California Energy Commission
January 24, 2024 Business Meeting
Backup Materials for Agenda Item No 09b:
Noble Thermodynamic Systems, Inc.

The following backup materials for the above-referenced agenda item are available in this PDF packet as listed below:

1. Proposed Resolution
2. Grant Request Form
3. Scope of Work

RESOLUTION NO: 24-0124-09b

STATE OF CALIFORNIA

STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION: **Noble Thermodynamic Systems, Inc.**

RESOLVED, that the State Energy Resources Conservation and Development Commission (CEC) adopts the staff CEQA findings contained in the Agreement or Amendment Request Form (as applicable); and

RESOLVED, that the CEC approves agreement PIR-23-009 with Noble Thermodynamic Systems, Inc. for a $4,242,259 grant to develop and demonstrate the use of hydrogen gas, and using non-reactive argon to substitute nitrogen (in air) in a retrofitted, reciprocating, internal-combustion, piston engine with a nameplate capacity of at least 300 kilowatts in Pomona. The grant's purpose is to operate the engine on increasing blends of hydrogen compared to fossil gas without generating oxides of nitrogen emissions and capturing greenhouse gases while maintaining benchmark fuel-to-electricity efficiency and generation system performance; and

FURTHER BE IT RESOLVED, that the Executive Director or their designee shall execute the same on behalf of the CEC.

CERTIFICATION

The undersigned Secretariat to the CEC does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the CEC held on January 24, 2024.

AYE:
NAY:
ABSENT:
ABSTAIN:

Dated:

_____
Kristine Banaag
Secretariat

STATE OF CALIFORNIA
CALIFORNIA ENERGY COMMISSION

CEC-270 (Revised 9/2022)

GRANT REQUEST FORM (GRF)

A. New Agreement Number

IMPORTANT: New Agreement # to be completed by Contracts, Grants, and Loans Office.

New Agreement Number: PIR-23-009

B. Division Information

1. Division Name: ERDD
2. Agreement Manager: Nadia Richards
3. MS-:None
4. Phone Number: 916-897-3804

C. Recipient's Information

1. Recipient's Legal Name: Noble Thermodynamic Systems, Inc.
2. Federal ID Number: 47-4308893

D. Title of Project

Title of project: Demons**T**ration of an **A**dvanced **H**ydrogen-flexible gas engine delivering **Z**ero-**E**missions power for a prosperous California (Project TAH2ØE)

E. Term and Amount

1. Start Date: 1/31/2024
2. End Date: 12/31/2027
3. Amount: $4,242,259

F. Business Meeting Information

1. Are the ARFVTP agreements $75K and under delegated to Executive Director? No
2. The Proposed Business Meeting Date: 01/24/2024
3. Consent or Discussion? Discussion
4. Business Meeting Presenter Name: Nadia Richards
5. Time Needed for Business Meeting: 5 minutes.
6. The email subscription topic is: NaturalGas (NG Research Program).

Agenda Item Subject and Description:

Noble Thermodynamic Systems, Inc. Proposed resolution approving agreement PIR-23-009 with Noble Thermodynamic Systems, Inc. for a $4,242,259 grant to develop and demonstrate the use of hydrogen gas, and using non-reactive argon to substitute nitrogen (in air) in a retrofitted, reciprocating, internal-combustion, piston engine with a nameplate capacity of at least 300 kilowatts in Pomona, and adopting staff's determination that this project is exempt from CEQA. The grant's purpose is to operate the engine on increasing blends of hydrogen compared to fossil gas without generating oxides of nitrogen emissions and capturing greenhouse gases while maintaining benchmark fuel-to-electricity efficiency and generation system performance. (PIER NG funding) Contact: Nadia Richards

G. California Environmental Quality Act (CEQA) Compliance

1. **Is Agreement considered a "Project" under CEQA?**
   Yes

   If yes, skip to question 2.

   If no, complete the following (PRC 21065 and 14 CCR 15378) and explain why Agreement is not considered a "Project":

   Agreement will not cause direct physical change in the environment or a reasonably foreseeable indirect physical change in the environment because:

2. **If Agreement is considered a "Project" under CEQA answer the following questions.**
   a) Agreement **IS** exempt?

      Yes

      Statutory Exemption?
      No

      If yes, list PRC and/or CCR section number(s) and separate each with a comma. If no, enter "None" and go to the next question.

      PRC section number:

      CCR section number: None

      Categorical Exemption?
      Yes

      If yes, list CCR section number(s) and separate each with a comma. If no, enter "None" and go to the next question.

      CCR section number: Cal. Code Regs., tit. 14, §15301; Cal. Code Regs., tit. 14, §15306

      The project includes the laboratory-scale testing and pilot-scale demonstration of a reciprocating engine with a nameplate capacity of at least 300 kilowatts. The engine will be retrofitted to operate using increasingly higher volumetric blends of hydrogen (exceeding 30 percent by volume) up to 100 percent, along with the thermodynamic Argon Power Cycle (APC) without generating NOx emissions, while capturing GHG emissions. The APC uses the non-reactive gas, argon, to substitute for nitrogen (in air). The laboratory-scale work for the project will be for limited testing and control system development carried out at an existing research facility at the University of California, Berkeley, in Pacific Gas and Electric service territory. The pilot-scale demonstration is tentatively located at a Southern California Edison assembly facility site in Pomona, CA, which is in Southern California Gas and Electric Co. service territory.

      14 CCR 15301 provides that projects which consist of the operation, repair, maintenance, permitting, leasing, licensing, or minor alteration of existing public or private structures, facilities, mechanical equipment, or topographical features, and which involve negligible, or no expansion of use are exempt. The proposed project will first be located entirely within an existing research facility that already conducts engine research. There will be minor alterations to mechanical equipment because the project activities are to design, modify, and test the engine and its control system,

which are in line with normal activities at the existing facility and therefore involve negligible expansion of the existing facility's use. The pilot-scale demonstrations will be located at an established electric power generator assembly facility and will require a temporary or mobile structure for skid-mounting the demonstration engine for testing with a load bank. The project will be packaged into a 40-foot shipping container for ease of transportation, deployment, and temporary use at the project site. The demonstration unit will be containerized with the necessary soundproofing features to maintain noise level within permitted levels. No substantial increase in traffic is expected. A truck is expected to come to the site weekly for the span of 2 weeks of continued testing (300hr) to refill industrial gasses and fuel. The skid/container will be removed from the site and stored at the conclusion of the project. The proposed project will not expand the use of either existing facilities or have any alterations of existing public or private structures, facilities, or topographical features. Therefore, the project falls within section 15301 and will not have a significant effect on the environment.

14 CCR 15306 exempts projects that consist of basic data collection, research, experimental management, and resource evaluation activities which do not result in a serious or major disturbance to an environmental resource. The proposed project will involve research to operate on high blends of hydrogen, exceeding 30 percent by volume and going up to 100 percent, to maintain or increase the efficiency with little to no output GHG and zero NOx emissions. Within the scope of this project, when operating the APC with fossil gas, carbon dioxide (CO2) is produced and will be separated by the membranes and released. As the project progresses, efforts will be made to identify a CO2 off-taker for either usage or sequestration purposes. The increasing use of hydrogen to displace the fossil methane gas directly results in lower carbon-based GHGs, and the APC has the advantage of producing zero NOx emissions. Therefore, this work will not result in a serious or major disturbance to an environmental resource because the system is expected to perform for at least 500 total hours emitting little to no GHG and zero NOx emissions to demonstrate compliance with the South Coast Air Quality Management District's rules. For these reasons, the proposed project will have no significant effect on the environment and is categorically exempt under section 15306.

The project will not impact an environmental resource of hazardous or critical concern where designated, precisely mapped, and officially adopted pursuant to law by federal, state, or local agencies; does not involve any cumulative impacts of successive projects of the same type in the same place that might be considered significant; does not involve unusual circumstances that might have a significant effect on the environment; will not result in damage to scenic resources within a highway officially designated as a state scenic highway; the project site is not included on any list compiled pursuant to Government Code section 65962.5; and the project will not cause a substantial adverse change in the significance of a historical resource. Therefore, none of the exceptions to categorical exemptions listed in CEQA Guidelines section 15300.2 apply to this project, and this project will not have a significant effect on the environment.

Common Sense Exemption? 14 CCR 15061 (b) (3)
No

If yes, explain reason why Agreement is exempt under the above section. If no, enter "Not applicable" and go to the next section.

b) Agreement **IS NOT** exempt.
IMPORTANT: consult with the legal office to determine next steps.

No

If yes, answer yes or no to all that applies. If no, list all as "no" and "None" as "yes".

Additional Documents	Applies
Initial Study	No
Negative Declaration	No
Mitigated Negative Declaration	No
Environmental Impact Report	No
Statement of Overriding Considerations	No
None	Yes

H. Subcontractors

List all Subcontractors listed in the Budget (s) (major and minor). Insert additional rows if needed. If no subcontractors to report, enter "No subcontractors to report" and "0" to funds. **Delete** any unused rows from the table.

