SEAS
Scalable Biomass Energy from Marine Aquatic Sources

Marc von Keitz
Program Director, ARPA-E
marc.vonkeitz@hq.doe.gov

Pre-FOA Release Webinar
November 29, 2016
Outline

- ARPA-E Overview
- Program Motivation
- Program Structure
- Application Process Overview & Timeline
- Teaming
ARPA-E Mission

Catalyze the development of transformational, high-impact energy technologies

Reduce Energy-Related Emissions
Reduce Energy Imports
Improve Energy Efficiency

Ensure the U.S. maintains a lead in the development and deployment of advanced energy technologies
ARPA-E’s History

In 2007, The National Academies recommended Congress establish an Advanced Research Projects Agency within the U.S. Department of Energy* …“The new agency proposed herein [ARPA-E] is patterned after that model [of DARPA] and would sponsor creative, out-of-the-box, transformational, generic energy research in those areas where industry by itself cannot or will not undertake such sponsorship, where risks and potential payoffs are high, and where success could provide dramatic benefits for the nation.”…

Rising Above the Gathering Storm
Published
America COMPETES Act Signed

2007
2009
2010
2011
2012
2013
2014
2015
2016

Awards Announced

Programs To Date

37
1
7
12
16
20
23
32
500+
39

2007
Rising Above the Gathering Storm
Published

2009
American Recovery & Reinvestment Act
Signed

2010
America COMPETES Reauthorization
Signed

2011

2012

2013

2014

2015

2016

37
1
7
12
16
20
23
32

$400 Million (Recovery Act)
$180 Million (FY2011)
$275 Million (FY2012)
$251 Million (FY2013)
$280 Million (FY2014)
$280 Million (FY2015)
$291 Million (FY2016)

Anticipated

$400 Million (Recovery Act)
$180 Million (FY2011)
$275 Million (FY2012)
$251 Million (FY2013)
$280 Million (FY2014)
$280 Million (FY2015)
$291 Million (FY2016)
### ARPA-E Programs and OPENs

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OPEN 2009: 36 projects
OPEN 2012: 66 projects
OPEN 2015: 41 projects
ARPA-E Program Framing Questions

- What is the problem to be solved?
- What is the current state of R&D? How is the proposed program a transformative and disruptive approach?
- Why is now the right time to solve this problem?
- What research communities need to be brought together?
- What happens at the conclusion of the program? What are the barriers to commercialization and how might these problems be overcome?
- How does the program complement R&D efforts in other DOE programs, federal agencies, and the private sector?
- What are the program goals and how will progress towards those goals be measured?
- If successful, how will the proposed program impact one or more of ARPA-E’s mission areas?

Adapted from the DARPA Heilmeier questions
Developing ARPA-E Focused Programs

PROGRAM DEVELOPMENT CYCLE

ESTABLISH

Project Selection

Contract Negotiations & Awards

EXECUTE

Ongoing Technical Review

Project Handoff

ENVISION

Program Conception (Idea/Vision)

Workshop

ENGAGE

Program Approval

EVALUATE

Proposal Rebuttal

Merit Review of Proposals

FOA Development & Issuance

Transition Toward Market Adoption

ARPA-E Program Directors
ARPA-E Macroalgae Workshop

ARPA-E Macroalgae Workshop Agenda  
February 11-12, 2016  
Capital Hilton, 1001 16th St NW, Washington, DC 20036

Webpage  
http://arpa-e.energy.gov/?q=workshop/macroalgae-workshop

Contains links to workshop presentations, breakout sessions summary, literature review, other workshop resources
Scalable Biomass Energy from Marine Aquatic Sources

Macroalgae Biomass:
- No Land
- No Freshwater
- No Fertilizer

SEAS creates new biomass production opportunities for the vast ocean resources of the United States.

Anticipated FOA release in December 2016.

Photos copyright (top to bottom): Dana Barbour/National Geographic, the Island Institute, Bron Smith/Huffington Post
Scalable Biomass Energy from Marine Aquatic Sources

Program Motivation

If it works...

will it matter?
Biomass critical for reducing GHG emissions

In 2°C Scenario (2DS), biomass becomes largest primary energy source by 2050.

