SEAS

Scalable Biomass Energy from Marine Aquatic Sources

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Pre-FOA Release Webinar

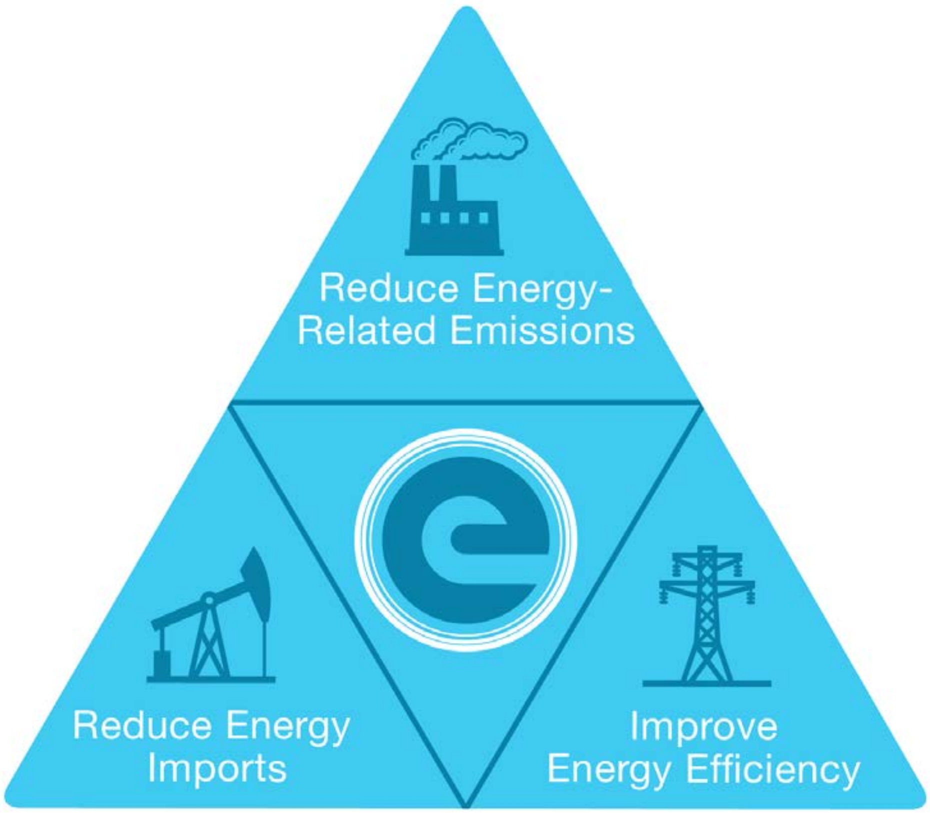
November 29, 2016

Outline

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

ARPA-E Mission

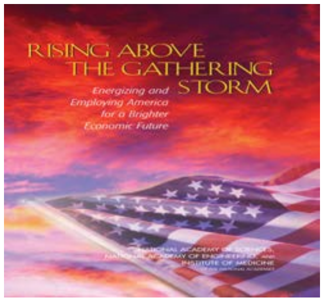
Catalyze the development of transformational, high-impact energy technologies



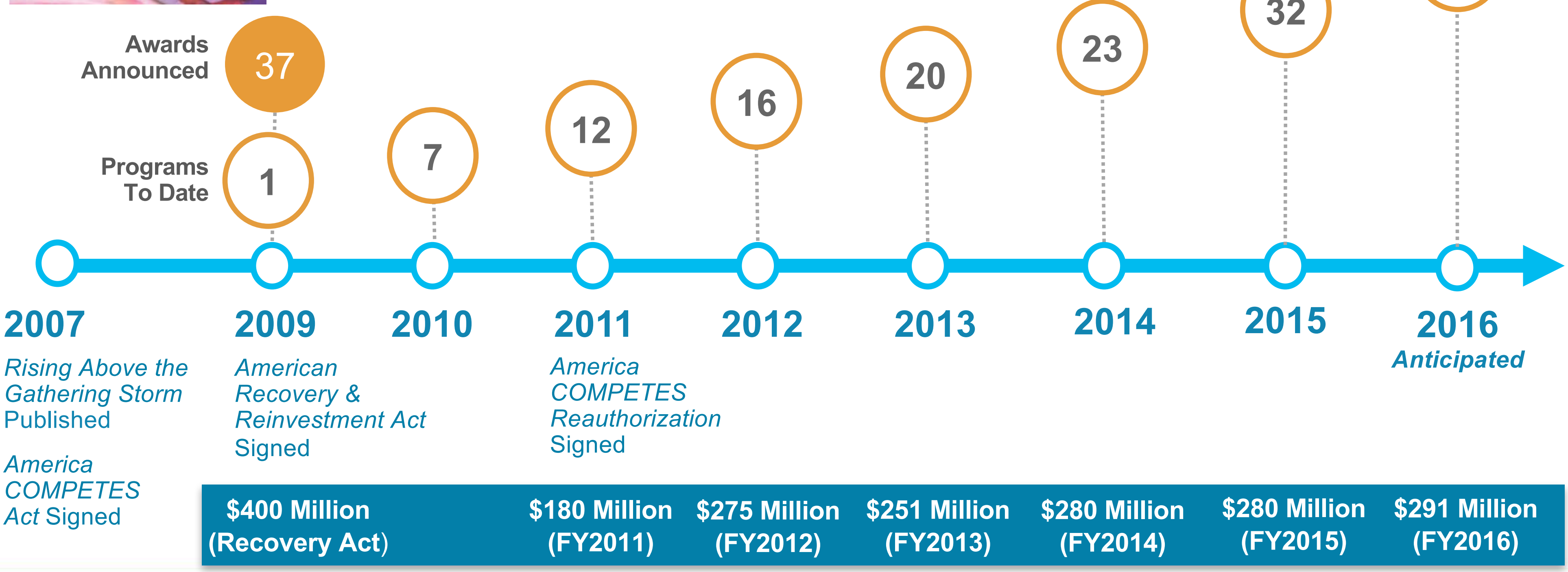
Ensure the U.S. maintains a lead in the development and deployment of advanced energy technologies

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."…



arpa·e
CHANGING WHAT'S POSSIBLE

ARPA-E Programs and OPENs

	2010 - 2012	2013-2014	2015	2016
ELECTRICITY GENERATION	IMPACCT, SOLAR ADEPT	FOCUS, REBELS	ALPHA, MOSAIC, GENSETS	
ELECTRICAL GRID & STORAGE	GENI, GRIDS, HEATS		NODES, CHARGES	GRID DATA, IONICS
EFFICIENCY & EMISSIONS	ADEPT, BEETIT, REACT	METALS, SWITCHES, DELTA, MONITOR	ARID	SHIELD, ENLITENED, ROOTS
TRANSPORTATION & STORAGE	BEEST, AMPED, ELECTROFUELS, PETRO, MOVE	RANGE, REMOTE	TRANSNET, TERRA	NEXTCAR, REFUEL