Subcontractor Legal Company Name	CEC Funds	Match Funds
U.S. Department of Energy, Sandia National Laboratories	$ 292,859	$3,300
Membrane Technology and Research, Inc.	$ 1,434,400	$358,600
Electric Power Research Institute, Inc.	$ 342,303	$136,049
TBD- Safety, Health, Environmental Hazards, and Operability	$ 75,000	$0

I. Vendors and Sellers for Equipment and Materials/Miscellaneous

List all Vendors and Sellers listed in Budget(s) for Equipment and Materials/Miscellaneous. Insert additional rows if needed. If no vendors or sellers to report, enter "No vendors or sellers to report" and "0" to funds. **Delete** any unused rows from the table.

Vendor/Seller Legal Company Name	CEC Funds	Match Funds
TBD - Assembly	$50,000	$0
TBD- Gas Supplier	$0	$100,000
TBD- Cryogenic Industrial Gas Supplier	$250,000	$0

J. Key Partners

List all key partner(s). Insert additional rows if needed. If no key partners to report, enter "No key partners to report." **Delete** any unused rows from the table.

Key Partner Legal Company Name
No key partners to report

K. Budget Information

Include all budget information. Insert additional rows if needed. If no budget information to report, enter "N/A" for "Not Applicable" and "0" to Amount. **Delete** any unused rows from the table.

Funding Source	Funding Year of Appropriation	Budget List Number	Amount
NG Subaccount, PIERDD	21-22	501.001	$ 4,242,259

TOTAL Amount: $ 4,242,259

R&D Program Area: EGRB: Renewables

Explanation for "Other" selection Not applicable

Reimbursement Contract #: Not applicable

Federal Agreement #: 601 Program Continuous Appropriation

L. Recipient's Contact Information

1. Recipient's Administrator/Officer

Name: Guillaume Beardsell

Address: 2900 Main St Ste 3210

City, State, Zip: Alameda, CA 94501-7243

Phone: 626)-787-4657

E-Mail: g.beardsell@noblethermo.com

3. Recipient's Project Manager

Name: Guillaume Beardsell

Address: 2900 Main St Ste 3210

City, State, Zip: Alameda, CA 94501-7243

Phone: 626)-787-4657

E-Mail: g.beardsell@noblethermo.com

M. Selection Process Used

There are three types of selection process. List the one used for this GRF.

Selection Process	Additional Information
Competitive Solicitation #	GFO-22-504
First Come First Served Solicitation #	Not applicable
Other	Not applicable

N. Attached Items

1. List all items that should be attached to this GRF by entering “Yes” or “No”.

Item Number	Item Name	Attached
1	Exhibit A, Scope of Work/Schedule	Yes
2	Exhibit B, Budget Detail	Yes
3	CEC 105, Questionnaire for Identifying Conflicts	Yes
4	Recipient Resolution	No
5	Awardee CEQA Documentation	No

Approved By

Individuals who approve this form must enter their full name and approval date in the MS Word version.

Agreement Manager: Nadia Richards

Approval Date: 11/29/2023

Branch Manager: Kevin Uy

Approval Date: 12/15/2023

Director: Kevin Uy for Angela Gould

Approval Date: 12/15/2023

Exhibit A
Scope of Work
Noble Thermodynamic Systems, Inc.

I. TASK ACRONYM/TERM LISTS

A. Task List

Task #	CPR[1]	Task Name
1		General Project Tasks
2		Development of Engine Retrofit Kit
3	X	Engineering Design and Testing
4		Safety, Health, Environmental Hazards, and Operability (HAZOP) Analysis
5		Procurement and Fabrication
6	X	Field Unit Deployment
7		Techno-economic Analysis
8		Life Cycle Assessment
9		Market Research
10		Evaluation of Project Benefits
11		Technology/Knowledge Transfer Activities

B. Acronym/Term List

Acronym/Term	Meaning
AACE	Association for the Advancement of Cost Engineering
APC	Argon Power Cycle
Ar	Argon
BFD	Block Flow Diagram
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CEC	California Energy Commission
CFD	Computational Fluid Dynamics
CHP	Combined Heat and Power
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPR	Critical Project Review
DAQ	Data Acquisition
GHG	Greenhouse gasses
H_2	Hydrogen
HAZOP	Safety, Health, Environmental Hazards, and Operability
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
LCE	Life Cycle Emissions
MCRE	Multi-Cylinder Research Engine

[1] Please see subtask 1.3 in Part III of the Scope of Work (General Project Tasks) for a description of Critical Project Review (CPR) Meetings.

Acronym/Term	Meaning
N_2	Nitrogen
NETL	National Energy Technology Laboratory
NOx	Oxides of Nitrogen
O_2	Oxygen
P&ID	Process and Instrumentation Diagram
PFD	Process Flow Diagram
RES	Renewable Energy Sources
RFQ	Request for Quotation
SCRE	Single Cylinder Research Engine
TAC	Technical Advisory Committee
TRL	Technology Readiness Level
UHC	Unburned Hydrocarbons
UFD	Utility Flow Diagrams

II. PURPOSE OF AGREEMENT, PROBLEM/SOLUTION STATEMENT, AND GOALS AND OBJECTIVES

A. Purpose of Agreement

The purpose of this Agreement is to fund the development and demonstration for using hydrogen (H_2) instead of fossil gas in the Argon Power Cycle (APC), which is a retrofittable thermodynamic power cycle technology that uses the non-reactive gas, Argon (Ar), to substitute for nitrogen (N_2) in air. A reciprocating internal combustion engine will be retrofitted to use the APC to operate with increasing blends of H_2 exceeding 30% by volume in fossil gas, and going up to 100% pure H_2, without generating oxides of nitrogen (NOx) emissions, while capturing greenhouse gas (GHG), while maintaining benchmark fuel-to-electricity efficiency and generation system performance.

B. Problem/ Solution Statement

Problem

The world has acknowledged the need to combat climate change through radically reducing anthropogenic GHG emissions and accelerating the energy transition away from fossil fuels. Low-carbon fuels such as H_2 have re-emerged as a potential means to accelerate the transition to a cleaner economy, providing a pathway by which GHG emissions are concentrated upstream (e.g., by power generation and fuel production), where they can be more easily captured, and sectors downstream are electrified or fed with H_2 (e.g., heavy duty transport and industrial heat).

An attractive path, because of its potential impact, is to retrofit conventional gas-fired generation with technologies that enable the substitution of conventional fuels (e.g., fossil gas) with H_2. However, technological solutions that enable H_2 switching often come at a trade-off between performance, cost and/or emissions (i.e., increasing NOx). The substitution of conventional fuel with H_2 often means 1) a derating of the power unit (due to the low energy [volumetric] density of H_2), 2) an increase in NOx emissions due to higher combustion temperatures, and 3) reduced turn down ratios due to H_2 flame stability challenges. Other systems struggle with complete

oxidation of the H_2 fuel, component degradation, and high costs due to the use of costly materials, such as platinum.

Solution
Ideal solutions are those able to simultaneously eliminate GHG and air polluting NOx emissions, and maintaining or increasing performance, all the while remaining cost-effective. In a grid increasingly dominated by intermittent Renewable Energy Sources (RES), flexibility and dispatchability become a fourth element of crucial consideration when evaluating new technologies.

The Recipient will develop and demonstrate the APC, which is a zero emission, dispatchable, and affordable H_2 fueled power generation solution, retrofittable into conventional gas-fired reciprocating engines. This retrofit solution is designed to facilitate a seamless and on-demand transition from 100% fossil gas to 100% H_2, and any blend in between and will enable the substitution of conventional fuels (e.g., fossil gas) with H_2 at no trade off with emissions, performance, and durability. Such approach could unlock Terawatts of existing worldwide nameplate capacity (e.g., grid scale power plants, combined heat and power (CHP) plants, local on-site generation), otherwise stranded as fossil assets, as means to radically accelerate the deployment and cost-effective integration of clean energy infrastructure across all sectors of the economy.

C. Goals and Objectives of the Agreement

Agreement Goals
The goals of this Agreement are to:

- Develop the APC retrofit for a reciprocating engine that optimizes cost-efficiency and minimizes carbon footprint.
- Develop and implement a safety plan for safe operation and procedures when using H_2 in the APC.
- Demonstrate the APC operating on high blends of H_2 exceeding 30% by volume up to, and including, pure 100% H_2.
- Demonstrate high generation efficiency, and emissions compliance with the applicable emissions rules and standards of the governing body in which the demonstration is located.
- Demonstrate the durability of the APC.
- Demonstrate an increase in maturity for the APC using the blended fuel.

Ratepayer Benefits: This Agreement will result in the ratepayer benefits of greater electricity reliability, lower costs, and increased safety by:

- Directly reducing GHG and NOx emissions from power generation and their impact on air quality and public health in disadvantaged and low-income communities, that most often are in close proximity to heavy industrial hubs and who bear the brunt of local air pollution. Indirectly, further GHG emission reduction will be achieved because increased dispatchability and energy storage will enable the deeper penetration of RES with the associated displacement of fossil sources. By implementing the proposed technology to retrofit 10% of California's stationary reciprocating engine power generation infrastructure, this would result in the abatement of 800,000 tons of carbon dioxide equivalent (tCO2e)

per year.[2] Furthermore, if 10% of the U.S. gas generation assets were replaced with this technology, there would be a reduction in GHG emissions, specifically 110 million tCO2 per year.[3]

- Reducing the cost of clean power infrastructure and the risk of stranded power generation investments shouldered by California ratepayers through increased electrical generation efficiency and affordable cost of the APC generator. As in the case of improved air pollution, this benefit will accrue the highest value for disadvantaged and low-income communities, for which energy affordability is strongly tied to energy access. This also benefits ratepayers by reducing the amount of oil, gas, and fossil-electricity the State imports to meet ratepayer energy demand.
- Reducing risk of blackouts and power outages and associated risk of public safety and economic productivity costs through increased supply of dispatchable assets to the grid to prevent or mitigate the impact of scheduled power outages and blackouts.
- Reducing the water consumption and associated impact on the State drought by providing a generator that not only does not consume water, but it generates it as a process byproduct. This water can be served to adjacent industries or agriculture.
- Creating local jobs related to the construction, operation, and maintenance of the plants alongside increased opportunity for local suppliers and service providers to do business with the power plant.