Source: ETP 2016, IEA
Oceans are the largest untapped growth opportunity for biomass

70% of world’s surface

Water

Nutrients
Macroalgae (aka seaweed) – the quintessential ocean crop

- Amenable to cultivation & harvest
- Mostly carbohydrate & protein

Global Algae Production, 2013

- Kappaphycus
- Laminaria
- Gracilaria

- Many different species
- Fast growth rate
An existing & growing industry

Global macroalgae biomass production

http://earthobservatory.nasa.gov/IOTD/view.php?id=85747
U.S. Exclusive Economic Zone (EEZ) is equivalent to the total U.S. land area

<table>
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<th>US Area (USDA 2006)</th>
<th>Sq km</th>
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<td>Total Land Area</td>
<td>9,158,022</td>
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<td>Grassland</td>
<td>2,370,000</td>
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<tr>
<td>Forestry</td>
<td>2,640,000</td>
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<tr>
<td>Cropland</td>
<td>1,786,000</td>
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<tr>
<td>Exclusive Economic Zone (offshore)</td>
<td>11,351,000</td>
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Key Questions for ARPA-E:

Can macroalgae ever be energy-relevant?

Photo: MBARI
How much is enough?

1 Quad \((10^{15} \text{ BTU})\) Ethanol \((\sim 13 \text{ billion gal})\)

210 million MT of dry seaweed \((\sim 2.1 \text{ billion MT wet})\)

100x current world production

18 million acres \((\sim 28,000 \text{ square miles})\)

\(\frac{1}{2}\) Size of Iowa

Photo: MBARI
Where should we focus our effort?
Focus on scalable, cost-competitive, and sustainable biomass production

- Production system should be scalable to millions of tons of dry biomass

- Target to be cost competitive with terrestrially produced biomass (at “ocean” farm gate)

- Energy input requirement should not be higher than for cellulosic biomass crops
Key requirements for macroalgae energy farms

- Accessing “free” nutrients predictably and reliably
- Expanding beyond the inter-tidal zone into deeper, off-shore waters
- Energy-efficient harvesting
- High productivity of individual plant and the whole system

Photo: Erik K Veland
Nutrient Supply and Management Strategies

- Nutrient availability is key factor in siting future farms and assessing maximum size

- Natural upwelling

- Coastal and river discharge (dead-zones)

- Deep water nutrients either by
  - Active pumping (possibly combined with OTEC)
  - Dipping (Marine Bioenergy – OPEN 2015)

- Modelling of nutrient flow/uptake through the farm is going to be critical to arrive at suitable designs
Key requirements for macroalgae energy farms

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Photo: Erik K Veland
Anchored long-lines are state of the art

As we go further out to sea, anchor lines get longer and wave forces get stronger.

We probably need new/better designs

Goudey, C.A. 2015 Kelp Farm Design for Long Island Sound, NACE/MAS Aquaculture Conference, Portland, ME
What is the (general) cost structure for a commercial operation?

**A.**

- Hatchery Capex: $17
- Hatchery Opex: $3
- Aquafarm Capex: $8
- Aquafarm Opex: $26
- H&T Capex: $35
- Total: $95

**B.**

<table>
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<th>Major Assumptions</th>
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<td>Hectares</td>
<td>3,000</td>
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<tr>
<td>Target yield, DMT/Ha</td>
<td>25</td>
</tr>
<tr>
<td>DMT/yr</td>
<td>61,000</td>
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<tr>
<td>WMT/yr</td>
<td>485,000</td>
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<tr>
<td>Capacity factor</td>
<td>90%</td>
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<tr>
<td>Seeding frequency/yr</td>
<td>1</td>
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<tr>
<td>Interest rate</td>
<td>0%</td>
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<tr>
<td>Fuel price/gallon</td>
<td>$3.00</td>
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<tr>
<td>Meter culture rope/Ha</td>
<td>6,600</td>
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<tr>
<td>Harvester boats</td>
<td>1</td>
</tr>
<tr>
<td>FTEs</td>
<td>47</td>
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<tr>
<td>Labor rate, fully loaded per FTE</td>
<td>$20,000</td>
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**Production cost, $/DMT**

$95
New designs are needed to reduce farm costs

Aquafarming Equipment Breakdown

- **Boats**: $5.0
- **Aquafarm Equipment**: $25.0
- **Installation**: 26%
- **Culture rope**: 20%
- **Anchors & chain**: 17%
- **Structural rope**: 9%
- **Hardware**: 13%
- **Buoys**: 10%
- **Survey**: 5%

Millions

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Key requirements for macroalgae energy farms