OPEN 2009
36 projects

OPEN 2012
66 projects

OPEN 2015
41 projects

CHANGING WHAT'S POSSIBLE

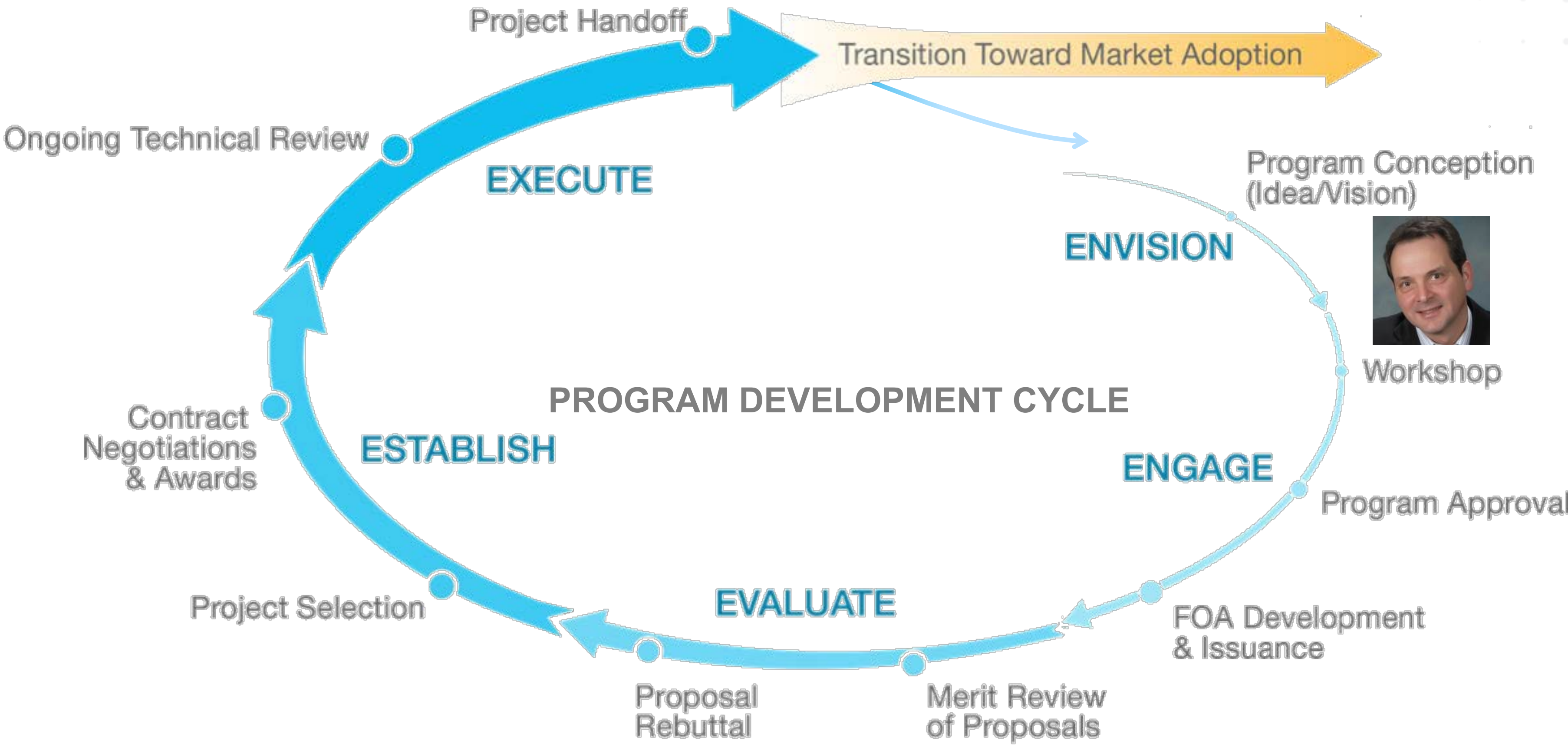
ARPA-E Program Framing Questions

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

Adapted from the DARPA Heilmeier questions

Developing ARPA-E Focused Programs

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

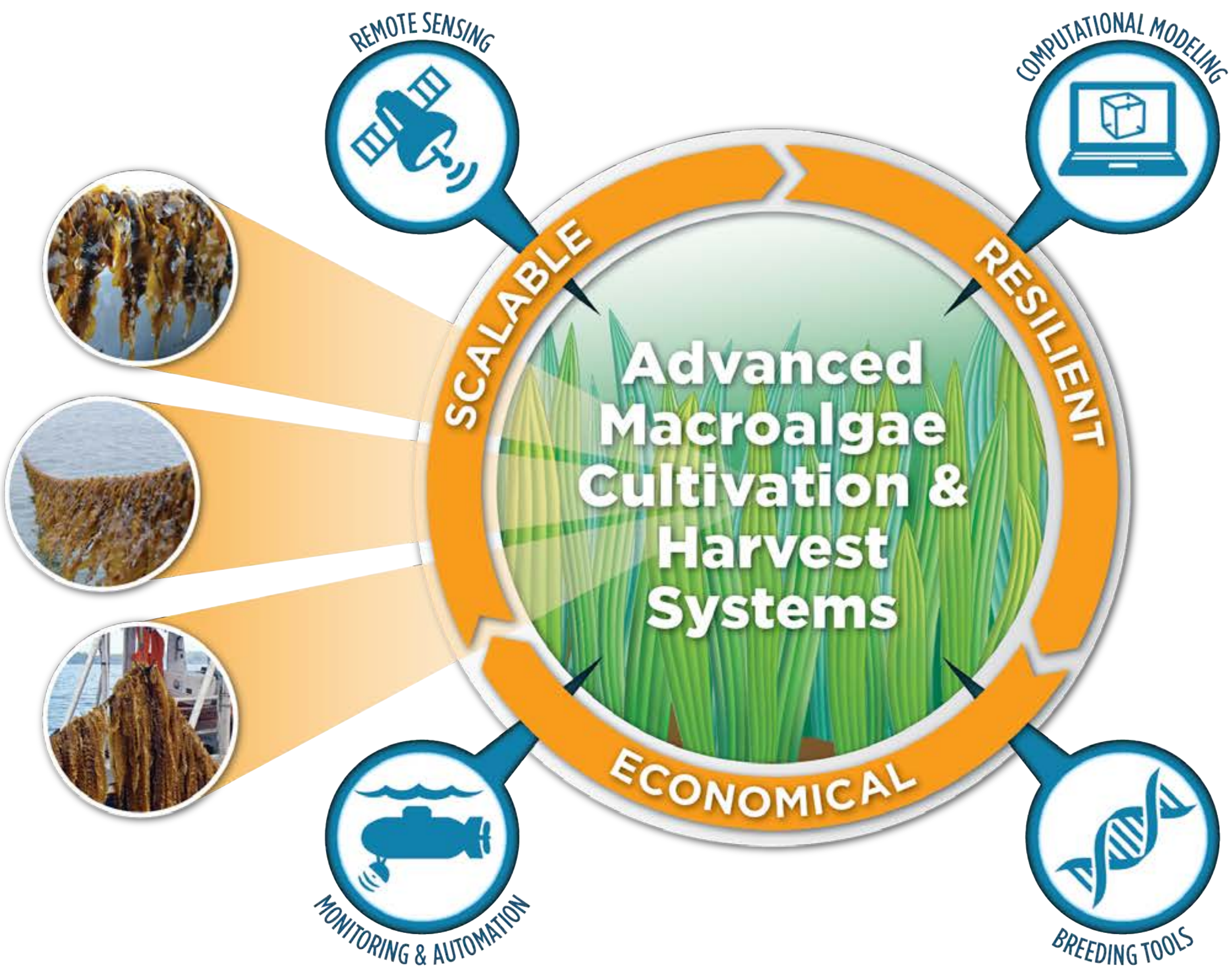
Webpage

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

Contains links to workshop presentations, breakout sessions summary, literature review, other workshop resources

SEAS
Macroalgae Production

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.

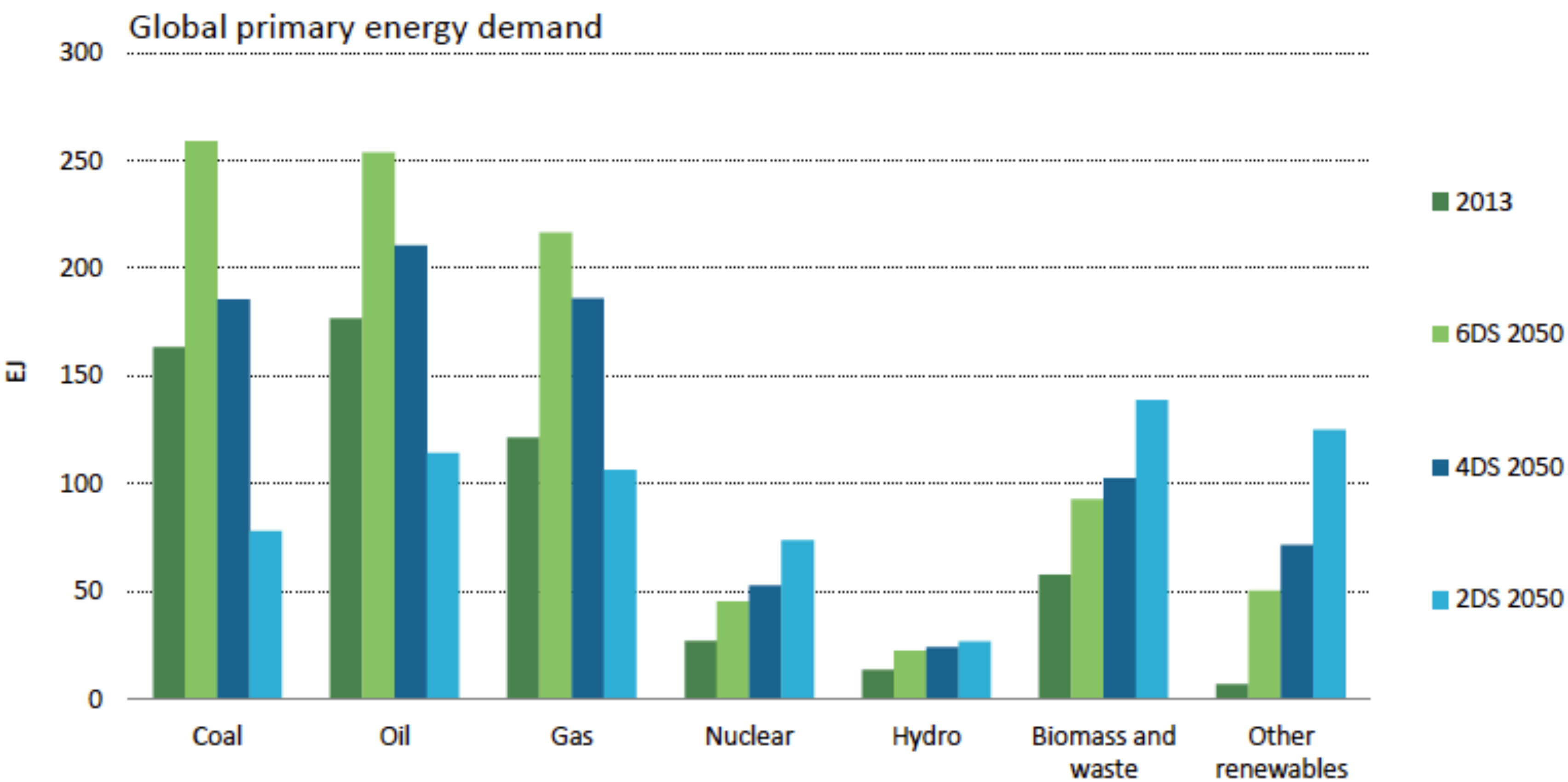
Photos copyright (top to bottom):
Daria Barbour/National Geographic; The Island Institute; Bren Smith/Huffington Post

