# ARPA-E and the Ocean:

## Harnessing U.S. Energy Resources through Transformational Marine Technologies

Dan Rogers

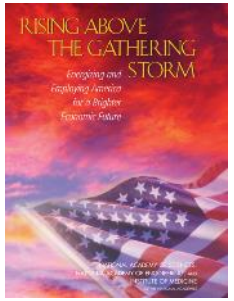
Technology-to-Market Advisor, Marine Technologies

March 3, 2023

# ABOUT ARPA-E

# History of ARPA-E

In 2007, The National Academies recommended Congress establish an Advanced Research Projects Agency within the U.S. Department of Energy to fund advanced energy R&D.



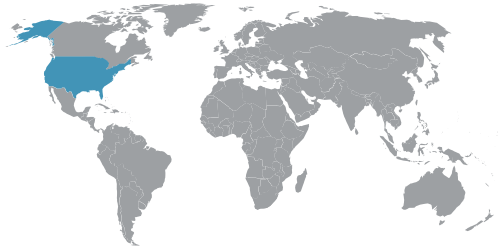

**2007**

*Rising Above the Gathering Storm* **Published** - warning policymakers that U.S. advantages in science and technology had begun to erode

*America COMPETES Act* **Signed** – authorizing the creation of ARPA-E

**2009**

*American Recovery & Reinvestment Act* **Signed** – Providing ARPA-E its first appropriations of $400 million, which funded ARPA-E's first projects



**2022**

**1,415+** Awards
**69+** Programs

Current Funding:
**$470M**
(FY23)

arpa·e
CHANGING WHAT'S POSSIBLE

# ARPA-E Mission

**Goal 1:** To enhance the economic and energy security of the United States through the development of energy technologies that—


