WORK STATEMENT

Packaged Microturbine / Boiler CHP System

Glossary:

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

Acronym	**Definition**
ASERTTI	Association of State Energy Research and Technology Transfer Institutions
~~BA~~AQMD	~~Bay Area~~ Air Quality Management District
BMS	Burner Management System
CARB	California Air Resources Board
CHP	Combined Heat and Power
CO	Carbon Monoxide
CPR	Critical Project Review
DG	Distributed Generation
FGR	Flue Gas Recirculation
KWe	Kilowatts Electricity
~~LBNL~~	~~Lawrence Berkeley National Laboratory~~
lb/MWh	Pounds per Megawatt Hour
MMBtu	Million British Thermal Units
MTG	Microturbine Generator
NOx	Oxides of Nitrogen
PE	Power Electronics
~~PG&E~~	~~Pacific Gas and Electric~~
PIER	Public Interest Energy Research
PO	Purchase Order
PID	Proportional-Integral-Derivative
RD&D	Research, Development and Demonstration
ROI	Return on Investment
SCMT	**Simple Cycle Microturbine**

Task #	CPR	Task Name
1	-	Administration
2	-	Engineer System
3	-	Purchase and Fabricate Equipment
4	-	Engineer and Fabricate Burner Controls
5	**X**	System Assembly and Checkout Tests
6	-	Site Coordination and Agreements
7	-	**Field** Installation ~~at NRG - SF Thermal~~
8	-	Field Demonstration Testing
9	-	Technology Transfer Activities

10	-	Commercialization Readiness Plant

Introduction:

The California Energy Commission (Energy Commission) manages the Public Interest Energy Research (PIER) Program. The mission of the PIER Program is to provide advanced energy innovations in hardware, software, systems, and concepts to support a balanced portfolio of sustainable energy options for utilities, state and local governments, and consumers in California. Among its goals, PIER aims to: (1) improve the availability and stability of electricity supply within the State, (2) improve the cost effectiveness of advanced generation technology with hybrids and Combined Heat and Power (CHP) systems; (3) reduce the energy cost and improve performance of end use systems; (4) expand distributed generation (DG) to help provide generation in areas of highest value (e.g., high grid congestion areas); and (5) develop and demonstrate innovative generation technologies.

PIER has supported the demonstrations of low cost, clean microturbine-based DG integrated with industrial burners as a way to address the industrial CHP market which is comprised of packaged industrial steam boilers and other fuel burning industrial furnaces, such as thermal oxidizers. For these applications, the 15-16% electrical efficiency for a low-cost unrecuperated microturbine **or 26-30% efficiency for a recuperated microturbine** ~~has~~ **have** no adverse impact on the return on investment (ROI) because most of the remaining ~~84-85%~~ waste heat can be efficiently allocated by the host site to their high-quality thermal needs. In fact, waste heat can be recovered in the boiler with efficiencies of 80% or above with re-fired CHP systems bringing the overall CHP efficiencies to >80% with a low power generation cost ($/kWh).

Under PIER Contract 500-03-037, PIER ~~has~~ sponsored the demonstration of a **simple cycle microturbine (SCMT) closely integrated with a Coen 15-ppm NOx emission burner. The project successfully completed an important and first-ever demonstration of the integrated microturbine-burner concept based on new technologies such as a SCMT modified with a** more robust ultra low-NOx silo combustor**, a novel interface between the microturbine exhaust and low-NOx burner, and integrated controls.** ~~that incorporates the low-swirl flame stabilizer nozzle developed at Lawrence Berkeley National Laboratory (LBNL). The silo combustor eliminates the partial oxidation burner used in the Elliott microturbines and provides a much more robust combustion system which will significantly enhance reliability of the system. Furthermore, along with this innovative combustor, the PIER Program has supported the development of a simple-cycle (unrecuperated) microturbine. The elimination of the recuperator voids current maintenance issues associated with this equipment while making the prime mover much more reliable, less costly, and requiring reduced floor space for tight spaces~~. **The microturbine-burner integrated CHP system extends also to CARB-certified recuperated microturbines, such as Casptone C65, which provide onsite power generation with a commercially available prime mover.** The availability of steam boilers ensures overall CHP efficiencies are consistently higher than any pre-packaged CHP **hot-water** systems **currently** offered by the vendors. This is because steam boilers are inherently more efficient **and more robust waste heat recovery devices** ~~than conventional recuperators~~ and **use preheated combustion air for boiler burners**. ~~more robust~~. In addition, the production of steam is inherently more valuable than production of hot water and thus improves the overall cost-effectiveness and ROI of small-scale CHP.