Program Motivation

If it works…

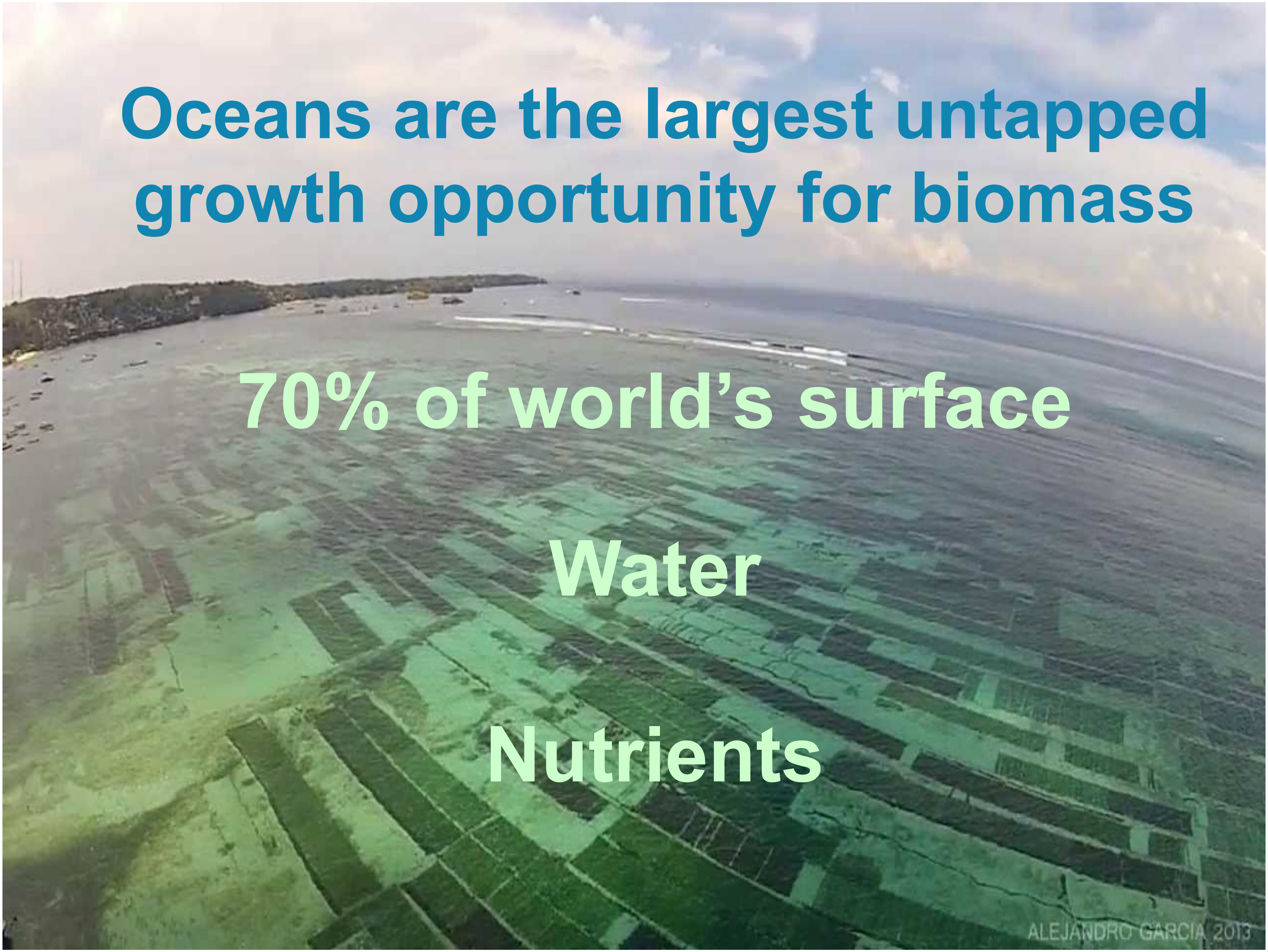
will it matter?

Biomass critical for reducing GHG emissions

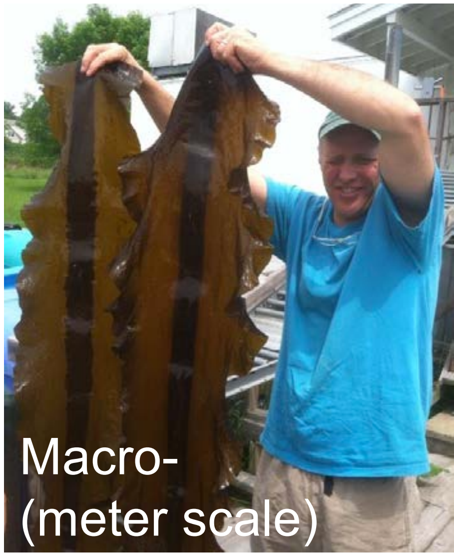


In 2°C Scenario (2DS), biomass becomes largest primary energy source by 2050.

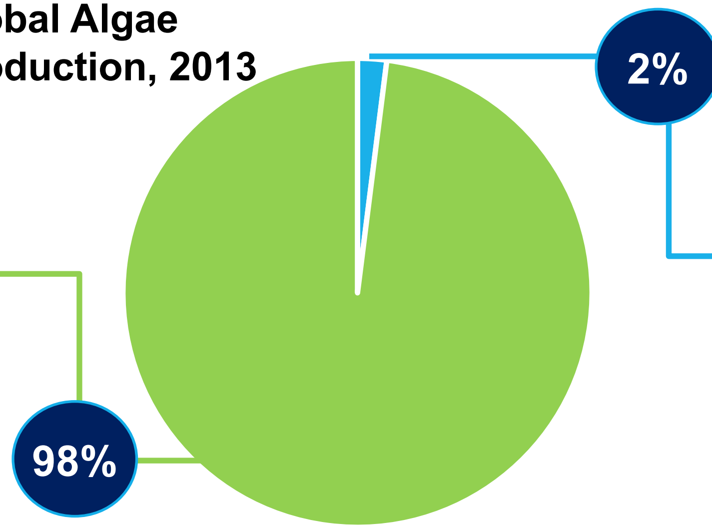
Source: ETP 2016, IEA

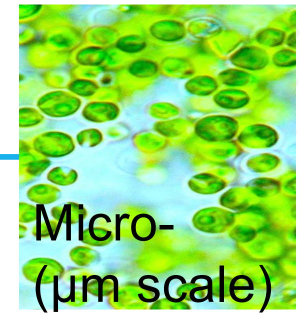

Oceans are the largest untapped growth opportunity for biomass
70% of world's surface
Water
Nutrients
ALEJANDRO GARCIA 2013

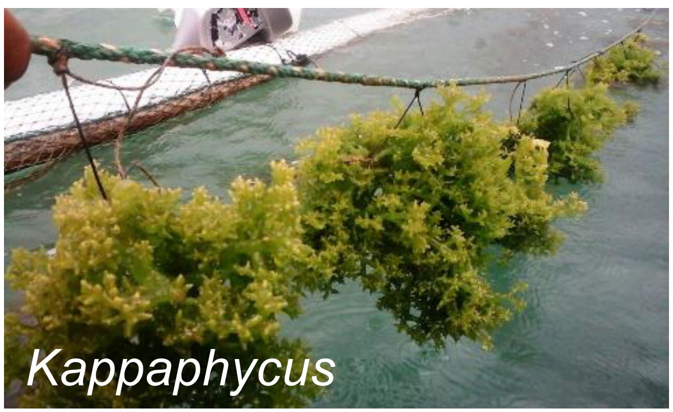
Macroalgae (aka seaweed) – the quintessential ocean crop