Technological Advancement and Breakthroughs: This Agreement will lead to technological advancement and breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals, specifically those outlined in SB 100 and SB 350, by providing zero-carbon dispatchable power and enabling a deeper and faster penetration of renewable generation sources and the development of low-carbon H_2 energy storage infrastructure. The system is based on a novel thermodynamic cycle that uses Ar as a working fluid instead of N_2 (in air). The thermodynamic efficiency of an engine strongly depends on the ratio of specific heat (κ) of the working fluid. Replacing air (used in conventional engines) with Ar allows for dramatic efficiency improvements. The higher κ for Ar (1.67) compared to N_2 (1.4) allows the engine to approach simple-cycle energy conversion efficiencies over 24% points higher than a traditional air-breathing engine. More importantly, the substitution of N_2 with Ar eliminates the risk of NOx formation. The APC represents the engineering integration of this concept on a closed-loop Ar recirculating engine. Through the APC's realization, the engine system is enhanced with extra control knobs for load and combustion stability control (e.g., Ar dilution, CO_2 recirculation, etc.), which in combination with the efficiency gains and the lack of air pollutant formation, renders a clean, dispatchable, and cost-effective method for producing power.

Agreement Objectives

The objectives of this Agreement are to:

- Retrofit a reciprocating engine with a nameplate capacity of at least 300 kilowatts (kW) to use the APC technology.
- Demonstrate the APC under 3 operating scenarios:
    - Scenario 1: As a firm zero-carbon power generation resource, fueled with 100% fossil gas (0% H_2) and delivering engine benchmark fuel to electrical efficiency while emitting zero GHGs and NOx emissions.

[2] Data from: Thermal Efficiency of Natural Gas-Fired Generation in California: 2019 Update, (2020)

[3] Data from: EPA Flight Emissions Tool, (2022)

  - Scenario 2: As a versatile zero-carbon power generation resource, fueled with potential fossil gas-H_2 pipeline steady blends that are greater than 30% H_2, but not 100% pure H_2, and delivering engine benchmark fuel to electrical efficiency while emitting zero GHGs and NOx emissions.
  - Scenario 3: As part of an energy storage framework, fueled with 100% pure H_2 (0% fossil gas) and delivering fuel to electrical efficiency comparable to fuel cells and emitting zero NOx emissions.
- Demonstrate the APC using the blended fuel (>30% H2) for a minimum of 500 cumulative hours that includes at least 300 continuous hours of operation (as part of the 500 cumulative hours), and assess the performance degradation and fuel impact on the power output (derating).
- Increase the technology readiness level (TRL) of the APC using the blended fuel (>30% H_2) to reach a TRL 7 by the end of the project.
- Complete a Safety, Health, Environmental Hazards, and Operability Analysis to assess and mitigate safety risks both proactively and retrospectively.
- Conduct a techno-economic analysis and a carbon intensity analysis that uses key factors in the cost of H_2 based on the U.S. DOE's Hydrogen Shot goal for the procurement and generation costs.[4]

III. TASK 1 GENERAL PROJECT TASKS

PRODUCTS

Subtask 1.1 Products

The goal of this subtask is to establish the requirements for submitting project products (e.g., reports, summaries, plans, and presentation materials). Unless otherwise specified by the Commission Agreement Manager (CAM), the Recipient must deliver products as required below by the dates listed in the **Project Schedule (Part V).** All products submitted which will be viewed by the public, must comply with the accessibility requirements of Section 508 of the federal Rehabilitation Act of 1973, as amended (29 U.S.C. Sec. 794d), and regulations implementing that act as set forth in Part 1194 of Title 36 of the Federal Code of Regulations**.** All technical tasks should include product(s). Products that require a draft version are indicated by marking **"(draft and final)"** after the product name in the "Products" section of the task/subtask. If "(draft and final)" does not appear after the product name, only a final version of the product is required. With respect to due dates within this Scope of Work, **"days"** means working days.

The Recipient shall:

For products that require a draft version, including the Final Report Outline and Final Report

- Submit all draft products to the CAM for review and comment in accordance with the Project Schedule (Part V). The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt, unless otherwise specified in the task/subtask for which the product is required.
- Consider incorporating all CAM comments into the final product. If the Recipient disagrees with any comment, provide a written response explaining why the comment was not incorporated into the final product.

[4] U.S. Department of Energy. Hydrogen Shot. USDOE. (https://www.energy.gov/eere/fuelcells/hydrogen-shot)

- Submit the revised product and responses to comments within 10 days of notice by the CAM, unless the CAM specifies a longer time period, or approves a request for additional time.

For products that require a final version only

- Submit the product to the CAM for acceptance. The CAM may request minor revisions or explanations prior to acceptance.

For all products

- Submit all data and documents required as products in accordance with the following.

  Instructions for Submitting Electronic Files and Developing Software:

  - **Electronic File Format**
    - Submit all data and documents required as products under this Agreement in an electronic file format that is fully editable and compatible with the California Energy Commission's (CEC) software and Microsoft (MS)-operating computing platforms, or with any other format approved by the CAM. Deliver an electronic copy of the full text of any Agreement data and documents in a format specified by the CAM, such as memory stick.

    The following describes the accepted formats for electronic data and documents provided to the CEC as products under this Agreement, and establishes the software versions that will be required to review and approve all software products:
    - Data sets will be in MS Access or MS Excel file format (version 2007 or later), or any other format approved by the CAM.
    - Text documents will be in MS Word file format, version 2007 or later.
    - Project management documents will be in Microsoft Project file format, version 2007 or later.

  - **Software Application Development**

    Use the following standard Application Architecture components in compatible versions for any software application development required by this Agreement (e.g., databases, models, modeling tools), unless the CAM approves other software applications such as open-source programs:
    - Microsoft ASP.NET framework (version 3.5 and up). Recommend 4.0.
    - Microsoft Internet Information Services (IIS), (version 6 and up) Recommend 7.5.
    - Visual Studio.NET (version 2008 and up). Recommend 2010.
    - C# Programming Language with Presentation (UI), Business Object and Data Layers.
    - SQL (Structured Query Language).
    - Microsoft SQL Server 2008, Stored Procedures. Recommend 2008 R2.
    - Microsoft SQL Reporting Services. Recommend 2008 R2.
    - XML (external interfaces).

    Any exceptions to the Electronic File Format requirements above must be approved in writing by the CAM. The CAM will consult with the CEC's Information Technology Services Branch to determine whether the exceptions are allowable.

Exhibit A
Scope of Work
Noble Thermodynamic Systems, Inc.

MEETINGS

Subtask 1.2 Kick-off Meeting

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

The Recipient shall:

- Attend a "Kick-off" meeting with the CAM, the Commission Agreement Officer (CAO), and any other CEC staff relevant to the Agreement. The Recipient will bring its Project Manager and any other individuals designated by the CAM to this meeting. The administrative and technical aspects of the Agreement will be discussed at the meeting. Prior to the meeting, the CAM will provide an agenda to all potential meeting participants. The meeting may take place in person or by electronic conferencing (e.g., WebEx), with approval of the CAM.

  The administrative portion of the meeting will include discussion of the following:
  - Terms and conditions of the Agreement;
  - Invoicing and auditing procedures;
  - Administrative products (subtask 1.1);
  - CPR meetings (subtask 1.3);
  - Match fund documentation (subtask 1.7);
  - Permit documentation (subtask 1.8);
  - Subcontracts (subtask 1.9); and
  - Any other relevant topics.

  The technical portion of the meeting will include discussion of the following:
  - The CAM's expectations for accomplishing tasks described in the Scope of Work;
  - An updated Project Schedule;
  - Technical products (subtask 1.1);
  - Progress reports (subtask 1.5);
  - Final Report (subtask 1.6);
  - Technical Advisory Committee meetings (subtasks 1.10 and 1.11); and
  - Any other relevant topics.

- Provide *Kick-off Meeting Presentation* to include but not limited to:
  - Project overview (i.e. project description, goals and objectives, technical tasks, expected benefits, etc.)
  - Project schedule that identifies milestones
  - List of potential risk factors and hurdles, and mitigation strategy

- Provide an *Updated Project Schedule, Match Funds Status Letter,* and *Permit Status Letter*, as needed to reflect any changes in the documents.

The CAM shall:

- Designate the date and location of the meeting.
- Send the Recipient a *Kick-off Meeting Agenda*.