Many Air Districts in California have recently passed more stringent emission limits for packaged industrial boilers (for example, Regulation 9, Rule 7 of the Bay Area Air Quality Management District). These new regulations will require owners/operators to meet NOx emissions to as low as 9 ppm, dry corrected to 3% excess O_2, significantly lower than the level proven under the PIER-03-037 project. Compliance will likely be met with new ultra-low NOx burners such as, the NOXmatic™ burner offered by S.T. Johnson Company in Oakland, CA or the RMB™ burner offered by John Zink in Tulsa, OK, which are currently the only two commercial burner technologies capable of this performance. Integration of the microturbine with these ultra-low NOx burners must consider the design limits of these burner technologies, which are critical to their 9-ppm NOx performance. The selection of the microturbine technology will also be impacted by the new boiler NOx regulations. For example, if the ultra-low NOx burner is not designed for high combustion air preheat, the application of SCMT technology with high 1100 °F exhaust may be precluded. Also, excessive NOx emission from the microturbine can represent a significant percentage of the new boiler NOx limit.

Project Description:

This project will demonstrate the microturbine-boiler CHP technology **on an existing packaged (single burner) industrial boiler at a site in California using a microturbine/generator interfaced with a NOXmatic™ 9-ppm ultra-low NOx burner. The microturbine may be configured for operation in either simple-cycle or regenerative (recuperated) mode as required by the host site, and shall be rated in the 65-100 kWe class. The NOXmatic™ burner will be modified to accept vitiated combustion air from the turbine exhaust for the fully premixed radiant burner and will have upgraded controls to permit the operation of the burner and microturbine independently of each other as well as in CHP mode. The final configuration and operating requirements will be dictated by the host site and the operating load cycle on the selected retrofit boiler.**

~~for a District Heating Plant in San Francisco. This facility is especially attractive as a demonstration site because (1) it requires more electricity for expansion and improvements; (2) it can use high temperature waste heat from the microturbine to improve boiler part load and standby performance; and (3) it will reduce the overall cost of operating the facility. These immediate benefits will be a valuable testament to low-cost simple cycle microturbine retrofit in CHP assembly for large packaged industrial boilers. Coupled with the ongoing PIER program at the Hitachi plant, this demonstration will address the retrofit of both small and large packaged industrial boilers in CHP configuration with 100 kWe~~

~~simple-cycle microturbines. Therefore, it is a good complement to the ongoing PIER integrated CHP for boilers.~~

~~After the final selection of the boiler at the NRG SF Thermal District Heating Plant, the selected boiler, with either its existing low-NOx burner or a new low-NOx burner, will be retrofitted with the microturbine CHP assembly.~~

~~An Elliott 100 kWe microturbine will be equipped with low-NOx silo combustor developed under PIER Contract 500-03-037. The combustor will be resized to permit higher firing rates to boost~~

~~power output from 80 to 100 kWe and will be able to meet CARB 2007 DG emission standards under CHP configuration. Under the ongoing PIER program, Recipient has obtained a permit for the installation at the Hitachi Plant in San Jose, CA.~~ The **project will identify and secure a host site that will require compliance with the new boiler emission regulations and will agree to consider a CHP assembly based on the proposed microturbine-burner integrated technology. The project team will secure an air permit from the** relevant Air Quality Management District (~~BA~~AQMD)**, including any applicable waivers or relaxation of permit limits based on the experience gained under PIR-03-037. S.T. Johnson and CMCE, Inc will supply match funds to provide a new NOXmatic™ burner for the project at no cost to the Commission.** ~~is expected to be more rapid as all parties are more familiar with the technology and application.~~ The installation will be tested to monitor performance and **demonstrate attainment of** emission compliance goals.

Project Goal:

The project goal is to engineer, design, fabricate, and test the performance of the ~~simple cycle~~ microturbine **(simple-cycle or recuperated, 65-100kWe)** retrofitted and integrated with the operation of an ~~existing Coen~~ ultra low NOx burner (~~QLN~~**NOXmatic**™ burner **or equivalent**) on an industrial boiler located in ~~at NRG SF Thermal in San in Francisco,~~ California. **Installation of the integrated CHP assembly will take place after modifications are made to a conventional NOXmatic™ burner, and controls are designed, implemented, and tested at the ST Johnson Company in Oakland, California.**

