferred combustion strategy, and recommendations for piston bowl shape (e.g. injector nozzle geometry, swirl, etc.) to implement desired combustion strategy.

Product:

- Provide report on a set of predictions of engine performance, efficiency and emissions trade-offs to evaluate various advance combustion strategies. Identify preferred combustion strategy, and recommendations for piston bowl shape (e.g.injector nozzle geometry, swirl, etc.) to implement desired combustion strategy

Task 3.3 Analysis of After-treatment Strategies to Downsize/Eliminate Diesel Particulate Filter and Nox After-treatment Systems

The Recipient shall:

- Review available literature on combustion regimes responsible for suppressing in-cylinder production of the NOx and PM emissions.
- Identify various state-of-the art NOx and PM after-treatment technologies available for heavy duty natural gas engines.
- Analyze effectiveness of various NOx and PM after-treatment technologies within the constraints of engine operating and exhaust characteristics.
- Identify engine combustion and operation strategies to downsize or eliminate NOx and PM after-treatment systems.
- Analyze exhaust thermal management strategies to raise exhaust temperature to improve catalyst efficiency (e.g. rich combustion, exhaust system insulation).
- Rank various after-treatment options from cost reduction point of view and review availability of prototype hardware for testing.
- Estimate emissions impact of various after-treatment options.
- Prepare a report on ranking of various NOx and PM after treatment strategies and its impact on engine emissions, efficiency and system cost, availability of prototype hardware for testing, and recommendations for lower cost NOx and PM after treatment strategy.

Product:

- Provide a report on ranking of various NOx and PM aftertreatment strategies and its impact on engine emissions, efficiency and system cost, availability of prototype hardware for testing, and recommendations for lower cost NOx and PM after-treatment strategy

Task 3.4 Review Available Virtual Sensing Technologies and Select Hardware (SOC, UEGO etc.)

The Recipient shall:

- Review capabilities of various sensor technologies available.
- Define fuel composition variability expected for CNG, liquefied natural gas (LNG) and biogas (bio-methane) type of fuels in the United States. Define metrics to measure acceptable engine performance.

- Develop an integrated model of the engine in-cylinder and exhaust parameters which respond to changing gas quality. Review inputs (signals) that provide potential improvements in control strategy and system robustness in light of fuel composition variation.
- Use the model to determine how the virtual sensors (e.g. SOC, UEGO and other) could be used to detect changes in engine performance for variable gas quality. Consider additional or alternate sensors if better or are more cost effective.
- Analyze how these technologies could enhance overall engine emission, performance and operating stability with varying fuel supply.
- Prepare report on various sensor technologies available, and recommendations for a Virtual Sensor system and its integration and control with the engine, diagnostics, and expected benefits and limitations.

Product:

- A report on various sensor technologies available, and recommendations for a Virtual Sensor system and its integration and control with the engine, diagnostics, and expected benefits and limitations

Task 3.5 Ranking and Selection of Preferred Hardware/Software

The Recipient shall:

- Rank hardware approaches according to cost, performance, efficiency and power density benefits.
- Consider other benefits such as simplicity, technology maturity and risk.
- Investigate durability and production readiness of hardware options with partners/suppliers.
- Prepare report on hardware/software rankings based on selected criteria, recommendations to improve ranking for any items that still have perceived potential benefits, and refinements to overall project development strategy/timelines.

Product:

- Provide report on hardware/software rankings based on selected criteria, recommendations to improve ranking for any items that still have perceived potential benefits, and refinements to overall project development strategy/timelines
- CPR Meeting

TASK 4 TEST ENGINE BUILD AND COMMISSIONING

The goal of this task is to procure engine and associated hardware as identified from Tasks 2 and 3, integrate and build the test engine, and commission the engine in a dynamometer engine test cell.

Task 4.1 Procure Test Engine, Associated Engine Parts, Fuel Rail Pressure Control and After-treatment Components

The Recipient shall:

- Procure a commercially available heavy-duty natural gas engine.
- Procure custom designed parts (e.g. modified pistons, injector/fuel rail pressure control module).
- Procure NOx and PM after-treatment systems from vendors.
- Prepare report on inventory of engine and custom design parts procured and status of readiness for building the prototype-A test engine.

