

GRANTS/CONTINGENT AWARD REQUEST



To: Grants and Loans Office

Date: 4/3/2012

Project Manager: Guido Franco

Phone Number: 916-327-2392

Office: Energy Generation Research Office

Division: Energy Research and Development

MS- 43

Project Title: Carbon Dioxide Capture and Conversion to Chemical Products

Type of Request: (check one)

[X] New Agreement: (include items A-F from below) Agreement Number: PIR-11-019
Program: PIER E / Environmental Area
Solicitation Name and/or Number: PON-11-502-15 (Solicitation to Address Environmental Issues Related to Clean Energy Systems)
Legal Name of Recipient: Oakbio, Inc.
Recipient's Full Mailing Address: 265 SOBRANTE WAY STE T SUNNYVALE, CA 94086-4809
Recipient's Project Officer: Russell Howard Phone Number: (408)9307004
Agreement Start Date: 6/29/2012 Agreement End Date: 3/31/2015

[ ] Amendment: (Check all that apply) Agreement Number:
[ ] Term Extension - New End Date:
[ ] Work Statement Revision (include Item A from below)
[ ] Budget Revision (include Item B from below)
[ ] Change of Scope (include Items A - F as applicable from below)
[ ] Other:

ITEMS TO ATTACH WITH REQUEST:

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

California Environmental Quality Act (CEQA)

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

Funding Information:

\*Source #1: PIER-E Amount: \$ 474,843.00 Statute: 11- FY: 11-12 Budget List #: 501.027J
\*Source #2: Amount: \$ Statute: FY: Budget List #:
\*Source #3: Amount: \$ Statute: FY: Budget List #:

If federally funded, specify federal agreement number:

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

Business Meeting Approval: (refer to Business Meeting Schedule)

Proposed Business Meeting Date: 5/9/2012 [ ] Consent [X] Discussion
Business Meeting Participant: Guido Franco Time Needed: 5 minutes

Agenda Notice Statement: (state purpose in layperson terms)

Possible approval of a [X] Grant / [ ] Contingent Award to...
Possible approval of Agreement PIR-11-019 for a grant of \$474,843.00 to Oakbio, Inc. to field test a novel technology using a microbial system to capture and convert waste carbon dioxide from industrial flue gas sources such as power plants, oil refineries, and cement plants to valuable biochemicals. (PIER electricity funding.) Contact: Guido Franco. (5 minutes)

Project Manager Date Office Manager Date Deputy Director Date

## Exhibit A WORK STATEMENT

### TASK LIST

Task #	CPR	Task Name
1	N/A	Administration
2		Establish Gas Analytics in Laboratory and at Cement Plant
3		Measure Key Performance Indices at Cement Plant
4		Measure Key Performance Indices at Sunnyvale Laboratory Using Flue Gas from Coal and Natural Gas Combustion
5		Prepare Data-Driven Feasibility Assessment for Cement Industry and Power Generation Industry

### KEY NAME LIST

Task #	Key Personnel	Key Subcontractor(s)	Key Partner(s)
1	Russell Howard – Oakbio, Inc. Pierre Pujol – Oakbio, Inc.		
2,3,5	Brian Sefton – Oakbio, Inc. Russell Howard – Oakbio, Inc.		Lehigh Southwest Permanente
4	Brian Sefton – Oakbio, Inc. Russell Howard – Oakbio, Inc.		

### GLOSSARY

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

Term/ Acronym	Definition
CC	Carbon Capture
CCS	Carbon Capture and Sequestration
CO <sub>2</sub>	Carbon Dioxide
CPR	Critical Project Review
Energy Commission	California Energy Commission
GHG	Greenhouse Gas
H <sub>2</sub>	Hydrogen
LSC	Lehigh Southwest Cement, a Permanente cement manufacturing plant in Cupertino, CA that is the site of the Oakbio test bioreactor
MEA	Monoethanolamine, an amine used for CO <sub>2</sub> capture from flue gas
O <sub>2</sub>	Oxygen
PHA	Polyhydroxyalkanoate, a valuable biodegradable bioplastic
PIER	Public Interest Energy Research