**Goal 2:** To ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.

arpa·e
CHANGING WHAT'S POSSIBLE


arpa·e
CHANGING WHAT'S POSSIBLE

# ARPA-E Impact Indicators 2022

Since 2009 ARPA-E has provided

**$3.27 billion**

in R&D funding to more than **1,415 projects**

**200 projects**

have attracted more than

**$11 billion**

in private-sector follow-on funding

**131 companies**

formed by **ARPA-E projects**

**26 exits**

market valuations worth

**$21.8 billion**

from mergers, acquisitions, and IPOs

**281 projects**

have **partnered with other government agencies** for further development

**6,257**

peer-reviewed **journal articles** from ARPA-E projects

**934 patents**

issued by U.S. Patent and Trademark Office

**289 licenses**

reported from ARPA-E projects

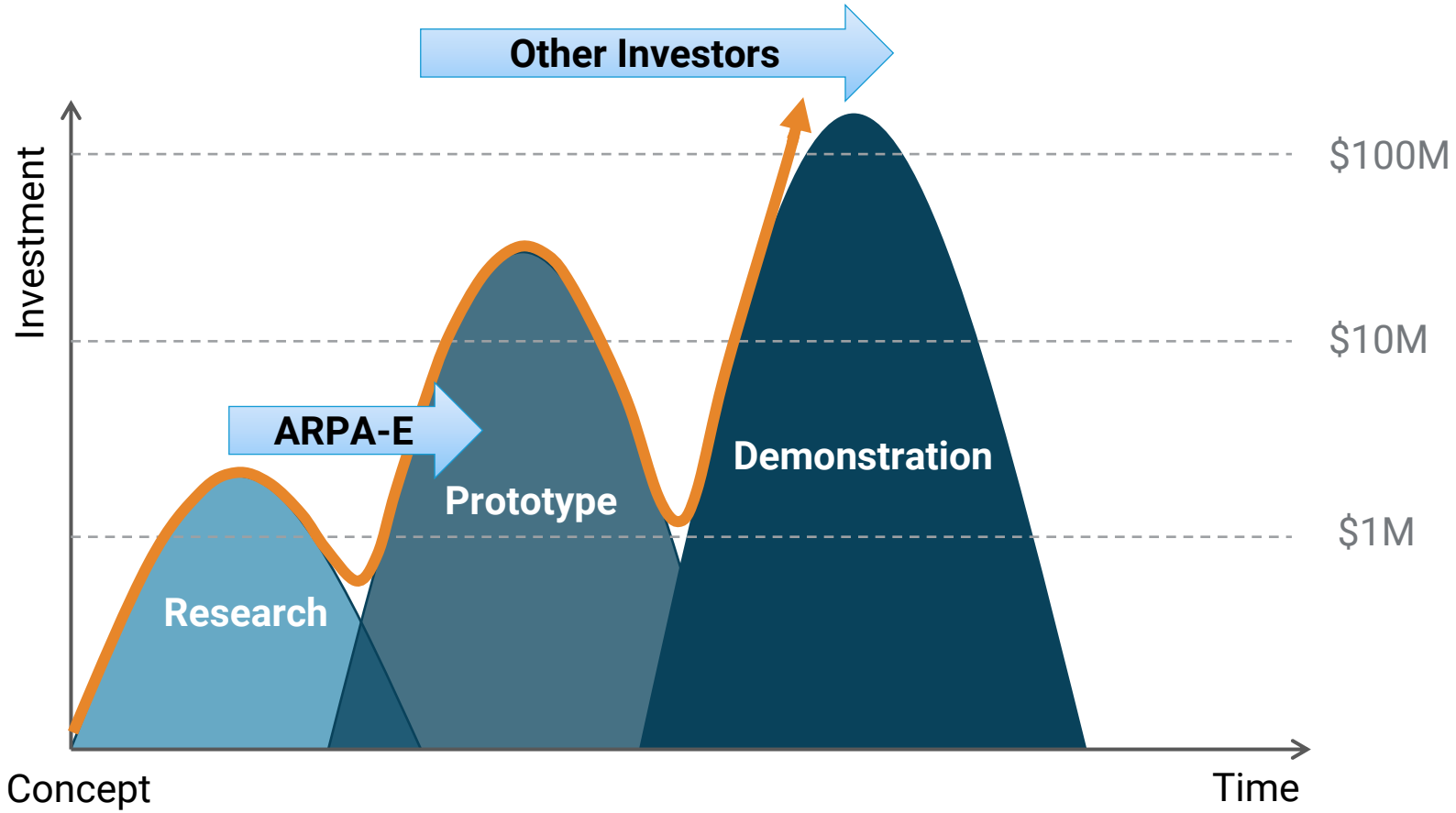
As of September 2022

arpa·e
CHANGING WHAT'S POSSIBLE

# ARPA-E OPERATIONS

# Built on DARPA foundation, but with key differences…

# ARPA-E Creates a "Mountain of Opportunity" for Energy Technology




***High risk, high impact!***

arpa·e
CHANGING WHAT'S POSSIBLE

# 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**

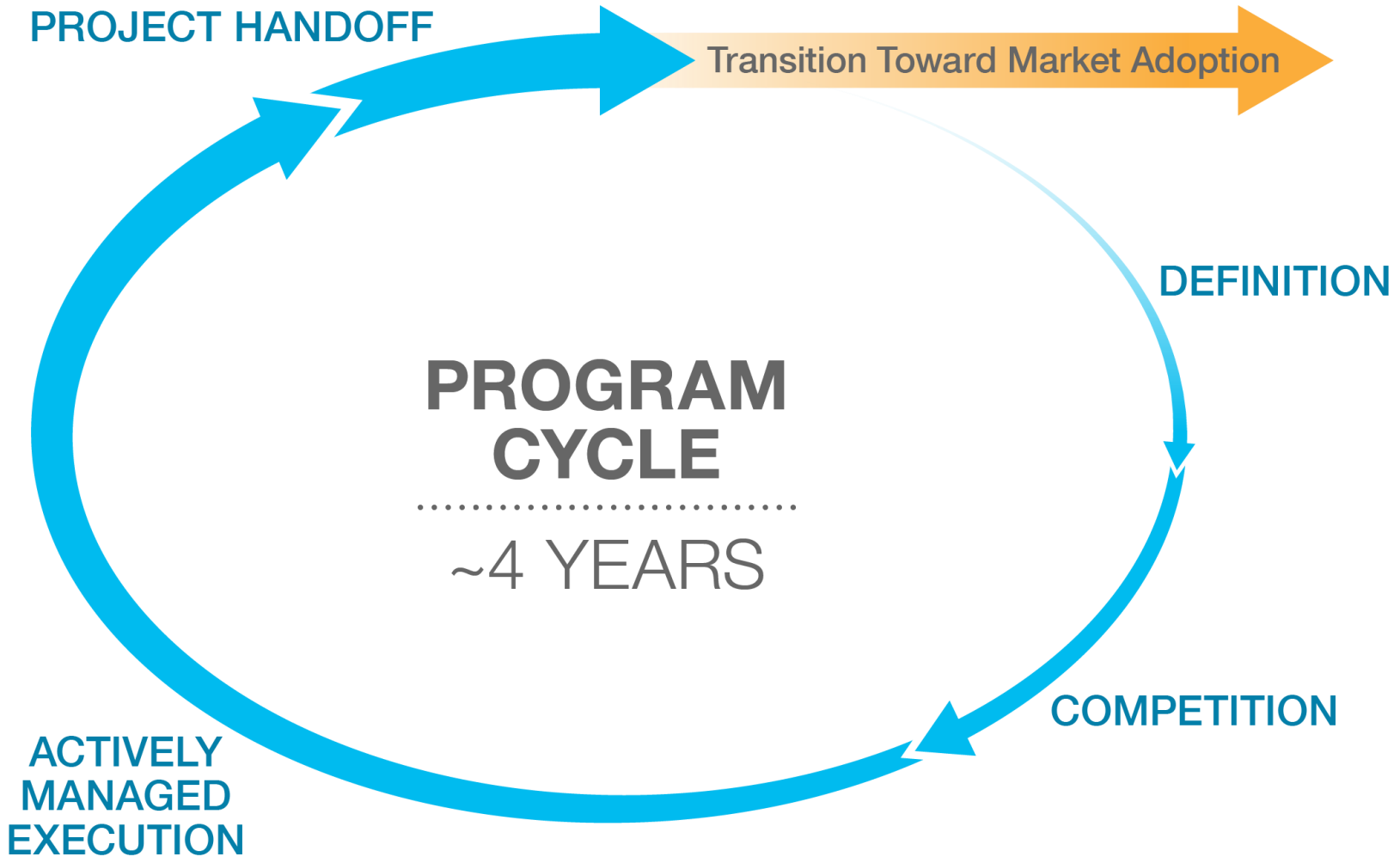
- Translates science into breakthrough technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

