FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

ADVANCED RESEARCH PROJECTS AGENCY – ENERGY (ARPA-E)
U.S. DEPARTMENT OF ENERGY

MACROALGAE RESEARCH INSPIRING NOVEL ENERGY RESOURCES (MARINER)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA- 0001726
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	Friday December 16, 2016
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, Friday February 3, 2017
Submission Deadline for Concept Papers:	5 PM ET, Tuesday February 14, 2017
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	5 PM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Expected Date for Selection Notifications:	TBD
Total Amount to Be Awarded	Approximately $25 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $250,000 and $10 million.

- For eligibility criteria, see Section III.A of the FOA.
- For cost share requirements under this FOA, see Section III.B of the FOA.
- To apply to this FOA, Applicants must register with and submit application materials through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). For detailed guidance on using ARPA-E eXCHANGE, see Section IV.H.1 of the FOA.
- Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.
- For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 through III.C.4 of the FOA.

Questions about this FOA? Check the Frequently Asked Questions available at http://arpa-e.energy.gov/faq. For questions that have not already been answered, email ARPA-E-CO@hq.doe.gov (with FOA name and number in subject line); see FOA Sec. VII.A. Problems with ARPA-E eXCHANGE? Email ExchangeHelp@hq.doe.gov (with FOA name and number in subject line).

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REQUIRED DOCUMENTS CHECKLIST

For an overview of the application process, see Section IV.A of the FOA.

For guidance regarding requisite application forms, see Section IV.B of the FOA.

For guidance regarding the content and form of Concept Papers, Full Applications, and Replies to Reviewer Comments, see Sections IV.C, IV.D, and IV.E of the FOA.

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. Concept Papers that address Category 1 or more than just one Category shall not exceed six (6) pages in length including graphics, figures, and/or tables. Concept Papers that address only one among Categories 2, 3, 4, or 5 shall not exceed five (5) pages in length including graphics, figures, and/or tables. Concept Papers must include the following: o Concept Summary o Innovation and Impact o Proposed Work o Team Organization and Capabilities	Mandatory	IV.C	5 PM ET, Tuesday February 14, 2017
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]	Mandatory	IV.D	5 PM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]	Optional	IV.E	5 PM ET, TBD

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

The Advanced Research Projects Agency – Energy (ARPA-E), an organization within the Department of Energy (DOE), is chartered by Congress in the America COMPETES Act of 2007 (P.L. 110-69), as amended by the America COMPETES Reauthorization Act of 2010 (P.L. 111-358) to:

"(A) to enhance the economic and energy security of the United States through the development of energy technologies that result in—
(i) reductions of imports of energy from foreign sources;
(ii) reductions of energy-related emissions, including greenhouse gases; and
(iii) improvement in the energy efficiency of all economic sectors; and
(B) to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies."

ARPA-E issues this Funding Opportunity Announcement (FOA) under the programmatic authorizing statute codified at 42 U.S.C. § 16538. The FOA and any awards made under this FOA are subject to 2 C.F.R. Part 200 as amended by 2 C.F.R. Part 910.

ARPA-E funds research on and the development of high-potential, high-impact energy technologies that are too early for private-sector investment. The agency focuses on technologies that can be meaningfully advanced with a modest investment over a defined period of time in order to catalyze the translation from scientific discovery to early-stage technology. For the latest news and information about ARPA-E, its programs and the research projects currently supported, see: http://arpa-e.energy.gov/.

ARPA-E funds transformational research. Existing energy technologies generally progress on established "learning curves" where refinements to a technology and the economies of scale that accrue as manufacturing and distribution to develop drive down the cost/performance metric in a gradual fashion. This continual improvement of a technology is important to its increased commercial deployment and is appropriately the focus of the private sector or the applied technology offices within DOE. By contrast, ARPA-E supports transformative research that has the potential to create fundamentally new learning curves. ARPA-E technology projects typically start with cost/performance estimates well above the level of an incumbent technology. Given the high risk inherent in these projects, many will fail to progress, but some may succeed in generating a new learning curve with a projected cost/performance metric that is significantly lower than that of the incumbent technology.

ARPA-E funds technology with the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately

become disruptive – that is, they are widely adopted and displace existing technologies from the marketplace or create entirely new markets. ARPA-E understands that definitive proof of market disruption takes time, particularly for energy technologies. Therefore, ARPA-E funds the development of technologies that, if technically successful, have the clear disruptive potential, e.g., by demonstrating capability for manufacturing at competitive cost and deployment at scale.

ARPA-E funds applied research and development. The Office of Management and Budget defines "applied research" as "systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met" and defines "development" as the "systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements."[1] Applicants interested in receiving financial assistance for basic research should contact the DOE's Office of Science (http://science.energy.gov/). Office of Science national scientific user facilities (http://science.energy.gov/user-facilities/) are open to all researchers, including ARPA-E applicants and awardees. These facilities provide advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. Projects focused on the improvement of existing technology platforms along defined roadmaps may be appropriate for support through the DOE offices such as: the Office of Energy Efficiency and Renewable Energy (http://www.eere.energy.gov/), the Office of Fossil Energy (http://fossil.energy.gov/), the Office of Nuclear Energy (http://www.energy.gov/ne/office-nuclear-energy), and the Office of Electricity Delivery and Energy Reliability (http://energy.gov/oe/office-electricity-delivery-and-energy-reliability).

B. PROGRAM OVERVIEW

Summary:

The United States has the world's largest marine Exclusive Economic Zone, an area of ocean along the nation's coast lines which is equivalent to the total land area of all 50 states. The nation has the potential to utilize this resource to build and grow a thriving marine biomass industry for the production of fuels, chemicals, feed, and food. Growing macroalgal biomass in the oceans offers a unique opportunity to sidestep many of the challenges associated with terrestrial biomass production systems, particularly the growing competition for land and freshwater resources, which are likely to result from the 50 to 100% increase in demand for

[1] OMB Circular A-11 (http://www.whitehouse.gov/sites/default/files/omb/assets/a11_current_year/a11_2014.pdf), Section 84, p. 8.

food expected for 2050.[2] The overall goal of this program is to develop the critical tools that will allow the nascent macroalgae industry in the United States to leverage this tremendous resource and grow into a world leader in the production of marine biomass. The program will focus on developing advanced cultivation technologies that enable the cost and energy efficient production of macroalgal biomass in the ocean at a scale suitable as feedstock for the production of fuels and chemicals. The challenge is to dramatically reduce capital and operating cost of macroalgae cultivation, while significantly increasing the range of deployment by expanding into more exposed, off-shore environments. Specifically, this program is interested in new designs and approaches to macroalgae cultivation, with harvesting and transport being an integral part of such systems. These new systems may leverage new material and engineering solutions, and autonomous and robotic operations, as well as advanced sensing and monitoring capabilities. To further accelerate the development and deployment of such systems, the program will also focus on the development of computational modeling tools and ocean-deployable sensor platforms, as well as advanced macroalgal breeding tools. ARPA-E expects that the MARINER program will support development of technologies that will accelerate the deployment of advanced ocean farming systems capable of delivering renewable biomass feedstock at a cost competitive with terrestrial biomass feedstocks.

Introduction:

Macroalgae refers to a set of exceptionally diverse multicellular, non-vascular marine plants. Also referred to as seaweed, macroalgae broadly describes a number of green, red, and brown species that can be found in disparate geographic locations across the planet's vast oceans. Coastal human populations for hundreds of years have harvested macroalgae from native, near-shore ocean environments. In addition to wild harvesting, macroalgae are predominately cultivated and produced on marine "farms." Nearly 25 million metric tons (wet) were produced globally in 2014. Macroalgae is primarily used directly as food for human consumption, but also serves as a feedstock for the extraction of naturally occurring alginate, agar, and carrageenan compounds. Beyond these well established applications, there is a growing number of additional opportunities for large-scale macroalgae utilization, from the production of fuels and chemicals to animal feed.[3,4,5] Yet, to realize this potential will require a significant expansion of production volumes over current levels, as well as drastic reduction in the cost of production, especially when aiming at the conversion of macroalgae to fuels.

[2] Valin, H. et al. The future of food demand: understanding differences in global economic models. *Agricultural Economics*. 45 (1) 51-67 (2014).

[3] Wargacki, A.J. *et al.* An engineered microbial platform for direct biofuel production from brown macroalgae. *Science.* **335**, 308-313 (2012).

[4] Neushul, M. Marine farming: Macroalgal production and genetics – final technical report. Gas Research Institute, Chicago, IL. (1987)

[5] Ashare, E. *et al.* Cost analysis of aquatic biomass systems - final report. Dynatech R/D Company, Cambridge, MA. (1978).

Over the previous 25 years, global production of macroalgae has increased 6-fold, driven by an increasing demand for macroalgae and macroalgae products for food consumption. Much of this increase is due to scaling in China and Indonesia, the two countries that dominate world production (Figure 1).[6] Increased production has also been seen in other Asian countries. At least 50 countries around the world are now engaged in aquatic plant farming in ocean waters, according to data from the United Nations Food and Agriculture Organization.[7]

However, even with such impressive growth, the current state of macroalgae mariculture is not capable of achieving the scale, efficiency, and production cost necessary to support a seaweed-to-fuels industry. This will require a transformational change from the low tech, labor-intensive methods used today, to a technology-driven, marine agronomic industry. Innovative engineering and systems-level solutions along with a suite of critical supporting technologies are necessary to build a commercially viable seaweed industry in the United States, capable of delivering a scalable, affordable, and renewable resource.

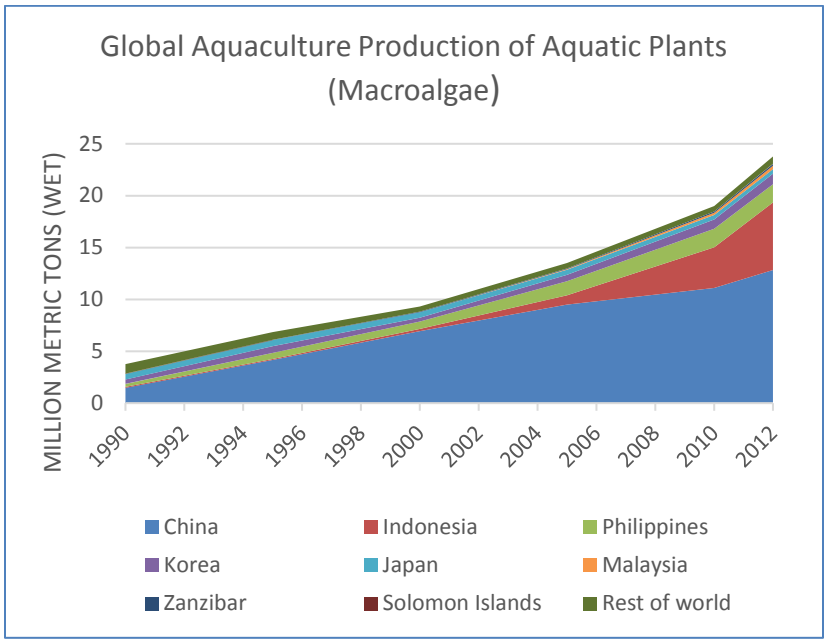


Figure 1. Led by China and Indonesia, global aquaculture production of macroalgae has grown 6-fold over the past 25 years, while capture from wild harvesting has remained static at approximately 1 million wet metric tons (data from wild harvesting not shown).[8]

Motivation:

[6] The state of world fisheries and aquaculture: opportunities and challenges. Food and Agriculture Organization of the United Nations, Rome. (2014) http://www.fao.org/3/a-i3720e/index.html

[7] FAO. 2016. *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all.* Rome. 200 pp.

[8] Cottier-Cook, E.J. *et al.* (2016). Safeguarding the future of the global seaweed aquaculture industry. United Nations University (INWEH) and Scottish Association for Marine Science Policy Brief. ISBN 978-92-808-6080-1. 12pp.

Biomass-derived energy is the largest form of renewable energy for the nation, contributing about 5% of U.S. primary energy supply. This biomass is being used primarily in the generation of electricity and the production of liquid biofuels. In 2015, the U.S. produced approximately 11.5 billion "Gasoline Gallon Equivalents" (GGE) of liquid biofuels, equivalent to 5% of all the nation's transportation energy demand.[9] Domestically produced biofuels reduce the need for petroleum imports and build industry and jobs in typically rural areas. In the future, biomass-derived energy has the potential to play an even bigger role in the nation's energy portfolio. The ability to produce sufficient quantities of biomass offers the U.S. strategic flexibility to exploit carbon-neutral feedstock for fuels, biogas/synthesis gas, heat & power, and electricity.[10,11]

Significant investments have already been made to use cellulosic biomass sources, such as agricultural residues, as feedstock for the production of both ethanol and more infrastructure-compatible "drop-in" fuels. The U.S. Department of Energy BioEnergy Technologies Office (BETO) estimates that by 2030, 1-1.5 billion dry tons of biomass – an amount sufficient to displace at least 30% of the nation's demand for petroleum derived liquid fuels – could be available at a farmgate price as low as $60 per dry ton (or a $0.70 feedstock cost per gallon cellulosic ethanol) (Figure 2).[12]

[9] U.S. Department of Energy Energy Information Agency 2015 Energy Outlook

[10] Energy Technology Perspectives 2016 - Towards Sustainable Urban Energy Systems, IEA Webinar, June 2016 http://www.iea.org/media/etp/etp2016/ETP2016_Webinar_ALL.pdf

[11] Williams, J.H., B. Haley, F. Kahrl, J. Moore, A.D. Jones, M.S. Torn, H. McJeon (2014). *Pathways to deep decarbonization in the United States*. The U.S. report of the Deep Decarbonization Pathways Project of the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations. Revision with technical supplement, Nov 16, 2015.

[12] U.S. Department of Energy. 2016. *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks*. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p.

