U.S. Department of Energy
Advanced Research Projects Agency – Energy

Request for Information (RFI) on Funding Opportunity Announcement (FOA) DE-FOA-0000671 for Chemo/electro-autotrophic Synthesis of Liquid Fuels at Scale

Objective: Information is requested regarding the development of technologies to support transformational research and development (R&D) of chemo/electro-autotrophic fuel production beyond bench-scale. ARPA-E seeks input from researchers in industry, academia, and other interested biofuels and bioproducts stakeholders regarding technologies essential for energy assimilation, carbon fixation, and direct fuel/fuel precursor synthesis by chemo/electro-autotrophic microorganisms, termed in this document as "chemolithoautotrophs." The information you provide may be used by ARPA-E in support of program planning. THIS IS A REQUEST FOR INFORMATION ONLY. THIS NOTICE DOES NOT CONSTITUTE A FUNDING OPPORTUNITY ANNOUNCEMENT (FOA) AND NO FOA EXISTS AT THIS TIME.

Background: Biofuels are an important component of the nation's liquid transportation fuel market. The U.S. is the global leader in the production of biofuels, in 2010 producing over 13 billion gallons of ethanol, or 9 billion gasoline gallon equivalents (GGE), from corn grain starch. Estimates from the Renewable Fuels Association suggest that the U.S. ethanol industry was important to the employment of over 400,000 people, and contributed $50 billion to the national Gross Domestic Product (GDP) in 2010. The U.S. has also recently surpassed Brazil as the world's top ethanol exporter, driven largely by demand from Brazil. However, further development of corn grain ethanol beyond current volumes is constrained for several reasons, including, expiration of the Volumetric Ethanol Excise Tax Credit (VEETC), capped Renewable Fuel Standard (RFS) identification numbers for corn grain starch based biofuels, slow roll-out of E15 fuel dispensers, and growing concerns over the balance between food and fuel demand.

"Advanced biofuel" is defined by the RFS as a fuel derived from lignocellulosic biomass, algae, or grains from non-corn feedstocks, and has been identified as potential means to add additional biofuel production capacity in a manner that is both sustainable and does not directly compete for food resources. The Departments of Energy, Agriculture, and Defense have invested billions of dollars to accelerate the development and cost competitiveness of advanced biofuels through the development of various dedicated energy feedstock crops and algae, feedstock conversion technologies, and supply chain infrastructure required to procure feedstocks at relevant scales. Despite the many benefits derived from these efforts, the advanced biofuels industry has evolved slowly, and current advanced biofuel production lags the original mandate prescribed by the RFS.

All biofuels approaches – both those currently deployed and various advanced approaches – suffer from poor solar energy capture and transduction to fixed carbon. Both plants and algae rely on photosynthesis to capture and use carbon dioxide from the atmosphere to support growth and metabolism. Yet the efficiency to harness and convert energy from solar photons into energy stored in harvestable biomass under field conditions by plants and algae is estimated to be less than 2%. The inherent inefficiency of photosynthesis, coupled with the spatial, water and nutrient requirements for plant or algae biofuel systems, present challenges for deployment of these approaches at scale.

To address these challenges, ARPA-E created the "Electrofuels" applied research program to encourage development of new biological routes to fuels that bypass the limits of photosynthesis. Specifically, the Electrofuels program relies on the biology of chemolithoautotrophic microorganisms. These microorganisms derive energy from the oxidation of various reduced inorganic compounds, such as hydrogen, reduced metals, and, in the case of "electrotrophs," electrons, which live on direct electrical current. As autotrophs, these organisms can use inorganic carbon as the only carbon source and thus are capable of growth and production in the complete absence of either sunlight or reduced carbon. Prior to creation of the Electrofuels program, no concerted effort had been made to investigate the potential for chemolithoautotrophy as a platform for biofuel production.