**TEAM**

- Comprises best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

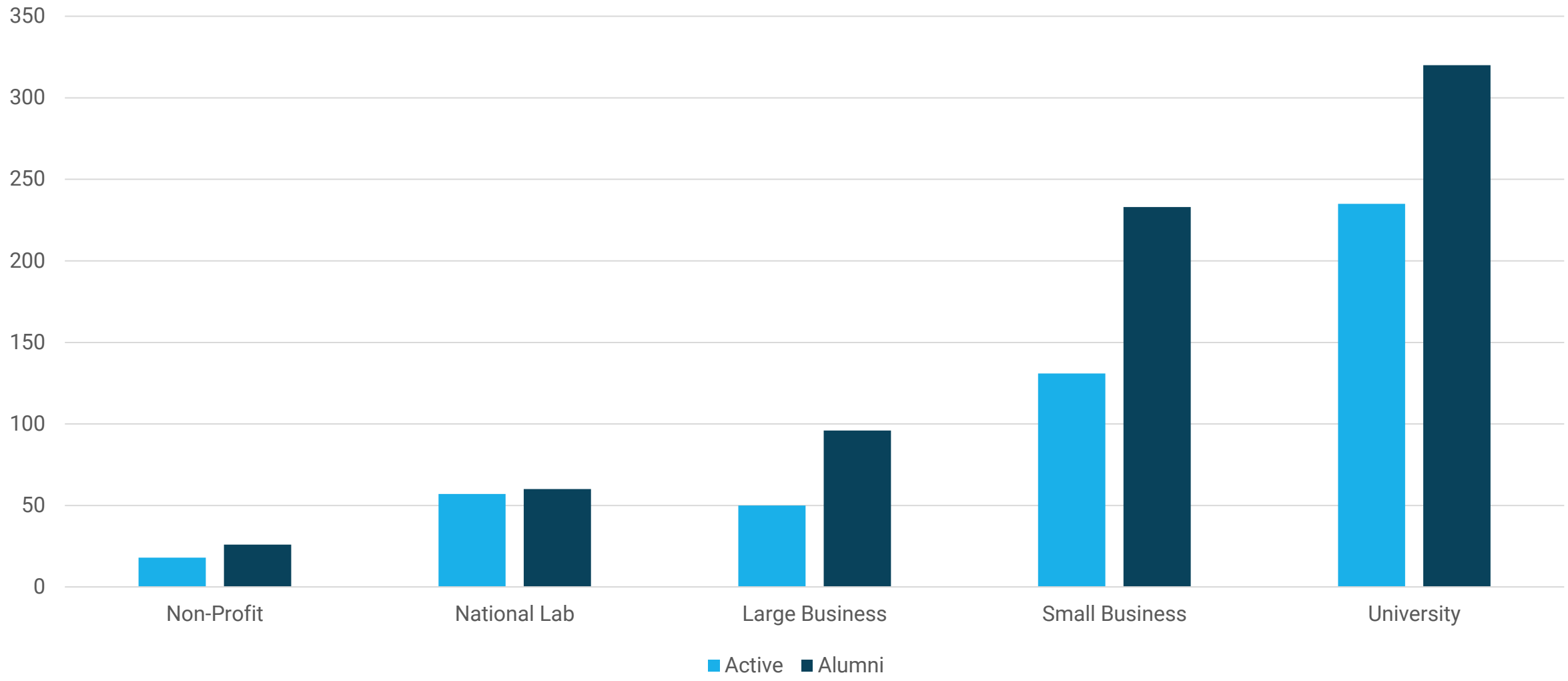
arpa·e
CHANGING WHAT'S POSSIBLE

# Technology Acceleration Model




arpa·e
CHANGING WHAT'S POSSIBLE

# ARPA-E Projects by Organization Type




CHANGING WHAT'S POSSIBLE

As of September 2022

# ARPA-E PROGRAMS

# ARPA-E Program Types

ARPA-E projects are funded through programs, where each program comprises a number of projects. ARPA-E generally runs two different program types:
**Open** and **Focused.**

**$100M**

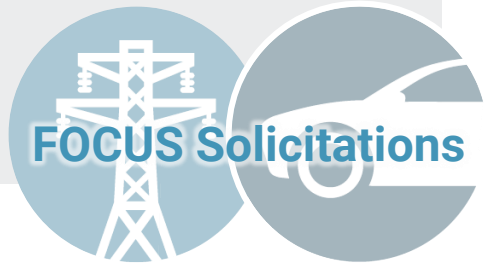
**OPEN** programs support new technologies across the full spectrum of energy applications.

- Complement focused programs
- Support innovative “one off” projects
- Historically run once every 3 years, with smaller


**$30-50M**

**FOCUS** programs support a defined technology or application area.

- Technical opportunities for transformation
- Portfolio of projects with different approaches
- Several programs released per year




arpa·e
CHANGING WHAT'S POSSIBLE

# SCALEUP Program ($100M, every 2 years)

**Small business, company, and industry participation is at the core of the SCALEUP program**

Focuses on scale-up and pre-pilot projects of promising technologies that ARPA-E has funded and for which the scale-up would substantially build upon innovations achieved under the original ARPA-E award