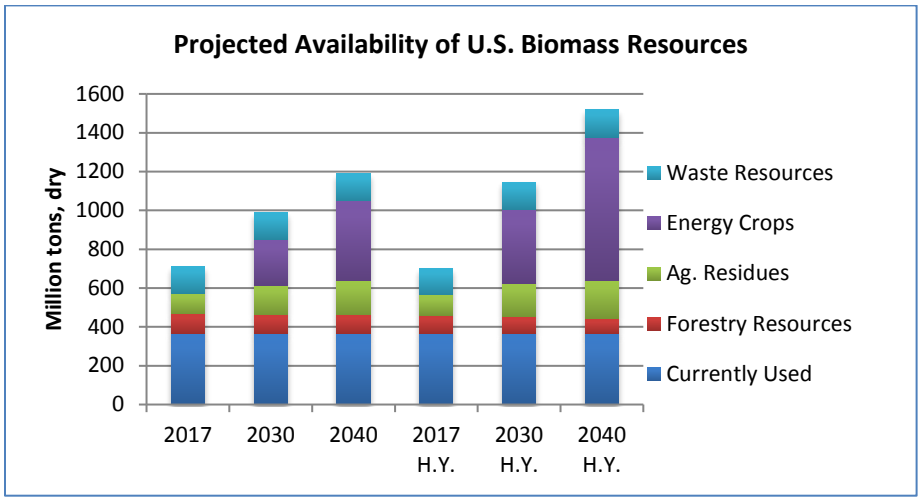


Figure 2. Projected availability of biomass resources for biofuel production potential under basecase scenario and high yield (H.Y.) scenario.

While encouraging, the BETO analysis relies heavily on deployment of "energy crops", such as perennial grasses. Many such feedstocks are under various stages of development. For example, the acceleration of domestic energy sorghum production is a particular focus of the ARPA-E TERRA program.[13] Ongoing research and development in this area is expected to advance adoption, but other risks remain to using terrestrially sourced biomass as feedstock for energy. Such risks include freshwater availability, land availability, and material handling and logistics. In particular, competition for land and fresh water is likely to increase as a growing world population (9 billion by 2050) is expected to increase the demand for food production by 59-98% by 2050.[14] At the same time, the increasing frequency of extreme weather conditions around the world can potentially further constrain the availability of suitable quantities of fresh water and arable land for terrestrial biomass production. Expanding biomass production into the oceans offers an important opportunity to bypass these constraints.

Our planet's oceans cover nearly 70% of the world's surface area; yet, at this time, they supply only 1% of the world's food and even less non-food biomass. Over thousands of years, humans have continuously improved their ability and technologies to extract resources from the ocean. In recent decades, humans have been rapidly developing and deploying new technologies in support of economically viable and environmentally sustainable aquaculture and mariculture. While the gains made in both of these areas have been impressive, the majority of these production gains are being realized primarily in Asia, and not in the U.S. despite compatible and favorable conditions. A recent assessment (funded by ARPA-E) of global geospatial conditions for potential red and brown macroalgae production considered four primary parameters: water temperature, nutrient concentration, bathymetry, and photosynthetically active radiation. The results of this analysis are summarized In Figure 3. Based on this preliminary assessment,

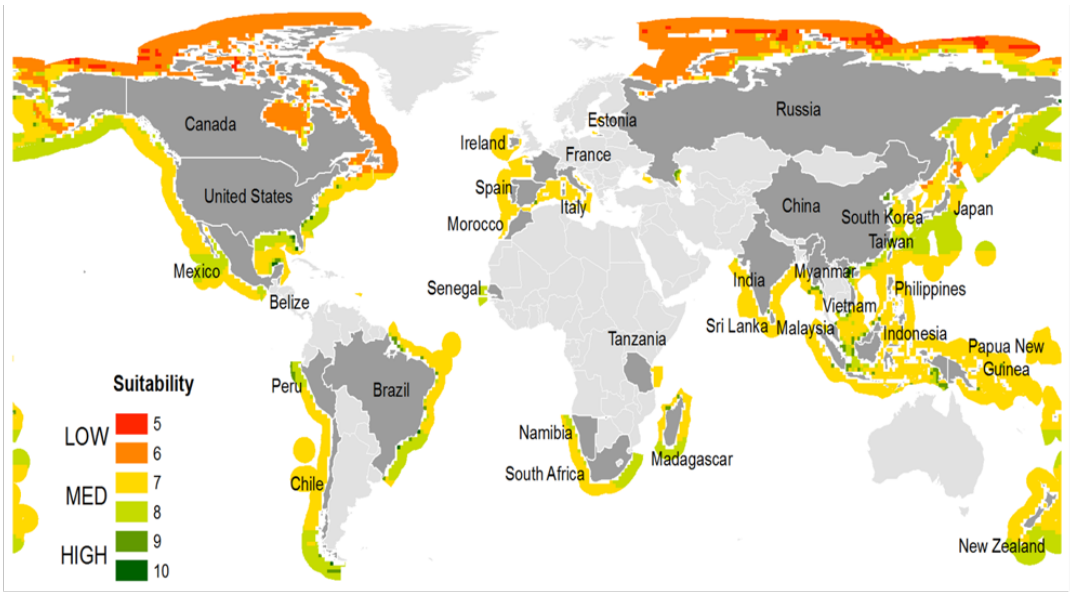
[13] https://arpa-e.energy.gov/?q=arpa-e-programs/terra

[14] Valin, H. *et al.* (2014), The future of food demand: understanding differences in global economic models. Agricultural Economics, 45: 51–67

ARPA-E estimates that the U.S. has suitable conditions and geography for producing approximately 200 million dry metric tons (DMT) of brown macroalgae and 300 million DMT of red macroalgae.[15] Such production volumes could potentially yield approximately 2.7 Quads of energy in the form of liquid fuel – an amount equivalent to roughly 10% of the nation's annual transportation energy demand.[16]

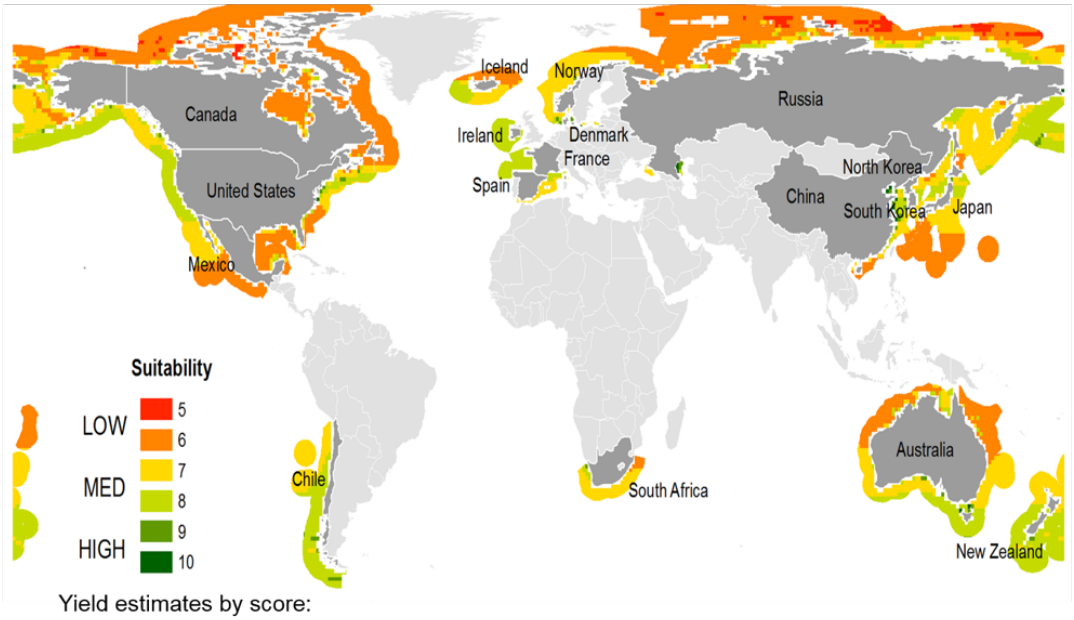
[15] Internal ARPA-E funded geo-spatial analysis conducted by Lux Research (Boston, MA)

[16] Energy calculation assumes a conversion efficiency of 230 liters of ethanol per DMT (from experimental data from Dr. Alejandro Buschmann, Macrocystis production and conversion in Chile ARPA-E Macroalgae Workshop, Feb. 2016.) which is equivalent to 23.6 billion gallons of gasoline equivalent (GGE) or 2.7 Quads energy. ARPA-E views this value as a conservative conversion factor in light of recent data that suggests a conversion of factor of nearly 600 liters ethanol per DMT is possible (See: Camus, C., et al. Scaling up bioethanol production from the farmed brown macroalgae Macrocystis pyrifera in Chile. Biofuels, Bioprodu. Bioref. 10:673-685 (2016))



Yield estimates by score:
10: 150 wet MT/ ha-yr , **9:** 133 wet MT/ ha-yr , **8:** 116 wet MT/ ha-yr , **7:** 98 wet MT/ ha-yr

A.



Yield estimates by score:
10: 147 wet MT/ ha-yr , **9:** 141 wet MT/ ha-yr , **8:** 135 wet MT/ ha-yr , **7:** 129 wet MT/ ha-yr

B.

Figure 3. A) Red macroalgae suitability map B) Brown macroalgae suitability map

The oceans represent the next frontier for production of industrially relevant quantities of biomass feedstock for fuels and chemicals. The U.S. has the technical, engineering, as well as geographic potential to realize this vision – the nation's marine exclusive economic zone (EEZ) is equivalent to the total land area of the United States. Production of biomass resources in the oceans has many advantages. Macroalgae do not require freshwater, nor land, and in many

cases do not require "feeding" with nitrogen. The production and application of nitrogen fertilizer is a significant energy component of terrestrial crops – consuming approximately 50% of the energy budget of corn grain production. Additionally, macroalgae are better than terrestrial plants at fixing carbon dioxide, and produce a plant that is nearly 100% harvestable (Table 1).

Table 1. Macrocytsis advantages versus corn.

Plant	Photosynthetic Efficiency	Yield	Recoverable Carbon	Nitrogen Share of "Embedded Energy"
Field Corn (*Zea mays*)	4-6% max[17]	16 DMT/Ha [18]	~70%[19]	>50%[20]
Giant kelp (*Macrocystis pyrifera*)	4-10% max[21]	30 DMT/Ha [22]	>95%[23]	≥0%[24]

In support of ARPA-E's mission, this FOA seeks to significantly broaden the opportunities for macroalgae to be a significant energy contributor to a future low-carbon world, especially for the production of biofuels. ARPA-E supports the development of technologies under this FOA that are capable of providing economically viable, renewable biomass for energy applications that does not compete for land use. Additionally, ARPA-E has determined that near-term economic opportunities exist for macroalgae as a new and substantial source of protein and carbohydrate for livestock feed, which might provide economically viable bridging applications while the market for biofuels evolves and matures. With such potential in mind, ARPA-E is committed to the development of transformational technologies to enable a U.S. based macroalgae industry capable of producing up to 2 Quads of bioenergy by 2050, while also supplying the world's ever expanding need for animal feed. The ARPA-E MARINER Program will meet these goals by developing innovative cultivation & harvest systems able to produce macroalgae biomass that is cost competitive with terrestrial biomass at energy-relevant scale.

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[17] Borak, B., Ort, D.R., Burbaum, J.J. Energy and carbon accounting to compare bioenergy crops. Current Opinions Biotechnology 2013 Jun;24(3):369-75

[18] Theoretical yield based on average U.S. corn grain yield 168 bushels per acre and harvesting all grain and max 50% of above ground biomass (data source USDA National Agriculture Statistics Service Quick Stats (https://quickstats.nass.usda.gov/results/90C69DEC-38D6-31B4-9953-4C6EB5E82D79?pivot=short_desc)

[19] Recoverable carbon refers to the amount of carbon that can be reasonably and sustainably removed from the field. Theorectical value based on average U.S. corn grain yield (iBid) and 100% removal of grain (10.7 DMT total), 50% removal of corn stover (5.4 DMT total), and 0% removal of underground biomass (0.6 DMT total).

[20] Nitrogen share of embedded energy refers to the percentage of energy contained/used to generate nitrogen fertilizer relative to all energy used for corn cultivation and harvest. (See 2015 Energy Balance for the Corn-Ethanol Industry, USDA Office of the Chief Economist, Office of Energy Policy and New Uses, February 2016.)

[21] Fernandez *et al.* Photosynthesis Research 2015 124:293-304.

[22] Experimental plot data from Dr. Alejandro Buschmann, (See Macrocystis production and conversion in Chile ARPA-E Macroalgae Workshop, Feb. 2016.) While high yields have been reported in experimental plots for macrocytsis, yields vary widely depending on species, nutrients, and geography, among other factors.

[23] Theoretical assumption that nearly all marine biomass can be harvested considering the lack of requirement to maintain soil carbon "health" in the case of terrestrial crops.

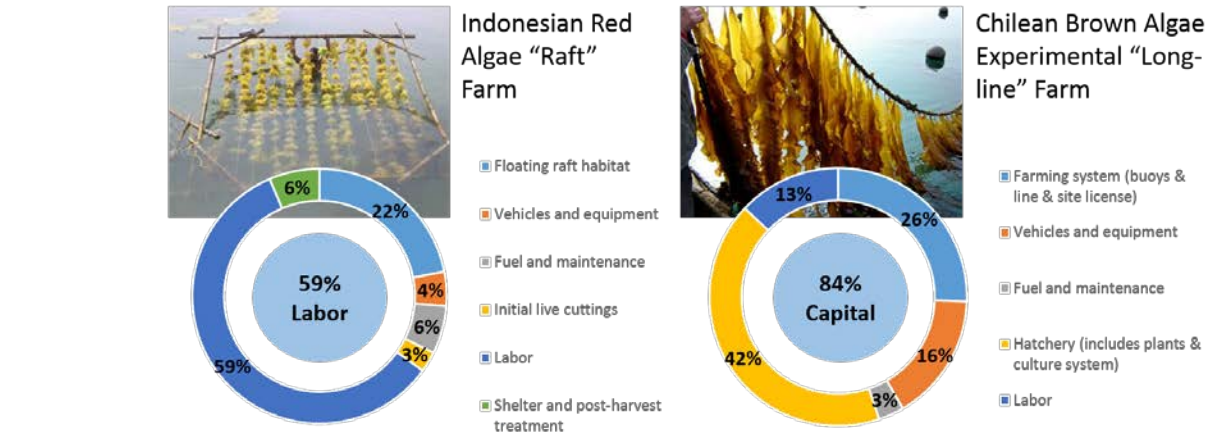
[24] Assumes zero additional fertilizer input in the aquatic system.