Recipient Products:

- Kick-off Meeting Presentation
- Updated Project Schedule *(if applicable)*
- Match Funds Status Letter (subtask 1.7) *(if applicable)*
- Permit Status Letter (subtask 1.8) *(if applicable)*

CAM Product:
- Kick-off Meeting Agenda

Subtask 1.3 Critical Project Review (CPR) Meetings
The goal of this subtask is to determine if the project should continue to receive CEC funding, and if so whether any modifications must be made to the tasks, products, schedule, or budget. CPR meetings provide the opportunity for frank discussions between the CEC and the Recipient. As determined by the CAM, discussions may include project status, challenges, successes, advisory group findings and recommendations, final report preparation, and progress on technical transfer and production readiness activities (if applicable). Participants will include the CAM and the Recipient and may include the CAO and any other individuals selected by the CAM to provide support to the CEC.

CPR meetings generally take place at key, predetermined points in the Agreement, as determined by the CAM and as shown in the Task List on page 1 of this Exhibit. However, the CAM may schedule additional CPR meetings as necessary. The budget will be reallocated to cover the additional costs borne by the Recipient, but the overall Agreement amount will not increase. CPR meetings generally take place at the CEC, but they may take place at another location, or may be conducted via electronic conferencing (e.g., WebEx) as determined by the CAM.

The Recipient shall:
- Prepare and submit a *CPR Report* for each CPR meeting that: (1) discusses the progress of the Agreement toward achieving its goals and objectives; and (2) includes recommendations and conclusions regarding continued work on the project.
- Attend the CPR meeting.
- Present the CPR Report and any other required information at each CPR meeting.

The CAM shall:
- Determine the location, date, and time of each CPR meeting with the Recipient's input.
- Send the Recipient a *CPR Agenda* with a list of expected CPR participants in advance of the CPR meeting. If applicable, the agenda will include a discussion of match funding and permits.
- Conduct and make a record of each CPR meeting. Provide the Recipient with a schedule for providing a Progress Determination on continuation of the project.
- Determine whether to continue the project, and if so whether modifications are needed to the tasks, schedule, products, or budget for the remainder of the Agreement. If the CAM concludes that satisfactory progress is not being made, this conclusion will be referred to the Deputy Director of the Energy Research and Development Division.
- Provide the Recipient with a *Progress Determination* on continuation of the project, in accordance with the schedule. The Progress Determination may include a requirement that the Recipient revise one or more products.

Recipient Products:
- CPR Report(s)

CAM Products:
- CPR Agenda
- Progress Determination

IV. Subtask 1.4 Final Meeting
The goal of this subtask is to complete the closeout of this Agreement.

The Recipient shall:
- Meet with CEC staff to present project findings, conclusions, and recommendations. The final meeting must be completed during the closeout of this Agreement. This meeting will be attended by the Recipient and CAM, at a minimum. The meeting may occur in person or by electronic conferencing (e.g., WebEx), with approval of the CAM.

  The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be divided into two separate meetings at the CAM's discretion.
  - The technical portion of the meeting will involve the presentation of findings, conclusions, and recommended next steps (if any) for the Agreement. The CAM will determine the appropriate meeting participants.
  - The administrative portion of the meeting will involve a discussion with the CAM and the CAO of the following Agreement closeout items:
    - Disposition of any procured equipment.
    - The CEC's request for specific "generated" data (not already provided in Agreement products).
    - Need to document the 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.
- Prepare a *Final Meeting Agreement Summary* that documents any agreement made between the Recipient and Commission staff during the meeting.
- Prepare a *Schedule for Completing Agreement Closeout Activities*.
- Provide copies of *All Final Products* on a USB memory stick, organized by the tasks in the Agreement.

Products:
- Final Meeting Agreement Summary *(if applicable)*
- Schedule for Completing Agreement Closeout Activities
- All Final Products

REPORTS AND INVOICES

Subtask 1.5 Progress Reports and Invoices
The goals of this subtask are to: (1) periodically verify that satisfactory and continued progress is made towards achieving the project objectives of this Agreement; and (2) ensure that invoices contain all required information and are submitted in the appropriate format.

The Recipient shall:
- Submit a monthly *Progress Report* to the CAM. Each progress report must:
  - Summarize progress made on all Agreement activities as specified in the scope of

work for the preceding month, including accomplishments, problems, milestones, products, schedule, fiscal status, and an assessment of the ability to complete the Agreement within the current budget and any anticipated cost overruns. See the Progress Report Format Attachment for the recommended specifications.

- Submit a monthly or quarterly *Invoice* that follows the instructions in the "Payment of Funds" section of the terms and conditions, including a financial report on Match Funds and in-state expenditures.

Products:
- Progress Reports
- Invoices

Subtask 1.6 Final Report
The goal of this subtask is to prepare a comprehensive Final Report that describes the original purpose, approach, results, and conclusions of the work performed under this Agreement. When creating the Final Report Outline and the Final Report, the Recipient must use the CEC Style Manual provided by the CAM.

Subtask 1.6.1 Final Report Outline

The Recipient shall:
- Prepare a *Final Report Outline* in accordance with the *Energy Commission Style Manual* provided by the CAM.

Recipient Products:
- Final Report Outline (draft and final)

CAM Product:
- Energy Commission Style Manual
- Comments on Draft Final Report Outline
- Acceptance of Final Report Outline

Subtask 1.6.2 Final Report

The Recipient shall:
- Prepare a *Final Report* for this Agreement in accordance with the approved Final Report Outline, Energy Commission Style Manual, and Final Report Template provided by the CAM with the following considerations:
  - Ensure that the report includes the following items, in the following order:
    - Cover page (**required**)
    - Credits page on the reverse side of cover with legal disclaimer (**required**)
    - Acknowledgements page (optional)
    - Preface (**required**)
    - Abstract, keywords, and citation page (**required**)
    - Table of Contents (**required**, followed by List of Figures and List of Tables, if needed)
    - Executive summary (**required**)
    - Body of the report (**required**)
    - References (if applicable)

  - Glossary/Acronyms (If more than 10 acronyms or abbreviations are used, it is required.)
  - Bibliography (if applicable)
  - Appendices (if applicable) (Create a separate volume if very large.)
  - Attachments (if applicable)
- Submit a draft of the Executive Summary to the TAC for review and comment.
- Develop and submit a *Summary of TAC Comments on Draft Final Report* received on the Executive Summary. For each comment received, the recipient will identify in the summary the following:
  - Comments the recipient proposes to incorporate.
  - Comments the recipient does propose to incorporate and an explanation for why.
- Submit a draft of the report to the CAM for review and comment. The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt.
- Incorporate all CAM comments into the Final Report. If the Recipient disagrees with any comment, provide a *Written Responses to Comments* explaining why the comments were not incorporated into the final product.
- Submit the revised Final Report electronically with any Written Responses to Comments within 10 days of receipt of CAM's Written Comments on the Draft Final Report, unless the CAM specifies a longer time period or approves a request for additional time.

Products:
- Summary of TAC Comments on Draft Final Report
- Draft Final Report
- Written Responses to Comments *(if applicable)*
- Final Report

CAM Product:
- Written Comments on the Draft Final Report

MATCH FUNDS, PERMITS, AND SUBCONTRACTS

Subtask 1.7 Match Funds

The goal of this subtask is to ensure that the Recipient obtains any match funds planned for this Agreement and applies them to the Agreement during the Agreement term.

While the costs to obtain and document match funds are not reimbursable under this Agreement, the Recipient may spend match funds for this task. The Recipient may only spend match funds during the Agreement term, either concurrently or prior to the use of CEC funds. Match funds must be identified in writing, and the Recipient must obtain any associated commitments before incurring any costs for which the Recipient will request reimbursement.

The Recipient shall:
- Prepare a *Match Funds Status Letter* that documents the match funds committed to this Agreement. If no match funds were part of the proposal that led to the CEC awarding this Agreement and none have been identified at the time this Agreement starts, then state this in the letter.

  If match funds were a part of the proposal that led to the CEC awarding this Agreement, then provide in the letter:

  - A list of the match funds that identifies:
    - The amount of cash match funds, their source(s) (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied.
    - The amount of each in-kind contribution, a description of the contribution type (e.g., property, services), the documented market or book value, the 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 must identify its owner and provide a contact name, address, telephone number, and the address where the property is located.
    - If different from the solicitation application, provide a letter of commitment from an authorized representative of each source of match funding that the funds or contributions have been secured.
- At the Kick-off meeting, discuss match funds and the impact on the project if they are significantly reduced or not obtained as committed. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide a *Supplemental Match Funds Notification Letter* to the CAM of receipt of additional match funds.
- Provide a *Match Funds Reduction Notification Letter* to the CAM if existing match funds are reduced during the course of the Agreement. Reduction of match funds may trigger a CPR meeting.

Products:
- Match Funds Status Letter
- Supplemental Match Funds Notification Letter *(if applicable)*
- Match Funds Reduction Notification Letter *(if applicable)*

Subtask 1.8 Permits
The goal of this subtask 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, with the exception of costs incurred by University of California recipients. Permits must be identified and obtained before the Recipient may incur any costs related to the use of the permit(s) for which the Recipient will request reimbursement.

