ARPA-E Programs in Macroalgal Mariculture and Hydrokinetic Energy Systems

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Presentation Overview

• Overview of ARPA-E
• MARINER Program – Offshore Macroalgae Mariculture
• Potential New Program in Hydrokinetic Energy Systems
What is ARPA-E?

The Advanced Research Projects Agency-Energy (ARPA-E) is an agency within the U.S. Department of Energy that:

- Provides **Research and Development** funding for high-risk, high-reward, transformational ideas

- Focuses on technologies that could **fundamentally change** the way we get, use and store energy

- Accelerates energy innovations that will create a more secure, affordable, and sustainable **American energy future**
**ARPA-E Mission**

**Mission:** To overcome long-term and high-risk technological barriers in the development of energy technologies

Ensure U.S. Technological Lead & U.S. Economic and Energy Security

- REDUCE IMPORTS
- IMPROVE EFFICIENCY
- REDUCE EMISSIONS
ARPA-E Impact Indicators

Since 2009 ARPA-E has provided
$2 billion in R&D funding to more than 800 projects

145 Projects have attracted more than $2.9 billion in private-sector follow-on funding

76 projects have formed new companies

131 projects have partnered with other government agencies for further development

2,489 peer-reviewed journal articles from ARPA-E projects

346 patents issued by U.S. Patent and Trademark Office

As of March 2019
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
If it works... will it matter?
Where Can We Work Together?

Near Term: How can we structure the hydrokinetic FOA to address specific concerns?

Long Term (2-4 years): Are there opportunities for prototype deployment projects?

PROGRAM CYCLE
~4 YEARS

PROJECT HANDOFF
Transition Toward Market Adoption
DEFINITION
COMPETITION
ACTIVELY MANAGED EXECUTION
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Macroalgae Research Inspiring Novel Energy Resources (MARINER)

Dr. Marc von Keitz  Dr. Krishna Doraiswamy
Program Director    T2M Advisor
This Program Is All About Macroalgae aka Seaweed

- Many different species
- Fast growth rate

- Amenable to cultivation & harvest
- Mostly carbohydrate & protein
Why Do We Care About Macroalgae?

• By 2050: ~9 billion people = 30% more energy & 50-100% more food

• Biomass is critical for both and provides important flexibility for low-carbon energy.

• However, we should not rely on terrestrial biomass alone…due to other land use needs, freshwater challenges, and climate change uncertainties.

• Oceans are the largest untapped opportunity for biomass production…
  …70% of the planet’s surface; abundant light, water, and nutrients.

• The U.S. has great potential to produce energy, as well as food and feed from ocean farmed seaweeds!
Initial Focus on Biomass Production…

Multi Point Moorings

Single Point Moorings

Free Floating

Seaweed Ranching
...Starting to Look at Conversion to Biogas

- Research is needed to make seaweed feedstock cost competitive.
- There may be specific markets where it could be deployed earlier.
- Is there a chance to deploy a prototype system?
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Hydrokinetics: Tidal and Riverine Energy Conversion Systems

Dr. Mario Garcia-Sanz
Program Director

Michael Olsen
T2M Advisor
Why Tidal and Riverine Energy?

- Large resources
- Precise generation prediction. No uncertainty
- Low visual impact. Low land use
- No risk of extreme weather conditions. Long-term survivability
- Opens space for new business. Potentially great impact of small business
- Economically attractive (LCOE)
- Technically achievable

How does an ideal energy system look?

- Enormous. Larger than described in publications
- Intersection of Wind & Marine Engineering
- Like a clock. Moon/Sun/Topology
- Inside the water
- Protected at seabed
- New space!!!!

Tidal
Riverine

Still expensive LCOE. New program
Lunar Energy: The Tidal Resource

**Alaska**

Tidal power in Alaska (GeorgiaTech)

Available = ~ 415.2 TWh/yr
Extractable = ~ 12 GW

**Local area**

Coastal topography
Bathymetry
Resonances

We need **turbines** not only for high tides but also for **lower tide** places

The 4th largest tidal worldwide **Tide bore** (9.2 m in height max, travel at 7 m/s, 4.7 GW extractable)

Current Energy In Rivers and Canals

- Generated by Earth’s gravity
- Existing plants based on head (h) or flow (Q)

\[ P = \gamma hQ \]

Francis & Kaplan turbines
Reactive –low h, high Q
Based on pressure

Large infrastructure

We need turbines that use hydrodynamic (lift) breakthroughs, like wind

\[ P = \frac{1}{2} \rho A_r C_p \mu v^3 \]

Pelton turbines
Impulsive –high h, low Q
Based on water velocity

Small infrastructure
When limitations in current assessments are considered, overall resources increase between 30-50%

Current Systems Are Still Too Expensive

**Tidal Turbines**

- **SeaGen**, 2008
  - 2x600 kW

- **AR-1000**, 2011
  - 1 MW

- **AR-1500**, 2017
  - 1.5 MW

- **Andritz Hydro Hamm.**
  - 1 MW

**Riverine & Canal Turbines**

- **Verdant Power**
  - 35 kW

- **ORPC**, RivGen, 2015
  - 50 kW

- **Emrgy/GE**, Twin, 2019
  - 7.5 to 15 kW
Remote Communities May Be Early Adopters

A 40 kW riverine energy project in Igiugig, Alaska to replace diesel loads in the village

**Project Details:**

- Current energy costs are $0.98/kWh.
- Historic loads of 40 kW (summer) – 95 kW (winter).
- Short (225 ft) underwater cable for grid connection.
- CapEx estimated at $300,000 ($7.5/MW) and OpEx at $12,000 per year ($300/kW/yr). Payback period of 3 years.

These Deployments Have Unique Challenges

Aspects we are asking teams to design for:

Need to be Robust to Operate in Harsh Environments

• Handle debris during operations.
• Be designed for areas that may freeze or see drastically reduced water levels seasonally.
• Require little operational maintenance and be easy to install, remove, and access.
• Ready for micro-grid deployment.
These Deployments Have Unique Challenges

Aspects we are asking teams to design for:

Need to be designed for minimum impact on ecosystems:
- Avoid disruption of fish migration and sense the presence of aquatic species.
- Avoid collisions with marine mammals.
- Minimize impact on sea/river bed, sediment transport, and other structures in the local environment.
These Deployments Have Unique Challenges

**Design for micro-grid operation**
(e.g., voltage control, frequency control)

- **Type 1** – Conventional Induction Generator
- **Type 2** – Variable Rotor-Resistance Induction Generator
- **Type 3** – Doubly-Fed Asynchronous Generator
- **Type 4** – Synchronous generator with full-power converter

These deployments have unique challenges.
Question 1: What Other Challenges Are There?
We Want To Fund Radical New Designs…

…And We Want to Test Them in Physical Environments
This Can Start In a Tank and Move to The Real World

Scaled Model Experiments

3+ Year Timeline

Real World Prototype Deployment
Question 2: Where Can We Deploy Prototype Systems?
Thank You

Any Questions?

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