Current State Of The Art and Techno-Economics:

As previously mentioned, many Asian countries, notably China and Indonesia, produce the vast preponderance of the world's supply of macroalgae. Macroalgae farming is currently practiced on a cottage-industry scale; the output of a typical farm can be measured in tens rather than hundreds or thousands of dry metric tons. Macroalgae production systems are typified by either "rafts" or anchored "long line" farm designs. The raft design is typically deployed in shallow, often intertidal waters and can be tethered to float, or be fixed at a precise depth. Rafts are often useful for production of macroalgae species such as *Kappaphycus alvarezii*, a red algae that grows vegetatively via branching. Anchored long line designs are representative of the state of the art for brown algae such as *Saccharina japonica* that are capable of growing to 10 meters in length. Such brown algae can be germinated in a hatchery directly on nylon strands, which are then deployed at the aquafarm site by wrapping around long structural support lines. A single support line can be considered analogous to a single row of plants on a typical terrestrial farm. Algae support lines are run in parallel to one another and are spaced apart for optimization of light and nutrient flux.[25,26] The macroalgae is typically harvested by cutting the plant with a blade and lifting the biomass into a boat.

Two examples of macroalgae farm designs are presented in Figure 4. The Indonesian raft farm is capable of producing red algae at a marketable cost for current food applications; however, in this case, the raft farm production cost is dominated by labor.[27] Considering that labor costs inherently do not decrease with scale, the scalability of raft systems to larger farms and to open ocean environments is severely limited. Additionally, current raft production systems are likely limited to tropical latitudes with low energy waves, and therefore also face geographic constraints to scaling. Anchored long line systems on the other hand are typically more capital intensive, but are more productive and efficient. The example shown is from data acquired from an experimental Chilean *Macrocystis* farm.[28] In that case, the current production cost is not competitive because of the high capital investment relative to production volume; this suggests that new technologies are required to improve return on capital for long line systems through increased yield and scale, and to decrease production costs. Current production data from China remains elusive, but ARPA-E believes that the long line systems deployed in China are also very labor intensive and are therefore only profitable at very low labor rates.

[25] Flavin, K., *et al.* Kelp Farming Manual. Ocean Approved (2013).
[26] Redmond, S., L. Green, C. Yarish, , J. Kim, and C. Neefus. New England Seaweed Culture Handbook-Nursery Systems. Connecticut Sea Grant CTSG-14-01. 2014. (http://seagrant.uconn.edu/publications/aquaculture/handbook.pdf)
[27] Valderrama, D. *et al.* Social and economic dimensions of carrageenan seaweed farming. FAO Fisheries and Aquaculture Technical Paper 580, Food and Agriculture Organization of the United Nations (Rome) 2013.
[28] Correa, T., et al. Production and economic assessment of giant kelp Macrocystis pyrifera cultivation for abalone feed in the south of Chile. Aquaculture Research 47: 698-707 (2016)



Total line	33 km line
Total Yield	33 dry metric tons (DMT)
Cost per DMT	$223
Productivity	1 DMT/km

Labor intense –
Does not benefit from economies of scale.
Restricted to calm waters.

20 km line
56 dry metric tons (DMT)
~$500
2.8 DMT/km

Capital Intense –
Can benefit from economies of scale.
More robust for open ocean waters.

Figure 4. Examples of current macroalgae cultivation systems.

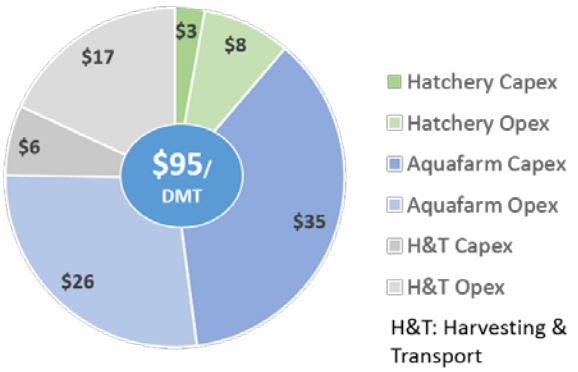
Attempts have been made in the United States over the past 100 years to utilize macroalgae for the production of potash, and as a feedstock for biogas and biofuel production. The techno-economics of these highly-engineered solutions were never rigorously evaluated, and in all cases the solutions failed.[29,30] Such projects were typically initiated in response to a temporary resource crisis. However, much can be learned from these efforts and from the current state of macroalgae production outside of the U.S. in conceiving of new macroalgae systems that take advantage of economies of scale, maximize nutrient uptake, and are sufficiently robust for high(er) energy ocean environments. ARPA-E is interested in new systems that minimize capital costs per unit of output by maximizing yields (i.e. intensification), and that enable production over wider areas by reducing the need for labor, while overcoming nutrient limitations that may diminish farm productivity.

ARPA-E recognizes the significant challenges of developing and deploying biomass cultivation systems in the open ocean. In order to assess the potential for large-scale macroalgae production, ARPA-E simulated various techno-economic scenarios for the cultivation of the giant kelp *Macrocystis* through scenario analyses that are aspirational yet technically reasonable,[31] and that are based on the best information available. While the analysis

[29] Ashare, E. *et al.* Cost analysis of aquatic biomass systems - final report. Dynatech R/D Company, Cambridge, MA. (1978).
[30] Neushul, M. and Harger, B.W.W. Kelp biomass production: Annual technical report. Gas Research Institute, Chicago, IL. (1985)
[31] Camus, C. and Buschmann, A.H. Macrocystis pyrifera aquafarming: production optimization of rope-seeded juvenile sporophytes. Aquaculture 468:107-114 (2017).

framework makes several assumptions that may not translate to all ocean environments, farm designs, and/or macroalgae species, it is believed to be a reasonable representation of the variables that need to be considered in planning for high volume cultivation. Figure 5 presents results from a modeled *Macrocystis* farm at 3,000 hectare (Ha) scale. In this case, the target yield was set at 25 DMT/Ha, a value consistent with yields occasionally seen in highly productive systems.

A.



B.

Major Assumptions	
Hectares	3,000
Target yield, DMT/Ha	25
DMT/yr	61,000
WMT/yr	485,000
Capacity factor	90%
Seeding frequency/yr	1
Boat fuel price/gallon	$3.00
Meter culture rope/Ha	6,600
Harvester boats	1
FTEs	47
Labor rate, fully loaded per FTE*	$20,000
Production cost, $/DMT	**$95**

*With a higher labor rate assumption of $40,000 fully loaded per FTE, production cost increases to $99/DMT.

C.

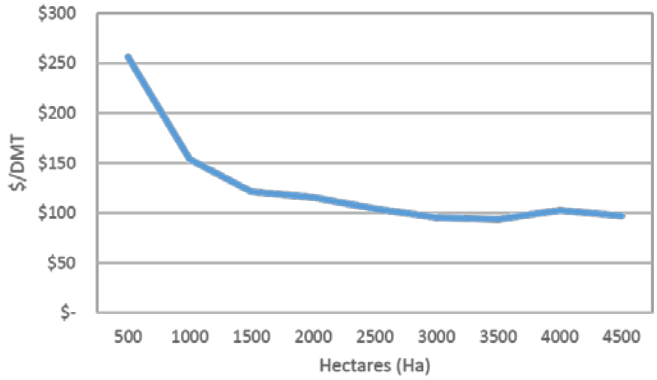


Figure 5. A) Full CapEx and OpEx breakdown necessary to achieve $95/DMT; B) List of assumptions used in the model*; C) Relationship between production cost and scale (at 25 DMT/Ha)

This model is based on the "anchored long line" design described earlier, and is intended to illustrate how costs may be distributed across the three primary operational segments of a hypothetical macroalgae farm: a hatchery where macroalgae is germinated on culture rope until it is ready for deployment; an aquafarm where the culture rope is deployed on structural rope supports over the intended cultivation area; and a harvesting and transport operation which gathers the mature crop and delivers it to shore.[32] The model incorporates additional assumptions about the operating parameters of each of these segments, including anticipated growth periods, productivity of labor, operational capabilities of necessary equipment (e.g. boats) , costs of installation, and consumption rates of electricity, water and fuel. All of these inputs are then used to compute an integrated and internally consistent estimate of overall

[32] This model is based on information provided by Bio Architecture Lab (BAL). BAL has previously received funding from ARPA-E for a macroalgae to fuels project (OPEN 2009).

production capability and associated costs. Note that this model and the derived numbers shown here are for illustration only. ARPA-E anticipates that teams responding to this FOA will develop and justify their own cost models, based on appropriate assumptions consistent with their specific concepts and designs.

In the ARPA-E "anchored long line" model, the costs associated with the aquafarm dominate, strongly suggesting that technologies to reduce aquafarm costs and/or maximize yield per unit of capital are necessary. The model also predicts a non-linear relationship between total production cost and scale, and illustrates the limits of economies of scale under the current set of assumptions. In this particular case, production costs bottom out at 2,500 Ha and remain flat because production capacity is added in modular increments based on the capabilities of existing capital equipment; farms much smaller than 2,500 Ha would have a difficult time competing.

A.

CAPEX Assumptions	Sub-components	Approximate capex ($ MM)	Assumed Lifetime (yrs)	Annual depreciation ($K)
Hatchery	Hatchery - Building	0.95	15	63
	Hatchery - Water System	0.1	10	10
	Hatchery - Tanks + Equipment	0.9	10	90
Aquafarm	Anchors & chain	3.0	50 yrs	60
	Survey	0.9	50 yrs	18
	Culture Rope and Structural Rope	4.8	5	960
	Buoys, Hardware & Installation	8.3	10	830
	Aquafarm - Boats	7.1	30	236
H&T	H&T - Boats	10.0	30	333
	H&T - Docks	6.6	30	220

B.

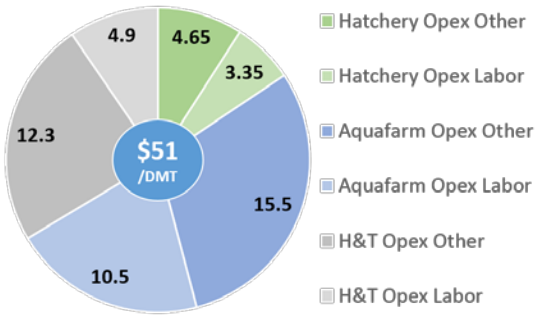


Figure 6. A) CapEx breakdown for farm sub-components; B) OpEx breakdown; all values derived for modeled $95/DMT production system (assumptions can be found in Figure 4B).

Operational Expenditure (OpEx) is also a large contributor to the final production cost (Figure 6). Again, in this particular case, OpEx costs represent 53% of the total cost. The high OpEx costs can be attributed to labor and fuel. Therefore, technologies that reduce the amount of labor required and/or reduce the amount of energy required will increase the productivity of the farm and drive down costs. Specific examples of such technologies include new automated monitoring and support systems, automation of hatchery, farm, and harvesting operations, and integration of low cost renewable energy with harvesting and transport systems. ARPA-E seeks solutions to dramatically improve performance at the component and system level.

The ARPA-E modeling results clearly identify yield as the most significant driver of production cost (Figure 7A). To date, significant yield improvements have not been realized through system-level design, engineering, and operation, or through biology. In the absence of dramatic

yield improvements, macroalgae production at industrial scale will fail.

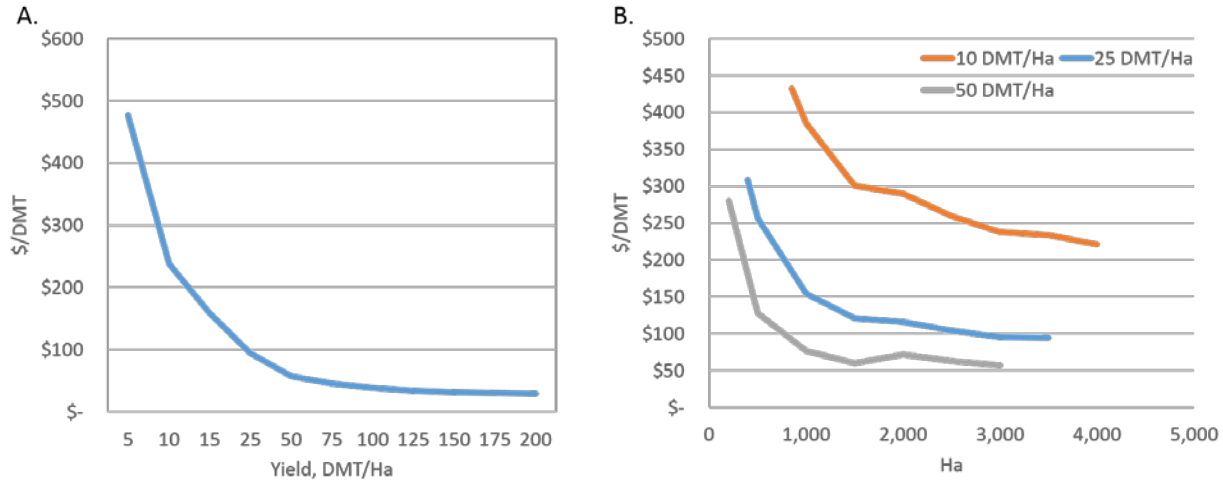


Figure 7. A) Relationship between production cost and yield (at 3,000 Ha scale); B) Impact of yield on cost at increasing scale.

Currently, to our best knowledge, most commercial macroalgae production rarely achieves yields exceeding 10 DMT/Ha. At that level of productivity, the model indicates a production cost floor of $238/DMT (Figure 7B), a value which cannot compete with the anticipated cost of terrestrial energy crops. This analysis demonstrates quite convincingly that the benefits of scale can only be realized if sustained farm level yields can be increased significantly beyond the capabilities of current production systems.

The growth of macroalgae requires light, carbon dioxide, nitrogen, phosphorous, and trace-level micro-nutrients. Of all of these requirements, biologically available nitrogen is the limiting factor to growth and yield. In the open ocean, biologically available nitrogen may be provided by point sources such as anthropogenic waste water discharge or fertilizer runoff, from microbial nitrogen fixation, and nutrient "up-welling" from the deep ocean. Deep water nutrients can potentially also be accessed via pumping or by physically submerging plants to depths where nutrients are available (i.e. below the thermocline). Additionally, macroalgae farms can be actively fertilized. Regardless of which solutions are employed, these new macroalgae cultivation systems must be capable of delivering sufficient quantities of nutrients effectively without environmental damage, and at negligible cost, in order to be highly productive and economical.