Table 1 summarizes the technical and performance goals of the proposed CHP installation ~~at SF Thermal~~. The proposed system can boost overall conversion of microturbine fuel to useful energy (electricity + thermal) to **82**~~78~~% (15% for the power generation and **67**~~63~~% from the **77**~~74~~% recovery by the boiler of the remaining 85% left in the microturbine exhaust). This demonstration will significantly enhance the validity of this CHP approach and the market for retrofit of the industrial boiler base, both large and small packaged boilers. An 80% retrofit penetration of packaged boilers with capacities in the range of 10,000-150,000 lb/hr of steam with 100 kWe simple cycle microturbines would add about 2,700 MWe of additional DG power nationwide and result in more than 16 billion cft of natural gas savings per year nationally. For California, the overall market for DG would add 1,400 MWe and save the State 670 MMcft/yr of natural gas. **Carbon dioxide** ~~CO2~~ (one of the greenhouse gases affecting climate change) emission reductions associated with these fuel savings would amount to more than 10 million tons/yr nationwide and 0.68 million tons/yr from California.

Table 1. Technical and Performance Goals of Proposed CHP Installation ~~at NRG SF Thermal~~

Parameter	~~Simple Cycle 100~~ **MTG***	~~100K lb/hr~~ Package Boiler[~~2~~**3**] ~~NGR SFT~~	CHP	Facilitating Technologies
Efficiency (conversion to electricity for MTG and conversion to steam for boiler)	~~15~~ **28**% HHV w/o CHP 7~~0~~**8**% w/CHP	77%	**82**~~78~~%	Conversion to electricity for MTG; Conversion to steam for boiler; Conversion to combined power and steam for CHP
Natural gas use, 1000 cft/hr	**0.86**[**(1)**]~~2.4~~	~~112.6~~**13**	**12.6**~~111.2~~	**Recovery of microturbine waste heat in the boiler**
Efficiency at boiler 20% load	NA Full load only	68%	72%	Waste heat from MTG significantly improves standby boiler efficiency
NOx emissions	<**0.28**~~0.343~~[~~1~~**2**] lb/MWh	0.01 lb/MMBtu[~~3~~**4**]	0.01 lb/MMBtu[~~3~~**4**]	MTG NOx does not add noticeably to overall boiler emissions. CHP credited emissions in compliance at 0.062 lb/MWh
CO emissions	18 lb/MWh	0.01 lb/MMBtu	0.01 lb/MMBtu	High CO emissions are burned in the boiler. Overall CO emissions from boiler remain unaffected

* Microturbine Generator **(Capstone C65 or modified SCMT TA-100)**

NA – Not applicable. Microturbine will fire at full load only

(1) –0.86 MMBtu/hr for C65 or 2.4 MMBtu/hr for TA-100)

(~~1~~**2**) – **Equivalent to <9ppm @15% O_2.** Emissions are reduced to 0.066 lb/MWh when waste heat recovery credits are applied.

(3) – Typical 10,000 lb steam/hr boiler

(4) – Equivalent to 9 ppm NOx @3% O_2

*CARB 2007 DG Emission Standards (**See CARB 2007 DG Emission Standards at** http://www.arb.ca.gov/energy/dg/2006regulation.pdf)

~~CARB 2007 DG (Fossil Fuel) Emission Standards~~

~~Pollutant Emission Standard (lb/MW-hr)~~

~~NOx 0.07~~
~~CO 0.10~~
~~VOCs 0.02~~
~~DG Units that produce combined heat and power may take a credit to meet the emission standard above. Credit shall be at the rate of one MW-hr for each 3.4 million Btu's of heat recovered as per specified requirements.~~

Project Objectives:
The objectives of this Agreement are to:

- Engineer, design, fabricate and install a **65-100**~~packaged simple cycle 100~~ kWe **(Capstone C65 or SCMT TA-100 or equivalent)** microturbine in a CHP configuration with a ~~large~~ package (single burner) industrial boiler at **a site in California** ~~the NRG SF Thermal district heating plant in San Francisco.~~

- Demonstrate overall CHP efficiency of **82**~~78~~%, ~~slightly~~ exceeding the current efficiency of the steam boiler at full load because of performance improvements.

- Demonstrate the microtubine NOx emission level lower than CARB 2007 DG emission standards* (<0.07 lb/MWh) with CHP heat recovery credits for the heat recovered in the boiler.

- Demonstrate CO emission compliance of the microturbine with CARB 2007 emission standards by achieving <0.01 lb/MMBtu at the boiler stack and based on the total input to the CHP system consisting of the simple cycle microturbine exhausting to a burner fired steam boilers.

- Demonstrate added energy (fuel and electricity) savings in excess of 4% associated with improved boiler operation at part and boiler standby loads. This assessment will be based on comparing fuel used by the boiler without and with the microturbine firing and providing high temperature waste heat and combustion air to the boiler.