Product:

- Report on inventory of engine and custom design parts procured and status of readiness for building the prototype-A test engine

Task 4.2 Engine Prototype-A Build

The Recipient shall:

- Build the prototype-A test engine with custom parts for installation in a dynamometer engine test cell.
- Instrument the engine and fuel system.

Product:

- A report on prototype-A test engine build with modified hardware ready for installation in a dynamometer engine test cell, and test cell hardware and engine instrumentation documentation

Task 4.3 Integrate Virtual Sensors and Controls with Engine Prototype-A Hardware

The Recipient shall:

- Modify existing engine controller code for Virtual Sensor.
- Verify sensors operation, control and diagnostics.
- Prepare summary report on description of Virtual Sensor operation and control strategy and diagnostics.

Product:

- Summary description of Virtual Sensor operation and control strategy and diagnostics

Task 4.4 Adapt Existing Engine Controller for Prototype-A Hardware

The Recipient shall:

- Adapt engine controller code for the prototype-A engine.
- Integrate modified hardware and its operation with original engine calibration, revise control strategy and diagnostics.
- Prepare summary report on control system modification, verification and diagnostics, and recommendations for future improvements.

Product:

- Summary report on control system modification, verification and diagnostics, and recommendations for future improvements

Task 4.5 Engine Prototype-A and Test Cell Commissioning, Baseline Testing

The Recipient shall:

- Install the prototype-A test engine in the dynamometer test cell.
- Instrument the engine with sensors (pressure, temperature, flow etc.) for data acquisition.
- Commission prototype-A engine and test cell equipment to enable engine operation and testing.
- Perform initial testing on the prototype-A engine hardware to create a performance, emissions and efficiency profile.
- Prepare a document summarizing prototype-A test engine build with modified hardware, installation in a dynamometer test cell and commissioning, and a set of steady state performance, emissions and efficiency results to serve as a reference baseline against all future testing.

Product:

- A document summarizing prototype-A test engine build with modified hardware, installation in a dynamometer test cell and commissioning, and a set of steady state performance, emissions and efficiency results to serve as a reference baseline against all future testing

Task 4.6 Engine Valvetrain Low Friction Coating Diamond Like Carbon (Dlc) Study

The Recipient shall:

- Summarize and rank coating options.
- Calculate potential benefits of reduced valvetarin friction, particularly under marginal conditions such as low speed.
- Select candidate coatings such as DLC or other coating technology from potential US national lab or commercial suppliers. Decide whether coating provides sufficient benefits to warrant proceeding to experimental tests based on efficiency benefits alone.

- Modify valvetrain components with best low friction coating – candidate parts include cam lobes, lifters, rocker arm contact points.
- Conduct motored friction tests with and without DLC coated valve train components. Calculate change in friction.

Products:

- Provide report with:
  - Short listing of main coating technologies and published benefits;
  - Calculations on friction levels for base and prototype coated engine valvetrain;
- CPR Meeting
  - Projected and measured friction data for engine at certain load / speed conditions; and
  - Recommendation on the value of DLC coatings to improving brake specific fuel consumption

TASK 5 ENGINE COMBUSTION, PERFORMANCE AND EMISSIONS DEVELOPMENT

The goal of this task **i**s to conduct experimental and analytical investigation of various engine combustion and operating strategies for the purpose engine combustion, performance and emissions development. Various combustion strategies such as HPDI, HCCI and a combination of the two (also called Homogeneous Charge Direct Injection [HCDI] or other low temperature combustion ideas will be tested at selected engine operating conditions (i.e. steady state speed-load operating points on the engine map) to achieve set performance, efficiency and emissions targets. Limited testing of NOx and PM after-treatment systems will be undertaken depending on the availability of hardware.

Task 5.1 Test Engine Operating and Combustion Robustness with Virtual Sensor

The Recipient shall:

- Investigate various combustion control strategies with the Virtual sensor.
- Investigate engine robustness against fuel composition variations (within limits expected in the USA) and strategies to mitigate its impact on combustion and emissions.
- Prepare report summarizing description of combustion control strategies with the Virtual Sensor, and on engine robustness study to natural gas quality variations.