C. PROGRAM VISION

ARPA-E is committed to the development of transformational technologies to enable a U.S. based macroalgae industry capable of producing up to 2 Quads of bioenergy by 2050. The ARPA-E MARINER Program will meet these goals by developing innovative cultivation and harvesting systems, and the supporting tools necessary to produce macroalgae biomass that is cost competitive with terrestrial biomass at energy-relevant scale.

The primary challenges are to dramatically increase yield per unit of capital, reduce overall capital requirements and minimize the operating cost of macroalgae cultivation, and to significantly increase the range of deployment by expanding into more exposed, off-shore environments.

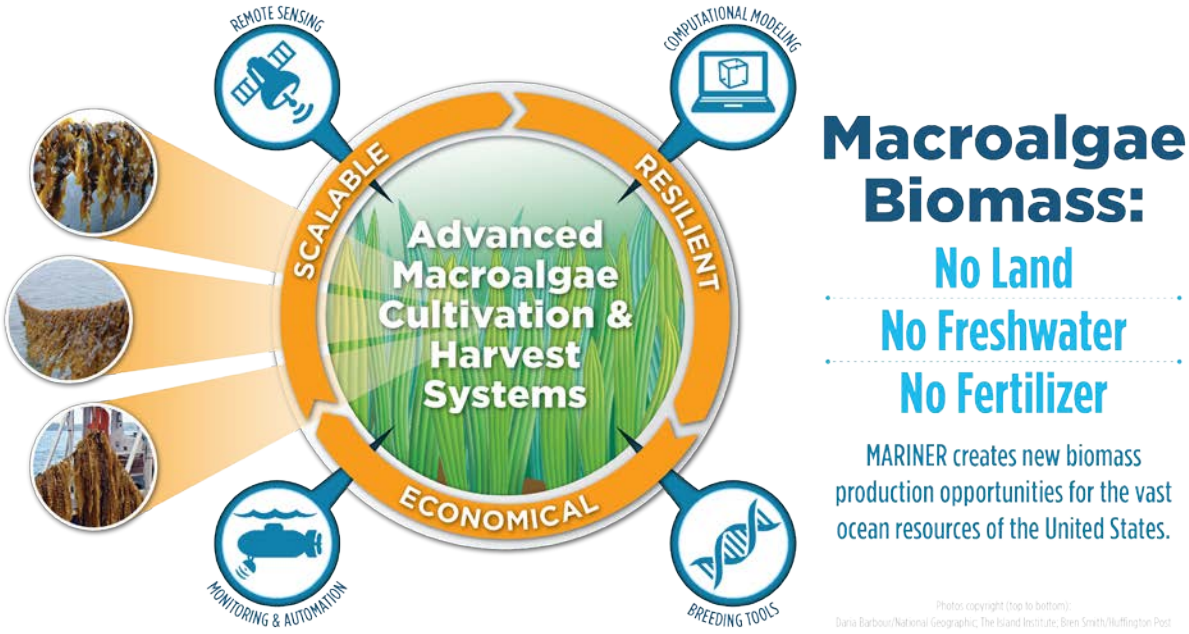


Figure 8. MARINER Program Vision

The technology opportunities envisioned by the program are illustrated in Figure 8. Technologies developed under the MARINER program will address marine system design/engineering and integration with biomass production, hydrodynamic and ocean modeling, sensor technology development, macroalgae breeding tools, and field testing of cultivation systems and sensor technologies.

D. PROGRAM STRUCTURE AND TECHNICAL CATEGORIES OF INTEREST

The MARINER program is focused on supporting the development of biological and engineering solutions for sustainable and cost-competitive production of macroalgae in both near-shore and off-shore ocean environments. Specifically, ARPA-E is soliciting proposals that address one or more of the following categories:

- **CATEGORY 1: Design & Experimental Deployment of Integrated Cultivation and Harvesting Systems**
- **CATEGORY 2: Design & Experimental Deployment of Advanced Component Technologies**
- **CATEGORY 3: Design & Testing of Computational Modeling Tools**
- **CATEGORY 4: Design & Testing of Aquatic Monitoring Tools**
- **CATEGORY 5: Research & Development of Advanced Breeding and Genetic Tools**

ARPA-E anticipates proposals will address only one category. ARPA-E may be open to proposals that address more than one category if such a proposal is clearly integrated and thoroughly addresses relevant performance targets for each category. Proposals that address more than one category must show significant synergy between the respective categories addressed. Alternatively, per Section III.C.4 of this FOA, ARPA-E is not limiting the number of submissions from Applicants. Applicants may submit more than one application to this FOA, provided that each application is scientifically distinct.

CATEGORY 1: Design & Experimental Deployment of Integrated Cultivation and Harvesting Systems

ARPA-E is interested in fundamentally new designs and approaches to macroalgae cultivation and production with integrated harvesting solutions. These systems may leverage new material and engineering solutions, autonomous and/or robotic operations, advanced sensing and monitoring capabilities, as well as advanced ecological systems approaches such as co-cultivation of multiple species of algae. In addition to "field-type" cultivation, ARPA-E is also interested in unconventional approaches, for example avoiding the use of cultivation support infrastructure via "ranching" where free floating macroalgae are harvested at locations predicted or determined by satellite imaging and current/drift modeling. Given the enormous size and geographic diversity of the U.S. offshore exclusive economic zone (EEZ), we expect that there will be different system solutions based on the intended area of deployment, macroalgal species to be cultivated, and downstream processing methods. Nonetheless, in all cases ensuring appropriate nutrient management and/or delivery to and within macroalgae cultivation systems will be critical to achieve desirable yield targets.

Category 1 projects will be structured in a two-phase approach, with Phase 1 focusing on system design and techno-economic as well as life-cycle analysis (TEA and LCA), and Phase 2 consisting of building, deploying and testing a pilot-scale system to demonstrate key performance metrics. The initial period of performance for Category 1 awards will be for Phase 1 and will not exceed 12 months. Upon successful completion of Phase 1 and subject to the availability of appropriated funds, only the most promising projects will be selected for a Phase 2 award, which can run up to an additional 3 years.

CATEGORY 2: Design & Experimental Deployment of Advanced Component Technologies

ARPA-E is also interested in new or improved components to significantly improve performance and reduce costs within today's standard approaches to cultivation and harvesting of macroalgal biomass, e.g. anchored long line cultivation systems. This category seeks technologies that can significantly reduce the overall capital and/or operating cost as well as the energy requirement of the system. ARPA-E is most interested in enabling advances of components with the highest impact on cost and/or energy efficiency, including low energy harvesting and handling technologies, cultivation system components such as lines and anchors, as well as increased productivity of macroalgae hatcheries, specifically for red algae species, which currently face more productivity challenges than do brown algae. Technology for automation of any of these operations is of particular interest. In addition, ARPA-E is interested in innovations that allow these existing systems to be economically deployed over significantly larger and more remote areas, e.g. by enabling the systems to move from relatively protected bays to more exposed stretches of ocean.

CATEGORY 3: Design & Testing of Computational Modeling Tools

To accelerate the design, testing, and operation of new cultivation and harvest systems, ARPA-E is interested in the development of appropriate computational modeling tools. Tools of particular interest are those for hydrodynamic modeling which can simulate the performance of a given cultivation system design in response to ocean current conditions over time and space, and storm events. Another application of interest is nutrient flux modeling within a farm "field." In addition to the hydrodynamic components such nutrient flux models will need to incorporate models for nutrient uptake by the macroalgae. ARPA-E is also interested in larger scale nutrient flux models, which provide the capability to assess the effect on primary phytoplankton productivity of larger, regional-scale deployment of macroalgae farms. The modeling tools developed under this category should be flexible enough to accommodate a wide variety of cultivation system designs. They are also intended to work in conjunction with advanced marine systems mapping or marine spatial planning tools to identify appropriate deployment opportunities for macroalgal cultivation.

CATEGORY 4: Design & Testing of Aquatic Monitoring Tools

ARPA-E is interested in the development of sensor and analysis tools which allow in-situ monitoring of macroalgae in a farm-sized cultivation system. Specifically, ARPA-E is interested in the ability to monitor growth, spatial distribution, and composition of macroalgal biomass, as well as nutrient concentrations in the waters of a macroalgae farm. Furthermore, ARPA-E is interested in sensors and technologies for biosecurity, including the detection and prevention of disease and herbivory. In-field (ocean) sensor systems should be deployable on autonomous, or semi-autonomous, surface or underwater vehicles, and should include onboard sensor data analysis as appropriate to deliver actionable information to a grower or an automated management system. In addition, tools for the analysis of data acquired via remote (aerial or surface) sensing or satellite imaging are of interest.

CATEGORY 5: Research & Development of Advanced Breeding and Genetic Tools

Finally, ARPA-E is interested in the development of advanced breeding and genetic tools, to accelerate the development of macroalgae cultivars with improved performance parameters including higher yield, improved composition, and temperature and disease tolerance. An important starting point is the development of rapid screening tools to assess genetic diversity in natural populations of macroalgae. In a variety of geographies, this information will be critical for expediting the regulatory approval process for macroalgae farms. In addition, this information is expected to improve the selection of appropriate local or regional breeding stock for subsequent breeding programs. ARPA-E is especially interested in the adaptation of modern breeding methods such as marker assisted selection or genomic selection to the unique life cycles of macroalgae, with the goal of enabling rapid, high-throughput strain development. Development of hybrid seed systems and inbred propogation systems (cytoplasmic sterility systems), and mapping populations (recombinant inbred lines, nested association mapping panels, etc.), are of interest in this category to capitalize on well-described hybrid vigor and to assist in gene identification. However, at this point, ARPA-E is not interested in developing tools to genetically engineer macroalgae.

E. TECHNICAL PERFORMANCE TARGETS

Responses to this FOA must have a well-justified and realistic potential to meet or exceed the following Primary Technical Targets by the end of the project period. A description of each of the Technical Categories together with the applicable Technical Performance Targets is provided below. ARPA-E recognizes that there may be certain solutions that do not match perfectly with the expected performance targets. In those cases, a logical and well-articulated explanation must be provided as a justification for any deviation from the prescribed performance targets.

CATEGORY 1: Design & Experimental Deployment of Cultivation and Harvesting Systems

The final objective for Category 1 is ocean deployment of a prototype macroalgae cultivation system with an integrated harvesting technology. A successful Category 1 prototype will validate all of the following primary technical targets:

Category 1 Primary Technical Targets

ID	Metric	Primary Design Targets
1.1	Full System Size	≥ 1,000 hectares
1.2	Range of Deployment	≥ 100,000 hectares
1.3	Biomass Production Cost	≤ $80/dry metric ton biomass
1.4	Net Energy Return	≥ 5:1
1.5	Nutrient source	Needs to be scalable. Direct application of synthetic fertilizer is not permitted.

Metric Descriptions – Primary Technical Targets

1.1 Full System Size

System size and scalability are critical to establishing a macroalgae ocean farming industry that is capable of achieving an energy-relevant scale. Indeed, this FOA Category requires the development and deployment of technology capable of achieving farm productivity and scale that will eventually supply biomass at costs competitive with terrestrial biomass feedstocks such as agricultural residues or energy crops, both of which are assumed to be collected from millions of hectares of U.S. cropland. ARPA-E requests that applicants propose and present convincing information and arguments that demonstrate the potential for a proposed system design to scale to ≥ 1,000 hectares. This information should include a diagram of the farm and description of the scaling factors necessary to achieve the 1000 hectares farm size. Additionally this should include a description of the size and number of all critical unit operations, from hatchery to harvesting. In Phase 2, the Experimental Deployment Phase, the underlying assumptions for system scalability will need to be validated experimentally with an ocean deployed prototype.

1.2 Range of Deployment

The applicants must clearly identify specific ocean areas that are suited for deployment of the specified design. The specific ocean area or areas must in aggregate add up to at least 100,000 hectares. The minimum criteria that must be considered and justified when assessing the availability of suitable ocean area are sufficient nutrient availability and compatibility of the system design with prevailing current and weather conditions.

1.3 Production Cost

For macroalgae biomass to serve as feedstock for biofuel production, production costs must be competitive with terrestrial biomass feedstocks. ARPA-E expects that applicants will demonstrate at the end of Phase 1, via techno-economic modeling, the potential of their proposed system to achieve macroalgae biomass production at a cost of ≤ $80/DMT of harvested biomass (cost attributed to drying of wet biomass need not be considered at this time).

All proposals must clearly articulate why their design is unique, and specify where significant improvements are expected versus the current state of technology. This must be convincingly demonstrated with exceptional engineering design and techno-economic analysis. Responses to Category 1 must clearly identify the primary assumptions and key calculations that connect farm design to final product cost of biomass ($/DMT). The techno-economic analysis presented in Section I.B. above for the long-line cultivation system can serve as an example of the type of analysis ARPA-E expects will be included with every Category 1 Full Application submission. To be explicit, these calculations are not expected to be included in the Concept Paper submission. In particular, system productivity, e.g. expressed as annual biomass yield in DMT per unit area, is a major driver of macroalgae production cost, and the underlying assumptions, such as species used, geographic location and nutrient availability, need to be made explicit. The expected target yield for the proposed system should be clearly identified, as well as the sensitivity of the production cost to changes in target yield. Finally, it is important that the underlying assumptions are adjusted for the anticipated location of deployment, for example the cost of labor and transportation of product back to shore should be expressed as a function of distance from shore.

1.4 Net Energy Return

The net energy return is defined as the energy content, expressed as lower heating value (LHV), of the final product versus the amount of process energy from all unit operations involved in the production of the final product. Energy from solar radiation should not be included in this calculation. ARPA-E seeks concepts and technologies capable of delivering a net energy return ≥ 5:1, meaning that the final product, i.e. the harvested kelp, will contain 5 times the amount of energy relative to the amount of energy required to produce the biomass product. Energy required for drying the harvested biomass need not be considered in this calculation. This net energy return must be calculated from design and engineering techno-economics. The key assumptions used for these calculations will need to be validated as closely as possible experimentally. Just for clarity, ARPA-E does not require attribution of the energetics of biomass conversion (e.g. hydrothermal liquefaction (HTL)) for this calculation and demonstration.

1.5 Nutrient Supply

Direct fertilization of the macroalgae farm with synthetic or mineral fertilizer is not acceptable. However, supplementing the nutrient supply by recycling nutrients contained in

byproducts of macroalgae processing to fuel may be considered. The source of nutrients needs to be specified (e.g. anthropogenic run-off, upwelling, etc.) and clear evidence needs to be provided that this nutrient source will be sufficient to supply a full scale farm (Target 1.1) over the course of the annual production cycle. The source of nutrients also needs to be scalable over the project deployment range of the farm as specified under Target 1.2.