TASK 1.0 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 Energy 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

Energy 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 Energy 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 1.7)
- Permit documentation (Task 1.8)

The technical portion of the meeting shall include, but not be limited to, the following:

- The Energy Commission Project Manager's expectations for accomplishing tasks described in the Scope of Work
- An updated Schedule of Products
- An updated Gantt Chart
- Discussion of Progress Reports (Task 1.4)
- Discussion of Technical Products (Special Conditions)
- Discussion of the Final Report (Task 1.5)

The Energy Commission Project Manager shall designate the date and location of this meeting.

Recipient Products:

- An Updated Schedule of Products
- An Updated Gantt Chart
- An Updated List of Match Funds
- An Updated List of Permits

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, if it should, any modifications that need to be made 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 Energy Commission Project Manager and as shown in the Technical Task List above and in the Schedule of Products. However, the Energy Commission Project Manager may schedule additional CPRs as necessary, and any additional costs will be borne by the Recipient.

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

The Energy 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 to modify the tasks, schedule, products, and budget for the remainder of the Agreement, including not proceeding with one or more tasks. If the Energy 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 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 products 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 Work Statement. Submit these documents to the Energy 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.

Recipient Products: CPR Report(s)

Project Manager Products:

- Agenda and a List of Expected Participants
- Schedule for Written Determination
- Written Determination

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 Energy Commission Grants Officer, and the Energy 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 Energy Commission Project Manager.

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

The administrative portion of the meeting shall be a discussion with the Energy Commission Project Manager and the Grants Officer about the following Agreement closeout items:

- What to do with any state-owned equipment (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.

The Recipient shall prepare a report documenting the final meeting agreements as well as a schedule for completing the closeout activities for this Agreement.

Products:

- Written Documentation of Meeting Agreements
- Schedule for Completing Closeout Activities

Task 1.4 Monthly 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 Monthly Progress Reports which summarize 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 Energy Commission Project Manager within 10 working days of the end of the reporting period. The required specifications for progress reports are contained in the Terms and Conditions of this Agreement.

Products: Monthly 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 Recipient has obtained confidential status from the Energy Commission and will be preparing a confidential version of the Final Report as well, the Recipient shall perform the following activities 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 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 Energy 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.
  - 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 Energy Commission Project Manager if during the course of the Agreement additional match funds are received.

- Notify the Energy Commission Project Manager within 10 working days if during the course of the Agreement existing match funds are reduced. Reduction in match funds may trigger an additional CPR.

Products:

- A letter regarding Match Funds or stating that no Match Funds are provided
- A copy of each Match Fund commitment letter (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 show match funds for this task. Permits must be identified in writing and obtained before the Recipient can incur any costs related to the use of the permits for which the Recipient will request reimbursement.

The Recipient shall:

- Prepare a letter documenting the permits required to conduct this Agreement and submit it to the Energy 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:

  - 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 Energy Commission Project Manager.

- As permits are obtained, send a copy of each approved permit to the Energy Commission Project Manager.

- If during the course of the Agreement permits are not obtained on time or are denied, notify the Energy Commission Project Manager within 5 working days. Either of these events may trigger an additional CPR.

Products:

- A letter documenting the Permits or stating that no Permits are required
- Updated list of Permits as they change during the Term of the Agreement
- Updated schedule for acquiring Permits as it changes during the Term of the Agreement
- A copy of each approved Permit

TECHNICAL TASKS

Unless otherwise provided in the individual Task, the Recipient shall be responsible for all products and shall prepare and submit all products specified in the work statement. Some products will have major contributions from the key subcontractors. The Recipient shall track their delivery status and ensure adherence to the delivery schedules. Unless otherwise provided in the individual Task, the Recipient shall prepare all Products in accordance with the terms and conditions of this Agreement.

Task 2 Engineer System

The goal of this task is to evaluate all design and operational aspects of the selected boiler and burner when operating in combination with the microturbine in a CHP configuration. This analysis will permit the development of detailed process flows, controls, operational guidelines, energy and emission performance, and selection of key components parts for purchase and fabrication. The analysis will be assisted by the site coordination and target boiler/burner selection performed concurrently in Task 6.

The objective of this task is to perform detailed engineering analyses of the entire CHP system and each component to arrive at design and operating specifications for the performance of the entire system. The list of key elements of this engineering analysis include: (1) the microturbine generator (MTG) hot temperature exhaust treatment and interconnection with electrical panel, (2) the low-NOx silo combustor developed under the current PIER Program, (3) the design enclosure for the microturbine, (4) the size, configuration and insulation requirements for the heat recovery ducts size, (5) the burner management control upgrade necessary to interface the microturbine exhaust, (6) the changes and controls necessary to the existing flue gas recirculation (FGR) system **(if any)**, and (7) an evaluation of the boiler burner NOx performance and combustion stability as a result of the added microturbine exhaust.