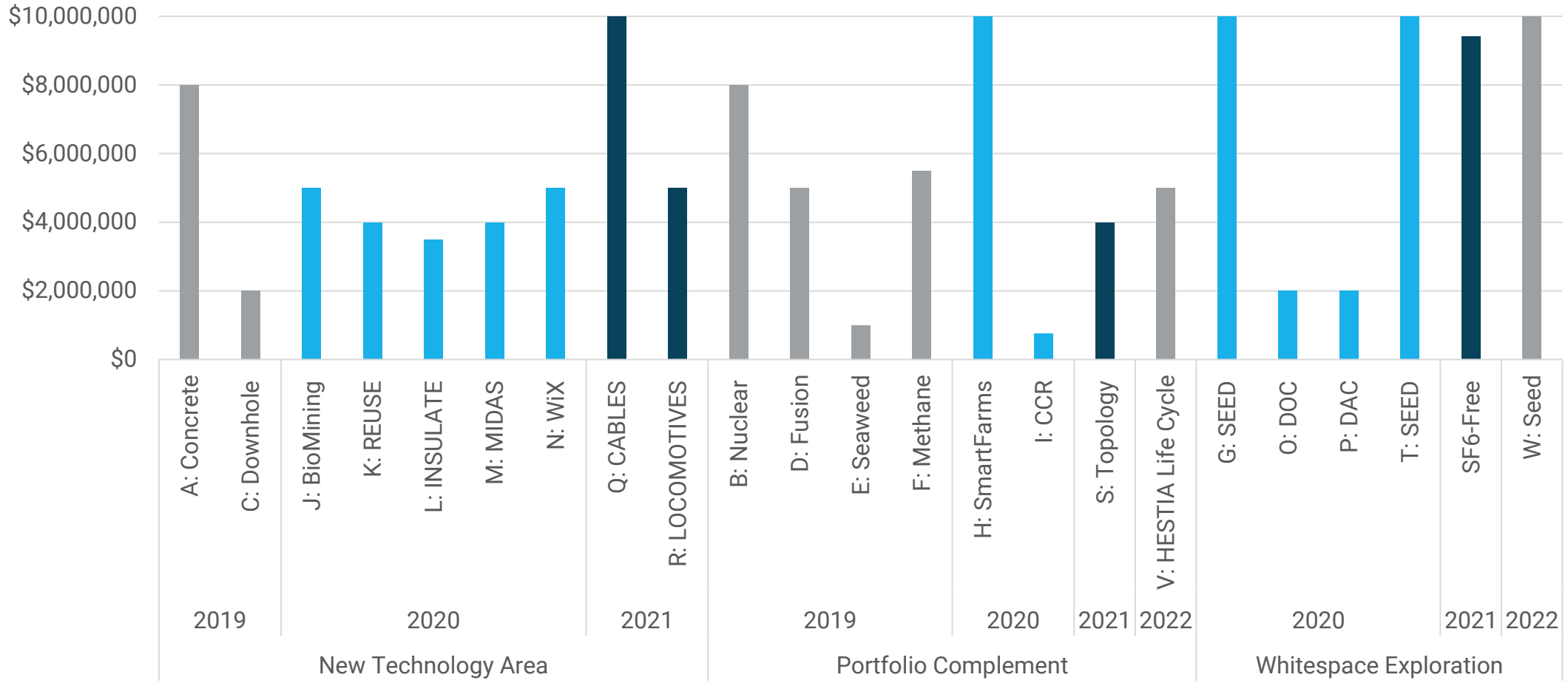
Applicants must own/control ***subject invention(s) or software*** arising from ARPA-E award(s).

SCALEUP is designed to encourage ***company and industry*** participation. Must ***partner*** with potential customers, end-users, suppliers, etc.

arpa·e
CHANGING WHAT'S POSSIBLE

# Exploratory Topics

Topics explore new areas of technology development that, if successful, could establish new program areas for ARPA-E, or complement the current portfolio of ARPA-E programs




**$129M allocated to 23 Topics as of September 2022**

# ARPA-E Program Portfolio


arpa·e
CHANGING WHAT'S POSSIBLE

# MARINE TECHNOLOGY PROGRAMS

# ATLANTIS

**Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control**

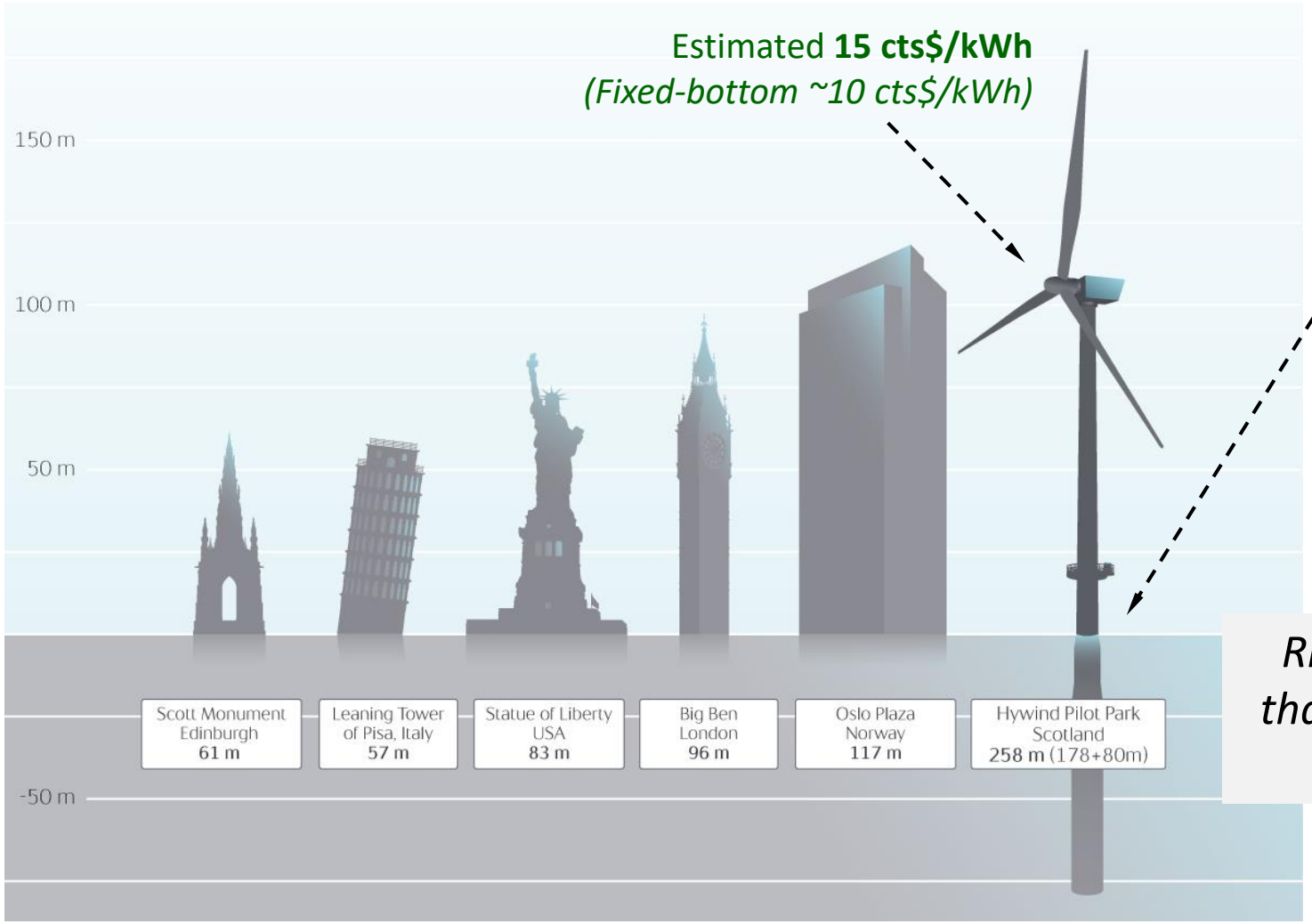
- ATLANTIS is developing technical pathways to enable low-cost floating offshore wind turbines
- ATLANTIS utilizes control co-design, an approach that considers controls from the early stages of design to enable fundamentally new systems. The goal is to dramatically reduce the mass of the floating platform, which is the primary cost driver
- The program aims to reduce Levelized cost of energy to $0.075/kWh