### Problem Statement:

Carbon derived from fuel combustion during energy production or industrial processes is released into the atmosphere, predominantly as Carbon Dioxide (CO<sub>2</sub>) that contributes to global warming. On-site capture of CO<sub>2</sub> is currently accomplished

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through a chemical process that typically uses Monoethanolamine (MEA), an amine used for CO<sub>2</sub> capture from flue gas. This process is highly efficient but very expensive in materials, capital infrastructure, and energy expended to recycle the amine.. Additional energy, expense, and infrastructure are invested in the captured CO<sub>2</sub> to handle, transport, and bury it (geo-sequestration).

The Recipient is developing a way to reduce the costs of CO<sub>2</sub> uptake and sequestration. The Recipient's process turns waste CO<sub>2</sub> into chemicals that can be sold to generate revenues. These chemicals are cost-competitive by virtue of access to low cost-free CO<sub>2</sub> in flue gas. Earnings from chemical sales offset part or all costs of the carbon capture (CC) process, depending on the value of the chemical. Revenues from chemicals made from flue gas CO<sub>2</sub> will decrease the costs of compliance in California with the Global Warming Solutions Act of 2006 (AB 32) and Executive Order S-3-05.

The Recipient's *in situ* bioreactor installation at the Lehigh Southwest Cement manufacturing plant has allowed it to identify certain microbes (OB213 and OB311) that grow and adapt to faster growth in flue gas. These microbes make valuable chemicals including bioplastics, wherein the only source of carbon for increasing biomass and bioplastic derives from CO<sub>2</sub> in cement flue gas. Microbes that have not been adapted over months are unable to grow in cement flue gas, even though they can grow chemoautotrophically in laboratory synthetic gas mixtures.

This project will attempt to prove that these adapted microbes substantially reduce the level of CO<sub>2</sub> in flue gas in addition to turning CO<sub>2</sub> into chemicals. Uptake into microbes and chemicals should match depletion of CO<sub>2</sub> from the gas phase. Alongside every experiment at the cement plant, the Recipient performs a parallel experiment using synthetic gas mixtures in order to provide baseline microbial growth. The Recipient needs gas analytics equipment to add important data on gas depletion at the cement plant and in control experiments. Success in the cement plant may lead to the scale-up and implementation of this new technology to capture and convert CO<sub>2</sub> to chemical value.

The Recipient will also test flue gas from coal-and natural gas-fired power plants, to determine if these quantitatively important sources of CO<sub>2</sub> emissions can be used to make chemicals. These gas samples will be shipped for testing in the Recipient's laboratory. Finally, the Recipient will test the gas from MEA-CC (carbon capture using the MEA amines) to show that this virtually pure CO<sub>2</sub> is also suitable for growth and conversion of this waste carbon source into biopolymers. Success in this study will open up the exciting possibility of process integration with existing and planned MEA-CCS (carbon capture and sequestration using MEA amines) facilities. The flow of carbon from MEA-CC into the Recipient's process could reduce the scale of geo-sequestration in California and create revenues from chemicals, further reducing compliance costs.

All of the experimental results will be integrated using the Recipient's techno-

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economic model. The Recipient will make recommendations on the technical challenges for the next stage of scale up, plus the commercial feasibility of large-scale CO<sub>2</sub> capture and concurrent bioplastics manufacture. The Recipient's technical experience will position it for testing *in situ* at other CO<sub>2</sub>-emitting facilities in California such as coal-and natural gas-fired power plants.

#### **Goals of the Agreement:**

The Recipient aims to reduce the cost of CO<sub>2</sub> compliance by generating revenues from CO<sub>2</sub> capture, converting captured CO<sub>2</sub> into a commodity and specialty chemical value.