The Recipient shall:

- Prepare the list of performance objectives in synch with the project goals and objectives, and operational attributes of the CHP system.

- Perform an engineering analysis of the **effect of air preheat on NOXmatic™ performance** ~~silo combustor design characteristics~~ and operating requirements with higher required firing rates.

- Analyze the NOx and CO performance impacts on the **NOXmatic**~~QLN~~™ burner with preheated engine exhaust vitiated air and FGR requirements **(if any)**.

- Prepare a detailed list of system components, parts, and specifications.

- Prepare a detailed and configuration design of equipment to be fabricated and assembly drawings.

- Prepare a draft Task 2 Report that describes the engineering evaluations of the retrofit CHP system on the selected boiler/burner system. The draft report shall describe and include, but not be limited to:

    - Layout of boiler/burner system selected for the retrofit.
    - Nameplate data and operating characteristics of the boiler and current burner.
    - Baseline energy and mass balance of selected boilers/burner.
    - Baseline efficiency and emission performance of the boiler/burner.
    - Preliminary layout of microturbine retrofit in CHP mode.
    - Energy and mass balance through load range with microturbine exhaust.
    - Estimates of impact on boiler emissions with microturbine exhaust.
    - Detailed list of parts and CHP components.
    - Engineering specifications for selected CHP components.
    - Proportional-Integral-Derivative (PID) control and demonstration system construction drawing.

- Submit draft Task 2 Report to Energy Commission Project Manager for review and comments.

- Revise draft Task 2 Report by incorporating and addressing Energy Commission Project Manager's comments.

- Submit final Task 2 Report to Energy Commission Project Manager for approval.

Product: Draft Task 2 Report

Product: Final Task 2 Report

Task 3 Purchase and Fabricate Equipment

The goal of this task is to secure all the parts and system components for assembly and testing. This task will entail preparing and releasing purchase orders (PO), securing the match funds to purchase the equipment and complete the purchase of all the CHP equipment. This task will be performed in coordination with planned site coordination efforts in Task 6 related to assisting the host site as the match co-funder and hardware purchaser for this project.

The objective of this task is to prepare a part list; assist the host site in placing order for microturbine; prepare PO for retrofit parts including ductwork, burner management system (BMS) upgrades, and insulation; release POs to vendors; follow up on the delivery of equipment to the host site; and arrange for temporary storage of equipment at the site. The microturbine will come equipped from the vendor with **CARB 2007 compliance capability when in CHP mode** ~~low-NOx capability using the silo combustor developed under the PIER program~~.

The Recipient shall:

- Coordinate with the microturbine vendor to supply a complete CARB 2007 DG standard compliant package.

- Issue purchase and fabrication orders.

- ~~Fabricate new silo combustor (combustor may be part of purchased parts from Elliott).~~

- Purchase microturbine ~~with low NOx silo and auxiliaries~~ from **vendor.** ~~Elliott~~.

- List of potential spare parts.

- Assemble CHP components and fabricate parts ready for assembly.

- Prepare a draft Task 3 Report on the fabrication, purchase, and assembly of microturbine and other CHP equipment for delivery to host site and for assembly. The report shall describe and include but not be limited to:

    - Detailed inventory list of all the purchased parts
    - Copies of purchase orders
    - Related photographs of purchased equipment

- Submit the draft Task 3 Report to the Energy Commission Project Manager for review and comments.

- Revise the draft Task 3 report by incorporating and addressing the Energy Commission Project Manager comments.

- Submit the final Task 3 Report to the Energy Commission Project Manager for approval.

Product: Draft Task 3 Report

Product: Final Task 3 Report

Task 4 Engineer and Fabricate Burner Controls

The controls for the existing burner at the host site will require modifications to permit the operation with the microturbine. The degree of modifications necessary will depend on the selection of the burner and its emission performance requirements. Generally, ultra-low-NOx burners have reduced operation tolerances and therefore will require added control logic and microturbine signal interface to ensure safe operation with assured compliance. Concurrently to the activities of Task 3, the Recipient shall ensure that the interface of the microturbine power electronics (PE) with the ~~Fyr-Monitor~~ burner management system (BMS) for the ultra low-NOx **NOXmatic**~~QLN~~^{TM} burner is evaluated. Therefore, the goal of this task is to design, fabricate and test a new BMS system that will be necessary to ensure continued performance of the boiler burner when operating with or without microturbine hot exhaust.

