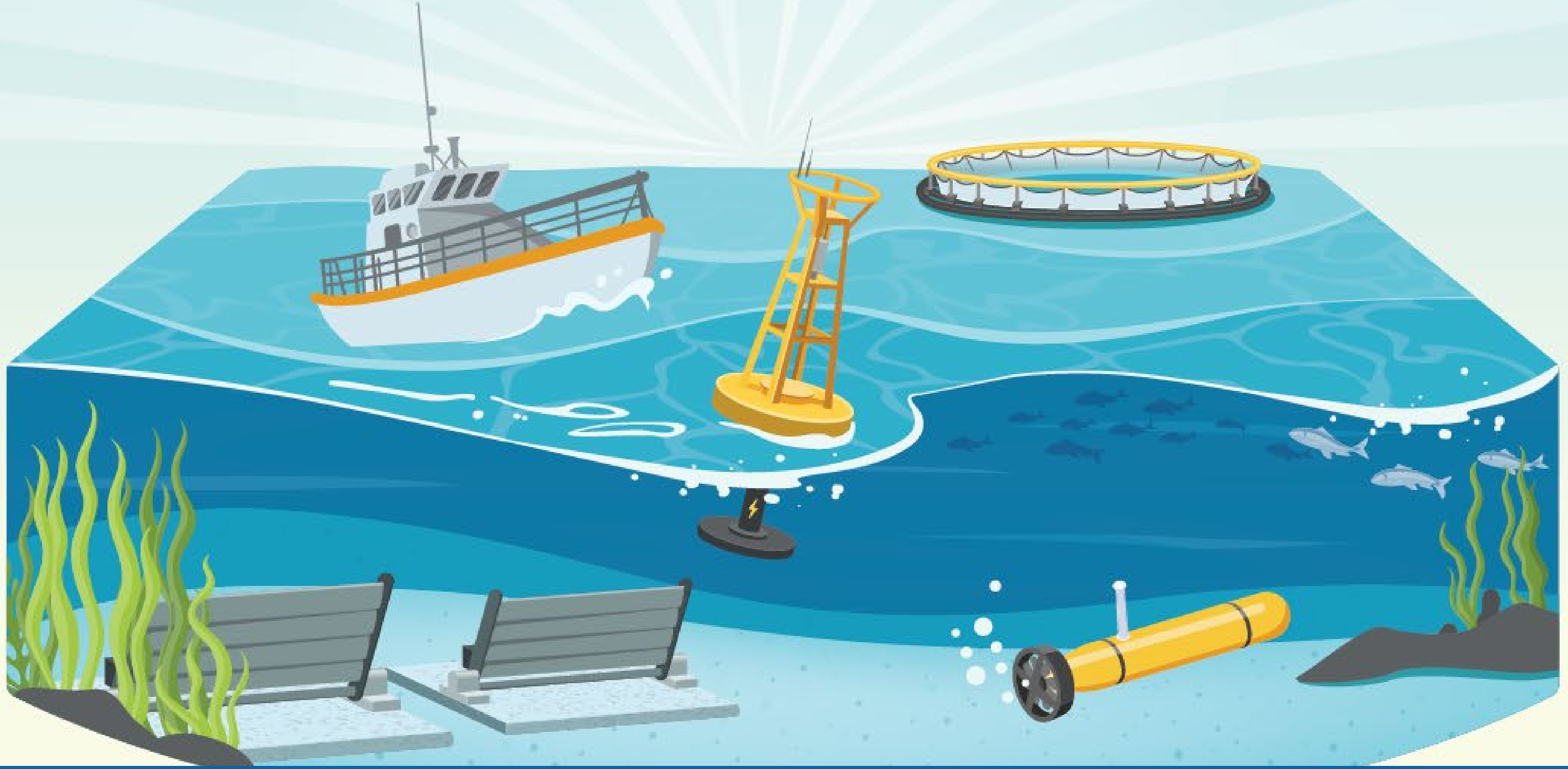
POWERING THE BLUE ECONOMY™:

POWER AT SEA PRIZE

AMERICAN MADE CHALLENGES

U.S. DEPARTMENT OF ENERGY

NOAA



Power at Sea Prize: EXPLORE!

April 22, 2024

Housekeeping

This webinar is being recorded.

Please post your questions in the Q&A and we'll answer them at the end of the presentation.