Electricity Generation

## PROGRAM OVERVIEW

| Funding Amount | Project Count | Program Director | T2M Advisor | Year |
|---|---|---|---|---|
| $43 million | 15 | Dr. Mario Garcia-Sanz | Ken Pulido | 2019 |

# Currently: Floating Wind is too Expensive




***Copying* the land-based solution for floating offshore!**

**= *Colossal Mass* to stabilize system**

*(~70% of CapEx is Floating Platform)*

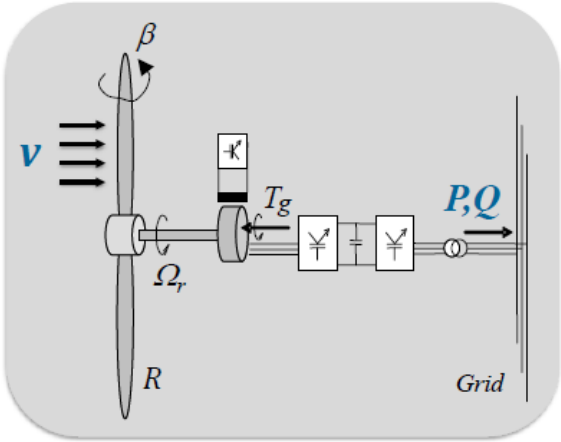
*Risks for FOWTs are different than for O&G. Need to **change the design paradigm.***

***Control Co-Design***
***= Radical mass reduction***

# SHARKS

## Submarine Hydrokinetic And Riverine Kilo/megawatt Systems

- The SHARKS program seeks to develop new designs for economically attractive Hydrokinetic Turbines (HKT) for tidal and riverine currents.
- Applying: Control Co-Design (CCD), Co-Design (CD), and Designing-for-OpEx(DFO)
- Significant reduction in LCOE (~60%) compared to the current state-of-the-art by reducing mass and reducing OpEx




Electricity Generation

### PROGRAM OVERVIEW

| Funding Amount | Project Count | Program Director | T2M Advisor | Year |
|---|---|---|---|---|
| $38 million | 11 | Dr. Mario Garcia-Sanz | Dan Rogers | 2020 |

# What are Hydrokinetic Turbines?

**Underwater turbines** that harness the energy of moving water in **rivers and tidal streams**

- Potential to provide energy across a **wide variety of regions**.
- Forecastable and predictable -> **complement other renewable energy** sources.
- The **cost is too high** to be viable.
- Driven by high **OpEx**, low **technical readiness**, and difficulty of deploying in **aquatic environments.**

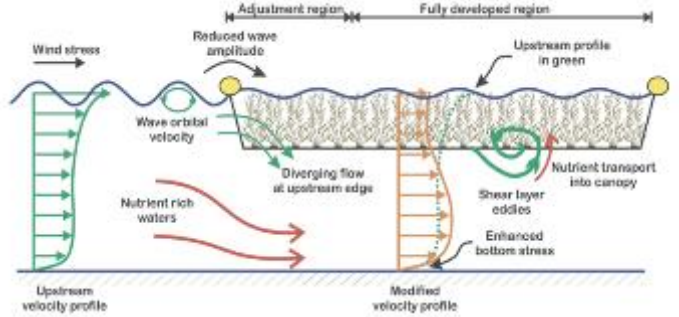
# MARINER: Macroalgae Research Inspiring Novel Energy Resources