Although Category 1 focuses on integrated cultivation and harvesting systems, ARPA-E will require applicants to conceptually delineate technical solutions for macroalgal biomass transport and storage for a proposed system solution. Additionally, ARPA-E does not envision funding of concepts under this FOA that address macroalgal biomass conversion to biofuels or other end products. However, ARPA-E acknowledges that the intended use of the harvested macroalgae may influence the design of the most optimal harvesting, transport, and storage solutions to meet expected end use outcomes. Therefore, ARPA-E requires that applicants specify which of the following three potential pathways for conversion to fuel they assume will be supplied with biomass from their system: 1) Hydrothermal liquefaction, 2) Anaerobic digestion, or 3) Carbohydrate extraction and fermentation. Conceptual solutions for biomass transport and storage that are aligned with the specification of an anticipated conversion platform will support a more accurate TEA and LCA.

Successful execution of Category 1 projects will occur in two phases over 48 months, as follows:

Phase 1 (Design Phase): The Design Phase will consist of design and techno-economic assessment including life cycle assessment of a complete macroalgae cultivation and harvesting ocean-farm system. ARPA-E anticipates that the Design Phase will be completed within a budget of $500,000. ARPA-E will complete a project review of the Design Phase within 12 months from the start of the project. The most promising projects will be selected for advancement to the Experimental Deployment Phase. At the Design Phase Project Review, all projects will be evaluated based on the following considerations:

- Potential of a full-scale system to achieve final primary Category 1 target metrics;
- Infrastructure robustness/resilience;
- Geographic and macroalgae species factors;
- Siting hazard assessment and mitigation plan;
- Environmentally sound provision of nutrients;
- Weather impact assessment;
- Design considerations for animal welfare;
- Design of Experimental Deployment system and its ability to derisk key technical innovations;
- Status of permits necessary to operate in ocean waters;
- Construction schedule; and,
- Overall execution plan.

Phase 2 (Experimental Deployment Phase): The Experimental Deployment Phase will consist of construction, ocean testing/validation, and performance of a complete cultivation and

harvesting system. ARPA-E anticipates that the Experimental Deployment Phase will be completed within 36 months from selection of a project to advance to the Experimental Deployement Phase. The exact size of the Experimental Deployment system will need to be specified during the Design Phase and is expected to be system specific. The key goal is to demonstrate the system at the smallest scale possible, while ensuring that critical design features of the full scale system can be validated and derisked. During the Experimental Deployment Phase, ARPA-E anticipates the potential for integration and/or use of technologies developed under MARINER FOA Categories 2 – 5.

CATEGORY 2: Design & Experimental Deployment of Cultivation and Harvesting System Component Technologies

The final objective for Category 2 is development and delivery of cultivation and harvesting system component technologies. ARPA-E is interested in receiving concepts that address the major techno-economic drivers of the final production cost as spelled out in Section I.B. above in the techno-economic analysis for long line cultivation. In addition, ARPA-E is interested in technology advancements that can significantly expand the scale of macroalgae cultivation without negatively impacting cost and performance. To the extent possible, technologies addressing Category 2 should incorporate automation in order to reduce labor cost. Proposed concepts must be delineated from design to the point of integration with a complete cultivation and harvesting system. Concepts must convincingly articulate a feasible solution capable of meeting at least one of the following primary technical targets:

Category 2 Primary Technical Targets

ID	Metric	Targets
2.1	Performance Enhanced Cost Contribution Reduction	The chosen component technology and/or unit operation cost must be lower by 50% relative to current state of the technology selected for substitution. Prior to improvements, the chosen component technology and/or unit operation should have contributed at least 30% of the overall CapEx or OpEx cost, based on current state of technology.
2.2	Performance Enhanced Expansion of Scale	The chosen component technology needs to enable an increase in farm size or potential area of deployment by at least a factor of 5 relative to current practice.

Metric Descriptions – Primary Technical Targets

2.1 Performance Enhanced Cost Contribution Reduction

Internal ARPA-E analysis, as shown in Figures 5 and 6, based on the current state of technology indicates that the capital expenses of the production system are dominated by farm equipment costs closely followed by the expenditure for boats for harvest and cultivation. The largest operating cost drivers are boat fuel, particularly for harvesting, and labor. Any technology proposed to reduce capital or operating cost should focus on those areas which contribute more than 30% to the overall CapEx or OpEx of the operation. The targeted improvement should achieve at least 50% cost reduction compared to current state of the art. One example would be a new harvest system design that reduces fuel consumption for that operation by at least 50%. The overall effect of the expected performance improvements will need to be demonstrated with a rigorous techno-economic analysis which clearly spells out underlying assumptions. Other potential areas for significant cost reductions are farm system CapEx and nursery CapEx.

2.2 Performance Enhanced Expansion of Scale

To achieve a scale relevant to the energy sector, the production of macroalgae needs to expand by at least two orders of magnitude beyond current total global levels of production. Production of seedlings, particularly for red algal species, is often seen as a bottle neck for expanding production. Innovative technologies to expand production need to demonstrate an improvement of at least 5x over the current state of the art up to a total farm area of 3000 ha. In addition to the need for more productive processes, macroalgae farms are typically confined at present to relatively protected bays. ARPA-E is seeking novel approaches to increasing the resilience of key system components, which expand the range of deployment of existing farm systems by at least a factor of five. The increased resilience will need to be demonstrated experimentally, and the expanded areas of ocean that become available have to be mapped out.

Successful execution of Category 2 projects will occur in a single phase over a period of up to 36 months. Category 2 technologies will be expected to validate primary technical targets in an ocean environment. Preferably, this should be done at a suitable, existing macroalgae farm site or in conjunction with a Category 1 project during the final 12 months of the Category 2 project period of performance in order minimize expenses.

During the in-ocean validation effort, ARPA-E anticipates the potential for integration and/or use of technologies developed under MARINER FOA Categories 1 and 3 – 5.

CATEGORY 3: Design & Deployment of Computational Modeling Tools

The objective for Category 3 is development and delivery of computational modeling tools that facilitate the development and assessment of new macroalgae cultivation systems at the farm level. It is expected that these modeling tools will be developed within 12 months from the start of the project and made available to and tested with systems developed by teams in Category 1 (and Category 2, as applicable). Close communication and collaboration with applicable Category 1 and 2 teams is encouraged to ensure usefulness of the developed tools to the overall program effort.

ARPA-E is interested in tools to model the following farm-level processes:

- Response of farm structural components to hydrodynamic stresses
- Interaction between macroalgae and farm structural components
- Nutrient flux including uptake by macroalgae

In addition, ARPA-E is also interested in models assessing competition for nutrient consumption between macroalgae farms and natural phytoplankton populations on a regional scale.

Primary Technical Targets

ID	Metric	Targets
3.1	Resolution	• 1 m^3 (farm-level processes) • 1 hectare (regional scale models)
3.3	Flexibility	Tool applicable to multiple system designs

Metric Descriptions – Primary Technical Targets

3.1 Resolution

A spatial resolution of 1 m^3 is anticipated in order to enable modeling capabilities for making exploratory, predicative, and dynamic decisions on the macroalgae farm level. A three-dimensional model is required for farm level processes in order to account for the vertical axis present in most if not all farm designs. At the regional scale, two-dimensional models should target a resolution of 1 hectare.

3.2 Flexibility

Farm-level models should be flexible to accommodate different farm designs for modeling dynamics within a farm system.

Successful execution of Category 3 projects will occur in a single phase over a period of up to 24 months. There is a strong preference for projects addressing the modeling of farm structural components in order to have usable models available within the first 12 months that can be applied to Category 1 and 2 projects. For nutrient flux models at the farm or regional scale a

plan to validate the models with in-field data should be included. Projects that include in-field data collection may be extended to 36 months.

CATEGORY 4: Design & Deployment of Aquatic Monitoring Technology & Tools

The objective for Category 4 is development and delivery of technologies capable of autonomous or semi-autonomous monitoring of macroalgae farms. The minimum deliverable will be a functional prototype with one or more monitoring properties identified below that has completed testing in an ocean environment. Additionally, ARPA-E is interested in tools that utilize data from remote sensing platforms and/or satellite imaging.

Specific Properties of Interest are:

Properties
Plant level
Biomass growth rate
Macromolecular biomass composition
Presence of disease and herbivory
In-Field level
Biomass distribution variability
Dissolved nitrogen concentration
Presence of disease and occurrence of herbivory
Remote Sensing level
Identification of macroalgae fields
Quantification of algal biomass density
Photosynthetic activity/growth rate
Plant health (indicators of nutrient deficiencies)

Examples of technologies that may be useful for monitoring include:

- Multi-channel/spectral imaging
- Acoustic imaging
- Autonomous biomass sampling
- Autonomous, surface and/or submersed movement

ARPA-E is interested in submissions that propose the various in-ocean sensor technologies deployed on unmanned underwater vehicles (UUV) to conduct field level sampling. Most likely, there will not be enough funds to develop new underwater vehicles under this program. Instead, applicants should try to utilize or modify existing UUV systems.

Considering the power requirements for analytical equipment and data transfer, ARPA-E is particularly interested in technologies capable of integration with renewable energy captured

in-field. ARPA-E anticipates that Category 4 technologies will have an opportunity to be tested in-field at locations/farms developed under Category 1 or 2 of this FOA. Applicants must propose what instrumentation specific technical targets they anticipate will be achieved during the proposed performance period. Proposals also need to describe an appropriate calibration plan to validate sensor accuracy. In addition, sensor technologies proposed under this category must meet the following primary technical targets:

Primary Technical Targets

ID	Metric	Targets
4.1	Instrumentation Target	Precision: +/-5% of target property Accuracy: +/-20% of ground truth value
4.2	Scalability	≥ 20 hectares
4.3	Data Capture Rate	≥ 2 times/sampling location/week; including environmental measurements such as nutrient concentration
4.4	Environmental Operating Tolerance	Temperature range 32-100°F; prototype will be capable of performing 100 hours of data collection in an ocean environment

Metric Descriptions – Primary Technical Targets

4.1 Instrumentation Target

All instruments being developed should at least achieve a precision of +/- 5% of the target property measured. The accuracy should be at least +/- 20% relative to the ground truth value. Applicants need to specify the method used to establish the ground truth value.

4.2 Scalability

All "in-field" monitoring technologies need to be scalable for deployment over areas ≥ 20 hectares without interruption.

4.3 Data Capture Rate

Technologies anticipated to be deployed "in-field" will be expected to capture data at the rate ≥ 2 times/sampling location/week. In the case of a plant-level analysis, "sampling location" means an individual plant. In the case of in-field level analysis, sampling location refers to a given location specified by longitude and latitude data or relative to the coordinates of the farm grid. The sampling frequency value is determined by ARPA-E to be the minimal data capture rate necessary to provide enough data to identify trends and inform models. The applicant must justify any expected deviation from this technical target.

4.4 Environmental Operating Tolerance

All technologies that will be deployed "in-field" must be compatible with harsh ocean conditions, including but not limited to biofouling, corrosion, and ocean currents. All "in-field" prototypes must demonstrate the capability of performing 100 hours of data

collection in an ocean environment. It is expected that the 100 hours of data collection will not necessarily be continuous but tests should be designed to assess feasibility of long-term operation.

Successful execution of Category 4 projects will occur in a single phase over a period of up to 36 months.

CATEGORY 5: Research & Development of Breeding and Genetic Tools

The objective for Category 5 is research and development (R&D) leading to technology transfer of new macroalgae breeding and genetic tools. Macroalgae species have significant genetic diversity (more so than terrestrial, vascular plants), yet suffer from a dearth of knowledge and information on species identification (genotype) and the relationship of genetic information to traits observed in a species environment (phenotype). R&D is needed on breeding and genetic tools (analogous to terrestrial plants) that enable breeders to develop elite cultivars that perform under state-of-the-art agronomic practice and that realize higher species yield potentials. Currently this area of R&D is challenged by macroalgal polyploidy, high "GC" rich sequences, and significant genetic "contamination" with microbial DNA. Specific areas of interest to ARPA-E in Category 5 include:

- Extensive species "barcoding";
- Technology and/or methods to enable high throughput, high accuracy DNA sequencing (e.g. removal/separation and/or deconvolution of microbial genetic contamination);
- Technologies leading to the identification of trait linked genetic markers such as single nucleotide polymorphisms (SNPs); and/or
- Technologies to efficiently produce hybrid macroalgae cultivars.

Ideally, technologies developed under Category 5 will lead to the development of new macroalgae strains with traits more suited for ocean agronomic deployment. However, this outcome may not be achievable during a 36-month period of performance. Rather, ARPA-E will target the development of technologies that will enable macroalgae strain development work which continues beyond the period of performance under the ARPA-E MARINER program. Concepts addressing sequencing and marker identification must meet at least two of the primary technical targets 5.1 – 5.3. Target 5.4 is a requirement for proposals targeting hybridization technologies:

Primary Technical Targets

ID	Metric	Targets
5.1	Macroalgae Species Catalogue	Identification and submission of ≥ 20 macroalgae species "barcodes" from U.S ocean waters to NCBI[33]
5.2	Technologies/methods for Robust Macroalgae DNA Sequencing	Reduction of microbial genetic contamination to ≤ 1% prior to sequencing
5.3	Technologies/methods for Identification of Biomarkers	1. Warm water tolerance: genetic biomarker attributable to increasing the water temperature tolerance of the selected macroalgae species ≥ 2°F 2. Biomass productivity: genetic biomarker attributable to ≥ 10% increase in biomass mass. 3. Pest and disease resistance: genetic biomarker attributable to ≥ 5% in increase in common pest and disease resistance mechanisms. 4. Nutrient uptake & storage: genetic biomarker attributable to ≥ 5% increase in nitrogen storage capacity under relatively low nutrient concentration intervals.
5.4	Macroalgae Strain Hybridization and Propagation	50% increase in throughput relative to state of the art methodology for macroalgae strain hybridization, and micropropagation

Metric Descriptions – Primary Technical Targets

5. 1 Macroalgae Species Catalogue

ARPA-E seeks to genetically identify and catalogue at least 20 macroalgae species native to U.S. ocean waters. Genetic cataloging will be measured by a "barcode" sequence, which is typically a short nucleotide sequence from a standard genetic locus. Target species should be representative of the highest biomass producing brown and red macroalgae.