The webinar recording and questions/answers will be added to HeroX.

Agenda

Types of Marine Renewable Energy

Example Applications

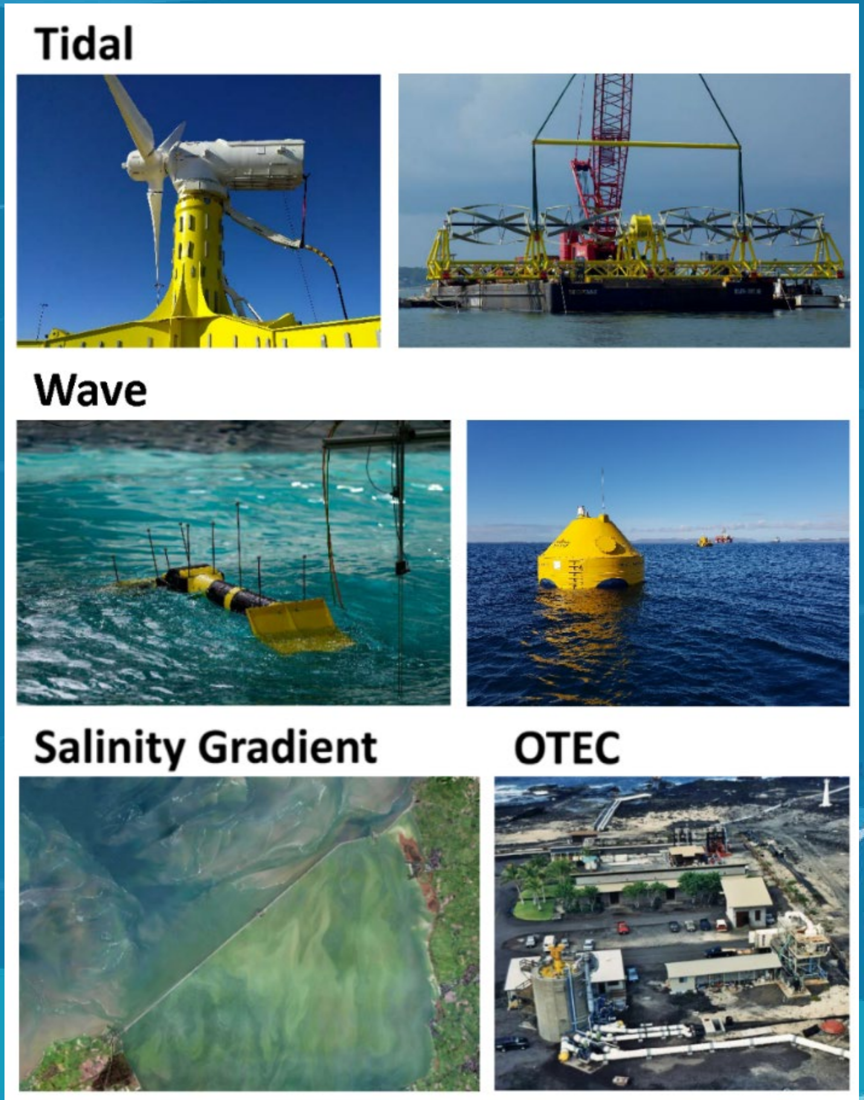
Challenge Areas

Power at Sea Prize Overview

Questions

Background: Marine Renewable Energy

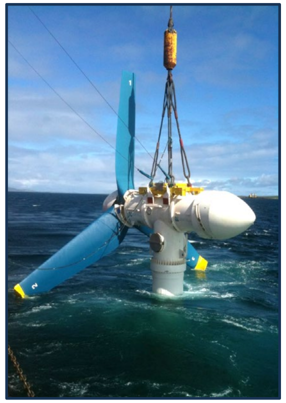
- Marine energy encompasses the harvest of energy waves, tides, and ocean currents, as well as from other energy sources.
- To date, most commonly achieved with turbines in tidal channels and the utilization of wave energy converters of many designs.
- Marine energy also includes the harvest of energy from salinity and temperature gradients, including from ocean thermal energy conversion (OTEC).
- Within each subcategory, there have been significant variances to device attributes, creating a wide range of potential solutions.