Global Algae Production, 2013

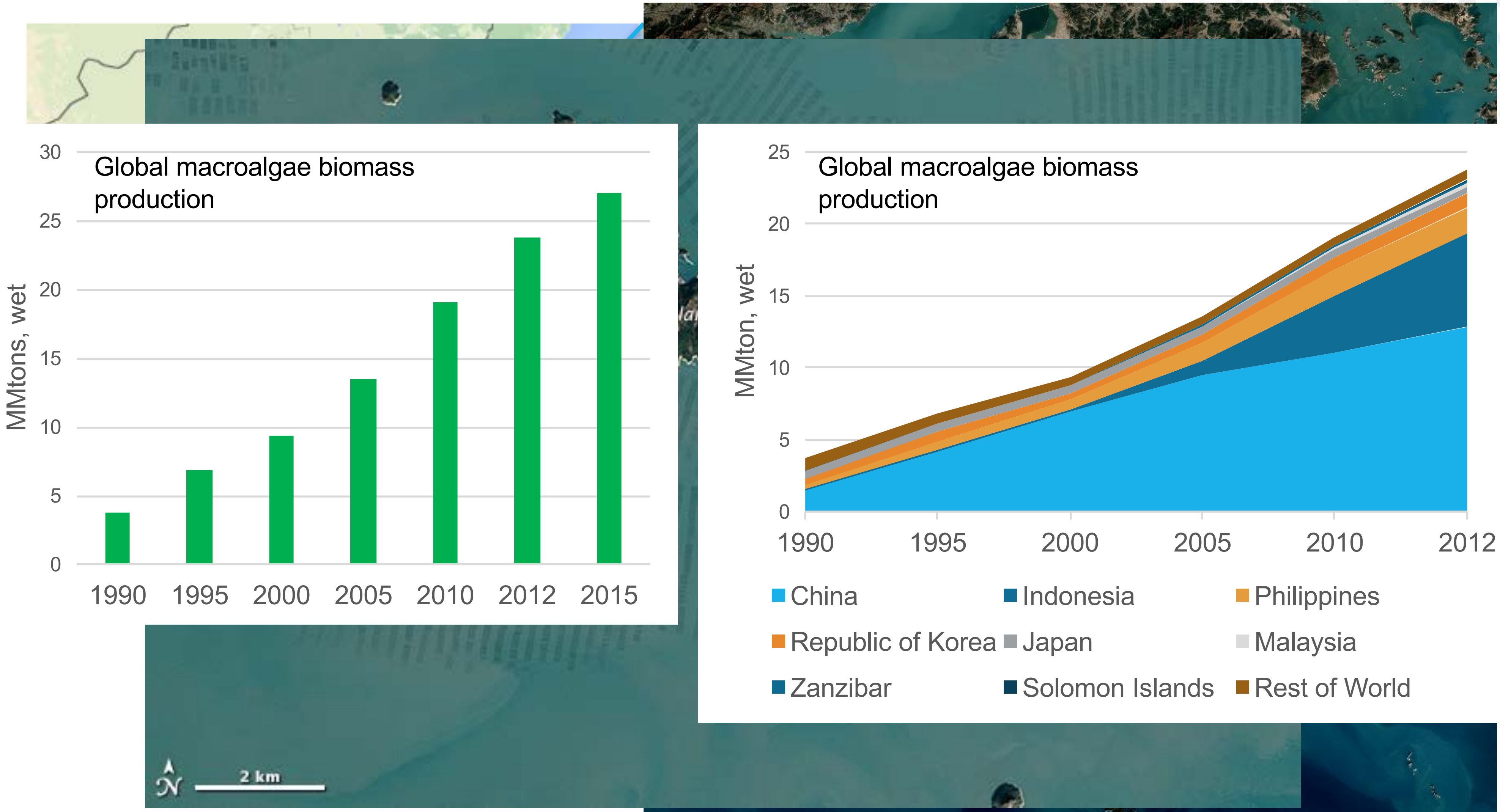






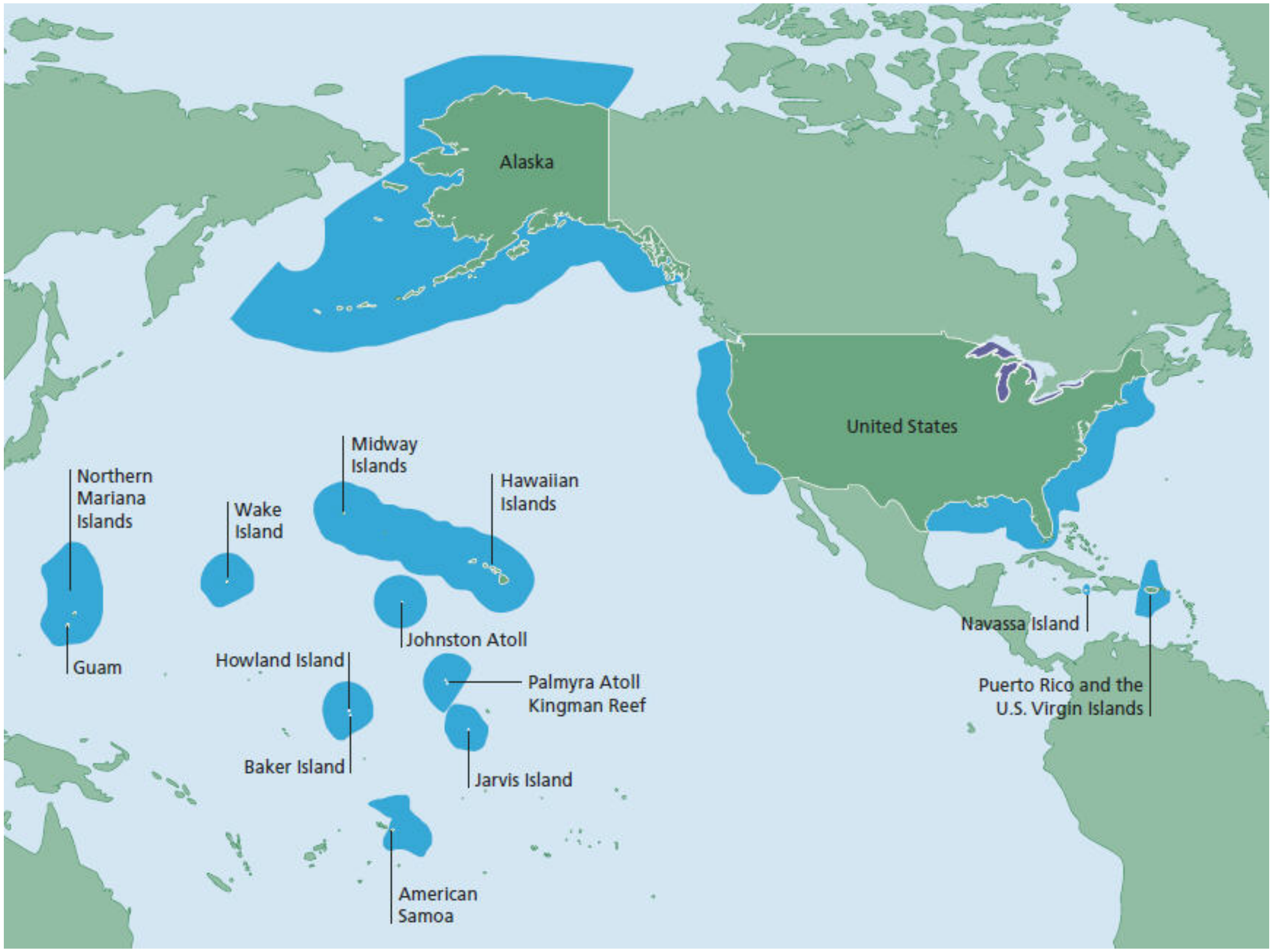
- **Amenable to cultivation & harvest**
- **Mostly carbohydrate & protein**
- **Many different species**
- **Fast growth rate**

An existing & growing industry



http://earthobservatory.nasa.gov/IOTD/view.php?id=85747

U.S. Exclusive Economic Zone (EEZ) is equivalent to the total U.S. land area

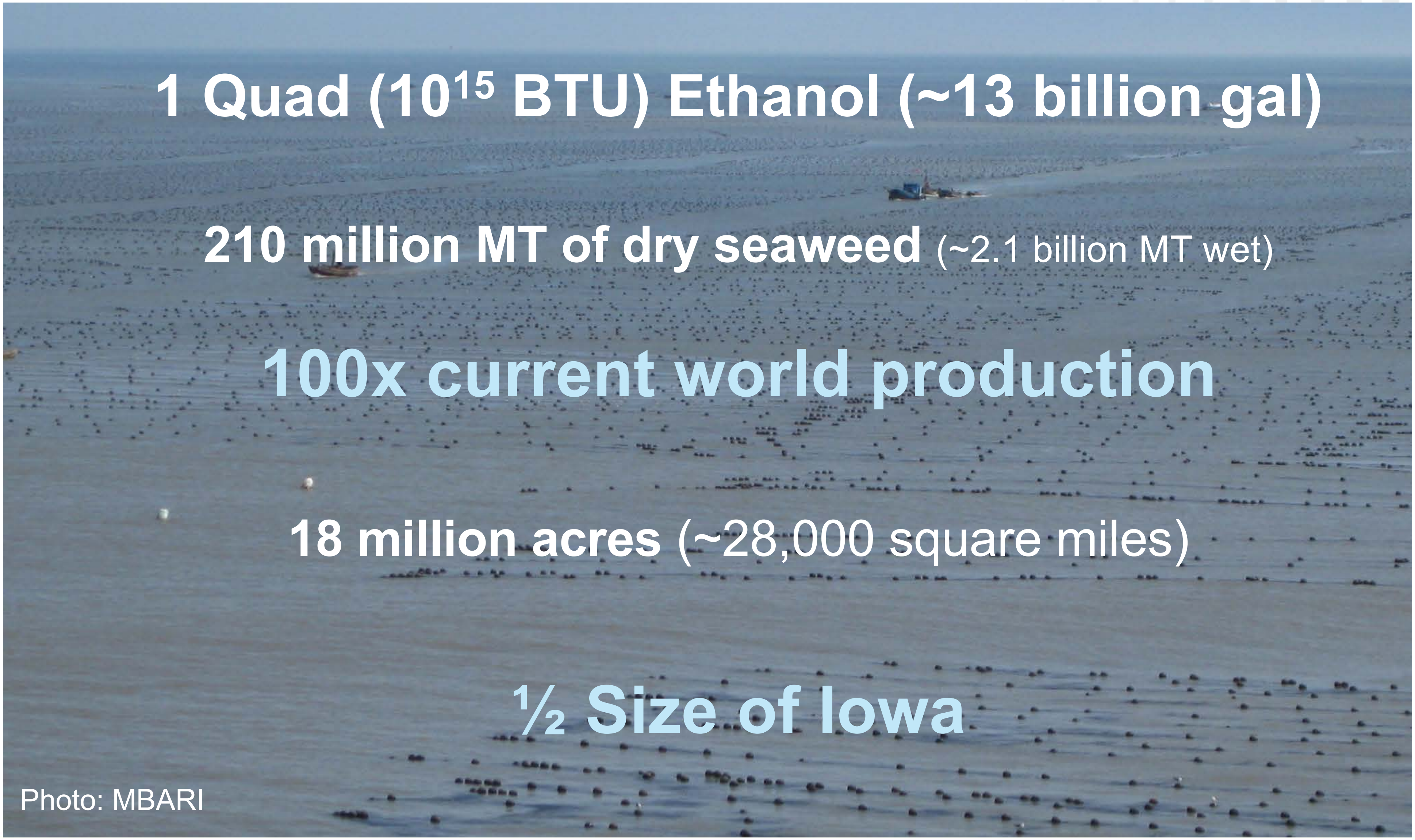


US Area (USDA 2006)	Sq km
Total Land Area	9,158,022
Grassland	2,370,000
Forestry	2,640,000
Cropland	1,786,000
Exclusive Economic Zone (offshore)	11,351,000

arpa·e CHANGING WHAT'S POSSIBLE

Key Questions for ARPA-E:

How much is enough?