Product:

- Provide a report summarizing description of combustion control strategies with the Virtual Sensor, and on engine robustness study to natural gas quality variations

Task 5.2 Engine Testing of Various Combustion Strategies

The Recipient shall:

- Investigation of pilot diesel HPDI (HPDI with pilot diesel ignition) combustion strategies at selected engine operating conditions.
- Investigation of HCCI and HCDI as well as other low temperature combustion concepts at selected engine operating conditions.
- Investigate effect of engine parameters – injection timings for pilot diesel and gas, injection pressure, intake charge temperature, boost pressure, EGR level, air/fuel ratio, **pilot quantity, multiple injections of gas, multiple pilot injections,** swirl ratio etc. on HPDI, HCCI and HCDI operation at selected engine operating conditions.

Products:

- Provide a report containing the following:
  - Summary test data for individual engine operating conditions
  - Summary test data for ESC 13-mode steady state cycle operation
  - Summary report and recommendations on potential virtual sensor diagnostics for combustion control
  - Summary report on effect of various combustion and operating strategies on engine performance, emissions and efficiency trade-offs
  - Summary report identifying portions of engine map (torque verses engine crank revolutions per minute) most suitable for HPDI, HCCI or HCDI type of operations respectively
  - Summary report identifying engine hardware constraints encountered (if any) while attempting HPDI, HCCI or HCDI operation

Task 5.3 Engine Testing for Nox and PM Mitigation

The Recipient shall:

- Conduct engine testing to identify combustion regimes (if any) generates lowest in-cylinder NOx and PM emissions at selected engine operating conditions.
- Conduct engine testing with a NOx after-treatment system to achieve desired NOx conversion efficiency (the scope of testing will be subject to availability of NOx after-treatment hardware) at selected engine operating conditions.
- Engine testing with a PM after-treatment system to achieve desired PM conversion efficiency (the scope of testing will be subject to availability of PM after-treatment hardware) at selected engine operating conditions.
- **Jointly evaluate prototype PM and NOx aftertreatment systems as part of the overall system level optimization for cost reduction and take into account significant interactions between modifications of the engine and the aftertreatment system.**
- Test various exhaust thermal management strategies to raise exhaust

temperature to improve catalyst efficiency at selected engine operating conditions.

- Prepare a summary report containing test results of engine operating strategies that lead to either reduction of in-cylinder production of NOx or PM emissions, test results quantifying the effectiveness of the NOx an PM after-treatment systems, and a set of recommendations for downsizing NOx and PM after treatment systems, relative performance/efficiency/cost trade-offs, report any system limitations.

Product:

- Provide a summary report containing test results of engine operating strategies that lead to either reduction of in-cylinder production of NOx or PM emissions, test results quantifying the effectiveness of the NOx an PM after-treatment systems, and a set of recommendations for downsizing NOx and PM aftertreatment systems, relative performance/efficiency/cost trade-offs, report any system limitations

Task 5.4 Engine Modeling and Review of Virtual Sensor to Refine the Prototype-A Engine Hardware

The Recipient shall:

- Run engine models developed during tasks 3.1 and 3.2 with available experimental data from task 5.1 to examine whether changes to prototype-A hardware are required.
- **Use computational fluid dynamics (CFD) modeling to find a piston shape optimized for the prototype J236 injectors. Extend piston bowl shape modification to HPDI combustion in order to control engine emissions in conjunction with the prototype aftertreatment systems that will be tested.**
- Review the virtual sensor for further improvements.
- Perform cost/benefit analysis of further improvements to prototype hardware-A and specify modifications (if any).
- Prepare a report with recommendations for modifying prototype-A hardware as necessary.

Product:

- Provide a report with recommendations for modifying prototype-A hardware as necessary

Task 5.5 Refine Prototype-A Engine Hardware, Procure Parts and Build Prototype-B Engine

The Recipient shall:

- Procure custom designed parts (if any) to build the prototype-B engine.
- **Test prototype camshafts with various valve timing (either on a multi-cylinder or a single cylinder engine).**

- Build the prototype-B test engine (if required) with modified parts and install the engine in dynamometer test cell.
- Prepare a report with summary description of the prototype-B test engine build with modified hardware ready for installation in a dynamometer engine test cell.