The objective of this task is to: (1) define the BMS logic necessary to operate the burner safely with the hot exhaust and vitiated combustion air (FGR); (2) evaluate the upgrades necessary to the existing burner BMS servicing the selected boiler/burner system; and implement the modifications.

The Recipient shall:

- Identify changes to the current burner BMS control panel.

- Prepare electrical drawings and evaluate software changes.

- Identify electrical interfaces.

- Fabricate a new BMS control panel or modify the existing panel.

- Evaluate the interface of the microturbine power electronics (PE) with the BMS for the ultra low-NOx **NOXmatic**~~QLN~~™ burner.

- Prepare a draft Task 4 Report that addresses the required BMS upgrades necessary to incorporate the microturbine in a CHP configuration. The draft report shall include, but not limited to:

  - Burner control logic requirements
  - BMS logic signal diagram
  - List of modifications necessary

- Submit the draft Task 4 Report to the Energy Commission Project Manager for review and comments.

- Revise the draft Task 4 Report by incorporating and addressing Energy Commission Project Manager's comments.

- Submit the final Task 4 Report to the Energy Commission Project Manager for approval.

Product: Draft Task 4 Report

Product: Final Draft 4 Report

Task 5 System Assembly and Checkout Tests

The goal of this task is to have ~~a simple-cycle~~ **the** microturbine ~~package~~ ready for assembly in CHP configuration with **a new NOXmatic**™ ~~existing~~ burner ~~ductwork~~ at **the S.T. Johnson Company in Oakland, CA or directly at the host facility** ~~NRG-SF Thermal~~ and test fire the microturbine ~~prior to interconnection~~ with the **applicable** site ductwork or **modified burner controls** electrical panel.

The objective of this task is to: (1) ensure all the parts for the simple-cycle microturbine package are delivered to the ~~NRG-SF Thermal~~ **selected** site **for pretest**; (2) assemble all the parts in an enclosure provided by the microturbine vendor; (3) install ~~temporary~~ connection for natural gas; (4) install the ductwork interconnecting the microturbine exhaust to the boiler/**burner** air intake; and (5) confirm the operational readiness of the **CHP assembly package**~~microturbine~~.

The Recipient shall:

- ~~Assemble a fully functional simple-cycle microturbine package at NRG-SF Thermal site.~~
- Perform initial startup tests and document the operational readiness of all components **with microturbine exhaust or equivalent hot vitiated exhaust**.

- Prepare a draft Task 5 Report for review and approval by the Energy Commission Project Manager. The report shall include but not be limited to:

  - Test data from the preliminary test firing at the site to establish the operational readiness of the delivered microturbine equipment.

  - Final layout diagram of the system.

- Submit the draft Task 5 Report to the Energy Commission Project Manager for review and comments.

- Revise the draft Task 5 Report by incorporating and addressing Energy Commission Project Manager's comments.

- Submit the final Task 5 Report to the Energy Commission Project Manager for approval.

Product: Draft Task 5 Report

Product: Final Task 5 Report

[1ST CRITICAL PROJECT REVIEW MEETING. SEE TASK 1.2 FOR DETAILS]

Task 6 Site Coordination and Site Agreements

The goal of this task is for the Recipient to secure all necessary signed agreements and field retrofit contracts with **a host site** ~~NRG-SF Thermal~~ and provide ongoing coordination with equipment purchase, site storage and site preparation. This task shall be performed in coordination with Task 2 activities while focusing on the engineering aspects of the retrofit as they relate to the impact on the project activities including air permitting, technical approach and final CHP configuration.

The objectives of this task are to:

- Initiate the discussions with the host site management early enough in the project to secure a timely availability of the site for engineering evaluation and site retrofit detail.

- Obtain agreement for the storage of equipment purchased for the project in preparation for final assembly.
- Perform engineering and economic analyses to assist the host site in the final selection of the target boiler and cost of host site-purchased equipment.
- Assist the host site in arranging communication and purchase order release for the hardware from the microturbine vendor.
- Establish coordination between Recipient, key subcontractor and equipment vendors.

The Recipient shall:

- Secure field test agreement and installation contract with **host site** ~~SF Thermal~~.

- Prepare a draft Task 6 Report for review and approval by the Energy Commission Project Manager. The report shall include, but not be limited to:

  - Economic analysis results for cost savings to the host site
  - Copies of field test agreements and contracts
  - Copy of air quality permit from **applicable** ~~BA~~AQMD **with jurisdiction over the selected host site**
  - Purchase order agreements for microturbine equipment

- Submit the draft Task 6 Report to the Energy Commission Project Manager for review and comments.