1 Quad (10^{15} BTU) Ethanol (~13 billion gal)

210 million MT of dry seaweed (~2.1 billion MT wet)

100x current world production

18 million acres (~28,000 square miles)

½ 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

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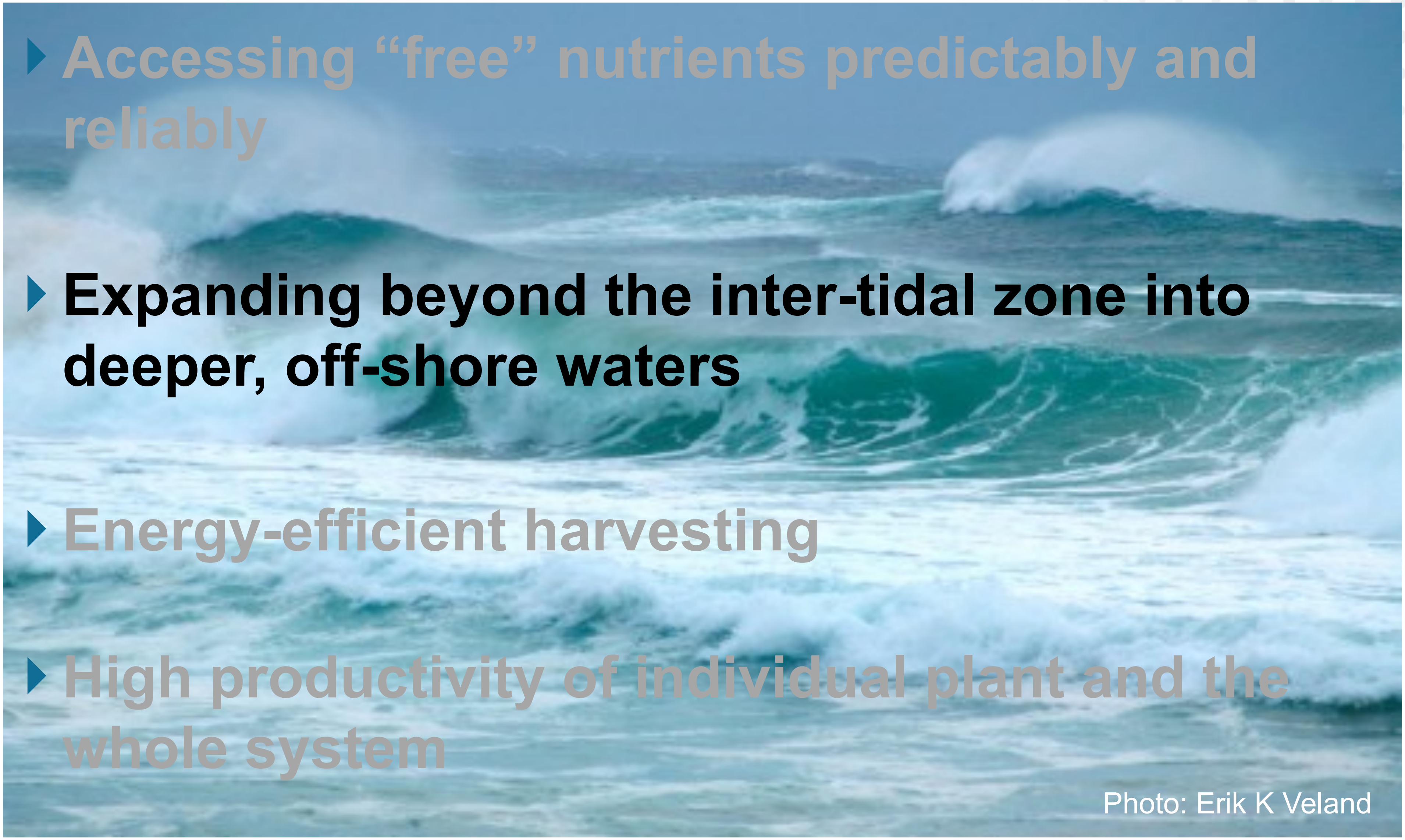
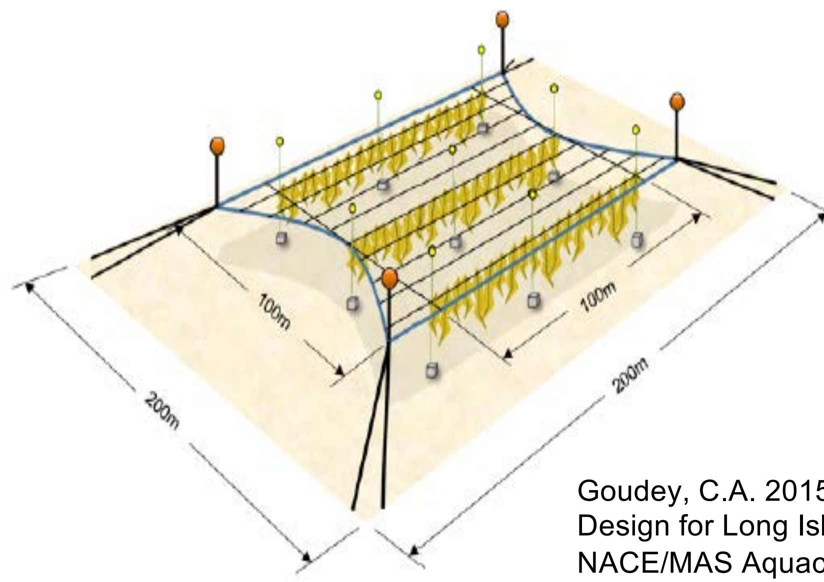


Photo: Erik K Veland

Anchored long-lines are state of the art

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

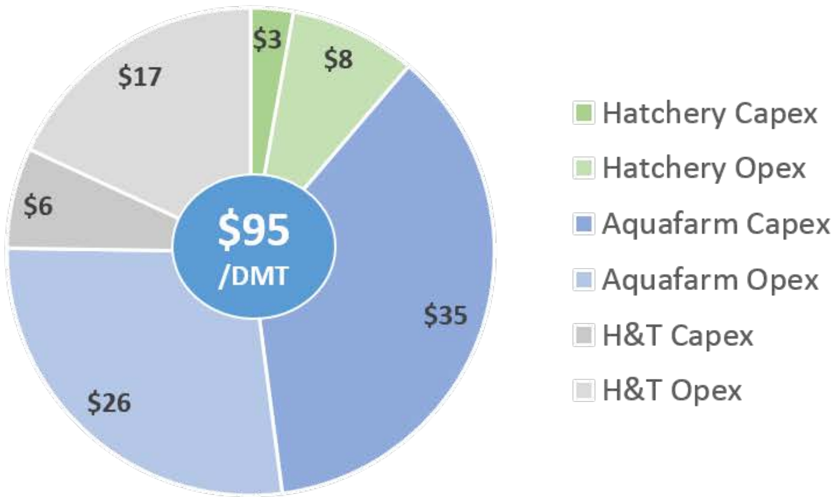


Goudey, C.A. 2015 Kelp Farm Design for Long Island Sound, NACE/MAS Aquaculture Conference, Portland, ME

We probably need new/better designs

What is the (general) cost structure for a commercial operation?

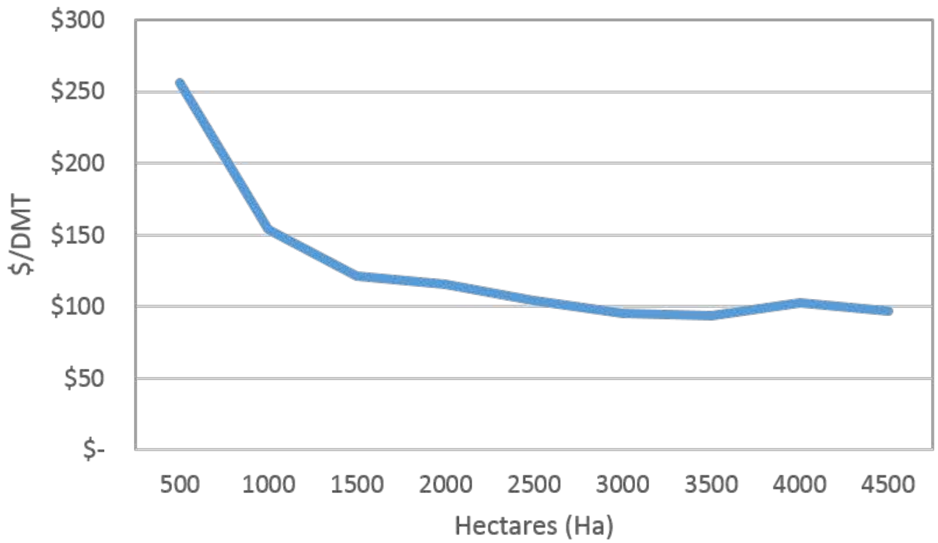
A.