5.2 Technologies/methods for Robust Macroalgae DNA Sequencing

One of the major challenges with nucleic acid sequencing is the significantly high percentage of "contaminating" foreign DNA. Foreign DNA is typically microbial and can account for up to 50% of the DNA per sample. Technologies are necessary to reduce the level of background DNA contamination and reduce the cost ($/base pair) of macroalgae genome sequencing to levels typical of bacteria such as *E. coli*. Additional technical approaches could include the development of chip or bead based genotyping methods, after an informative SNP set is determined.

[33] https://www.ncbi.nlm.nih.gov/genbank/barcode/

5.3 Technologies/methods for Identification of Biomarkers

ARPA-E has identified four phenotypes that are envisioned to be critical to deployment of a profitable and sustainable macroalgae cultivation industry. These phenotypes are: warm water tolerance, biomass productivity, pest and disease resistance, and nutrient uptake & storage. ARPA-E seeks the identification of linked DNA markers that can be reliably attributed to desired phenotypes.

5.4 Macroalgae Strain Hybridization and Propagation

The genetic diversity of macroalgae is currently undervalued from an industrial perspective. Preliminary studies indicate that significant potential improvements are possible for numerous phenotypic traits via strain hybridization.[34] ARPA-E seeks technologies that dramatically increase the rate of hybrid development. In parallel, improved methods for other advanced breeding techniques such as micropropagation or double haploid could significantly contribute to genetic gains. ARPA-E anticipates that technologies in this area will be transferred to the community through an open source model.

Successful execution of Category 5 projects will occur in a single phase over a period of up to 36 months.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $25 million available for new awards under this FOA for Phase 1 of Category 1 and Categories 2-5 (as described below), subject to the availability of appropriated funds. ARPA-E anticipates making approximately 15 - 20 awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

Individual awards may vary between $250,000 and $10 million.

The period of performance for funding agreements for Categories 2 – 5 may not exceed 36 months. For Category 1, ARPA-E anticipates a 2-phase, 4-year program, but the period of performance for funding agreements for Category 1 will be for Phase 1 only and will not exceed 12 months. Phase 2 of Category 1, a maximum of 3 years, may be awarded to selected Phase 1 projects and will be subject to the availability of appropriated funds. ARPA-E expects the start date for funding agreements to be December 2017, or as negotiated.

[34] Westermeier, R. et al. Macrocystis mariculture in Chile: growth performance of heterosis genotype constructs under field conditions. Journal of Applied Phycology 23:819-825 (2011).

ARPA-E encourages submissions stemming from ideas that still require proof-of-concept R&D efforts as well as those for which some proof-of-concept demonstration already exists.

Submissions requiring proof-of-concept R&D can propose a project with the goal of delivering on the program metric at the conclusion of the period of performance. These submissions must contain an appropriate cost and project duration plan that is described in sufficient technical detail to allow reviewers to meaningfully evaluate the proposed project. If awarded, such projects should expect a rigorous go/no-go milestone early in the project associated with the proof-of-concept demonstration. Alternatively, submissions requiring proof-of-concept R&D can propose a project with the project end deliverable being an extremely creative, but partial solution. However, the Applicants are required to provide a convincing vision how these partial solutions can enable the realization of the program metrics with further development.

Applicants proposing projects for which some initial proof-of-concept demonstration already exists should submit concrete data that supports the probability of success of the proposed project.

ARPA-E will provide support at the highest funding level only for submissions with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

ARPA-E will accept only new submissions under this FOA. Applicants may not seek renewal or supplementation of their existing awards through this FOA.

ARPA-E plans to fully fund your negotiated budget at the time of award.

B. ARPA-E FUNDING AGREEMENTS

Through Cooperative Agreements, Technology Investment Agreements, and similar agreements, ARPA-E provides financial and other support to projects that have the potential to realize ARPA-E's statutory mission. ARPA-E does not use such agreements to acquire property or services for the direct benefit or use of the U.S. Government.

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[35] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.C below.

1. COOPERATIVE AGREEMENTS

[35] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[36]

Cooperative Agreements involve the provision of financial or other support to accomplish a public purpose of support or stimulation authorized by Federal statute. Under Cooperative Agreements, the Government and Prime Recipients share responsibility for the direction of projects.

ARPA-E encourages Prime Recipients to review the Model Cooperative Agreement, which is available at http://arpa-e.energy.gov/arpa-e-site-page/award-guidance.

2. FUNDING AGREEMENTS WITH FFRDCS/DOE LABS, GOGOS, AND FEDERAL INSTRUMENTALITIES

Any Federally Funded Research and Development Centers (FFRDC) involved as a member of a Project Team must provide the information requested in the "FFRDC Lab Authorization" and "Field Work Proposal" section of the Business Assurances & Disclosures Form, which is submitted with the Applicant's Full Application.

When a FFRDC/DOE Lab (including the National Energy Technology Laboratory or NETL) is the *lead organization* for a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the rest of the Project Team. Notwithstanding the use of multiple agreements, the FFRDC/DOE Lab is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

When a FFRDC/DOE Lab is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the rest of the Project Team. Notwithstanding the use of multiple agreements, the Prime Recipient under the Cooperative Agreement is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

Funding agreements with DOE/NNSA FFRDCs take the form of Work Authorizations issued to DOE/NNSA FFRDCs through the DOE/NNSA Field Work Proposal system for work performed under Department of Energy Management & Operation Contracts. Funding agreements with non-DOE/NNSA FFRDCs, GOGOs (including NETL), and Federal instrumentalities (e.g., Tennessee Valley Authority) will be consistent with the sponsoring agreement between the U.S. Government and the Laboratory. Any funding agreement with a FFRDC or GOGO will have similar terms and conditions as ARPA-E's Model Cooperative Agreement (http://arpa-e.energy.gov/arpa-e-site-page/award-guidance).

[36] The Prime Recipient is the signatory to the funding agreement with ARPA-E.

Non-DOE GOGOs and Federal agencies may be proposed to provide support to the project team members on an applicant's project, through a Cooperative Research and Development Agreement (CRADA) or similar agreement.

3. TECHNOLOGY INVESTMENT AGREEMENTS

ARPA-E may use its "other transactions" authority under the America COMPETES Reauthorization Act of 2010 or DOE's "other transactions" authority under the Energy Policy Act of 2005 to enter into Technology Investment Agreements (TIAs) with Prime Recipients. ARPA-E may negotiate a TIA when it determines that the use of a standard cooperative agreement, grant, or contract is not feasible or appropriate for a project.

A TIA is more flexible than a traditional financial assistance agreement. In using a TIA, ARPA-E may modify standard Government terms and conditions. See 10 C.F.R. § 603.105 for a description of a TIA.

In general, TIAs require a cost share of 50%. See Section III.B.2 of the FOA.

C. STATEMENT OF SUBSTANTIAL INVOLVEMENT

ARPA-E is substantially involved in the direction of projects from inception to completion. For the purposes of an ARPA-E project, substantial involvement means:

- Project Teams must adhere to ARPA-E's agency-specific and programmatic requirements.
- ARPA-E may intervene at any time in the conduct or performance of work under an award.
- ARPA-E does not limit its involvement to the administrative requirements of an award. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole.
- During award negotiations, ARPA-E Program Directors and Prime Recipients mutually establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. In addition, ARPA-E will negotiate and establish "Go/No-Go" milestones for each project. If the Prime Recipient fails to achieve any of the "Go/No-Go" milestones or technical milestones and deliverables as determined by the ARPA-E Contracting Officer, ARPA-E may – at its discretion - renegotiate the statement of project objectives or schedule of technical milestones and deliverables for the project. In the alternative, ARPA-E may suspend or terminate the award in accordance with 2 C.F.R. §§ 200.338 and 200.339.

- ARPA-E may provide guidance and/or assistance to the Prime Recipient to accelerate the commercial deployment of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits to provide mentoring and networking opportunities for Prime Recipients. ARPA-E may also organize and sponsor events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E may establish collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[37] as the lead for a Project Team,[38] or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits[39] that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

FFRDCs/DOE Labs are eligible to apply for funding as the lead organization for a Project Team or as a member of a Project Team that includes institutions of higher education, companies, research foundations, or trade and industry research collaborations, but not as a Standalone Applicant.

State, local, and tribal government entities are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

[37] A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.
[38] The term "Project Team" is used to mean any entity with multiple players working collaboratively and could encompass anything from an existing organization to an ad hoc teaming arrangement. A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.
[39] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

Federal agencies and instrumentalities (other than DOE) are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

3. FOREIGN ENTITIES

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team. Foreign entities must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed or to be formed) under the laws of a State or territory of the United States to receive funding. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate. The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at https://arpa-e-foa.energy.gov/. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. CONSORTIUM ENTITIES

Consortia, which may include domestic and foreign entities, must designate one member of the consortium as the consortium representative to the Project Team. The consortium representative must be incorporated in the United States. The eligibility of the consortium will be determined by reference to the eligibility of the consortium representative under Section III.A of the FOA. Each consortium must have an internal governance structure and a written set of internal rules. Upon request, the consortium entity must provide a written description of its internal governance structure and its internal rules to the Contracting Officer (ARPA-E-CO@hq.doe.gov).

Unincorporated consortia must provide the Contracting Officer with a collaboration agreement, commonly referred to as the articles of collaboration, which sets out the rights and responsibilities of each consortium member. This collaboration agreement binds the individual consortium members together and shall include the consortium's:

- Management structure;
- Method of making payments to consortium members;
- Means of ensuring and overseeing members' efforts on the project;
- Provisions for members' cost sharing contributions; and
- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

B. COST SHARING[40]

Applicants are bound by the cost share proposed in their Full Applications.

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.B.1 of the FOA). Under a Cooperative Agreement or Grant, the Prime Recipient must provide at least 20% of the Total Project Cost[41] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[42]

2. INCREASED COST SHARE REQUIREMENT

Large businesses are strongly encouraged to provide more than 20% of the Total Project Cost as cost share. ARPA-E may consider the amount of cost share proposed when selecting applications for award negotiations (see Section V.B.1 of the FOA).

Under a Technology Investment Agreement, the Prime Recipient must provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this minimum cost share requirement, as appropriate.

3. REDUCED COST SHARE REQUIREMENT

ARPA-E has reduced the minimum cost share requirement for the following types of projects:

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is required to provide at least 5% of the Total Project Cost as cost share.

- Small businesses – or consortia of small businesses - will provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the "Cost Share Grace Period").[43] If the project is continued beyond the Cost Share Grace Period, then at least 10% of the Total Project Cost (including the costs

[40] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.
[41] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.
[42] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.
[43] Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards). Applicants that are small businesses will be required to certify in the Business Assurances & Disclosures Form that their organization meets the SBA's definition of a small business under at least one NAICS code.

incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80%, but less than 100%, of the total work under the funding agreement (as measured by the Total Project Cost) the Project Team are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.[44]

- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs are required to provide at least 5% of the Total Project Cost as cost share.

- Project Teams where domestic educational institutions, domestic nonprofits, small businesses, and/or FFRDCs perform greater than or equal to 80%, of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity (such as a large business) receiving patent rights under a class waiver, or other patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.

- Projects that do not meet any of the above criteria are subject to the minimum cost share requirements described in Sections III.B.1 and III.B.2 of the FOA.

4. LEGAL RESPONSIBILITY

Although the cost share requirement applies to the Project Team as a whole, the funding agreement makes the Prime Recipient legally responsible for paying the entire cost share. The Prime Recipient's cost share obligation is expressed in the funding agreement as a static amount in U.S. dollars (cost share amount) and as a percentage of the Total Project Cost (cost share percentage). If the funding agreement is terminated prior to the end of the period of performance, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

The Prime Recipient is solely responsible for managing cost share contributions by the Project Team and enforcing cost share obligations assumed by Project Team members in subawards or related agreements.

[44] See the information provided in previous footnote.

5. COST SHARE ALLOCATION

Each Project Team is free to determine how much each Project Team member will contribute towards the cost share requirement. The amount contributed by individual Project Team members may vary, as long as the cost share requirement for the project as a whole is met.

6. COST SHARE TYPES AND ALLOWABILITY

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G of the FOA.

Project Teams may provide cost share in the form of cash or in-kind contributions. Cash contributions may be provided by the Prime Recipient or Subrecipients. Allowable in-kind contributions include but are not limited to personnel costs, indirect costs, facilities and administrative costs, rental value of buildings or equipment, and the value of a service, other resource, or third party in-kind contribution. Project Teams may use funding or property received from state or local governments to meet the cost share requirement, so long as the funding or property was not provided to the state or local government by the Federal Government.

The Prime Recipient may not use the following sources to meet its cost share obligations:

- Revenues or royalties from the prospective operation of an activity beyond the period of performance;
- Proceeds from the prospective sale of an asset of an activity;
- Federal funding or property (e.g., Federal grants, equipment owned by the Federal Government); or
- Expenditures that were reimbursed under a separate Federal program.

In addition, Project Teams may not use independent research and development (IR&D) funds[45] to meet their cost share obligations under cooperative agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under Technology investment Agreements.

Project Teams may not use the same cash or in-kind contributions to meet cost share requirements for more than one project or program.

[45] As defined in Federal Acquisition Regulation Subsection 31.205-18.

Cost share contributions must be specified in the project budget, verifiable from the Prime Recipient's records, and necessary and reasonable for proper and efficient accomplishment of the project. Every cost share contribution must be reviewed and approved in advance by the Contracting Officer and incorporated into the project budget before the expenditures are incurred.

Applicants may wish to refer to 2 C.F.R. Parts 200 and 910, and 10 C.F.R Part 603 for additional guidance on cost sharing, specifically 2 C.F.R. §§ 200.306 and 910.130, and 10 C.F.R. §§ 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

Because FFRDCs are funded by the Federal Government, costs incurred by FFRDCs generally may not be used to meet the cost share requirement. FFRDCs may contribute cost share only if the contributions are paid directly from the contractor's Management Fee or a non-Federal source.

Because GOGOs/Federal Agencies are funded by the Federal Government, GOGOs/Federal Agencies may not provide cost share for the proposed project. However, the GOGO/Agency costs would be included in Total Project Costs for purposes of calculating the cost-sharing requirements of the applicant.