#### **Objectives of the Agreement:**

The Recipient's objectives are to determine the technical and economic feasibility of a novel microbe-based process for the capture and conversion of flue gas CO<sub>2</sub> to bioplastics, using an operating test system at a Santa Clara cement plant. Key quantitative indices of system performance will be measured including CO<sub>2</sub> capture, microbial biomass production, and bioplastics production. The Recipient's final report, which will include a techno-economic model, will inform the cement industry and the CO<sub>2</sub>- emitting energy industry of the likely economic feasibility of the Recipient's system at a larger scale.

Technical success in this Public Interest Energy Research (PIER) project could lead to development scale-up of the Recipient's process for CO<sub>2</sub> capture in the cement industry. Furthermore, to explore even broader economic potential, the Recipient would hope to set up similar *in situ* test reactors at natural gas- and coal-fired power plants in California. A profitable process for the production of valuable chemicals at lower cost will lead to further investment in California technology process development, local jobs creation, reduced CO<sub>2</sub> release from critical local industries, and potentially dramatic expansion of the bioplastics industry driven by large-scale production at lower cost. Commercial success would lead to environmentally beneficial conversion of flue gas CO<sub>2</sub> to multiple plastic products, not only sequestering CO<sub>2</sub> in manufactured goods, but decreasing use of non-renewable petroleum oil for production of plastics products from petrochemicals.

### **TASK 1 ADMINISTRATION**

#### **Task 1.1 Attend Kick-off Meeting**

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

#### **The Recipient shall:**

- Attend a "Kick-Off" meeting with the Commission Project Manager, the Grants Officer, and a representative of the Accounting Office. The Recipient shall bring its Project Manager, Agreement Administrator, Accounting Officer, and others designated by the Commission Project Manager to this meeting. The administrative and technical aspects of this

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Agreement will be discussed at the meeting. Prior to the kick-off meeting, the Commission Project Manager will provide an agenda to all potential meeting participants.

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

- Discussion of the terms and conditions of the Agreement
- Discussion of Critical Project Review (Task 1.2)
- Match fund documentation (Task 1.6) No work may be done until this documentation is in place.
- Permit documentation (Task 1.7)
- Discussion of subcontracts needed to carry out project (Task 1.8)

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

- The Commission Project Manager's expectations for accomplishing tasks described in the Scope of Work
- An updated Schedule of Products
- Discussion of Progress Reports (Task 1.4)
- Discussion of Technical Products (Product Guidelines located in Section 5 of the Terms and Conditions)
- Discussion of the Final Report (Task 1.5)

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

#### **Recipient Products:**

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

#### **Commission Project Manager Product:**

- Kick-Off Meeting Agenda

#### **Task 1.2 Critical Project Review (CPR) Meetings**

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

CPRs provide the opportunity for frank discussions between the Energy Commission and the Recipient. The Commission Project Manager may schedule CPRs as necessary, and CPR costs will be borne by the Recipient.

Participants include the Commission Project Manager and the Recipient and may include the Commission Grants Officer, other Energy Commission staff and

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Management as well as other individuals selected by the Commission Project Manager to provide support to the Energy Commission.

#### **The Commission Project Manager shall:**

- Determine the location, date, and time of each CPR meeting with the Recipient. These meetings generally take place at the Energy Commission, but they may take place at another location.
- Send the Recipient the agenda and a list of expected participants in advance of each CPR. If applicable, the agenda shall include a discussion on both match funding and permits.
- Conduct and make a record of each CPR meeting. One of the outcomes of this meeting will be a schedule for providing the written determination described below.
- Determine whether to continue the project, and if continuing, whether or not modifications are needed to the tasks, schedule, products, and/or budget for the remainder of the Agreement. Modifications to the Agreement may require a formal amendment (please see section 8 of the Terms and Conditions).
- Provide the Recipient with a written determination in accordance with the schedule. The written response may include a requirement for the Recipient to revise one or more product(s) that were included in the CPR.

#### **The Recipient shall:**

- Prepare a CPR Report for each CPR that discusses the progress of the Agreement toward achieving its goals and objectives. This report shall include recommendations and conclusions regarding continued work of the projects. This report shall be submitted along with any other products identified in this scope of work. The Recipient shall submit these documents to the Commission Project Manager and any other designated reviewers at least 15 working days in advance of each CPR meeting.
- Present the required information at each CPR meeting and participate in a discussion about the Agreement.