- Revise the draft Task 6 Report by incorporating and addressing Energy Commission Project Manager's comments.

- Submit the final Task 6 Report to the Energy Commission Project Manager for approval.

Product: Copy of Field Test Agreement and Installation Contract

Product: Draft Task 6 Report

Product: Final Task 6 Report

Task 7 Field Installation ~~at NRG - SF Thermal~~

The goal of this task is to complete the retrofit of the assembled and tested equipment at **the host site** ~~SF Thermal~~ into a final CHP mode. This means that the equipment**, microturbine and ultra-low NOx burner with interconnection ducting,** shall be **installed on the selected boiler** ~~connected and interfaced with the selected boiler/burner ductwork at SF Thermal~~ and shall be ready for performance testing.

The objective of this task is to conclude all the installation in order to arrive at a complete CHP system package. Specifically, remaining installation activities during this task shall focus on: (1) i~~mplementing the changes to the existing BMS or replace the unit as necessary; (2)~~ installing the microturbine in its final location and connecting exhaust ~~and cooling~~ duct~~s~~; (3) connecting the microturbine power electronics cabinet to the service panel at the site; and (4) securing the field service for the microturbine for electrical connection and test fire.
The Recipient shall:

- **Install a new NOXmatic™ burner and controls**

- Interconnect the microturbine exhaust duct ~~and its cooling vent~~.

- Connect MTG power to ~~Pacific Gas and Electric~~ **electrical** service panel.

- Connect gas supply to compressor.

- ~~Install updated BMS control cabinet for burner.~~

- Secure the field service of the microturbine vendor to assist in the installation and checkout.

- Prepare a draft Task 7 Report that illustrates the complete installation and identifies each component of the installed CHP package assembled in its final operational configuration. The report shall include, but not limited to:

    - Schematics and photographs of fully installed CHP assembly
    - Specifications for each system component
    - Detailed description of process flows
    - Identification of key components

- Submit the draft Task 7 Report to the Energy Commission Project Manager for review and comments.

- Revise the draft report by incorporating and addressing the Energy Commission Project Manager's comments.

- Submit the final Task 7 Report to the Energy Commission Project Manager for approval.

Product: Draft Task 7 Report

Product: Final Task 7 Report

Task 8 Field Demonstration Testing

The goal of this task is to gather operating data on the CHP installation to document the energy efficiency improvements and compliance with the **local** ~~BAAQMD~~ air quality permit emission levels and CARB 2007 DG emission standards.

The objective of this task is to prepare a test plan and select a 2-week test period at the host site that provides adequate test conditions for monitoring CHP performance. During the test period, the Recipient shall follow the test matrix, test procedures and test methods outlined in the Test Plan. The testing shall include, at a minimum, the monitoring of fuel usage and energy output for the boiler and microturbine, the regulated NOx and CO emissions from the boiler stack, and other process flows and performance parameters to establish the operating envelope of the CHP system necessary for compliance with emissions and maximum energy savings as well as expressive of the project goals and objectives.

The Recipient shall:

- Develop and submit a Test Plan for approval by Energy Commission Project Manager. The Test Plan will adhere to appropriate ASERTTI testing and reporting procedures (if they are applicable) and include the following elements:
    - a description of the protocols to be tested;
    - the rationale for the tests, test objectives and technical approach;
    - a test matrix showing the number of test conditions and replicated runs;
    - a description of the facilities, equipment, and instrumentation that will be used to conduct the tests;
    - a description of test procedures, including parameters to be controlled and how they will be controlled;
    - parameters to be measured and instrumentation to measure them;
    - calibration procedures to be used;
    - recommended calibration interval and maintenance of the test log;
    - a description of the data analysis procedures;
    - a description of quality assurance procedures; and,
    - contingency measures to be considered if the test objectives are not met.
- Prepare and submit a Draft Test Plan for Energy Commission Project Manager's review and comment.

- Prepare and submit a Final Test Plan for Energy Commission Project Manager review and approval.

- Follow the Test Plan and applicable protocols approved by the Energy Commission Project Manager in the performance of the field tests.

- Document and compile all the operating data necessary to attain the performance goals for this technology.

- Prepare Draft Test Report that will address the results of the tests and the attainment of the performance objectives. The report shall include, but not limited to, the following:

    - Description of the test site
    - List of test objectives
    - Test matrix, equipment, and procedures
    - Process flow diagrams with identified test and measurement locations
    - Test data and data analysis

    - Conclusions and recommendations
    - Relevant appendices with raw data and supporting documentation

- Submit the test report to the Energy Commission Project Manager for review and comment.