Product:

- Provide a report with summary description of the prototype-B test engine build with modified hardware ready for installation in a dynamometer engine test cell

Task 5.6 Adapt Existing Engine Controller for Prototype B Hardware

The Recipient shall:

- Revise engine controller code for the prototype-B engine.
- Refine calibrations, strategy and diagnostics.
- Prepare a report on revised control system operation, verification and diagnostics.

Product:

- Provide a report on revised control system operation, verification and diagnostics
- CPR Meeting

TASK 6 ENGINE OPTIMIZATION AND FINAL PERFORMANCE AND EMISSIONS TESTING

The goal of this task is to conduct experimental investigation of prototype-B hardware to refine engine performance, emissions and efficiency to achieve desired project targets and conduct final engine performance and emissions testing.

Task 6.1 Refine Prototype-B Engine Operation to Achieve Project Targets and Develop Calibration

The Recipient shall:

- Conduct engine test cell refinement of prototype-B engine operation for emissions, power density and efficiency and develop engine calibration.
- **Accommodate prototype J236 injectors in conjunction with piston bowl shape optimization, and effect of valve timing.**
- Prepare a summary report on prototype-B engine operation refinement and trade-offs for performance, emissions and efficiency.

Product:

- Provide report on prototype-B engine operation refinement and trade-offs for performance, emissions and efficiency

Task 6.2 Final Performance and Emissions Verification of Prototype-B Engine

The Recipient shall:

- Conduct final test cell performance and emissions verification using the steady state ESC 13-mode test cycle on prototype-B engine.
- **Complete engine optimization with prototype-B hardware including J236 injectors with full range of engine parameters (e.g. EGR level, charge temperature, boost pressure, swirl ratio, pilot quantity, pilot injection timing, multiple gas injections, fuel injection pressure, gas premixing) identified from modeling and previous engine testing.**
- **Search, optimize, and verify the best overall strategy for the engine, including the aftertreatment system.**
- Prepare a summary report on prototype-B engine performance and emissions verification.

Product:

- Provide a summary report on prototype-B engine performance and emissions verification

Task 6.3 Quantify Overall Cost Reductions with Optimized Prototype-B Engine Hardware and Operating Strategies

The Recipient shall:

- Quantify capital cost reductions in terms simplified engine hardware (injector, fuel rail pressure control, after-treatment).
- Quantify effect of engine fuel consumption reduction on operating costs over the life of a vehicle.
- Prepare a report quantifying overall cost reductions benefits with the optimized prototype-B engine hardware and engine operating strategies.

Product:

- Provide a report quantifying overall cost reductions benefits with the optimized prototype-B engine hardware and engine operating strategies

TASK 7 TECHNOLOGY TRANSFER ACTIVITIES

The goal of this task is to develop a technology transfer plan for the low cost HPDI heavy duty natural gas engine as part of the commercialization activity. A progress update on technology transfer activities will be provided in the quarterly report as the project progresses. A final summary of these activities will be presented as part of the technology transfer plan towards the end of the project.

Task 7.1 Draft Technology Transfer Plan

The Recipient shall:

- Develop a technology transfer plan for the low cost HPDI heavy-duty natural gas engine.
- Prepare a draft report outlining technology transfer plan

Product:

- Provide a draft report outline technology transfer plan

Task 7.2 Final Technology Transfer Plan

The Recipient shall:

- Finalize technology transfer plan for the low cost HPDI heavy-duty natural gas engine.
- Prepare a report outlining finalized technology transfer plan.

Product:

- Provide a report outlining finalized technology transfer plan

TASK 8 PRODUCTION READINESS ACTIVITIES

The goal of this task is to develop a production readiness plan for the low cost HPDI heavy duty natural gas engine as part of the commercialization activity. A progress update on production readiness activities will be provided in the quarterly report as the project progresses. A final summary of these activities will be presented as part of the production readiness plan towards the end of the project.