#### **Commission Project Manager Products:**

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

#### **Recipient Product:**

- CPR Report(s)

#### **Task 1.3 Final Meeting**

The goal of this task is to closeout this Agreement.

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#### **The Recipient shall:**

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

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

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

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

- What to do with any equipment purchased with Energy Commission funds (Options)
- Energy Commission's request for specific "generated" data (not already provided in Agreement products)
- Need to document Recipient's disclosure of "subject inventions" developed under the Agreement
- "Surviving" Agreement provisions
- Final invoicing and release of retention
- Prepare a schedule for completing the closeout activities for this Agreement.

#### **Products:**

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

#### **Task 1.4 Quarterly Progress Reports**

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

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

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**The Recipient shall:**

- Prepare a Quarterly Progress Report to 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 Commission Project Manager within 10 days of the end of the reporting period. The recommended specifications for each progress report are contained in Section 6 of the Terms and Conditions of this Agreement.

**Product:**

- Quarterly Progress Reports

#### **Task 1.5 Final Report**

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

The objectives of the Final Report are to clearly and completely describe the project's purpose, approach, activities performed, results, and advancements in science and technology; to present a public assessment of the success of the project as measured by the degree to which goals and objectives were achieved; to make insightful observations based on results obtained; to draw conclusions; and to make recommendations for further projects and improvements to the Energy Commission's 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 Final Report guidelines which will be provided by the Commission Project Manager. 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 at least 60 days 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

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- 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 Energy Commission 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 Energy Commission funds for each task during the term of this Agreement. Match funds must be identified in writing and the associated commitments obtained before the Recipient can incur any costs for which the Recipient shall:

- Prepare a letter documenting the match funding committed to this Agreement and submit it to the Commission Project Manager at least 2 working days prior to the kick-off meeting. If no match funds were part of the proposal that led to the Energy Commission awarding this Agreement and none have been identified at the time this Agreement starts, then state such in the letter. If match funds were a part of the proposal that led to the Energy Commission awarding this Agreement, then provide in the letter a list of the match funds that identifies the:
  - Amount of each cash match fund, its source, including a contact name, address and telephone number and the task(s) to which the match funds will be applied.
  - 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. For match funds provided by a grant a copy of the executed grant shall be submitted in place of a letter of commitment.
- Discuss match funds and the implications to the Agreement if they are reduced or not obtained as committed, at the kick-off meeting. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide the appropriate information to the Commission Project Manager if during the course of the Agreement additional match funds are received.
- Notify the Commission Project Manager within 10 days if during the course of the Agreement existing match funds are reduced. Reduction in match funds must be approved through a formal amendment to the Agreement and may

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trigger an additional CPR.

#### **Products:**

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

#### **Task 1.7 Identify and Obtain Required Permits**

- The goal of this task is to obtain all permits required for work completed under this Agreement in advance of the date they are needed to keep the Agreement schedule on track.
- Permit costs and the expenses associated with obtaining permits are not reimbursable under this Agreement. Although the Energy Commission budget for this task will be zero dollars, the Recipient shall budget match funds for any expected expenditures associated with obtaining permits. Permits must be identified in writing and obtained before the Recipient can make any expenditure for which a permit is required.

#### **The Recipient shall:**

- Prepare a letter documenting the permits required to conduct this Agreement and submit it to the Commission Project Manager at least 2 working days prior to the kick-off meeting. If there are no permits required at the start of this Agreement, then state such in the letter. If it is known at the beginning of the Agreement that permits will be required during the course of the Agreement, provide in 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 Commission Project Manager.
- As permits are obtained, send a copy of each approved permit to the Commission Project Manager.
- If during the course of the Agreement permits are not obtained on time

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or are denied, notify the Commission Project Manager within 5 working days. Either of these events may trigger an additional CPR.