- Revise the test report by incorporating and addressing Energy Commission Project Manager's comments.

- Submit the final report to the Energy Commission Project Manager for approval.

Product: Draft Test Plan

Product: Final Test Plan

Product: Draft Test Report

Product: Final Test Report

Task 9 – Technology Transfer Activities

The goal of this task is to stimulate market adoption of the technology advances by disseminating information on project results with stakeholders and market participants.

The Objective of this task is to present advances in science and technology made under this project to the peer technical community, other stakeholders, and decision makers in the private and public sectors.

The Recipient shall:

- Prepare draft and final versions of technical papers, poster materials and view graph presentations and submit to Energy Commission Project Manager for review and comments.

- Make project presentations at selected and pre-approved conferences and meetings.

- Prepare trip reports for conferences emphasizing the value of attendance to the project and submit to the Energy Commission Project Manager.

- Describe planned and completed Technology Transfer Activities in Monthly Progress Reports.

Product: List of Technology Transfer Activities

Product: Draft versions of papers for publication

Product: Final versions of published papers

Product: Copies of meeting and conference agendas, presentations, reports, due within 30 days of attendance.

Product: Trip Reports for conferences emphasizing the value of attendance to the project

Task 10 Commercialization Readiness Plan

The goal of this task is to forecast the likelihood that the science and technology advancements will result in commercial products.

The objectives of this task are to identify the actions, time, and funding required to introduce the technology or product developed under this agreement to a commercial and commercially viable product that will provide California utility customer benefits, to quantify the expected market penetration of the product, and to identify and quantify the California utility customer return on investment.

The Recipient shall:

- Conduct a Technology Readiness Assessment. The assessment shall include, as appropriate, but not be limited to:

  - A Milestone Chart with dates beginning at the start of this agreement showing significant events such as project completion, alpha unit demonstration, beta unit demonstration, field demonstrations, and commercial product introduction.
  - For each Milestone in the Milestone Chart, describe the research, development, and demonstration or other technological efforts and the approximate cost required to achieve that Milestone.
  - An implementation plan to ramp up to full production of a commercial product.
  - Identification of critical production processes, equipment, facilities, personnel resources, and support systems that will be needed to produce a commercially viable product.
  - Internal manufacturing facilities, as well as supplier technologies, capacity constraints imposed by the design under consideration, identification of design critical elements and the use of hazardous or non-recyclable materials.
  - Identification of manufacturing partners.
  - The expected investment threshold to launch the commercial product.
- Conduct a Market Readiness Assessment. The assessment shall include but shall not be limited to:

  - Identification and discussion of regulatory and institutional factors that positively or negatively affect the purchase of your technology or product.
  - Identification of the business and commercial relationships that need to be established.
  - Quantification of technical market potential.
  - Quantification of economic market potential.
  - A projection of what the commercial product “should cost” as a function of sales per year.
  - Identification of the classes of customers that will purchase the product.
  - Discussion of their needs and desires that will induce them to buy the product.
  - Identification of competing manufacturers and competing technologies and their expected advantages and disadvantages at the same points in time.
  - Projected selling prices for your product consistent with the projected sales volume and market position.
  - Projected rate of penetration of sales of the product/technology in California and elsewhere, *including expected sales in each year.*

- Conduct a Public Benefits Assessment. Starting from the Market Readiness Assessment and projected market penetration, estimate the California utility customer benefits. The Public Benefits Assessment shall:

  - Identify Sources of public benefits, including, but not limited to:
    - Fuel and electricity savings
    - Greenhouse Gas Emission reductions
    - Criteria pollutant emission reductions
    - Projected royalty payments by year based on the projected penetration rate given in the Market Readiness Assessment: (Number of units sold) x (Selling price per unit) x (Percentage of product development attributable to PIER funding) x (1.5%)
    - Energy supply security
  - Describe a methodology and metric for valuing each public benefit, with a description of the approach for estimating the magnitude of the public benefit
  - Apply the methodology and tabulate the projected public benefits

- Prepare a Draft Commercialization Readiness Plan that integrates the findings of the Technology Readiness, Market Readiness and Public Benefits Assessments and submit to Energy Commission Project Manager for review and comments.

- Prepare a Final Commercialization Readiness Plan that integrates the findings of the Technology Readiness, Market Readiness and Public Benefits Assessments and submit to Energy Commission Project Manager for approval.

Product: Draft Commercialization Readiness Plan

Product: Final Commercialization Readiness Plan