**Category 2:** Design & Experimental Deployment of Critical Component Technologies


**Category 4:** Design & Deployment of Aquatic Monitoring Technology and Tools


**Category 1:** Design & Experimental Deployment of Cultivation and Harvesting Systems

**Category 3:** Development & Validation of Computational Modeling Tools



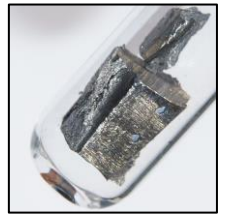

**Category 5:** Research & Development of Breeding and Genetic Tools

# How ARPA-E Values Macroalgae

MACROALGAE HARVEST

STABILIZATION

- EXTRACTION
  - Phycocolloids
  - Biochemicals
  - **Metals (Rare-Earth Elements)**
- FERMENTATION
  - Biogas
  - Alcohols
  - Esters, Acids
- HYDROTHERMAL PROCESSING
  - Gas
  - Chemicals
  - Liquid hydrocarbons
- PARTIAL PROCESSING
  - **Human foods**
  - **Animal feed**
  - **Methane abatement**
  - **Fertilizers**
  - **Carbon (CDR)**



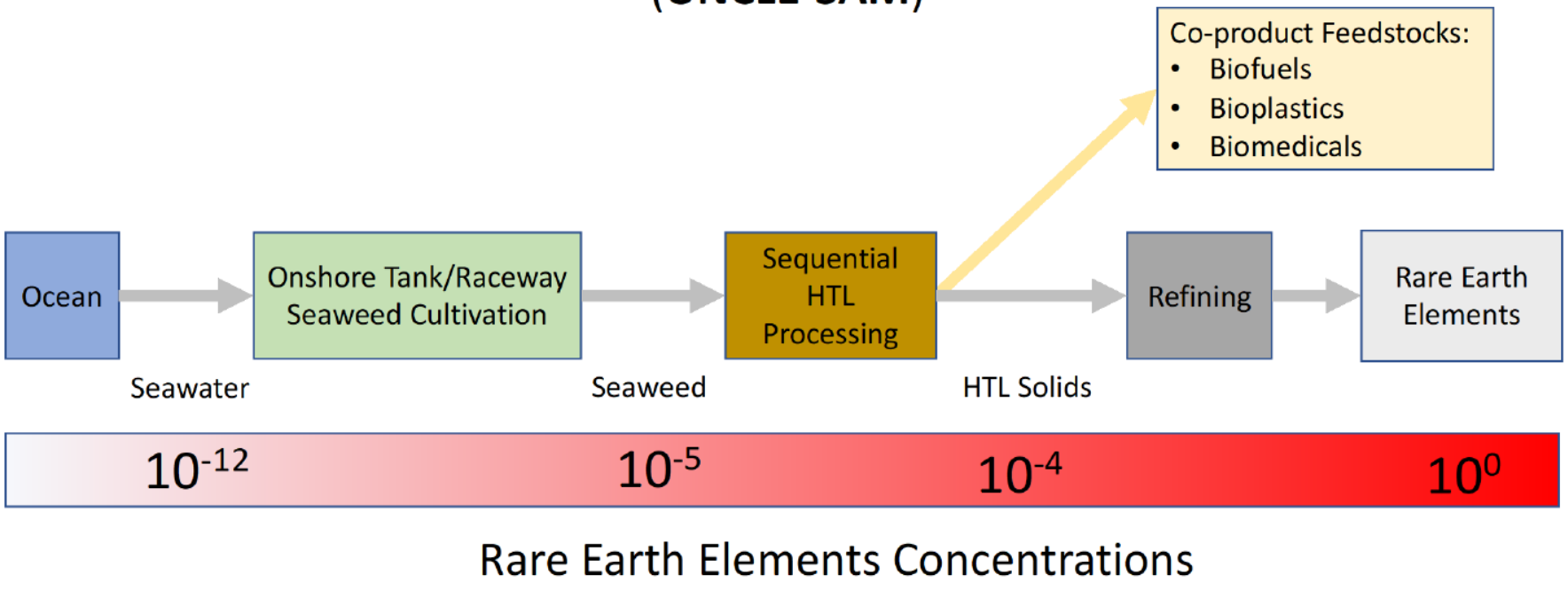

Based on: http://www.seaweed.ie/uses_general/usesdiagram.php

# Exploratory Topics on Algal Mining

Pacific Northwest NATIONAL LABORATORY

Colorado State University

**UN**realized **C**ritical **L**anthanide **E**xtraction via **S**ea **A**lgae **M**ining (**UNCLE-SAM**)

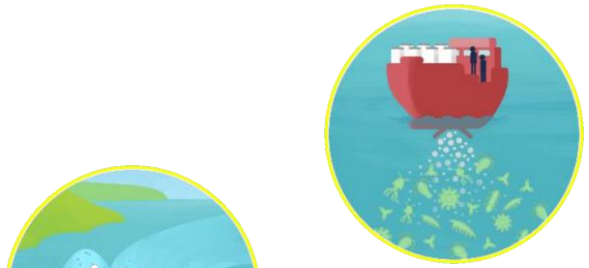


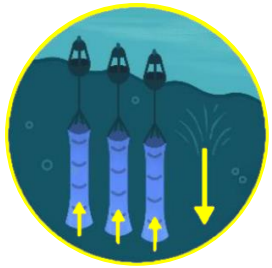

*Source: PNNL and CSU*

# SEA $CO_2$ Program:
## *Sensing Exports of Anthropogenic Carbon through Ocean Observation*

*"So in estimating the effectiveness of [**IRON FERTILIZATION**] for ocean CDR,* ***there remains a large uncertainty****…"*