- Accessing “free” nutrients predictably and reliably
- Expanding beyond the inter-tidal zone into deeper, off-shore waters
- Energy-efficient harvesting
- High productivity of individual plant and the whole system

Photo: Erik K Veland
Harvest technology paradigm shift

- Power harvest system with renewable energy
- High degree of automation, e.g. autonomous vehicles
- Slow speeds reduce energy consumption
Key requirements for macroalgae energy farms

- Accessing “free” nutrients predictably and reliably
- Expanding beyond the inter-tidal zone into deeper, off-shore waters
- Energy-efficient harvesting
- High productivity of individual plant and the whole system

Photo: Erik K Veland
Examples of top opportunities to drive down cost – it’s all about productivity

- Increase biomass yield per $ of invested CapEx
- Increase productivity through farm design (e.x. optimization of nutrient flow)
- Increase planting density
- Increase plot productivity with combination of farm design and genetics/strain development
- Integration of harvesting with the farm system to drive down cost

Change in Seaweed Cost (USD/DMT)

Change in variables between low and high values:

- Target Yield (DMT)
- dry weight (%)
- harvest rate, tons/hr
- hr unloading time/refuel/crew change
- Harvester cost
- boat worker salary, fully loaded
- Hectares
- m culture rope/Ha
- small boats/1000 Ha
- yrs, rope lifetime
- fuel price, $/gal
- hp auxiliary bow engine (during mowing)
- boat FTE annual salary, fully loaded
- aquafarm capacity utilization
- gal/hp/hr
- Ha serviced per day per workboat
- hp engine of work boat
- miles average round-trip distance
The path to fuels will likely go through the animal feed market
Program Structure
Scalable Biomass Energy from Marine Aquatic Sources

Macroalgae Biomass:
No Land
No Freshwater
No Fertilizer

SEAS creates new biomass production opportunities for the vast ocean resources of the United States.

Anticipated FOA release in December 2016.
Macroalgae to fuel unit operations

- Strain Development & Breeding
- Hatchery & Nursery
- Cultivation & Farm management
- Harvest & Transport
- Processing

Wild stocks
Germplasm
Korea

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arpa.e
CHANGING WHAT'S POSSIBLE
Program Structure/Categories

Cat 1: Novel Designs
Cat 2: Advanced Components

Cultivation & Harvesting System – Design & Demonstration

Phase 1 (12 mo) → Stage Gate → Phase 2 (36 mo)

Cat 3: Computational Modeling
- Computational Fluid Dynamics
- Finite Element
- Hydrodynamics
- Nutrient Flux
Up to 24 months

Cat 4: Aquatic Monitoring
- Biomass growth
- Biomass composition
- Disease/predation
- In situ nutrients
Up to 36 months

Cat 5: Advanced Breeding
- Hybridization Technologies
- Sequencing
- Genetic marker identification
Up to 36 months

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Scalable Biomass Energy from Marine Aquatic Sources

Application Process Overview & Timeline
Application Process (High-level view)

Receipt of Concept Papers
- 60 days

Concept Paper Review Process (Encourage/Discourage Full Application)
- 30 - 45 days

Receipt of Full Application (FA)
- 45 - 60 days

FA Review Process
- ~ 60 days

Notification of selection for award negotiations
Contracting Options

- Cooperative Agreement
- Technology Investment Agreement
- Work Authorization (DOE only)
- Interagency Agreement
- CRADA
What Makes an ARPA-E Project?

**IMPACT**
- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

**TRANSFORM**
- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today’s technologies

**BRIDGE**
- Translates science into breakthrough technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

**TEAM**
- Comprised of best-in-class people
- Cross-disciplinary skill sets
- Translation oriented
ARPA-E Resources

- ARPA-E UNIVERSITY
- REGIONAL RESOURCES
- ANNUAL ENERGY INNOVATION SUMMIT
- ACTIVE PROGRAM MANAGEMENT
- ARPA-E ENGAGE
Teaming
Teaming List – Building the Community

- https://arpa-e-foa.energy.gov (RFI-0000027)

- Opportunity to connect with interested parties in the field

- Tell people what your capabilities and relevant resources are

- Spell out areas of expertise you are looking for, if you are trying to form a team

- Link to enter your profile:
  https://arpa-e-foa.energy.gov/Applicantprofile.aspx
Teaming List Entries as of 11/28/2016

Red markers: Teaming list entries
Blue markers: Webinar participants not on teaming list
Thank you!

Questions?