#### **Products:**

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

#### **Task 1.8 Obtain and Execute Subcontracts**

The goal of this task is for Recipients to identify any subcontracts required to carry out the tasks under this Agreement and to procure them consistent with the terms and conditions of this Agreement and the Recipient's own procurement policies and procedures. It will also provide the Energy Commission an opportunity to review the subcontracts to ensure that the tasks are consistent with this Agreement, that the budgeted expenditures are reasonable and consistent with applicable cost principles.

#### **The Recipient shall:**

- Prepare a letter documenting the subcontracts required to conduct this Agreement, and submit it to the Commission Project Manager at least 2 working days prior to the kick-off meeting. If there are no subcontracts required at the start of this Agreement, then state such in the letter. If it is known at the beginning of the Agreement that subcontracts will be required during the course of the Agreement, provide in the letter:
  - A list of the subcontracts that describes the anticipated maximum budget and general scope of work for each,
  - A description of the procurement process to be used, and
  - The schedule the Recipient will follow in applying for and obtaining these subcontracts.
- Submit a draft of the subcontract that will include a budget with the information required in the budget details to the Commission Project Manager for review and approval, and incorporate any changes recommended by the Commission Project Manager.
- Submit a final copy of the executed subcontract.

#### **Products:**

- Letter describing the subcontracts needed, or stating that no subcontracts are required
- Draft subcontracts
- Final subcontracts

#### **TECHNICAL TASKS**

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The Recipient shall prepare all products in accordance with the requirements in Task 1.5. Products not requiring a draft version are indicated by marking “no draft” after the product name.

#### **TASK 2 ESTABLISH GAS ANALYTICS IN LABORATORY AND AT CEMENT PLANT**

The goal of this task is to perform real-time measurements of bioreactor inflow and exit gas composition and amount. This is essential to measure the depletion of CO<sub>2</sub> from flue gas. This should correspond to CO<sub>2</sub> uptake in microbe biomass.

##### **The Recipient shall:**

- Standardize all aspects of microbe culture in the Recipient’s Sunnyvale laboratory for standardized inoculation of 1-4 liter test bioreactors at the Lehigh Southwest cement plant.
- Purchase and set up analytical equipment at the Sunnyvale and Lehigh sites to allow continuous measurement of gas concentrations.
- Perform validation tests and standard curves with pure gases and synthetic mixtures to calibrate relative and absolute measurements of gas components.
- Demonstrate that real-time measurements can be recorded from several bioreactors in data formats suitable for later data inspection and analysis (dedicated software and hardware).
- Standardize methods for bioplastics assay at Sunnyvale (methods for biomass are already standardized; bioplastics methods are currently in test). Measure the total amount made and monomer composition.
- Place the following data on a CD:
  - Data showing performance validation of newly installed gas analytics equipment at the Sunnyvale and cement plant locations
  - Data showing that all other assays are fully operational and standardized

##### **Products:**

- Data on CD showing performance validation of newly installed gas analytics equipment at the Sunnyvale and cement plant locations (no draft)
- Data on CD showing that all other assays are fully operational and standardized (no draft)

#### **TASK 3 MEASURE KEY PERFORMANCE INDICES AT CEMENT PLANT**

The goal of this task is to determine the key performance indices of the bioreactor system at the Lehigh Southwest cement plant. The performance of two cement gas-adapted microbes, OB213 and OB311, will be compared at the cement plant with controls run in parallel using synthetic gas mixtures at the Sunnyvale Laboratory.

##### **The Recipient shall:**

- Measure the depletion of CO<sub>2</sub> in flue gas, plus CO<sub>2</sub> uptake into biomass

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and bioplastics under different gas mixture conditions including systematic variation in the ratios of flue gas (or pure CO<sub>2</sub> in baseline controls), Oxygen (O<sub>2</sub>), and Hydrogen (H<sub>2</sub>).