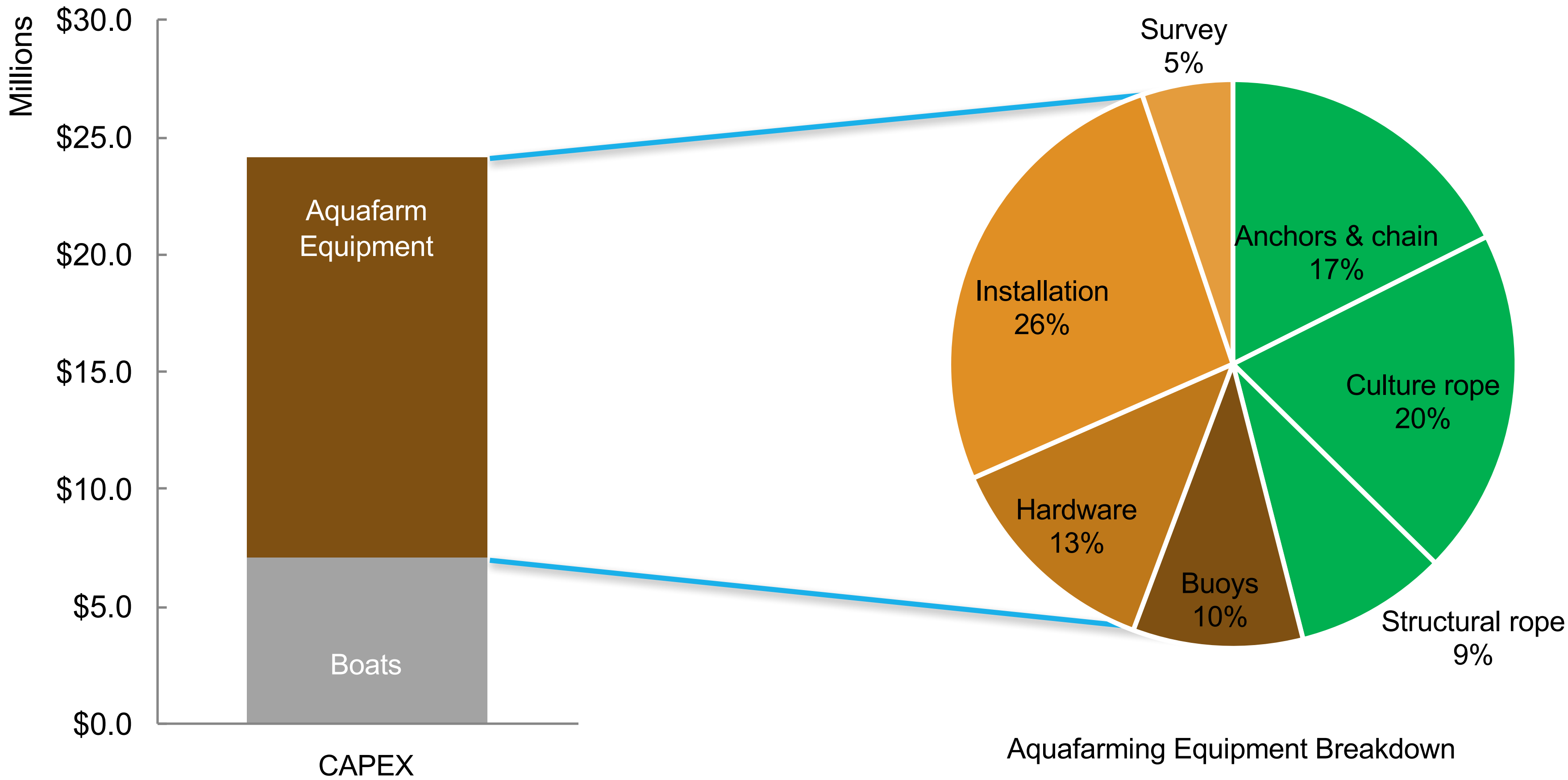
B.

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
Interest rate	0%
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**

C.



New designs are needed to reduce farm costs



Key requirements for macroalgae energy farms

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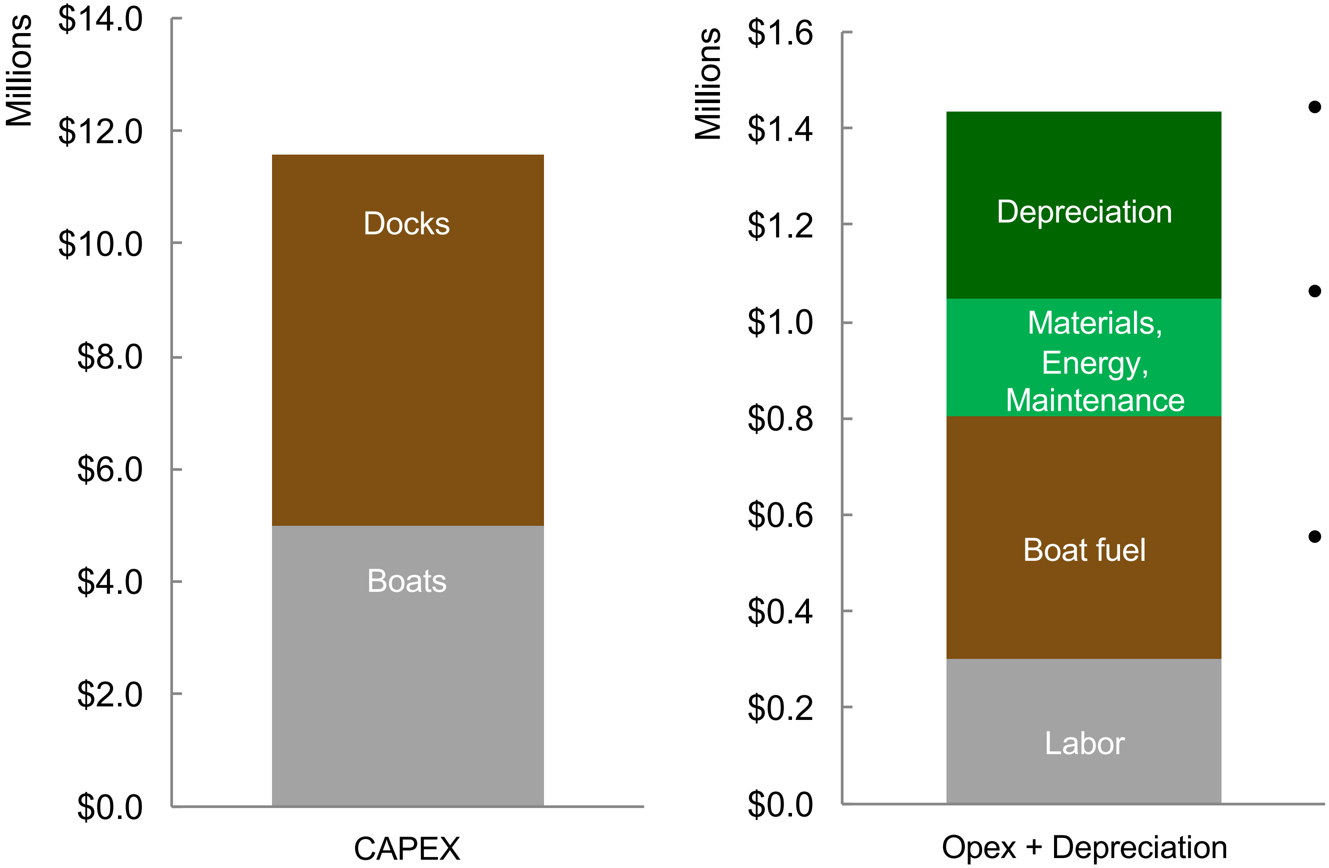
- **Energy-efficient harvesting**
- High productivity of individual plant and the whole system