The Recipient shall:
- Prepare a *Permit Status Letter* that documents the permits required to conduct this Agreement. If no permits are required at the start of this Agreement, then state this in the letter. If permits will be required during the course of the Agreement, provide in the letter:
  - A list of the permits that identifies: (1) the type of permit; and (2) the name, address, and telephone number of the permitting jurisdictions or lead agencies.
  - The schedule the Recipient will follow in applying for and obtaining the permits.

  The list of permits and the schedule for obtaining them will be discussed at the Kick-off meeting (subtask 1.2), and a timetable for submitting the updated list, schedule, and copies of the permits will be developed. The impact on the project 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 progress reports and will be a topic at CPR meetings.

- If during the course of the Agreement additional permits become necessary, then provide the CAM with an *Updated List of Permits* (including the appropriate information on each permit) and an *Updated Schedule for Acquiring Permits*.
- Send the CAM a *Copy of Each Approved Permit*.
- If during the course of the Agreement permits are not obtained on time or are denied, notify the CAM within 5 days. Either of these events may trigger a CPR meeting.

Products:
- Permit Status Letter
- Updated List of Permits *(if applicable)*
- Updated Schedule for Acquiring Permits *(if applicable)*
- Copy of Each Approved Permit *(if applicable)*

Subtask 1.9 Subcontracts
The goals of this subtask are to: (1) procure subcontracts required to carry out the tasks under this Agreement; and (2) ensure that the subcontracts are consistent with the terms and conditions of this Agreement.

The Recipient shall:
- Manage and coordinate subcontractor activities in accordance with the requirements of this Agreement.
- Incorporate this Agreement by reference into each subcontract.
- Include any required Energy Commission flow-down provisions in each subcontract, in addition to a statement that the terms of this Agreement will prevail if they conflict with the subcontract terms.
- If required by the CAM, submit a draft of each *Subcontract* required to conduct the work under this Agreement.
- Submit a final copy of each executed subcontract.
- Notify and receive written approval from the CAM prior to adding any new subcontractors (see the discussion of subcontractor additions in the terms and conditions).

Products:
- Subcontracts *(draft if required by the CAM)*

TECHNICAL ADVISORY COMMITTEE

Subtask 1.10 Technical Advisory Committee (TAC)
The goal of this subtask is to create an advisory committee for this Agreement. The TAC should be composed of diverse professionals. The composition will vary depending on interest, availability, and need. TAC members will serve at the CAM's discretion. The purpose of the TAC is to:
- Provide guidance in project direction. The guidance may include scope and methodologies, timing, and coordination with other projects. The guidance may be based on:
  - Technical area expertise;
  - Knowledge of market applications; or
  - Linkages between the agreement work and other past, present, or future projects (both public and private sectors) that TAC members are aware of in a particular area.

- Review products and provide recommendations for needed product adjustments, refinements, or enhancements.
- Evaluate the tangible benefits of the project to the state of California, and provide recommendations as needed to enhance the benefits.
- Provide recommendations regarding information dissemination, market pathways, or commercialization strategies relevant to the project products.
- Help set the project team's goals and contribute to the development and evaluation of its statement of proposed objectives as the project evolves.
- Provide a credible and objective sounding board on the wide range of technical and financial barriers and opportunities.
- Help identify key areas where the project has a competitive advantage, value proposition, or strength upon which to build.
- Advocate, to the extent the TAC members feel is appropriate, on behalf of the project in its effort to build partnerships, governmental support and relationships with a national spectrum of influential leaders.
- Ask probing questions that insure a long-term perspective on decision-making and progress toward the project's strategic goals.

The TAC may be composed of qualified professionals spanning the following types of disciplines:

- Researchers knowledgeable about the project subject matter;
- Members of trades that will apply the results of the project (e.g., designers, engineers, architects, contractors, and trade representatives);
- Public interest market transformation implementers;
- Product developers relevant to the project;
- U.S. Department of Energy research managers, or experts from other federal or state agencies relevant to the project;
- Public interest environmental groups;
- Utility representatives;
- Air district staff; and
- Members of relevant technical society committees.

The Recipient shall:

- Prepare a *List of Potential TAC Members* that includes the names, companies, physical and electronic addresses, and phone numbers of potential members. The list will be discussed at the Kick-off meeting, and a schedule for recruiting members and holding the first TAC meeting will be developed.
- Recruit TAC members. Ensure that each individual understands member obligations and the TAC meeting schedule developed in subtask 1.11.
- Prepare a *List of TAC Members* once all TAC members have committed to serving on the TAC.
- Submit *Documentation of TAC Member Commitment* (such as Letters of Acceptance) from each TAC member.

Products:

- List of Potential TAC Members
- List of TAC Members
- Documentation of TAC Member Commitment

Subtask 1.11 TAC Meetings

The goal of this subtask is for the TAC to provide strategic guidance for the project by participating in regular meetings, which may be held via teleconference.

The Recipient shall:

- Discuss the TAC meeting schedule with the CAM at the Kick-off meeting. Determine the number and location of meetings (in-person and via teleconference) in consultation with the CAM.
- Prepare a *TAC Meeting Schedule* that will be presented to the TAC members during recruiting. Revise the schedule after the first TAC meeting to incorporate meeting comments.
- Prepare a *TAC Meeting Agenda* and *TAC Meeting Back-up Materials* for each TAC meeting.
- Organize and lead TAC meetings in accordance with the TAC Meeting Schedule. Changes to the schedule must be pre-approved in writing by the CAM.
- Prepare *TAC Meeting Summaries* that include any recommended resolutions of major TAC issues.

The TAC shall:

- Help set the project team's goals and contribute to the development and evaluation of its statement of proposed objectives as the project evolves.
- Provide a credible and objective sounding board on the wide range of technical and financial barriers and opportunities.
- Help identify key areas where the project has a competitive advantage, value proposition, or strength upon which to build.
- Advocate on behalf of the project in its effort to build partnerships, governmental support and relationships with a national spectrum of influential leaders.
- Ask probing questions that insure a long-term perspective on decision-making and progress toward the project's strategic goals.
- Review and provide comments to proposed project performance metrics.
- Review and provide comments to proposed project Draft Technology Transfer Plan.

Products:

- TAC Meeting Schedule (draft and final)
- TAC Meeting Agendas (draft and final)
- TAC Meeting Back-up Materials
- TAC Meeting Summaries

Subtask 1.12 Project Performance Metrics

The goal of this subtask is to finalize key performance targets for the project based on feedback from the TAC and report on final results in achieving those targets. The performance targets should be a combination of scientific, engineering, techno-economic, and/or programmatic metrics that provide the most significant indicator of the research or technology's potential success.

The Recipient shall:

- Complete and submit the project performance metrics section of the *Initial Project Benefits Questionnaire,* developed in the Evaluation of Project Benefits task, to the CAM.
- Present the draft project performance metrics at the first TAC meeting to solicit input and comments from the TAC members.

- Develop and submit a *TAC Performance Metrics Summary* that summarizes comments received from the TAC members on the proposed project performance metrics. The *TAC Performance Metrics Summary* will identify:
  - TAC comments the Recipient proposes to incorporate into the *Initial Project Benefits Questionnaire*, developed in the Evaluation of Project Benefits task.
  - TAC comments the Recipient does not propose to incorporate with and explanation why.
- Develop and submit a *Project Performance Metrics Results* document describing the extent to which the Recipient met each of the performance metrics in the *Final Project Benefits Questionnaire,* developed in the Evaluation of Project Benefits task.
- Discuss the *Project Performance Metrics Results* at the Final Meeting.

Products:
- TAC Performance Metrics Summary
- Project Performance Metrics Results

V. TECHNICAL TASKS

TASK 2: DEVELOPMENT OF ENGINE RETROFIT KIT

The goal of this task is to develop and fabricate an engine retrofit kit that enables an off-the-shelf engine to render the APC and cleanly, safely, and reliably operate with H_2 and fossil gas fuel blends.

SUBTASK 2.1: Engine Retrofit Kit Components Design

The goal of this task is to define the engine retrofit kit design specifications.

The Recipient shall:

- Develop a surrogate chemical reaction mechanism (i.e., a virtual model of the chemical reactions in the engine, represented in a computer program) effective to model a wide range of steady H_2/fossil gas blends using the Recipient's in-house automatic mechanism reduction code (i.e., a computer code to reduce the modeled chemical reactions) that will:
  - Expand existing One-Dimensional (1D) process model capabilities to simulate H_2 blending, fueling, combustion of fossil gas blends with high H_2 content.
  - Expand existing Three-Dimensional (3D) Computational Fluid Dynamics (CFD) in-cylinder model capabilities to accurately predict the injection, mixing, and thermodynamics of fuel blends with high H_2 content.
- Prepare and provide a *Surrogate Model Report* that presents the design criteria and results for the model. The *Surrogate Model Report* shall include but is not limited to:
  - The assumptions and methodology used to develop the model.
  - A description of the challenges identified with the design.
  - A discussion on any adjustments that were needed to obtain the final design.
  - A discussion on the model results and plans for use in the demonstration testing.
  - A description of lessons learned.
- Prepare and provide a detailed *Simulation Test Campaign Report* (1D, 3D CFD) that supports the design of the final engine retrofit kit (i.e. piston shape, ignition system geometry, cam profiles) specifications and optimum combustion strategies across the full range of H_2/fossil gas blends. (A "campaign" means an extensive series of experimental

tests.) The *Simulation Test Campaign Report* shall include but is not limited to the descriptions of the:

- Method used to execute the simulation campaign. This includes setting up, running, and monitoring simulation progress, as well as adequate storage of relevant simulation data.
- Results and discussion of the collected and post-processed simulation data that includes a description of the indexed simulation database and plans for archiving data for future reference.
- Analysis of the data to define optimal control strategies for the multi-cylinder research engine (MCRE).