8. COST SHARE VERIFICATION

Upon selection for award negotiations, Applicants are required to provide information and documentation regarding their cost share contributions. Please refer to Section VI.B.3 of the FOA for guidance on the requisite cost share information and documentation.

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

- The Applicant meets the eligibility requirements in Section III.A of the FOA;
- The Concept Paper complies with the content and form requirements in Section IV.C of the FOA; and

- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

Concept Papers found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Concept Papers, including Concept Papers submitted through other means, Concept Papers submitted after the applicable deadline, and incomplete Concept Papers. A Concept Paper is incomplete if it does not include required information. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Full Applications are deemed compliant if:

- The Applicant submitted a compliant and responsive Concept Paper;
- The Applicant meets the eligibility requirements in Section III.A of the FOA;
- The Full Application complies with the content and form requirements in Section IV.D of the FOA; and
- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

Full Applications found to be noncompliant may not be merit reviewed or considered for award. ARPA-E will not review or consider noncompliant Full Applications, including Full Applications submitted through other means, Full Applications submitted after the applicable deadline, and incomplete Full Applications. A Full Application is incomplete if it does not include required information and documents, such as Forms SF-424 and SF-424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully uploads its response to ARPA-E eXCHANGE by the deadline stated in the FOA.
- The Replies to Reviewer Comments comply with the content and form requirements of Section IV.E of the FOA.

ARPA-E will not review or consider noncompliant Replies to Reviewer Comments, including Replies submitted through other means and Replies submitted after the applicable deadline. ARPA-E will not extend the submission deadline for Applicants that fail to submit required

information due to server/connection congestion. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be noncompliant.

2. RESPONSIVENESS CRITERIA

ARPA-E performs a preliminary technical review of Concept Papers and Full Applications. The following types of submissions may be deemed nonresponsive and may not be reviewed or considered:

- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that have been submitted in response to other currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.
- Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Submissions for large-scale demonstration projects of existing technologies.
- Submissions for proposed technologies that represent incremental improvements to existing technologies.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Submissions for proposed technologies that are not transformational, as described in Section I.A of the FOA.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be scalable such that they could be disruptive with sufficient technical progress.
- Submissions that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.
- Submissions that describe a technology but do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

Submissions that focus on the following topics will be deemed nonresponsive and will not be merit reviewed:

- Cultivation of microalgae
- Cultivation of macroalgae on land, for example in ponds, raceways, tanks. Exceptions may be considered for hatcheries, which are growing seedlings intended for outplanting into the ocean.

- Cultivation of macroalgae in freshwater bodies of water (lakes, streams & rivers)
- Experimental work on conversion processes for macroalgal biomass to fuels
- Genetically engineering macroalgae

4. LIMITATION ON NUMBER OF SUBMISSIONS

ARPA-E is not limiting the number of submissions from Applicants. Applicants may submit more than one application to this FOA, provided that each application is scientifically distinct.

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN ARPA-E eXCHANGE

The first step in applying to this FOA is registration in ARPA-E eXCHANGE, ARPA-E's online application portal. For detailed guidance on using ARPA-E eXCHANGE, please refer to Section IV.H.1 of the FOA and the "ARPA-E eXCHANGE User Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

2. CONCEPT PAPERS

Applicants must submit a Concept Paper by the deadline stated in the FOA. Section IV.C of the FOA provides instructions on submitting a Concept Paper.

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria in Section V.A.1 of the FOA.

ARPA-E will encourage a subset of Applicants to submit Full Applications. Other Applicants will be discouraged from submitting a Full Application in order to save them the time and expense of preparing an application submission that is unlikely to be selected for award negotiations. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. Unsuccessful Applicants should continue to submit innovative ideas and concepts to future FOAs.

3. FULL APPLICATIONS

Applicants must submit a Full Application by the deadline stated in the FOA. Applicants will have approximately 45 days from receipt of the Encourage/Discourage notification to prepare and submit a Full Application. Section IV.D of the FOA provides instructions on submitting a Full Application.

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Full Applications found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Full Application based on the criteria in Section V.A.2 of the FOA.

4. REPLY TO REVIEWER COMMENTS

Once ARPA-E has completed its review of Full Applications, reviewer comments on compliant and responsive Full Applications are made available to Applicants via ARPA-E eXCHANGE. Applicants may submit an optional Reply to Reviewer Comments, which must be submitted by the deadline stated in the FOA. Section IV.E of the FOA provides instructions on submitting a Reply to Reviewer Comments.

ARPA-E performs a preliminary review of Replies to determine whether they are compliant, as described in Section III.C.1 of the FOA. ARPA-E will review and consider compliant Replies only. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be non-compliant.

5. PRE-SELECTION CLARIFICATIONS AND "DOWN-SELECT" PROCESS

Once ARPA-E completes its review of Full Applications and Replies to Reviewer Comments, it may, at the Contracting Officer's discretion, conduct a pre-selection clarification process and/or perform a "down-select" of Full Applications. Through the pre-selection clarification process or down-select process, ARPA-E may obtain additional information from select Applicants through pre-selection meetings, webinars, videoconferences, conference calls, written correspondence, or site visits that can be used to make a final selection determination. ARPA-E will not reimburse Applicants for travel and other expenses relating to pre-selection meetings or site visits, nor will these costs be eligible for reimbursement as pre-award costs.

ARPA-E may select applications for funding and make awards without pre-selection meetings and site visits. Participation in a pre-selection meeting or site visit with ARPA-E does not signify that Applicants have been selected for award negotiations.

6. SELECTION FOR AWARD NEGOTIATIONS

ARPA-E carefully considers all of the information obtained through the application process and makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.A.2 and V.B.1 of the FOA. The Selection Official may select all or part of a Full Application for award negotiations. The Selection Official may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

Applicants are promptly notified of ARPA-E's selection determination. ARPA-E may stagger its selection determinations. As a result, some Applicants may receive their notification letter in advance of other Applicants. Please refer to Section VI.A of the FOA for guidance on award notifications.

7. MANDATORY WEBINAR

All selected Applicants, including the Principal Investigator and the financial manager for the project, are required to participate in a webinar that is held within approximately one week of the selection notification. During the webinar, ARPA-E officials present important information on the award negotiation process, including deadlines for the completion of certain actions.

B. APPLICATION FORMS

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424 and Budget Justification Workbook/SF-424A. A sample Summary Slide is available on ARPA-E eXCHANGE. Applicants may use the templates available on ARPA-E eXCHANGE, including the template for the Concept Paper, the template for the Technical Volume of the Full Application, the template for the Summary Slide, the template for the Summary for Public Release, the template for the Reply to Reviewer Comments, and the template for the Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures Form is available on ARPA-E eXCHANGE.

C. CONTENT AND FORM OF CONCEPT PAPERS

The Concept Paper is mandatory (i.e. in order to submit a Full Application, a compliant and responsive Concept Paper must have been submitted) and must conform to the following formatting requirements:

> Concept Papers that address Category 1 or more than just one Category shall not exceed six (6) pages in length including graphics, figures, and/or tables. Concept Papers that address only one among Categories 2, 3, 4, or 5 shall not exceed five (5) pages in length including graphics, figures, and/or tables.

- The Concept Paper must be submitted in Adobe PDF format.
- The Concept Paper must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11 inch paper with margins not less than one inch on every side. Single space all text and use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The ARPA-E assigned Control Number, the Lead Organization Name, and the Principal Investigator's Last Name must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.
- The first paragraph must include the Lead Organization's Name and Location, Principal Investigator's Name, Technical Category, Proposed Funding Requested (Federal and Cost Share), and Project Duration.

Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award (see Section III.C of the FOA).

Each Concept Paper must be limited to a single concept or technology. Unrelated concepts and technologies must not be consolidated into a single Concept Paper. However, a single concept or technology may address more than one of the Categories listed in Section I.D of the FOA.

A fillable Concept Paper template is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

Concept Papers must conform to the content requirements described below. If Applicants exceed the maximum page length indicated above, ARPA-E will review only the authorized number of pages and disregard any additional pages.

1. CONCEPT PAPER

a. CONCEPT SUMMARY

- Describe the proposed concept with minimal jargon, and explain how it addresses the Program Objectives of the FOA.

b. INNOVATION AND IMPACT

- Clearly identify the problem to be solved with the proposed technology concept.
- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.
- Explain the concept's potential to be disruptive compared to existing or emerging technologies.
- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the Technical Performance Targets in Section I.E of the FOA for the appropriate Technology Category in Section I.D of the FOA.

c. PROPOSED WORK

- Describe the final deliverable(s) for the project and the overall technical approach used to achieve project objectives.
- Discuss alternative approaches considered, if any, and why the proposed approach is most appropriate for the project objectives.
- Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach. Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.
- Describe why the proposed effort is a significant technical challenge and the key technical risks to the project. Does the approach require one or more entirely new technical developments to succeed? How will technical risk be mitigated?
- Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant.
- Estimated federal funds requested; total project cost including cost sharing.

d. TEAM ORGANIZATION AND CAPABILITIES

- Indicate the roles and responsibilities of the organizations and key personnel that comprise the Project Team.

- Provide the name, position, and institution of each key team member and describe in 1-2 sentences the skills and experience that he/she brings to the team.

- Identify key capabilities provided by the organizations comprising the Project Team and how those key capabilities will be used in the proposed effort.

- Identify (if applicable) previous collaborative efforts among team members relevant to the proposed effort.

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

F. INTERGOVERNMENTAL REVIEW

This program is not subject to Executive Order 12372 (Intergovernmental Review of Federal Programs).

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

H. OTHER SUBMISSION REQUIREMENTS

1. USE OF ARPA-E eXCHANGE

To apply to this FOA, Applicants must register with ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx). ARPA-E will not review or consider applications submitted through other means (e.g., fax, hand delivery, email, postal mail). For detailed guidance on using ARPA-E eXCHANGE, please refer to the "ARPA-E eXCHANGE User Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

Upon creating an application submission in ARPA-E eXCHANGE, Applicants will be assigned a Control Number. If the Applicant creates more than one application submission, a different Control Number will be assigned for each application.

Once logged in to ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx), Applicants may access their submissions by clicking the "My Submissions" link in the navigation on the left side of the page. Every application that the Applicant has submitted to ARPA-E and the corresponding Control Number is displayed on that page. If the Applicant submits more than one application to a particular FOA, a different Control Number is shown for each application.

Applicants are responsible for meeting each submission deadline in ARPA-E eXCHANGE. **Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.** Under normal conditions (i.e., at least 48 hours in advance of the submission deadline), Applicants should allow at least 1 hour to submit a Concept Paper, or Full Application. In addition, Applicants should allow at least 15 minutes to submit a Reply to Reviewer Comments. Once the application is submitted in ARPA-E eXCHANGE, Applicants may revise or update their application until the expiration of the applicable deadline.

Applicants should not wait until the last minute to begin the submission process. During the final hours before the submission deadline, Applicants may experience server/connection congestion that prevents them from completing the necessary steps in ARPA-E eXCHANGE to submit their applications. **ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.**

ARPA-E will not review or consider incomplete applications and applications received after the deadline stated in the FOA. Such applications will be deemed noncompliant (see Section III.C.1 of the FOA). The following errors could cause an application to be deemed "incomplete" and thus noncompliant:

- Failing to comply with the form and content requirements in Section IV of the FOA;
- Failing to enter required information in ARPA-E eXCHANGE;
- Failing to upload required document(s) to ARPA-E eXCHANGE;
- Failing to click the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA;
- Uploading the wrong document(s) or application(s) to ARPA-E eXCHANGE; and
- Uploading the same document twice, but labeling it as different documents. (In the latter scenario, the Applicant failed to submit a required document.)

ARPA-E urges Applicants to carefully review their applications and to allow sufficient time for the submission of required information and documents.

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

ARPA-E performs a preliminary review of Concept Papers and Full Applications to determine whether they are compliant and responsive (see Section III.C of the FOA). ARPA-E also performs a preliminary review of Replies to Reviewer Comments to determine whether they are compliant.

ARPA-E considers a mix of quantitative and qualitative criteria in determining whether to encourage the submission of a Full Application and whether to select a Full Application for award negotiations.

1. CRITERIA FOR CONCEPT PAPERS

(1) *Impact of the Proposed Technology Relative to FOA Targets* (50%) - This criterion involves consideration of the following:

- The potential for a transformational and disruptive (not incremental) advancement compared to existing or emerging technologies;
- Achievement of the technical performance targets defined in Section I.E of the FOA for the appropriate technology Category in Section I.D of the FOA;
- Identification of techno-economic challenges that must be overcome for the proposed technology to be commercially relevant; and
- Demonstration of awareness of competing commercial and emerging technologies and identifies how the proposed concept/technology provides significant improvement over existing solutions.

(2) *Overall Scientific and Technical Merit* (50%) - This criterion involves consideration of the following:

- The feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;
- Sufficiency of technical approach to accomplish the proposed R&D objectives, including why the proposed concept is more appropriate than alternative approaches and how technical risk will be mitigated;

- Clearly defined project outcomes and final deliverables; and

- The demonstrated capabilities of the individuals performing the project, the key capabilities of the organizations comprising the Project Team, the roles and responsibilities of each organization and (if applicable) previous collaborations among team members supporting the proposed project.

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement. The above criteria will be weighted as follows:

Impact of the Proposed Technology Relative to FOA Targets	50%
Overall Scientific and Technical Merit	50%

2. CRITERIA FOR FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

In addition to the above criteria, ARPA-E may consider the following program policy factors in determining which Concept Papers to encourage to submit a Full Application and which Full Applications to select for award negotiations:

I. **ARPA-E Portfolio Balance**. Project balances ARPA-E portfolio in one or more of the following areas:
   a. Diversity (including gender) of technical personnel in the proposed Project Team;
   b. Technological diversity;
   c. Organizational diversity;
   d. Geographic diversity;
   e. Technical or commercialization risk; or
   f. Stage of technology development.

II. **Relevance to ARPA-E Mission Advancement.** Project contributes to one or more of ARPA-E's key statutory goals:
   a. Reduction of US dependence on foreign energy sources;
   b. Stimulation of domestic manufacturing/U.S. Manufacturing Plan;
   c. Reduction of energy-related emissions;
   d. Increase in U.S. energy efficiency;
   e. Enhancement of U.S. economic and energy security; or
   f. Promotion of U.S. advanced energy technologies competitiveness.