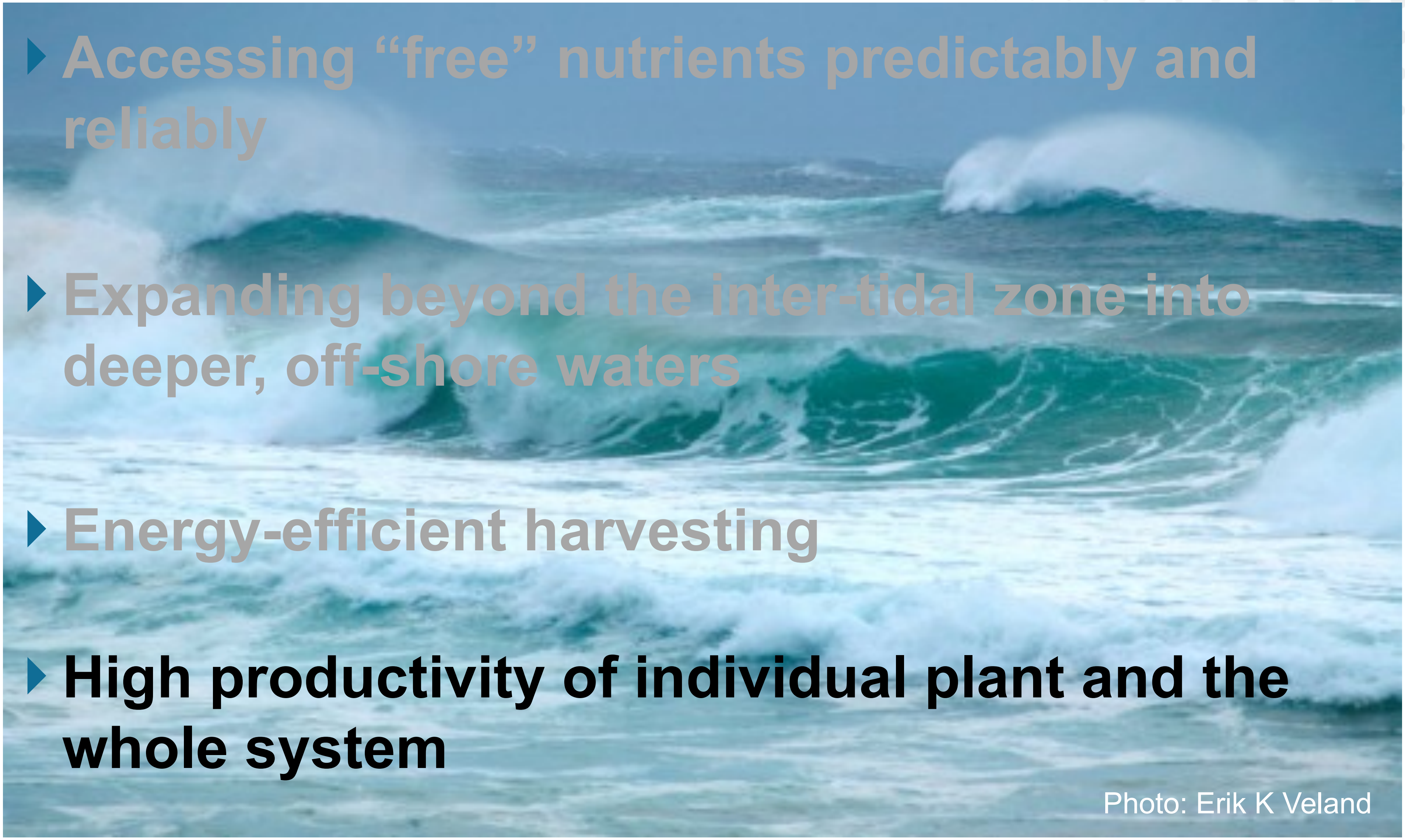
Photo: Erik K Veland

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
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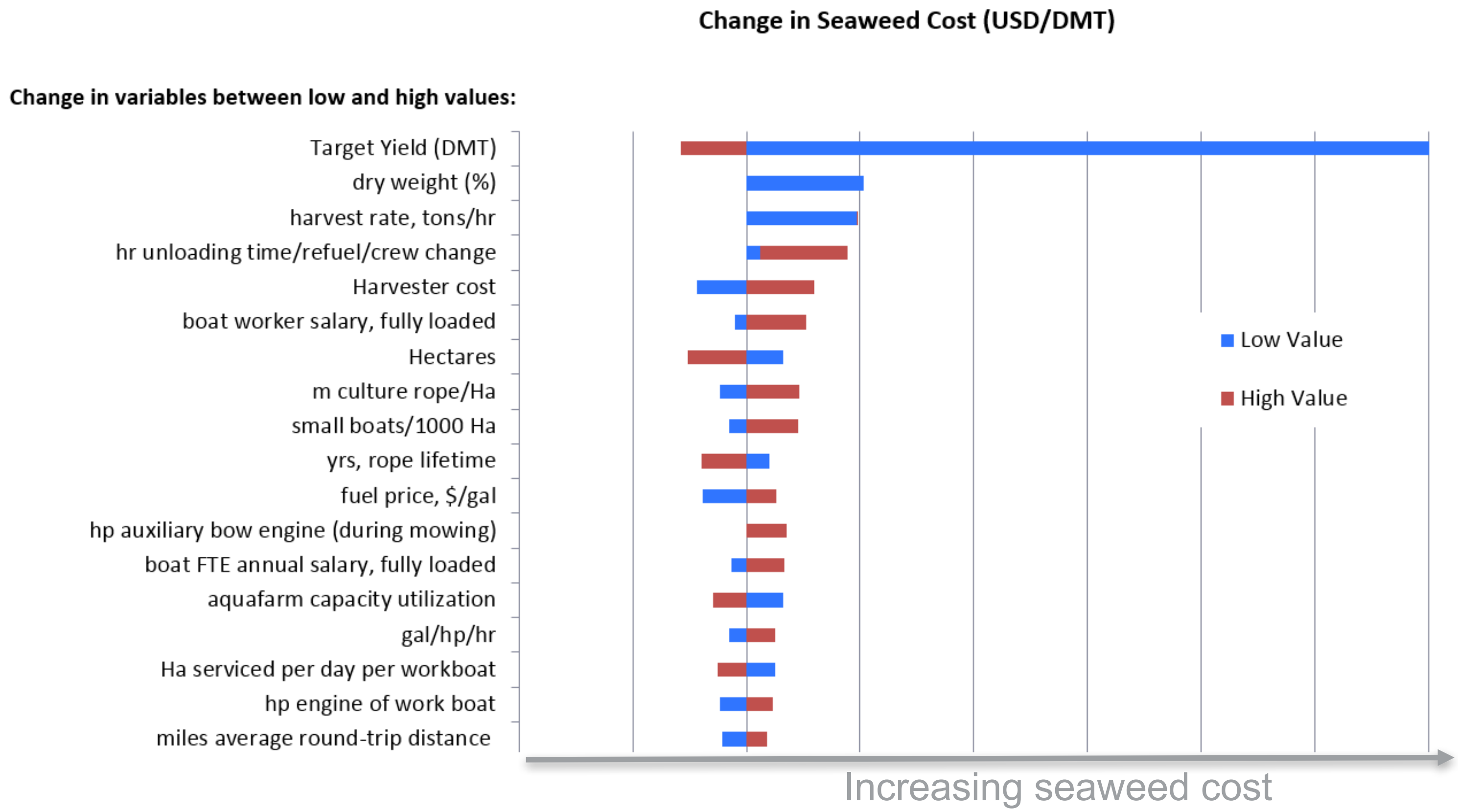
Photo: Erik K Veland

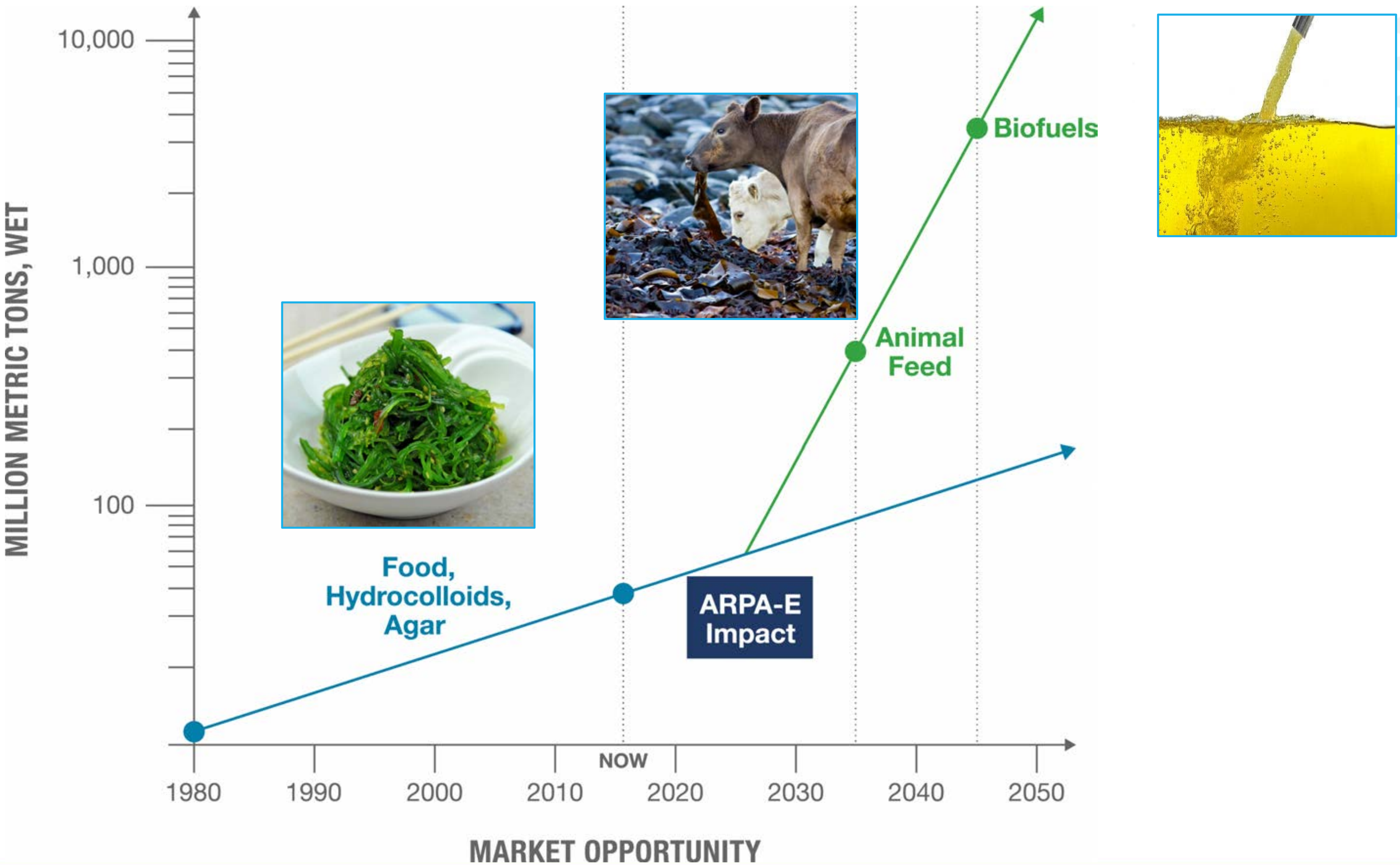
Examples of top opportunities to drive down cost – its all about productivity