Task 8.1 Draft Production Readiness Plan

The Recipient shall:

- Develop a production readiness plan for the low cost HPDI heavy-duty natural gas engine.
- Prepare a draft report outlining production readiness plan.

Product:

- Provide a draft report outlining production readiness plan

Task 8.2 Final Production Readiness Plan

The Recipient shall:

- Finalize production readiness plan for the low cost HPDI heavy-duty natural gas engine.
- Prepare a report outlining finalized production readiness plan.

Product:

- Provide a report outlining finalized production readiness plan

Category Budget

Budget Category Item	Original PIER Share ($)	**Amd #1 PIER Share ($)**	Original Match Share ($)	**Amd #1 Match Match Share ($)**	Original Total Cost ($)	**Amd #1 Total Cost ($)**
Personnel:						
Direct Labor	$ 171,623	$ 169,467	$ 171,623	$ 169,467	$ 343,246	$ 338,934
Fringe Benefits	$ 48,570	$ 47,960	$ 48,570	$ 47,960	$ 97,140	$ 95,920
Total Personal Services	$ 220,193	**$ 217,427**	$ 220,193	**$ 217,427**	$ 440,386	**$ 434,854**
Operating Expenses:						
Travel	$ 7,500	$ 7,500	$ 7,500	$ 7,500	$ 15,000	$ 15,000
Equipment	$ 82,030	$ 51,267	$ 82,030	$ 51,267	$ 164,060	$ 102,534
Materials/Supplies	$ 90,955	$ 95,955	$ 90,955	$ 95,955	$ 181,910	$ 191,910
Contractual	$ 7,500	$ -	$ 7,500	$ -	$ 15,000	$ -
Miscellaneous	$ 225,000	$ 265,625	$ 225,000	$ 265,625	$ 450,000	$ 531,250
Total Operating Expenses	$ 412,985	**$ 420,347**	$ 412,985	**$ 420,347**	$ 825,970	**$ 840,694**
Overhead:						
Overhead	$ 365,666	$ 361,070	$ 365,666	$ 361,070	$ 731,332	$ 722,140
Total Overhead	$ 365,666	**$ 361,070**	$ 365,666	**$ 361,070**	$ 731,332	**$ 722,140**
Total	*$ 998,844*	***$ 998,844***	*$ 998,844*	***$ 998,844***	*$ 1,997,688*	***$ 1,997,688***