III. **Synergy of Public and Private Efforts**.
   a. Avoids duplication and overlap with other publicly or privately funded projects;
   b. Promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer; or
   c. Increases unique research collaborations.

IV. **Low likelihood of other sources of funding.** High technical and/or financial uncertainty that results in the non-availability of other public, private or internal funding or resources to support the project.

V. **High-Leveraging of Federal Funds**. Project leverages Federal funds to optimize advancement of programmatic goals by proposing cost share above the required minimum or otherwise accessing scarce or unique resources.

VI. **High Project Impact Relative to Project Cost.**

2. ARPA-E REVIEWERS

By submitting an application to ARPA-E, Applicants consent to ARPA-E's use of Federal employees, contractors, and experts from educational institutions, nonprofits, industry, and governmental and intergovernmental entities as reviewers. ARPA-E selects reviewers based on their knowledge and understanding of the relevant field and application, their experience and skills, and their ability to provide constructive feedback on applications.

ARPA-E requires all reviewers to complete a Conflict-of-Interest Certification and Nondisclosure Agreement through which they disclose their knowledge of any actual or apparent conflicts and agree to safeguard confidential information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments. In addition, ARPA-E trains its reviewers in proper evaluation techniques and procedures.

Applicants are not permitted to nominate reviewers for their applications. Applicants may contact the Contracting Officer by email (ARPA-E-CO@hq.doe.gov) if they have knowledge of a potential conflict of interest or a reasonable belief that a potential conflict exists.

3. ARPA-E SUPPORT CONTRACTOR

ARPA-E utilizes contractors to assist with the evaluation of applications and project management. To avoid actual and apparent conflicts of interest, ARPA-E prohibits its support contractors from submitting or participating in the preparation of applications to ARPA-E.

By submitting an application to ARPA-E, Applicants represent that they are not performing support contractor services for ARPA-E in any capacity and did not obtain the assistance of ARPA-E's support contractor to prepare the application. ARPA-E will not consider any applications that are submitted by or prepared with the assistance of its support contractors.

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

Noncompliant and nonresponsive Concept Papers and Full Applications are rejected by the Contracting Officer and are not merit reviewed or considered for award. The Contracting Officer sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. The notification letter states the basis upon which the Concept Paper or Full Application was rejected.

2. CONCEPT PAPER NOTIFICATIONS

ARPA-E promptly notifies Applicants of its determination to encourage or discourage the submission of a Full Application. ARPA-E sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. ARPA-E provides feedback in the notification letter in order to guide further development of the proposed technology.

Applicants may submit a Full Application even if they receive a notification discouraging them from doing so. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily

reflect judgments on the merits of the proposed project. The purpose of the Concept Paper phase is to save Applicants the considerable time and expense of preparing a Full Application that is unlikely to be selected for award negotiations.

A notification letter encouraging the submission of a Full Application does not authorize the Applicant to commence performance of the project. Please refer to Section IV.G.2 of the FOA for guidance on pre-award costs.

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN MARCH 2017]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

Upon the issuance of a FOA, only the Contracting Officer may communicate with Applicants. ARPA-E personnel and our support contractors are prohibited from communicating (in writing or otherwise) with Applicants regarding the FOA. This "quiet period" remains in effect until ARPA-E's public announcement of its project selections.

During the "quiet period," Applicants are required to submit all questions regarding this FOA to ARPA-E-CO@hq.doe.gov. Questions and Answers (Q&As) about ARPA-E and the FOA are available at http://arpa-e.energy.gov/faq. For questions that have not already been answered, please send an email with the FOA name and number in the subject line to ARPA-E-CO@hq.doe.gov. Due to the volume of questions received, ARPA-E will only answer pertinent questions that have not yet been answered and posted at the above link.

- ARPA-E will post responses on a weekly basis to any questions that are received. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- ARPA-E will cease to accept questions approximately 5 business days in advance of each submission deadline. Responses to questions received before the cutoff will be posted approximately one business day in advance of the submission deadline. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- Responses are posted to "Questions and Answers" on ARPA-E's website (http://arpa-e.energy.gov/faq).

Applicants may submit questions regarding ARPA-E eXCHANGE, ARPA-E's online application portal, to ExchangeHelp@hq.doe.gov. ARPA-E will promptly respond to emails that raise legitimate, technical issues with ARPA-E eXCHANGE. ARPA-E will refer any questions regarding the FOA to ARPA-E-CO@hq.doe.gov.

ARPA-E will not accept or respond to communications received by other means (e.g., fax, telephone, mail, hand delivery). Emails sent to other email addresses will be disregarded.

During the "quiet period," only the Contracting Officer may authorize communications between ARPA-E personnel and Applicants. The Contracting Officer may communicate with Applicants as necessary and appropriate. As described in Section IV.A of the FOA, the Contracting Officer may arrange pre-selection meetings and/or site visits during the "quiet period."

B. DEBRIEFINGS

ARPA-E does not offer or provide debriefings. ARPA-E provides Applicants with a notification encouraging or discouraging the submission of a Full Application based on ARPA-E's assessment of the Concept Paper. In addition, ARPA-E provides Applicants with reviewer comments on Full Applications before the submission deadline for Replies to Reviewer Comments.

VIII. OTHER INFORMATION

A. FOAS AND FOA MODIFICATIONS

FOAs are posted on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/), Grants.gov (http://www.grants.gov/), and FedConnect (https://www.fedconnect.net/FedConnect/). Any modifications to the FOA are also posted to these websites. You can receive an e-mail when a modification is posted by registering with FedConnect as an interested party for this FOA. It is recommended that you register as soon as possible after release of the FOA to ensure that you receive timely notice of any modifications or other announcements. More information is available at https://www.fedconnect.net.

B. OBLIGATION OF PUBLIC FUNDS

The Contracting Officer is the only individual who can make awards on behalf of ARPA-E or obligate ARPA-E to the expenditure of public funds. A commitment or obligation by any individual other than the Contracting Officer, either explicit or implied, is invalid.

ARPA-E awards may not be transferred, assigned, or assumed without the prior written consent of a Contracting Officer.

C. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

Applicants are required to make a full and complete disclosure of the information requested in the Business Assurances & Disclosures Form. Disclosure of the requested information is mandatory. Any failure to make a full and complete disclosure of the requested information may result in:

- The rejection of a Concept Paper, Full Application, and/or Reply to Reviewer Comments;
- The termination of award negotiations;
- The modification, suspension, and/or termination of a funding agreement;
- The initiation of debarment proceedings, debarment, and/or a declaration of ineligibility for receipt of Federal contracts, subcontracts, and financial assistance and benefits; and
- Civil and/or criminal penalties.

D. RETENTION OF SUBMISSIONS

ARPA-E expects to retain copies of all Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions. No submissions will be returned. By applying to ARPA-E for funding, Applicants consent to ARPA-E's retention of their submissions.

E. MARKING OF CONFIDENTIAL INFORMATION

ARPA-E will use data and other information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments strictly for evaluation purposes.

Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions containing confidential, proprietary, or privileged information must be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

The cover sheet of the Concept Paper, Full Application, Reply to Reviewer Comments, or other submission must be marked as follows and identify the specific pages containing confidential, proprietary, or privileged information:

> Notice of Restriction on Disclosure and Use of Data:
>
> Pages [___] of this document may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for evaluation purposes or in accordance with a financial assistance or loan agreement between the submitter and the Government. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

The header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure." In addition, every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

F. TITLE TO SUBJECT INVENTIONS

Ownership of subject inventions is governed pursuant to the authorities listed below. Typically, either by operation of law or under the authority of a patent waiver, Prime Recipients and

Subrecipients may elect to retain title to their subject inventions under ARPA-E funding agreements.

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions. If they elect to retain title, they must file a patent application in a timely fashion.

- All other parties: The Federal Non-Nuclear Energy Act of 1974, 42. U.S.C. 5908, provides that the Government obtains title to new inventions unless a waiver is granted (*see below)*.

- Class Waiver: Under 42 U.S.C. § 5908, title to subject inventions vests in the U.S. Government and large businesses and foreign entities do not have the automatic right to elect to retain title to subject inventions. However, ARPA-E typically issues "class patent waivers" under which large businesses and foreign entities that meet certain stated requirements, such as cost sharing of at least 20% may elect to retain title to their subject inventions. If a large business or foreign entity elects to retain title to its subject invention, it must file a patent application in a timely fashion. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. §784.

- GOGOs are subject to the requirements of 37 CFR Part 501.

- Determination of Exceptional Circumstances (DEC): Each Applicant is required to submit a U.S. Manufacturing Plan as part of its Full Application. The U.S. manufacture provision included in Attachment 2 of an award is included as part of the U.S. Manufacturing Plan. If selected, the U.S. Manufacturing Plan may be incorporated into the award terms and conditions for domestic small businesses and nonprofit organizations. DOE has determined that exceptional circumstances exist that warrants the modification of the standard patent rights clause for small businesses and non-profit awardees under Bayh-Dole to the extent necessary to implement and enforce the U.S. Manufacturing Plan. For example, the commitments and enforcement of a U.S. Manufacturing Plan may be tied to subject inventions. Any Bayh-Dole entity (domestic small business or nonprofit organization) affected by this DEC has the right to appeal it. The DEC is dated September 9, 2013 and is available at the following link: http://energy.gov/gc/downloads/determination-exceptional-circumstances-under-bayh-dole-act-energy-efficiency-renewable.

G. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

Where Prime Recipients and Subrecipients retain title to subject inventions, the U.S. Government retains certain rights.

1. GOVERNMENT USE LICENSE

The U.S. Government retains a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States any subject invention throughout the world. This license extends to contractors doing work on behalf of the Government.

2. MARCH-IN RIGHTS

The U.S. Government retains march-in rights with respect to all subject inventions. Through "march-in rights," the Government may require a Prime Recipient or Subrecipient who has elected to retain title to a subject invention (or their assignees or exclusive licensees), to grant a license for use of the invention. In addition, the Government may grant licenses for use of the subject invention when Prime Recipients, Subrecipients, or their assignees and exclusive licensees refuse to do so.

The U.S. Government may exercise its march-in rights if it determines that such action is necessary under any of the four following conditions:

- The owner or licensee has not taken or is not expected to take effective steps to achieve practical application of the invention within a reasonable time;
- The owner or licensee has not taken action to alleviate health or safety needs in a reasonably satisfactory manner;
- The owner has not met public use requirements specified by Federal statutes in a reasonably satisfactory manner; or
- The U.S. Manufacturing requirement has not been met.

3. U.S. MANUFACTURING REQUIREMENT

ARPA-E requires that awards address whether products embodying or produced through the use of subject inventions (i.e., inventions conceived or first actually reduced to practice under ARPA-E funding agreements) are to be substantially manufactured in the United States by Project Teams and their licensees. The requirement varies depending upon whether an awardee is a small business, University or other type of awardee. The Applicant may request a modification or waiver of the U.S. Manufacturing Requirement.

H. RIGHTS IN TECHNICAL DATA

Data rights differ based on whether data is first produced under an award or instead was developed at private expense outside the award.

- Background or "Limited Rights Data": The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.

- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to five years in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

I. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

Applicants may not include any Protected Personally Identifiable Information (Protected PII) in their submissions to ARPA-E. Protected PII is defined as data that, if compromised, could cause harm to an individual such as identity theft. Listed below are examples of Protected PII that Applicants must not include in their submissions.

- Social Security Numbers in any form;
- Place of Birth associated with an individual;
- Date of Birth associated with an individual;
- Mother's maiden name associated with an individual;
- Biometric record associated with an individual;
- Fingerprint;
- Iris scan;
- DNA;
- Medical history information associated with an individual;
- Medical conditions, including history of disease;
- Metric information, e.g. weight, height, blood pressure;
- Criminal history associated with an individual;
- Ratings;
- Disciplinary actions;

- Performance elements and standards (or work expectations) are PII when they are so intertwined with performance appraisals that their disclosure would reveal an individual's performance appraisal;
- Financial information associated with an individual;
- Credit card numbers;
- Bank account numbers; and
- Security clearance history or related information (not including actual clearances held).

J. COMPLIANCE AUDIT REQUIREMENT

A prime recipient organized as a for-profit entity expending $750,000 or more of DOE funds in the entity's fiscal year (including funds expended as a Subrecipient) must have an annual compliance audit performed at the completion of its fiscal year. For additional information, refer to Subpart F of: (i) 2 C.F.R. Part 200, and (ii) 2 C.F.R. Part 910.

If an educational institution, non-profit organization, or state/local government is either a Prime Recipient or a Subrecipient, and has expended $750,000 or more of Federal funds in the entity's fiscal year, the entity must have an annual compliance audit performed at the completion of its fiscal year. For additional information refer to Subpart F of 2 C.F.R. Part 200.

IX. GLOSSARY

Applicant: The entity that submits the application to ARPA-E. In the case of a Project Team, the Applicant is the lead organization listed on the application.

Application: The entire submission received by ARPA-E, including the Concept Paper, Full Application, and Reply to Reviewer Comments.

ARPA-E: is the Advanced Research Projects Agency – Energy, an agency within the U.S. Department of Energy.

Cost Sharing: is the portion of project costs from non-Federal sources that are borne by the Prime Recipient (or non-Federal third parties on behalf of the Prime Recipient), rather than by the Federal Government.

Deliverable: A deliverable is the quantifiable goods or services that will be provided upon the successful completion of a project task or sub-task.

DOE: U.S. Department of Energy.

DOE/NNSA: U.S. Department of Energy/National Nuclear Security Administration

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

GOCOs: U.S. Government Owned, Contractor Operated laboratories.

GOGOs: U.S. Government Owned, Government Operated laboratories.

Milestone: A milestone is the tangible, observable measurement that will be provided upon the successful completion of a project task or sub-task.

Prime Recipient: The signatory to the funding agreement with ARPA-E.

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing inventive supportive work that is part of an ARPA-E project.

Standalone Applicant: An Applicant that applies for funding on its own, not as part of a Project Team.

Subject Invention: Any invention conceived or first actually reduced to practice under an ARPA-E funding agreement.

Task: A task is an operation or segment of the work plan that requires both effort and resources. Each task (or sub-task) is connected to the overall objective of the project, via the achievement of a milestone or a deliverable.

Total Project Cost: The sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs, FFRDCs, and GOCOs.

TT&O: Technology Transfer and Outreach. (See Section IV.G.8 of the FOA for more information).