Products:

- Surrogate Model Report (draft and final)
- Simulation Test Campaign Report (draft and final)

SUBTASK 2.2: Optical Engine Experimental Campaign

The goal of this task is to evaluate the impact on H_2 combustion of parameters such as working fluid composition, equivalence ratios, injection, and ignition strategies, to support the optimal design of the engine retrofit kit. ("Optical" refers to having visual access into the engine for diagnostic techniques such as taking pictures, taking video, and/or observing through a portal.)

The Recipient shall:

- Prepare and provide a detailed *Optical Engine Test Report* that evaluates the impact on H_2 combustion of parameters such as working fluid composition, equivalence ratios, injection, and ignition strategies. The *Optical Engine Test Report* shall include but is not limited to the descriptions of the:
  - Preparations for using Sandia's single cylinder (optical) research engine (SCRE) to accept synthetically prepared argon-heavy working fluids and be able to execute active prechamber injection strategies.
  - Approach used for rapidly prototyping a preliminary and partial engine retrofit kit that fits Sandia's SCRE.
  - Plans to execute an experimental campaign consisting of 100+ predefined test points and approximately 200+ additional exploratory test points.
  - Equipment used to acquire test data consisting of thermodynamic information (pressure traces, temperatures) and OH* chemiluminescence high-speed video. (OH* refers to the excited hydroxyl radical which is a physical parameter used to identify flame emission zones in high temperature flames.
  - Results from the analyzed SCRE data (e.g., heat-release rate, cyclic variability, knock frequency and intensity, jet penetration rate, etc.), presented in an indexed database for easy access and use, and adequately stored for future reference.

Products:

- Optical Engine Test Report (draft and final)

SUBTASK 2.3: Engine Retrofit Components Prototyping

The goals of this task are (**1**) to generate the relevant engine retrofit kit drawings and (**2**) to manufacture the engine retrofit kit prototype.

The Recipient shall:

- Complete the detailed design of the engine retrofit kit components.
- Fabricate first engine retrofit kit for testing on the Recipient's MCRE prototype.
- Prepare and provide the *Initial Engine Retrofit Kit Design Report* that includes but is not limited to:
    - A description of the engine retrofit kit including a parts, materials, or components list.
    - Simple computer aided design models, drawings, and renderings of the engine retrofit kit.

Products:

- Initial Engine Retrofit Kit Design Report (draft and final)

SUBTASK 2.4: Retrofit Kit Laboratory Testing

The goals of this task are (**1**) to experimentally evaluate the performance of the engine retrofit kit prototype and (**2**) to test combustion under H_2/fossil gas blends.

The Recipient shall:

- Execute a limited experimental testing campaign using the MCRE prototype to test combustion under H_2/fossil gas blends, using compressed pre-mixed fuel mixtures.
- Prepare and provide a *Limited Experimental Testing Campaign Report* that includes but is not limited to:
    - Background information about the experimental design.
    - Methods used during testing.
    - Results and analysis of the testing.
    - Proposed design improvements, if any, based on results.

Products:

- Limited Experimental Testing Campaign Report (draft and final)

TASK 3: ENGINEERING DESIGN AND LABORATORY TESTING

The goals of this task are (**1**) to perform the preliminary process engineering design of the Field Unit and (**2**) to test and validate the performance of the engine retrofit kit.

SUBTASK 3.1: PRELIMINARY ENGINEERING DESIGN

The goal of this task is to complete the preliminary process engineering design that defines the specification of all the system components.

The Recipient shall:

- Define and submit the *Project Design Basis Report* that includes, but is not limited to, the definition of site characteristics and ambient conditions, fuel feedstock specifications, environmental requirements, site specific design considerations, modularization requirements, etc.
- Create a portfolio that includes but is not limited to the preparation of simplified:
    - Block Flow Diagrams (BFDs)
    - Process Flow Diagrams (PFDs)
    - Utility Flow Diagrams (UFDs)

  - Process Equipment List.
  - Utility Equipment List.
  - Electrical One-Line Diagram.
- Prepare and provide the *Preliminary Engineering Design Package Report* that includes but is not limited to descriptions of the plans to:
  - Perform the preliminary process simulations to devise heat and material balances and inform preliminary equipment specifications and sizing.
  - Define preliminary system specifications relevant to the industry.
  - Devise a regulatory and permitting strategy that includes but is not limited to emissions compliance with the local governing rules and standards.
  - In consultation with the CAM, a mutually-agreed selection of simplified diagrams.

Products:
- Project Design Basis Report (draft and final)
- Preliminary Engineering Design Package Report (draft and final)

SUBTASK 3.2: DETAILED ENGINEERING DESIGN
The goals of this task are (**1**) to complete the detailed process engineering design that defines the specification of all the system components, (**2**) to complete the Measurement & Verification Plan to establish clear performance metrics and methodologies for data acquisition and analysis, and (**3**) to greenlight the commencing of procurement process.

The Recipient shall:
- Refine the preliminary set of technical documents (BFD, PFD, UFDs, etc.) and prepare a portfolio that includes:
  - Process and Instrumentation Diagrams (P&IDs)
  - Design Specifications & Datasheets for all the system components.
  - General Equipment Arrangement Drawings for the system.
  - Relevant Mechanical Discipline Drawings.
  - Relevant Electrical Discipline Drawings.
  - Instrumentation/Control System Discipline Drawings.
  - Structural/Site Discipline Drawings.
- Prepare and provide the *Detailed Engineering Design Package Report* that includes but is not limited to descriptions of the approach and outcomes of:
  - Performing a final set of process simulations to devise the nominal Heat and Material Balances of the Field Unit.
  - Preparing the final specification sheet of the Field Unit.
  - Devising a shipping and deployment strategic plan that strikes the most cost-effective balance between factory and on-site assembly.
  - In consultation with the CAM, a mutually-agreed selection of simplified engineering diagrams.
- Prepare and provide a *Measurement and Verification Plan* to summarize the metrics, data acquisition procedures, and analysis methods. This plan will include, but is not limited to:
  - Baseline Data: Clearly establish what baseline data will be used as a reference for comparison.
  - Measurement Tools and Techniques: Detail the equipment and methodologies that will be used to gather performance data, including an explanation of how H2 volumetric blend percentages will be measured and verified to remain accurate at the target blend percentage.

    - Data Acquisition Procedures: Set up procedures for consistent data collection, including sampling frequency.
    - Data Analysis Methods:
        - Detail how the data will be processed to derive performance metrics, including battery limits for each of the Key Performance Indicators (KPIs).
        - Outline the specific methods, formulas, or algorithms that will be used to evaluate the KPIs.
        - Determine accuracy of reported KPIs based on instrumentation specifications for defined system inputs and outputs, using uncertainty propagation techniques.
    - Verification procedure: describe how the analyzed data will be verified by the third party.
    - Reporting: Define the specifications of the Independent Analysis Report to be provided by the independent party.
- Consult with TAC on draft *Measurement and Verification Plan* to verify technical feasibility in accordance with subtask 1.10 (Technical Advisory Committee). Incorporate TAC feedback into the final *Measurement and Verification Plan* as appropriate.
- Prepare and provide *CPR Report #1* in accordance with Subtask 1.3 (CPR Meetings).
- Participate in a CPR Meeting.

Products:
- Detailed Engineering Design Package Report (draft and final)
- Measurement and Verification Plan (draft and final)
- CPR Report #1

SUBTASK 3.3: LABORATORY TESTING & VALIDATION
The goals of this task are (**1**) to test and validate the performance of the engine retrofit kit, and (**2**) to inform of needed modifications to the original design and control strategies.

The Recipient shall:
- Design, procure and fabricate a laboratory H_2/fossil gas blending train to accommodate higher fuel blend flow rates. (“Train” here means an assembled piping system used to accurately blend the different fuels).
- Design and execute necessary balance of plant modification to the MCRE prototype system and integrate the H_2/fossil gas blending train. This includes physical as well as software (control and data acquisition (DAQ) system) upgrades.
- Install the engine retrofit kit fabricated during Task 2 onto the MCRE prototype.
- Prepare and provide the *MCRE Experimental Testing Campaign Report* that incudes but is not limited to descriptions and discussions on the:
    - Laboratory experimental testing campaign that explains the methodology and supports the verification of the optimal control strategy devised through simulations in Task 2.
    - Execution of the experimental testing campaign.
    - Result test data consisting of process data (flow, temperature, pressure, gas composition), emissions (unburned hydrocarbons (UHC), O_2, CO, CO_2, NO_x), system performance (Efficiency, Power, CO_2 capture, H_2 substitution, etc.) and indicated crank resolved data (in-cylinder pressure, thermodynamic efficiency, etc.)