Schedule of Products and Due Dates

Task Number	*Task Name*	*Product(s)*	*Original Planned Start Date*	*Amendment 1 Planned Start Date*	*Original Due Date*	*Amendment 1 Due Date*
1.1	**Attend Kick-off Meeting**					
		Updated Schedule of Products	Effective Date	1/7/2010	8/7/2009	1/7/2010
		Updated List of Match Funds	Effective Date	1/7/2010	8/7/2009	1/7/2010
		Updated List of Permits	Effective Date	1/7/2010	8/7/2009	1/7/2010
		Kick-Off Meeting Agenda (CEC)	Effective Date	1/7/2010	8/7/2009	1/7/2010
1.2	**Critical Project Review Meetings**					
	1st CPR Meeting	CPR Report	5/31/2010	5/10/2011	6/30/2010	5/10/2011
		Agenda and a list of expected participants (CEC)	3/1/2010	5/3/2011	3/15/2010	5/10/2011
		Schedule for written determination (CEC)	4/1/2010	5/10/2011	4/15/2010	5/10/2011
		Written determination (CEC)	4/15/2010	5/17/2011	4/30/2010	5/17/2011
	2nd CPR Meeting	CPR Report	1/31/2010	1/17/2012	2/25/2010	1/17/2012
		Agenda and a list of expected participants (CEC)	11/1/2009	1/10/2012	11/15/2009	1/10/2012
		Schedule for written determination (CEC)	12/1/2009	1/17/2012	12/15/2009	1/17/2012
		Written determination (CEC)	12/15/2009	1/24/2012	12/31/2009	1/24/2012
	3rd CPR Meeting	CPR Report	7/31/2010	6/12/2012	8/31/2010	6/12/2012
		Agenda and a list of expected participants (CEC)	5/1/2010	6/5/2012	5/15/2010	6/5/2012
		Schedule for written determination (CEC)	6/1/2010	6/12/2012	6/15/2010	6/12/2012
		Written determination (CEC)	6/15/2010	6/19/2012	6/30/2010	6/19/2012
	4th CPR Meeting	CPR Report	4/30/2011	N/A	5/31/2011	N/A
		Agenda and a list of expected participants (CEC)	2/1/2011	N/A	2/15/2011	N/A
		Schedule for written determination (CEC)	3/1/2011	N/A	3/15/2011	N/A
		Written determination (CEC)	3/15/2011	N/A	3/30/2011	N/A
1.3	**Final Meeting**					
		Written documentation of meeting agreements	11/1/2011	10/1/2012	11/15/2011	10/30/2012
		Schedule for completing closeout activities	11/1/2011	10/1/2012	1/31/2012	10/30/2012
1.4	**Monthly Progress Reports**					
		Monthly Progress Reports	Upon full execution of agreement	Upon full execution of agreement	The 10th of each month during the approved term of this Agreement	The 10th of each month during the approved term of this Agreement
1.5	**Final Report**					
		Draft Outline of the Final Report	10/15/2011	7/13/2012	11/1/2011	7/20/2012
		Final Outline of the Final Report	11/1/2011	7/20/2012	11/15/2011	7/27/2012
		Draft Final Report	11/15/2011	7/27/2012	12/15/2011	8/3/2012
		Final Report	12/15/2011	8/3/2012	1/15/2012	9/28/2012
1.6	**Identify and Obtain Match Funds**					
		A letter regarding match funds or stating that no match funds are provided	N/A	N/A	N/A	N/A
		Copy(ies) of each match fund commitment letter(s) (if applicable)	7/1/2009	7/15/2009	8/31/2009	7/15/2009
		Letter(s) for new match funds (if applicable)	N/A	N/A	Within 10 days of identifying new match funds	Within 10 days of identifying new match funds
		Letter that match funds were reduced (if applicable)	N/A	N/A	Within 10 days of identifying new match funds	Within 10 days of identifying new match funds
1.7	**Identify and Obtain Required Permits**					
		Letter documenting the permits or stating that no permits are required	N/A	N/A	N/A	N/A
		A copy of each approved permit (if applicable)	N/A	N/A	Within 10 days of receiving each permit	Within 10 days of receiving each permit
		Updated list of permits as they change during the term of the Agreement (if applicable)	N/A	N/A	Within 10 days of change in list of permits	Within 10 days of change in list of permits
		Updated schedule for acquiring permits as changes occur during the term of the Agreement (if applicable)	N/A	N/A	Within 10 days of change in schedule for obtaining permits	Within 10 days of change in schedule for obtaining permits

2.1	**Mechanical Design Modification of the HPDI Injector and Fuel Rail Pressure Control Module**				
	A summary report on ranking and selection of various cost reduction strategies, description of engineering activities for fabricating the injector and associated fuel system parts, and estimates of costs before and after change	9/1/2009	1/1/2010	12/15/2009	9/30/2010
2.2	**Procure Parts, Build and TProcure Parts, Build and Test Simplified HPDI Injector and Fuel Rail Pressure Control System**				
	A summary report on the prototype injector and associated fuel system build and testing and its comparison to incumbent system	9/1/2009	1/15/2011	3/31/2010	12/31/2011
	A summary report on approximate percentage cost reduction achieved	9/1/2009	1/15/2011	3/31/2010	12/31/2011
2.3	**Test Durability of Modified Components - Injectors, Fuel Rail Pressure Control Module**				
	A summary report on the durability test data and of the characterization data, recommendations for design revisions, and viability of injector design for future production	2/1/2010	12/31/2011	5/31/2010	3/31/2012
3.1	**Engine Cycle Modeling and Analysis for Power Density and Efficiency, Specify Hardware Modifications**				
	Provide report on a set of recommendations and quantitative prediction of performance characteristics and efficiency trade-offs for various exhaust energy recovery schemes, a set of recommendations and prediction of engine performance and efficiency improvement trade-offs, and identify current engine hardware constraints, and specific engine hardware modifications necessary to implement exhaust energy recovery scheme and achieve desired boost pressure, EGR levels and air/fuel ratio control	9/1/2009	4/1/2010	1/31/2010	3/31/2011
3.2	**Engine Computational Fluid Dynamics (CFD) Modeling (With Chemical Kinetics) and Evaluation of Various In-Cylinder Advanced Combustion Strategies**				
	Provide report on a set of predictions of engine performance, efficiency and emissions trade-offs to evaluate various advanced combustion strategies. Identify preferred combustion strategy, and recommendations for piston bowl shape (e.g. injector nozzle geometry, swirl, etc.) to implement desired combustion strategy	9/1/2009	4/1/2010	1/31/2010	3/31/2011
3.3	**Analysis of Aftertreatment Strategies to Downsize/Eliminate Diesel Particulate Filter and Nox Aftertreatment Systems**				
	Provide a report on ranking of various NOx and PM aftertreatment strategies and its impact on engine emissions, efficiency and system cost, availability of prototype hardware for testing, and recommendations for lower cost NOx and PM aftertreatment strategy	9/1/2009	4/1/2010	1/31/2010	9/30/2010
3.4	**Review available Virtual sensing technologies and select hardware (SOC, UEGO etc.)**				