*"[**ALKALINITY ENHANCEMENT**] has potential benefits…although* ***empirical data are necessary to determine the effectiveness****…"*





*"…hence* ***there is significant uncertainty*** *as to where and when [**ARTIFICAL UPWELLING**] could generate net carbon sequestration."*

*"In principle, [**SEAWEED CULTIVATION**] should work, but* ***there is a large degree of uncertainty****…"*

*"Although [recovery of] **MARINE ECOSYSTEMS** have been proposed as a climate solution,* ***there is a fair amount of uncertainty****…"*

*"…**ELECTROCHEMICAL PROCESSES** that couple with the world's oceans* ***may exert unintended consequences****."*

arpa·e
CHANGING WHAT'S POSSIBLE

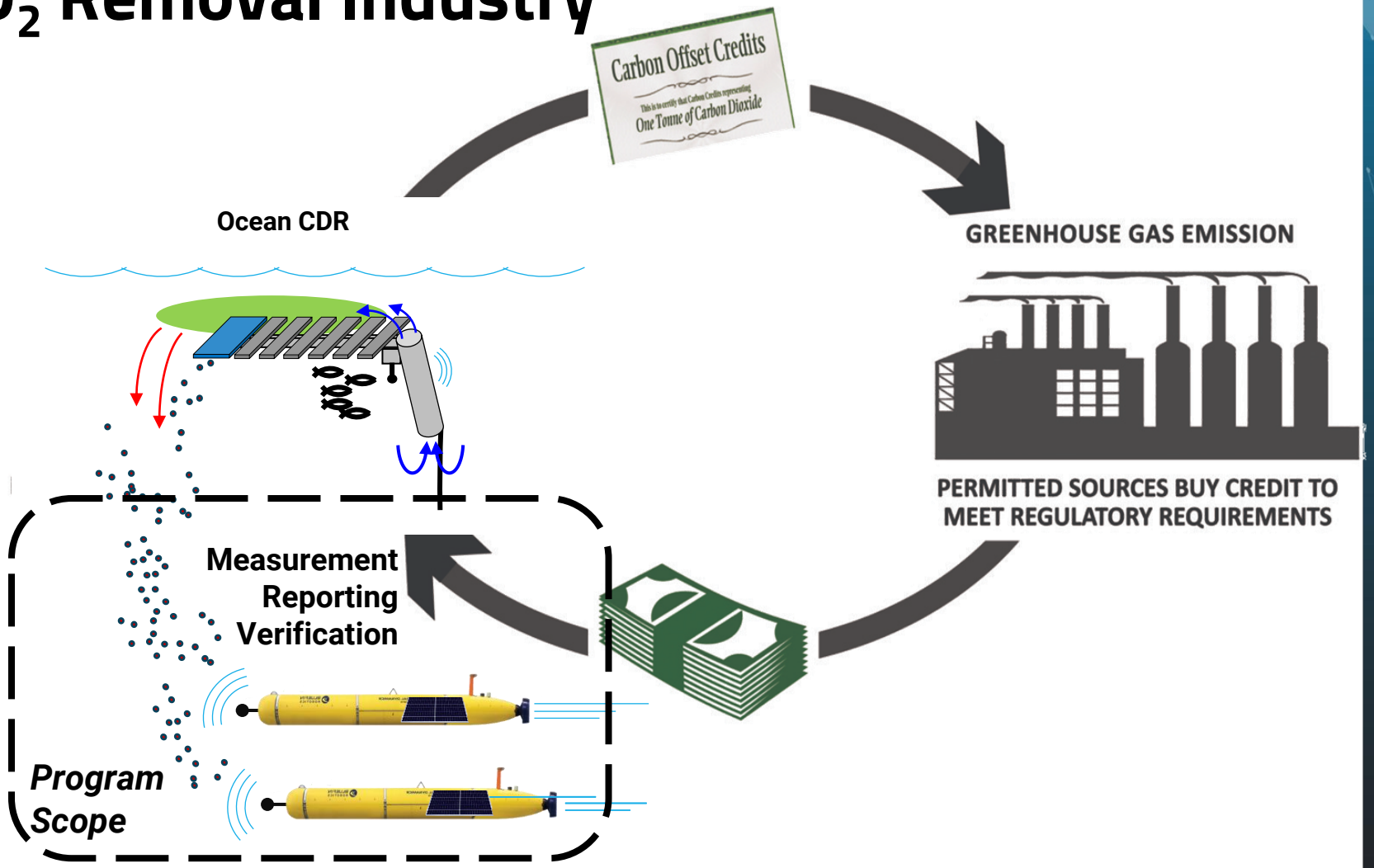


https://nap.nationalacademies.org/read/26278

# Enabling the Marine $CO_2$ Removal Industry

**Others: CDR Development, Environmental Impacts**

Philanthropies
Climate Venture Capital
DOE WPTO/FECM
NOAA, NSF
NGO's




**ARPA-E: This Program**

*MRV: Time and space make this "ARPA-hard" and high-risk, but it's a necessary task for an essential future industry too early for private investment*