Purpose and Need for Information: The purpose of this RFI is solely to solicit input for ARPA-E consideration to inform the possible development of future chemo/electro-autotrophic fuel production programs. Information obtained may be used by ARPA-E on a non-attribution basis. This RFI provides biofuel and bioproducts stakeholders with an opportunity to contribute views and opinions regarding the requirements to transition bench-scale (e.g. microgram–milligram $L^{-1}h^{-1}$ production rates) chemo/electro-autotrophic fuel production technologies to efficient and cost competitive integrated chemo/electro-autotrophic fuel production platforms (e.g. multi-gram $L^{-1}h^{-1}$ production rates at scale). Views are sought regarding various microbial systems, energy assimilation strategies, bioreactor development, scaling parameters, fuel/fuel precursor products, and cost of fuel/fuel precursor products, overall cost of program development and path to market adoption. ARPA-E may determine as the result of this RFI and other considerations to issue a formal FOA for this area. If a formal FOA is issued, it will be issued under a new FOA number. No FOA exists at this time and ARPA-E reserves the right to never issue a FOA in this area.

Request for Information Guidelines: ARPA-E will not pay for information provided under this RFI, and there is no guarantee that a project will be supported as a result of this RFI. This RFI is not a FOA, and ARPA-E is not accepting applications for financial assistance or financial incentives under this RFI. Response to the RFI will not be viewed as any commitment for the respondent to develop or pursue the project or ideas discussed. ARPA-E may decide at a later date to issue a FOA based on consideration of the input received from this RFI. Respondents shall not include any information in the response to this RFI that might be considered proprietary or confidential. Comments in response to this RFI should be submitted in PDF format to the email address ARPA-E-RFI-FUELS@hq.doe.gov by 8:00 PM Eastern Time on April 30, 2012. ARPA-E will not review or consider comments submitted by other means. Please insert "Responses for RFI for FOA DE-FOA-0000671" in the subject line of your email, and include your name, organization, email address, and telephone number in the body of your email. Responses to this RFI are limited to no more than 3,000 words in length (12 point font size).

Respondents are requested to include the following information as part of the response to this RFI: Company/Institution name; individual contact name and title; mailing address; phone number; email address; type of company/institution (e.g.. university, non-governmental organization, small business, large business, federally funded research and development center (FFRDC), government-owned/government-operated (GOGO)); and area of expertise. No material submitted for review will be returned and there will be no formal or informal debriefing concerning the review of any submitted material. ARPA-E reserves the right to contact a respondent to request clarification or other information relevant to this request. All feedback provided will be taken into consideration, but ARPA-E will not respond to individual submissions or publish publicly a compendium of responses.

RFI Response Instructions: The ARPA-E Electrofuels program has demonstrated technical feasibility; however, the program is not anticipated to deliver technology beyond Technology Readiness Level (TRL) – 4.[i] ARPA-E seeks information regarding the transition of chemo/electro-autotrophic fuel production technologies to TRL – 6, representative of the technology maturation required for eventual demonstration-scale to full-scale deployment (TRL – 7-9). ARPA-E seeks responses that address the most relevant metrics to achieve performance, and cost data necessary for confident modeling of a 1 million liters product per day production facility. ARPA-E prefers to receive responses that address each of the following questions, however responses that address only a subset of these questions will be accepted:

RFI Questions:

1. What is the maximum theoretical energy efficiency for an ideal chemo/electro-autotrophic fuel production platform, as measured by the energy content of the final fuel/fuel precursor product to energy content of input energy/reducing equivalents (include a break-out of energy required for generation of reducing equivalents)?
2. Assuming that the overall cost of the final fuel/fuel precursor product is most sensitive to the cost of input energy/reducing equivalents, what energy efficiency (relative to theoretical) is necessary for economical fuel/ fuel precursor production?
3. What are the critical technical challenges to achieving > 2 gram per liter per hour volumetric productivity?
4. At what reactor scale could one expect performance and cost data that could confidently be useful for modeling of a 1 million liters product per day production facility?
5. What is the largest feasible and optimal scale for a chemo/electro-autotrophic fuel production platform?
6. How important is product flexibility for an ideal chemo/electro-autotrophic fuel production platform?
7. What final fuel/fuel precursor is most achievable at > 2 gram per liter per hour? If the final fuel/fuel precursor is not a hydrocarbon, what is the downstream efficiency of conversion to a hydrocarbon?
8. What is a reasonable level of investment required to scale a chemo/electro-autotrophic fuel production technology from TRL – 3-4 to TRL – 6?
9. Assuming that a commercial partnership is necessary, what other considerations are important for moving chemo/electro-autotrophic fuel production technology to market?
10. Please include any additional information you deem relevant to this RFI.

[i] Technology Readiness Level; http://arpa-e.energy.gov/portals/0/Documents/Key%20Documents/TRL.PDF