	A report on various sensor technologies available, and recommendations for a Virtual Sensor system and its integration and control with the engine, diagnostics, and expected benefits and limitations	9/1/2009	4/1/2010	1/31/2010	9/30/2010
3.5	**Ranking and Selection of Preferred Hardware/Software**				
	Provide report on hardware/software rankings based on selected criteria, recommendations to improve ranking for any items that still have perceived potential benefits, and refinements to overall project development strategy/timelines	1/1/2010	6/1/2010	1/31/2010	9/30/2010
4.1	**Procure Test Engine, Associated Engine Parts, Fuel Rail Pressure Control and Aftertreatment Components**				
	Report on inventory of engine and custom design parts procured and status of readiness for building the prototype-A test engine	9/1/2009	4/1/2010	3/31/2010	5/31/2011
4.2	**Engine Prototype-A Build**				
	A report on prototype-A test engine build with modified hardware ready for installation in a dynamometer engine test cell, and test cell hardware and engine instrumentation documentation	11/1/2009	6/1/2010	3/31/2010	9/30/2010
4.3	**Integrate Virtual Sensors and Controls with Engine Prototype-A Hardware**				
	Summary report on description of Virtual Sensor operation and control strategy and diagnostics	11/1/2009	6/1/2010	3/31/2010	3/31/2011
4.4	**Adapt Existing Engine Controller for Prototype-A Hardware**				
	Summary report on control system modification, verification and diagnostics, and recommendations for future improvements	11/1/2009	6/1/2010	3/31/2010	3/31/2011
4.5	**Engine Prototype-A and Test Cell Commissioning, Baseline Testing**				
	A document summarizing prototype-A test engine build with modified hardware, installation in a dynamometer test cell and commissioning, and a set of steady state performance, emissions and efficiency results to serve as a reference baseline against all future testing	1/15/2010	9/1/2010	3/31/2010	9/30/2010
4.6	**Engine Valvetrain Low Friction Coating Diamond Like Carbon (Dlc) Study**				
	Provide a summary report	9/1/2009	9/31/2010	7/31/2010	3/31/2011
5.1	**Test Engine Operating and Combustion Robustness with Virtual Sensor**				
	Provide a report summarizing description of combustion control strategies with the Virtual Sensor, and on engine robustness study to natural gas quality variations	3/15/2010	6/1/2011	5/31/2010	12/31/2011
5.2	**Engine Testing of Various Combustion Strategies**				
	Provide a summary report	5/15/2010	6/1/2011	1/31/2011	3/30/2012
5.3	**Engine Testing for NOx and PM Mitigation**				