arpa·e
CHANGING WHAT'S POSSIBLE

# MRV Tech Can Ensure $CO_2$ Removals are "High-Quality"

**Measurability**
Can the amount of $CO_2$ removed be quantified?

**Verifiability**
Can the $CO_2$ removed be verified by a third party?

**Additionality & Baselines**
Can the $CO_2$ removal be claimed against a baseline?

**Durability**
How long does the $CO_2$ stay out of the atmosphere?

**Other Metrics**
- Harms & Benefits
- LCA "Leakage"
- Scalability

**From Carbon Direct*:**

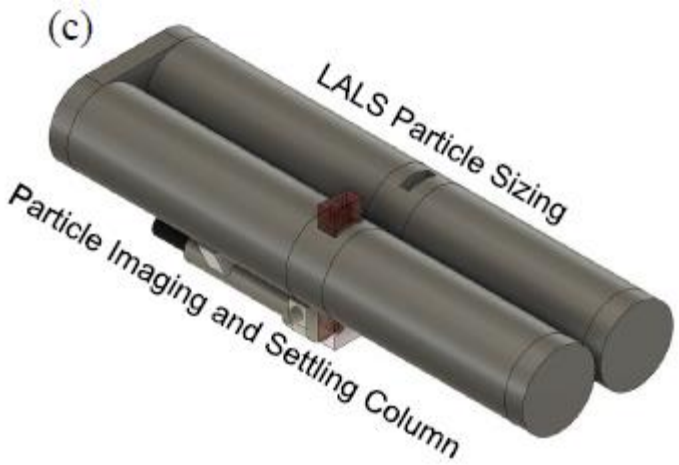
- Ideally, **directly measure carbon removed** rather than rely only on estimates from modeled processes
- Prove the **modeled performance** of proposed projects, based on data
- **Adapt MRV practices** based on the best available science and industry practices

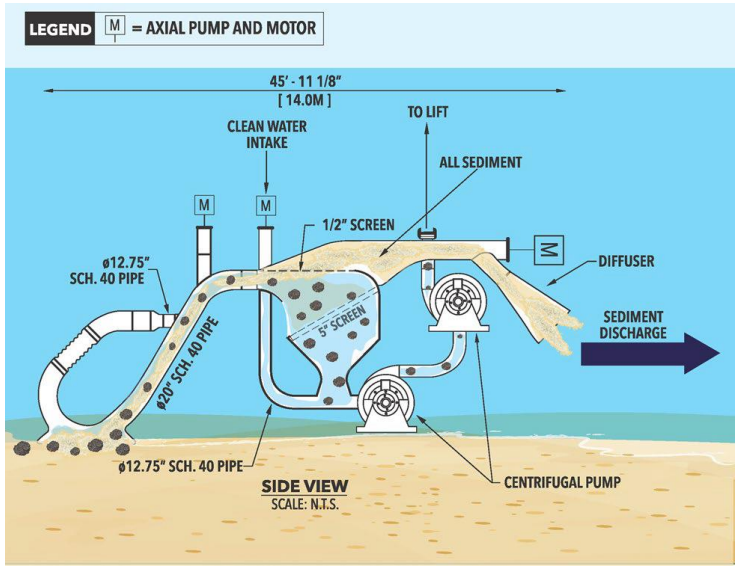
arpa·e CHANGING WHAT'S POSSIBLE

https://clearpath.org/tech-101/carbon-dioxide-removal-101
*https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RWGG6f

# Other ARPA-E Maritime Projects

| Project | Type | Performer | Description | Outcome |
|---|---|---|---|---|
| DE-AR0001241 | SEED | Otherlab | Flexible manipulator | Progress on the manipulator, however their TEA was unfavorable, and they pivoted toward other markets |
| DE-AR0001232 | SEED | Sequoia Scientific | In situ sensor development for plume characterization | Commercially viable sensor developed that can sense the size distribution of plume particles at a single point |
| DE-AR0001232 | SEED | Deep Reach | Electrocoagulation and inertial filtering of sediment | Sediment resuspension was reduced but at significant power input and no value add to the economics |



# JOIN US

# Join the Team that is Transforming the Energy of Tomorrow

### PROGRAM DIRECTOR

- Program development
- Active project management
- Thought leadership
- Explore new technical areas

### TECHNOLOGY-TO-MARKET ADVISOR

- Business development
- Technical marketing
- Techno-economic analyses
- Stakeholder outreach

### FELLOW

- Independent energy technology development
- Program Director support
- Organizational support

Learn more and apply: **www.arpa-e.energy.gov/jobs** or **arpa-e-jobs@hq.doe.gov**.

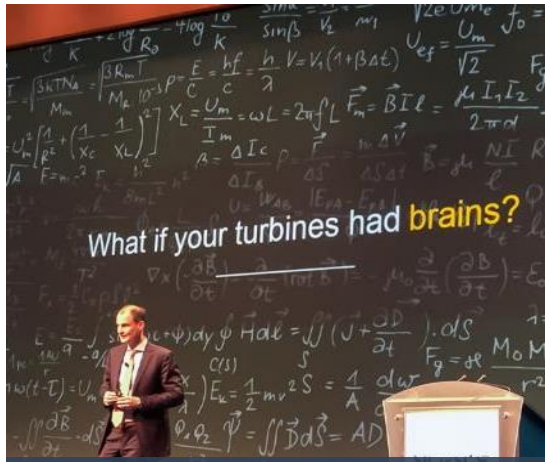
***3 to 5-year terms***

***2-year terms***

arpa·e
CHANGING WHAT'S POSSIBLE

# arpa·e energy innovation summit

**Highly Selective Technology Showcase**




**Inspiring Keynotes**


**Unparalleled Networking**

**Fast-Paced Technology Pitches**

## arpae-summit.com

## March 22-24, 2023 | National Harbor, Maryland

arpa·e
CHANGING WHAT'S POSSIBLE

https://arpa-e.energy.gov

**Dan Rogers**
**Tech-to-Market Advisor, Marine Technologies**
daniel.rogers@hq.doe.gov