- 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

CHANGING WHAT'S POSSIBLE

The path to fuels will likely go through the animal feed market



Program Structure

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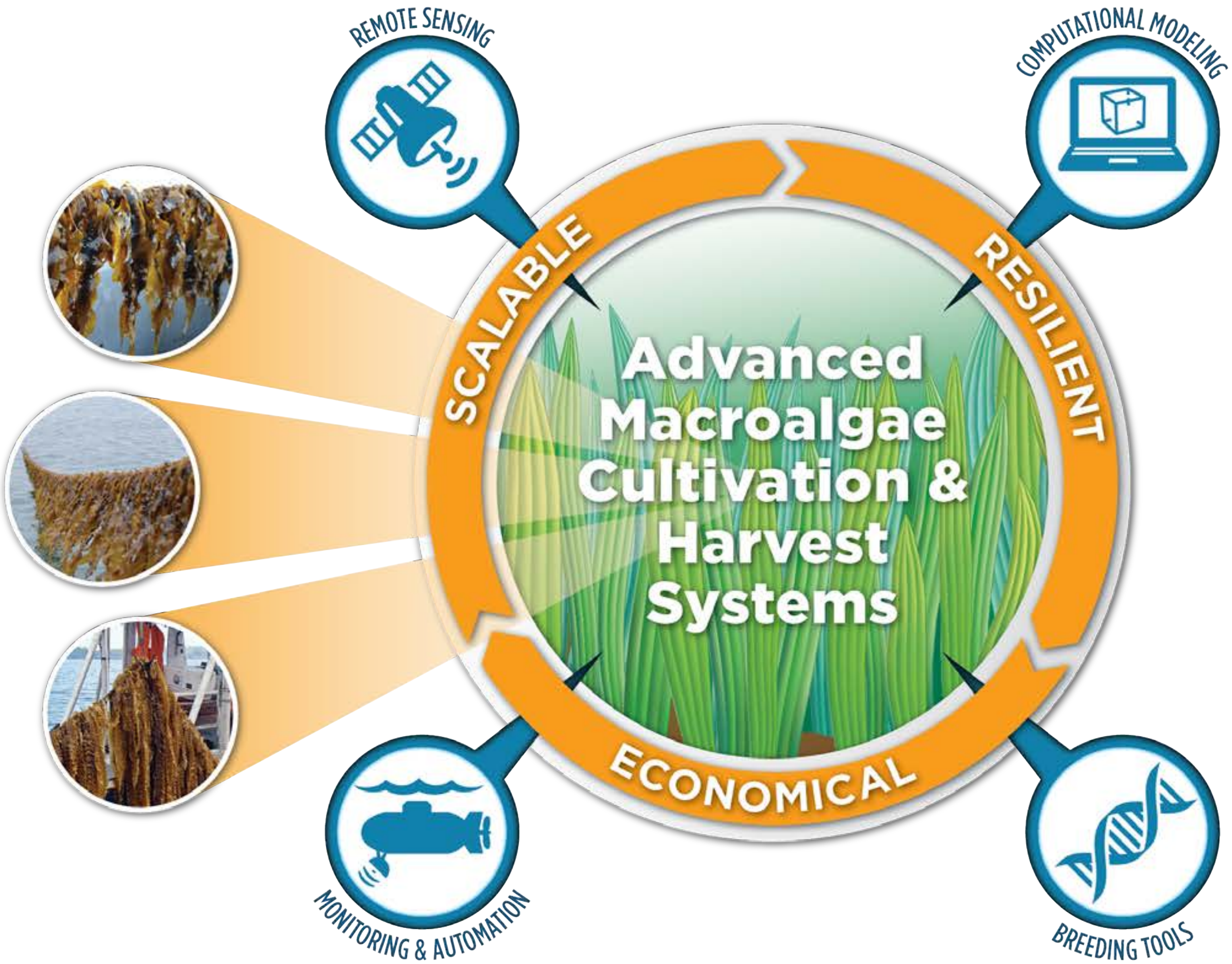

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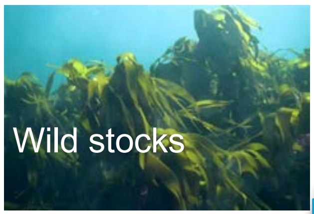
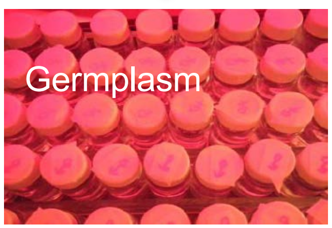
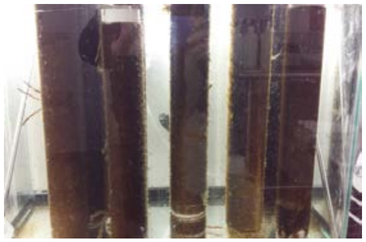
Macroalgae to fuel unit operations

Strain Development & Breeding

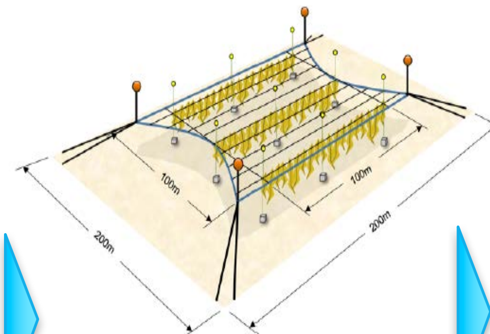




Hatchery & Nursery



Cultivation & Farm management



Harvest & Transport

~~Processing~~

Program Structure/Categories

Cat 1: Novel Designs

Cultivation & Harvesting System – Design & Demonstration

Cat 2: Advanced Components

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

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

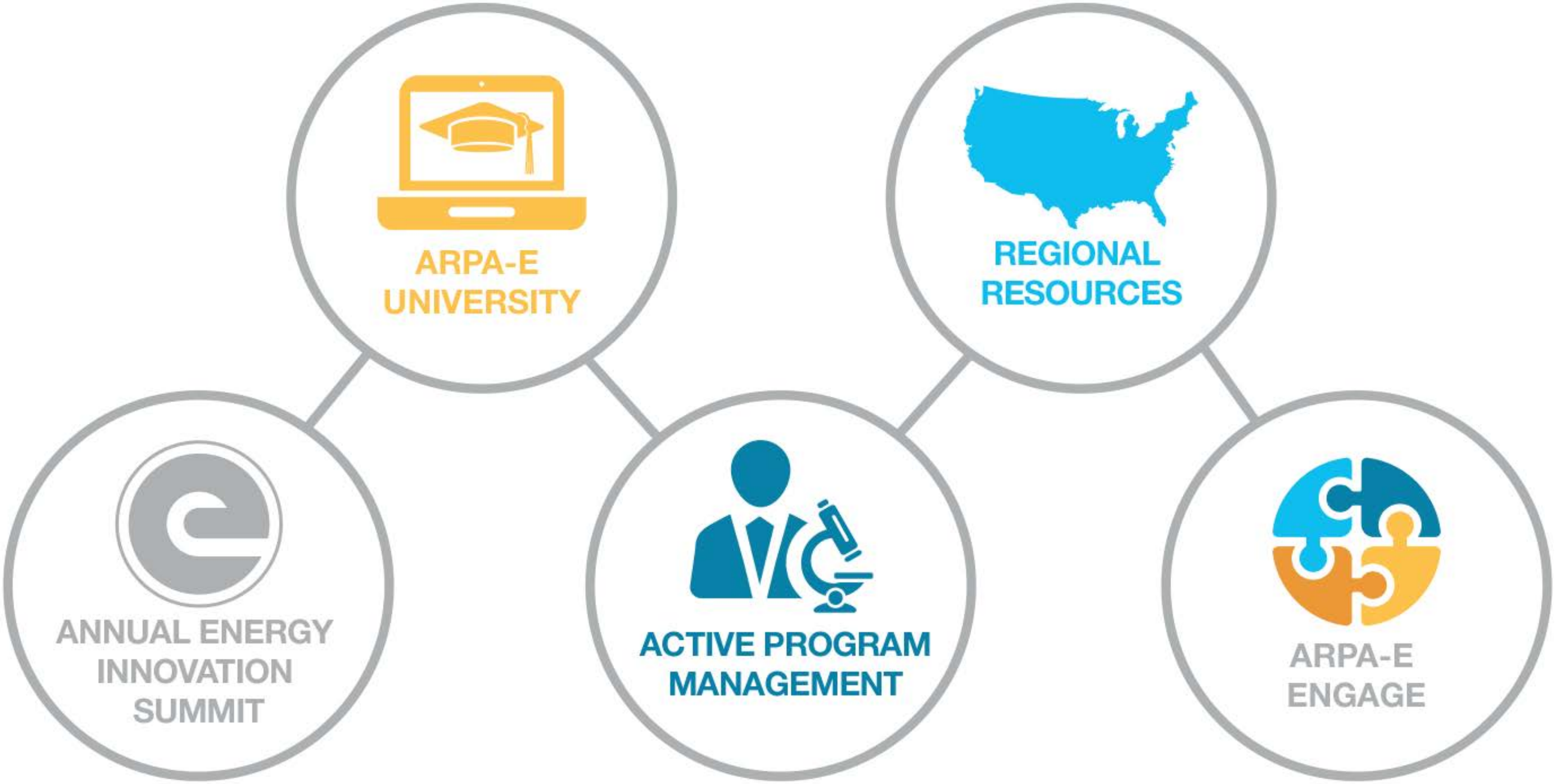
BRIDGE

- 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



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

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