	Provide a summary report containing test results of engine operating strategies that lead to either reduction of in-cylinder production of NOx or PM emissions, test results quantifying the effectiveness of the NOx an PM aftertreatment systems, and a set of recommendations for downsizing NOx and PM aftertreatment systems, relative performance/efficiency/cost trade-offs, report any system limitations	5/15/2010	6/1/2011	1/31/2011	3/30/2012
5.4	**Engine Modeling and Review of Virtual Sensor to Refine the Prototype-A Engine Hardware**				
	Provide a report with recommendations for modifying prototype-A hardware as necessary	1/1/2010	6/1/2011	10/31/2010	3/31/2012
5.5	**Refine Prototype-A Engine Hardware, Procure Parts and Build Prototype-B Engine**				
	Provide a report with summary description of the prototype-B test engine build with modified hardware ready for installation in a dynamometer engine test cell	9/1/2010	9/1/2011	4/30/2011	3/30/2012
5.6	**Adapt Existing Engine Controller For Prototype B Hardware**				
	Provide a report on revised control system operation, verification and diagnostics	1/1/2011	9/1/2011	4/30/2011	3/30/2012
6.1	**Refine Prototype-B Engine Operation to Achieve Project Targets and Develop Calibration**				
	a summary report on prototype-B engine operation refinement and trade-offs for performance, emissions and efficiency	5/1/2011	3/31/2012	8/31/2011	6/29/2012
6.2	**Final Performance and Emissions Verification of Prototype-B Engine**				
	Provide a summary report on prototype-B engine performance and emissions verification	7/1/2011	4/30/2012	8/31/2011	7/31/2012
6.3	**Quantify Overall Cost Reductions with Optimized Prototype-B Engine Hardware and Operating Strategies**				
	Provide a report quantifying overall cost reductions benefits with the optimized prototype-B engine hardware and engine operating strategies	5/1/2011	3/30/2012	10/31/2011	6/29/2012
7.1	**Draft Technology Transfer Activities**				
	Provide a draft report outlining technology transfer plan	5/1/2011	3/30/2012	8/31/2011	6/29/2012
7.2	**Final Technology Transfer Activities**				
	Provide a report outlining finalized technology transfer plan	9/1/2011	6/29/2012	12/31/2011	9/28/2012
8.1	**Draft Production Readiness Plan**				
	Provide a draft report outlining production readiness plan	5/1/2011	3/30/2012	8/31/2011	6/29/2012
8.2	**Final Production Readiness Plan**				
	Provide a report outlining finalized production readiness plan	9/1/2011	6/29/2012	12/31/2011	9/28/2012

CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA) COMPLIANCE

Award Number: PIR-08-045-01 Date: 11 / 18 / 2011

Note: The Energy Commission Project Managers Manual includes detailed instructions on how to complete this section, with examples of grants that are "Projects" and are not "Projects". When the Project Manager is completing this section, if questions arise as to the appropriate answers to the questions below, please consult with the Energy Commission attorney assigned to review grants or loans for your division.

1. Is grant/loan considered a "Project" under CEQA? ☒ Yes *(skip to question #2)* ☐ No *(continue with question #1)*

   Please complete the following: *[Public Resources Code (PRC) 21065 and 14 California Code of Regulations (CCR) 15378]:*

   Explain why the grant/loan is ***not*** considered a "Project"? The grant/loan will not cause a direct physical change in the environment or a reasonably foreseeable indirect physical change in the environment because grant/loan involves:

2. If grant/loan is considered a "Project" under CEQA: *(choose either **IS** or **IS NOT**)*

   ☐ Grant/loan **IS** exempt:

   ☐ Statutory Exemption: *(List PRC and/or CCR section numbers)* _____

   ☐ Categorical Exemption: *(List CCR section number)* _____

   ☒ Common Sense Exemption. *(14 CCR 15061(b)(3))*

   Explain reason why the grant/loan is exempt under the above section:

   The activity is covered by the general rule that CEQA applies only to projects which have the potential for causing a significant effect on the environment. Where it can be seen with certainty that there is no possibility that the activity in question may have a significant effect on the environment, the activity is not subject to CEQA.

Please attach draft Notice of Exemption (NOE). Consult with the Energy Commission attorney assigned to your division for instructions on how to complete the NOE.

☐ Grant/loan **IS NOT** exempt. The Project Manager needs to consult with the Energy Commission attorney assigned to your division and the Siting Office regarding a possible initial study.