- Calculate the amount of CO<sub>2</sub> taken up/volume/time and the mass of bioplastic produced/volume/time.
- Place the following data on a CD: system performance for two microbes and multiple flue gas samples installed in test bioreactor systems growing in a continuous flue gas stream at the cement plant.
- Prepare a report showing the sensitivity of outputs (CO<sub>2</sub> uptake, biomass and bioplastic) to gas ratio and other variables.

#### **Products:**

- Data on CD: System performance for two microbes and multiple flue gas samples installed in test bioreactor systems growing in a continuous flue gas stream at the cement plant (no draft)
- Report showing the sensitivity of outputs (CO<sub>2</sub> uptake, biomass, and bioplastic) to gas ratio and other variables (no draft)

#### **TASK 4 MEASURE KEY PERFORMANCE INDICES AT SUNNYVALE LABORATORY USING FLUE GAS FROM COAL AND NATURAL GAS COMBUSTION**

The goal of this task is to determine the key performance indices with cement gas-adapted microbes (OB213 and OB311) using gas from coal-and natural gas-fired power plants in California. These experiments will take place in the Sunnyvale laboratory. Gas from MEA- Carbon Capture will also be tested as a possible source of waste CO<sub>2</sub> for conversion to chemical value.

#### **The Recipient shall:**

- Arrange for the supply of gas samples to the Sunnyvale laboratory prior to the beginning of this task in Quarter 3 /year 1.
- Measure the uptake of CO<sub>2</sub> from coal-and natural gas-combustion into biomass and bioplastics. Different ratios of flue gas/H<sub>2</sub> and O<sub>2</sub> will be examined systematically.
- Measure the uptake of CO<sub>2</sub> from MEA-CC gas into biomass and bioplastic.
- Calculate the amount of CO<sub>2</sub> taken up/volume/time and the mass of bioplastic produced/volume/time.
- Place the following data on a CD: system performance with flue gas from coal-fired and natural gas-fired electricity generation for two microbes that perform well in cement flue gas.
- Prepare a report showing the sensitivity of outputs (biomass and bioplastic) to gas ratio and other variables for each test flue gas.

#### **Products:**

- Data on CD of system performance with flue gas from coal-fired and natural gas-fired electricity generation for two microbes that perform well

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- in cement flue gas (no draft)
- Report showing the sensitivity of outputs (biomass and bioplastic) to gas ratio and other variables for each test flue gas (no draft)

#### **TASK 5      PREPARE DATA-DRIVEN FEASIBILITY ASSESSMENT FOR CEMENT INDUSTRY AND POWER GENERATION INDUSTRY**

The goal of this task is to use the data from Tasks 2 and 3 with the Recipient's techno-economic model to describe the economic performance of the technology. From identification of the variables that most affect economic performance, the Recipient will be able to provide to the Energy Commission a techno-economic evaluation of feasibility of this CO<sub>2</sub> capture and chemical conversion process.

#### **The Recipient Shall:**

- Use project data and specific assumptions on projected technical performance characteristics and costs (capital and operational) as inputs, and note the effects on economic outputs.
- Build greater predictive capability in the existing model by adding consideration of chemical purification and processing costs specific to different product concepts.
- Draw conclusions on the viability of the process to meet the needs of the cement industry, and recommend how the process can best be developed another step in scale. The final report will include these conclusions.
- Draw conclusions on the viability of the process to meet the carbon capture needs of the energy industry, and the manner in which the process might perform to meet the needs of this industry. This will include consideration of combustion gases as well as MEA-CC gas as sources of waste CO<sub>2</sub> for conversion to chemicals. The final report will include these conclusions.
- Project system performance for implementation at commercial scale for the cement and energy production industries
- Prepare a manuscript ready for submission to a technical or trade journal
- Prepare an experimental framework for efficient testing with sources that emit CO<sub>2</sub>.

#### **Products:**

- Projected system performance for implementation at commercial scale for the cement and the energy production industries
- Copy of a manuscript ready for submission to a technical or trade journal
- Experimental framework for efficient testing in situ at other sites that emit CO<sub>2</sub>
- Plan for process development and scale-up