    - Analysis of the MCRE data (e.g., heat-release rate, cyclic variability, knock frequency and intensity, combustion phasing, peak pressures)
- Create and provide an *Indexed Experimental Database Report* that gives a simplified explanation on the development and use of an indexed database for easy access and use and plans for storing data for future reference.
- Prepare and provide the *Final Engine Retrofit Kit Design Report* which is an update to the Initial Engine Retrofit Kit Design Report that includes, but is not limited to, major changes from the initial design and justification for those changes.
- Prepare a *Detailed Test Plan* that includes:
    - Background information about the Design of Experiment framework.
    - Test plan for 200+ hours experimental campaign using the Design of Experiment framework. This test plan should aim to evaluate the sensitivity of different system parameters (Load (kWe), working fluid composition and pressure, equivalence ratios, injection, and ignition strategies, H_2 fuel blending, etc.) and identify opportunities to improve the unit's performance map.
    - Methodology for executing the 200+ hours experimental campaign following the devised test plan, acquiring test data consisting of process (flow, temperature, pressure, gas composition), emissions (UHC, O2, CO, CO2, NOx), system performance (Efficiency, Power, CO2 capture, H_2 substitution, etc.) and indicated crank resolved (in-cylinder pressure, thermodynamic efficiency, etc.) parameters.
    - Test plan for 300+ continuous hours experimental campaign. The Detailed Test Plan should aim to confirm the Field Unit's ability to deliver on the project metrics, mainly the unit's ability to operate with the prescribed H_2 blends, deliver the promised performance and emission levels. This plan will include but is not limited to a prescribed load and H_2 blending profile for the entirety of the continuous 300 hours of testing.
    - Methodology for executing a 300+ continuous hours experimental campaign following the Detailed Test Plan and acquire test data consisting of process (flow, temperature, pressure, gas composition), emissions (UHC, O_2, CO, CO_2, NO_x), system performance (Efficiency, Power, CO_2 capture, H_2 substitution, etc.) and indicated crank resolved (in-cylinder pressure, thermodynamic efficiency, etc.) parameters.
- Prepare and provide a *Joint Test Plan* that is a limited but detailed test plan developed by the Recipient in collaboration with an independent party to ensure verification of project results through an independent analysis. The Joint Test Plan includes but is not limited to:
    - Identifying and providing the credentials of the independent party that will be assisting with the development of the test plan.
    - Providing the methodology of the independent analysis and the associated acquisition of relevant test data by the Recipient, as agreed with the independent party, and as previously defined in the *Measurement and Verification Plan*.

Products:
- MCRE Experimental Testing Campaign Report (draft and final)
- Indexed Experimental Database Report (draft and final)
- Final Engine Retrofit Kit Design Report (draft and final)
- Detailed Test Plan (draft and final)
- Joint Test Plan (draft and final)

TASK 4: SAFETY, HEALTH, ENVIRONMENTAL HAZARDS, AND OPERABILITY (HAZOP) ANALYSIS

The goals of this task are (**1**) to identify safety, health, and environmental hazards and operability concerns with the preliminary and detailed engineering design package and (**2**) to propose corrective measures prior to the completion of the detailed engineering design package and the procurement and fabrication of the Field Unit.

SUBTASK 4.1: PRE-HAZOP ANALYSIS

The goals of this task are (**1**) to identify safety, health, and environmental hazards and operability concerns with the preliminary engineering design package and (**2**) to propose corrective measures prior to the completion of the detailed engineering design package.

The Recipient shall:

- Prepare and provide a *Pre-Safety, Health, Environmental Hazards, and Operability (HAZOP)Study Report* that includes but is not limited to summarizing the findings and recommendations from:
    - Conducting a systematic hazard and operability review based on the preliminary system engineering design provided in the *Preliminary Engineering Design Package Report* (Task 3.1).
    - Developing recommendations to mitigate or eliminate these risks. These recommendations will be incorporated into the detailed system engineering phase (Task 3.2).

Products:

- Pre-Safety, Health, Environmental Hazards, and Operability (HAZOP) Study Report (draft and final)

SUBTASK 4.2: POST-HAZOP ANALYSIS

The goals of this task are (**1**) to identify safety, health, and environmental hazards and operability concerns with the detailed engineering design package and (**2**) to propose corrective measures prior to commencing procurement and fabrication of the Field Unit.

The Recipient shall:

- Prepare and provide a *Safety, Health, Environmental Hazards, and Operability (HAZOP) Study Report* that includes but is not limited to summarizing the findings and recommendations from:
    - Conducting a systematic hazard and operability review based on the detailed engineering design summarized in the *Detailed Engineering Design Package Report* (Task 3.2).
    - Developing recommendations to mitigate or eliminate these risks. These recommendations will be incorporated into the final design before procurement and fabrication can begin.

Products:

- Safety, Health, Environmental Hazards, and Operability (HAZOP) Study Report (draft and final)

TASK 5: PROCUREMENT AND FABRICATION

The goals of this task are (**1**) to timely and cost-effectively procure and fabricate all the engineered components that make up the Field Unit, and (**2**) to secure the fuel procurement and host site commitment.

The Recipient shall:

- Prepare and provide a *Fuel Procurement Plan Report* that shows the use of Match Funds or other non-CEC funds for procuring the H_2 and fossil gas blends from a gas supplier that will have H_2 percentages greater than 30 percent volume. The Fuel Procurement Plan shall include but is not limited to the following:
    - Description of the approach for sourcing and procuring the H_2 to be used in the project.
    - Explanation of the process used to produce the H_2, and/or of the carbon intensity of the H_2 used in the fuel blend.
    - Explanation of how H2 volumetric blend percentages will be measured and verified to remain accurate at the target blend percentage.
- Prepare and provide an *Inventory and Costing Report* that includes but is not limited to the Recipient's process and outcomes for:
    - Issuing Request for Quotations (RFQs) for equipment, instrumentation and sensing devices required as defined in the *Detailed Engineering Design Package Report*.
    - Issuing RFQ for Fabrication services for the different custom components following the mechanical discipline drawings contained in the *Detailed Engineering Design Package Report*.
    - Selecting competitive bids based on cost, timeline, and associated risk, and issuing associated Purchase Orders (PO) with corresponding terms.
- Monitor fabrication and purchase orders fulfillment status. Take corrective actions when necessary to ensure progress remains within project timelines and budget.
- Arrange adequate shipping, rigging, storage, and inventory of procured equipment.
- Ensure that procured components conform to design specifications by measuring, examining, testing, or gauging various characteristics of a product and comparing them with the defined specifications.
- Fabricate final set of engine retrofit kit components for the Field Unit.
- Confirm a Pilot Demonstration Host Site.
- Provide an updated *Host Site Commitment Letter* signed by an authorized representative of the host site that includes but is not limited to:
    - Identifying the location of the host site.
    - An explanation of the suitability for testing the Field Unit using H_2 fuel at the site.
    - A commitment to providing the site for testing.

Products:

- Fuel Procurement Plan Report
- Inventory and Costing Report
- Host Site Commitment Letter

TASK 6: FIELD UNIT DEPLOYMENT

The goals of this task are (**1**) to ensure that the Field unit is timely, orderly, and safely deployed at the site, (**2**) to prepare the Field unit for commissioning, and (**3**) to demonstrate and evaluate

the technology's capabilities through continuous field operation (**4**) to demonstrate the APC under the 3 operating scenarios described in the Agreement Objectives.

SUBTASK 6.1: FIELD UNIT SHAKEDOWN AND COMMISSIONING

The goals of this task are (**1**) to verify that the Field Unit has been assembled as intended, and there is no violation of the designer's intent, (**2**) to confirm that the recommendations from the Safety, Health, Environmental Hazards, and Operability (HAZOP) analysis are incorporated, (**3**) to ensure that the Field Unit is timely, orderly, and safely deployed at the site, and (**4**) to confirm the preparedness of the operational team for start-up and operation of the unit.

The Recipient shall:

- Prepare and provide the *Installation and Integration Report* summarizing the deployment activities, including confirmation of system readiness for commissioning activities that include but are not limited to:
    - Conditioning the host site to ensure adequate access to the site and seamless integration with required utilities.
    - Defining shipping logistics (temporary storage, equipment packing, loading, transporting, unloading).
    - Issuing RFQ for professional rigging services and competitively select a rigging contractor based on cost, relevant experience, and timelines.
    - Coordinating and executing the loading, transportation and unloading of the Field Unit and H_2 gas supply components according to the shipping and deployment strategic plan from Subtask 3.1.
- Assemble and interconnect all relevant components.
- Prepare and provide the *Shakedown and Commissioning Report* summarizing the activities performed that include but are not limited to:
    - Performing a design and construction verification review to ensure the unit has been built and assembled as intended. This activity is likely to be carried out at the assembly site prior to shipment.
    - Performing a pre-startup Safety Review (PSSR) to ensure the safety and integrity of the system. This activity will be carried out at the host site.
    - Performing a comprehensive series of predefined tests to verify:
        1) The system behaves as expected under known, previously simulated conditions.
        2) Safety interlock systems function as intended.
        3) Control and DAQ systems are appropriately commanding and monitoring the Field Unit.
- Prepare and provide *CPR Report #2* in accordance with subtask 1.3 (CPR Meetings).
- Participate in a CPR Meeting.

Products:

- Installation and Integration Report (draft and final)
- Shakedown and Commissioning Report (draft and final)
- CPR Report #2

SUBTASK 6.2: FIELD TESTING

The goal is to demonstrate and evaluate the technology's capabilities through continuous field operation.

Exhibit A
Scope of Work
Noble Thermodynamic Systems, Inc.

The Recipient shall:

- Ensure that the *Measurement and Verification Plan* is adequately implemented to provide the information required for performance assessment.
- Analyze experimental campaign data and extract performance metrics as dictated in the *Measurement and Verification Plan*.
- Acquire, prepare and format experimental data as agreed with the independent party in the Joint Test Plan. Provide data to the independent party for analysis. The independent party will provide the Recipient with an *Independent Analysis Report* that includes but is not limited to detailing the activities performed and the results and conclusions reached.
- Execute a 200+ hours experimental campaign following the *Detailed Test Plan* and *Joint Test Plan.*
- Execute a 300+ continuous hours experimental campaign following the *Detailed Test Plan*.
- Prepare and provide the *Experimental Campaign Analysis Report* that includes but is not limited to the:
    - Description of a created indexed database of test results for easy access and use, storing data for future reference.
    - Discussion of the analyzed experimental campaign data and extraction of performance metrics as dictated in the Measurement and Verification Plan.
    - Discussion of the development of Standard Operating Procedures (SOPs) for the unit, based on lessons learned during field testing.
    - Results and analysis of the field testing that show compliance with the applicable emissions standards. At the minimum the emissions will show:
        - CO emissions reductions of at least 60 percent from the baseline taken at zero percent H_2 blend.
        - NOx emissions parity or better with baseline taken at zero percent H_2 blend.
    - Discussion of system durability after completion of field testing.
    - Discussion of electric generation efficiency parity or better with baseline taken at zero percent H_2 blend.
    - Justification for advancing technology maturity to TRL 7.
    - Discussion on lessons learned in safely testing using high blends of H_2.

Products:

- Independent Analysis Report (draft and final)
- Experimental Campaign Analysis Report (draft and final)

TASK 7: TECHNO-ECONOMIC ANALYSIS

The goal of this task is to evaluate the feasibility, cost-effectiveness, and overall performance of the Argon Power Cycle technology, specifically of the Field Unit.

The Recipient shall:

- Provide an independently prepared *Techno-Economic Analysis Report* describing assumptions, cost basis, and results that include but are not limited to:
    - A description of the approach using an AACE Class-1 cost estimate for the first-of-a-kind unit and for a nth-of-a-kind unit using standard learning curves.
    - The results from conducting a Techno-Economic Analysis (TEA) based on the Field Unit design, performance, and bill of materials (BOM) list.

  - An evaluation of performing an AACE Class-4 Cost Estimate for a scaled-up unit using cost scaling curves.
  - A description of the approach used for a break-even analysis, sensitivity analysis, assessment on the return on investment, payback period, and replicability of the project.
- Consult with TAC on draft *Techno-Economic Analysis Report* to verify technical feasibility in accordance with subtask 1.10 (Technical Advisory Committee). Incorporate TAC feedback into the final *Techno-Economic Analysis Report* as appropriate.

Products:
- Techno-Economic Analysis Report (draft and final)

TASK 8: LIFE CYCLE ASSESSMENT
The goals of this task are (**1**) to assess the lifecycle emissions (LCE) and water consumption of operating the APC technology on the proposed fuel blend(s) and (**2**) to perform a comparative analysis with the LCE of its conventional gas-fired counterpart.

The Recipient shall:
- Provide an independently prepared *Life Cycle Assessment*following National Energy Technology Laboratory (NETL)'s Life Cycle Analysis (LCA) template, or other relevant LCA templates that includes but is not limited to:
  - An overview of the LCA template used that includes explanations on any assumptions, public policies, or future environmental or economic goals used in the assessment.
  - A description of the approach for carrying out a Lifecycle Carbon Intensity Analysis following the International Organization for Standardization (ISO) ISO 14040:2006 LCA framework and ISO 14044:2006 LCA guidelines to assess the comprehensive environmental impacts that the APC, operating on the proposed fuel blend(s), will have over its lifetime.
  - A description of the approach for estimating the water consumption and the associated impact on the State drought by using the APC.
  - A definition of the LCA system boundaries in coordination with all project stakeholders.
  - A comparison between the APC's environmental impacts and that of its conventional gas fired counterpart.

Products:
- Life Cycle Assessment Report (draft and final)

TASK 9: MARKET RESEARCH
The goals of this task are (**1**) to gather insights from industry stakeholders, understand their needs and expectations, and (**2**) to use this information to guide the development, testing, and eventual deployment of the APC technology, ensuring it is aligned with market requirements and has the best chance of successful broad adoption.

The Recipient shall:

- Prepare a *Key Industry Stakeholders List*, including, but not limited to, names, organization, and relevancy to the project, and submit for CAM approval.
- Conduct a series of interviews with key industry stakeholders to collect feedback on the industry's needs for low-carbon power generation.
- Prepare and provide the *Market Research Report* summarizing the industry's feedback that includes but is not limited to:
    - Identifying in which areas of application these power industry organizations normally operate and an explanation of how representative these organizations are for the sector.
    - An outline of the interview questions asked to representative power industry organizations (at least 6).
    - Providing a summary of what their specifications and use cases are, and what their short- and long-term plans are in this space. Specifically, the Recipient shall gather feedback concerning the potential applicability and interest in the APC and what its perceived strengths and potential issues.
    - market trends, growth potential, competitive landscape, demand projections,

Products:
- Key Industry Stakeholders List
- Market Research Report (draft and final)

TASK 10: EVALUATION OF PROJECT BENEFITS
The goal of this task is to report the benefits resulting from this project.

The Recipient shall:
- Complete *the Initial Project Benefits Questionnaire*. The Initial Project Benefits Questionnaire shall be initially completed by the Recipient with 'Kick-off' selected for the 'Relevant data collection period' and submitted to the CAM for review and approval.
- Complete the *Annual Survey* by December 15th of each year. The Annual Survey includes but is not limited to the following information:
    - Technology commercialization progress
    - New media and publications
    - Company growth
    - Follow-on funding and awards received
- Complete the *Final Project Benefits Questionnaire*. The Final Project Benefits Questionnaire shall be completed by the Recipient with 'Final' selected for the 'Relevant data collection period' and submitted to the CAM for review and approval.
- Respond to CAM questions regarding the questionnaire drafts.
- Complete and update the project profile on the CEC's public online project and recipient directory on the Energize Innovation website (www.energizeinnovation.fund), and provide *Documentation of Project Profile on EnergizeInnovation.fund*, including the profile link.
- If the Prime Recipient is an Innovation Partner on the project, complete and update the organizational profile on the CEC's public online project and recipient directory on the Energize Innovation website (www.energize), and provide *Documentation of Organization Profile on EnergizeInnovation.fund*, including the profile link.

Products:

- Initial Project Benefits Questionnaire
- Annual Survey(s)
- Final Project Benefits Questionnaire
- Documentation of Project Profile on EnergizeInnovation.fund
- Documentation of Organization Profile on EnergizeInnovation.fund

TASK 11: TECHNOLOGY/KNOWLEDGE TRANSFER ACTIVITIES

The goal of this task is to conduct activities that will accelerate the commercial adoption of the technology being supported under this agreement. Eligible activities include, but are not limited to, the following:

- Scale-up analysis including manufacturing analysis, independent design verification, and process improvement efforts.
- Technology verification testing, or application to a test bed program located in California.
- Legal services or licensing to secure necessary intellectual property to further develop the technology.
- Market research, business plan development, and cost-performance modeling.
- Entry into an incubator or accelerator program located in California.

The Recipient Shall:

- Develop and submit a *Technology Transfer Plan* that identifies the proposed activities the recipient will conduct to accelerate the successful commercial adoption of the technology.
- Present the *Draft Technology Transfer Plan* to the TAC for feedback and comments.
- Develop and submit a *Summary of TAC Comments* that summarizes comments received from the TAC members on the *Draft Technology Transfer Plan*. This document will identify:
    - TAC comments the recipient proposes to incorporate into the *Final Technology Transfer Plan*.
    - TAC comments the recipient does not propose to incorporate with and explanation why.
- Submit the *Final Technology Transfer Plan* to the CAM for approval.
- Implement activities identified in the Final *Technology Transfer Plan.*
- Develop and submit a *Technology Transfer Summary Report* that includes high level summaries of the activities, results, and lessons learned of tasks performed relating to implementing the *Final Technology Transfer Plan*. This report should not include any proprietary information.
- When directed by the CAM, develop presentation materials for an CEC- sponsored conference/workshop(s) on the project.
- Provide at least (6) six *High Quality Digital Photographs* (minimum resolution of 1300x500 pixels in landscape ratio) of pre and post technology installation at the project sites or related project photographs.

Products:

- Technology Transfer Plan (draft and final)
- Summary of TAC Comments
- Technology Transfer Summary Report (draft and final)
- High Quality Digital Photographs

VI. PROJECT SCHEDULE

Exhibit A
Scope of Work
Noble Thermodynamic Systems, Inc.

Please see the attached Excel spreadsheet.