Pictured examples courtesy of: (1) ANDRITZ Hydrotidal turbine, (2) ORPC TidGen Power System, (3) Mocean Energy Blue Horizon attenuator, (4) CorPower Ocean C3 point absorber, (5) REDstack salinity gradient plant at Afsluitdijk (photo courtesy of Van Oord), (6) Natural Energy Laboratory of Hawaii Authority OTEC plant at Kona (photo courtesy of DOE).

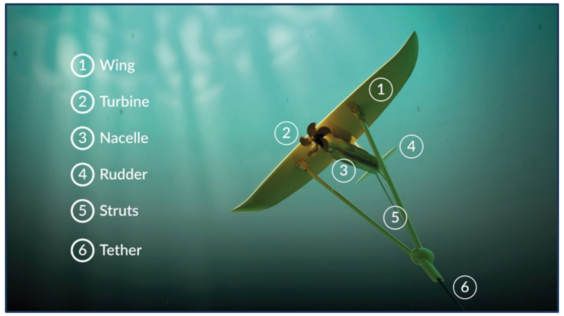
Tidal Energy

How it works: Power is produced from ocean tides. Traditionally, the flow of water drives a turbine to produce electricity.



SIMEC Atlantis AR1000

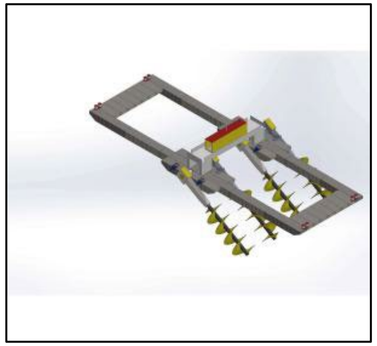
ORPC TidGen



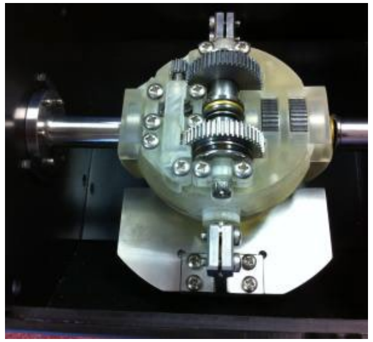
Minesto

Archetypes: Horizontal axis turbine, cross flow turbine, tidal kite, vortex induced vibration device, Archimedes screw

$$P = \frac{1}{2} C_P \rho A V^3$$



Jupiter Hydro



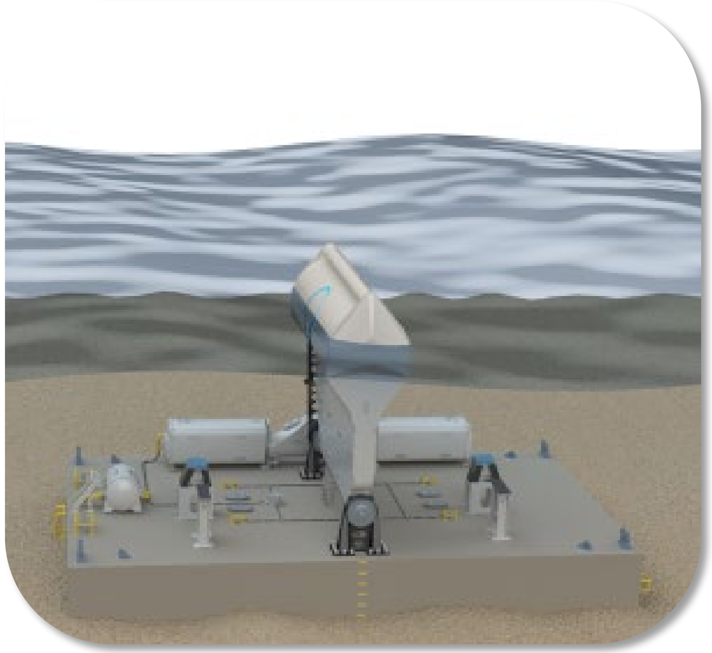
WITT Energy

Wave Energy

$$P = \frac{\rho g^2}{64\pi} H^2 T$$

How it works: Motion from the waves is harvested to move a working fluid or drive a generator.

Archetypes: There are many! Point absorber, oscillating water column, attenuator, oscillating wave surge, pressure differential



AW-Energy: WaveRoller

CalWave Power Technologies: xWave

Wave Dragon ApS/Ltd.

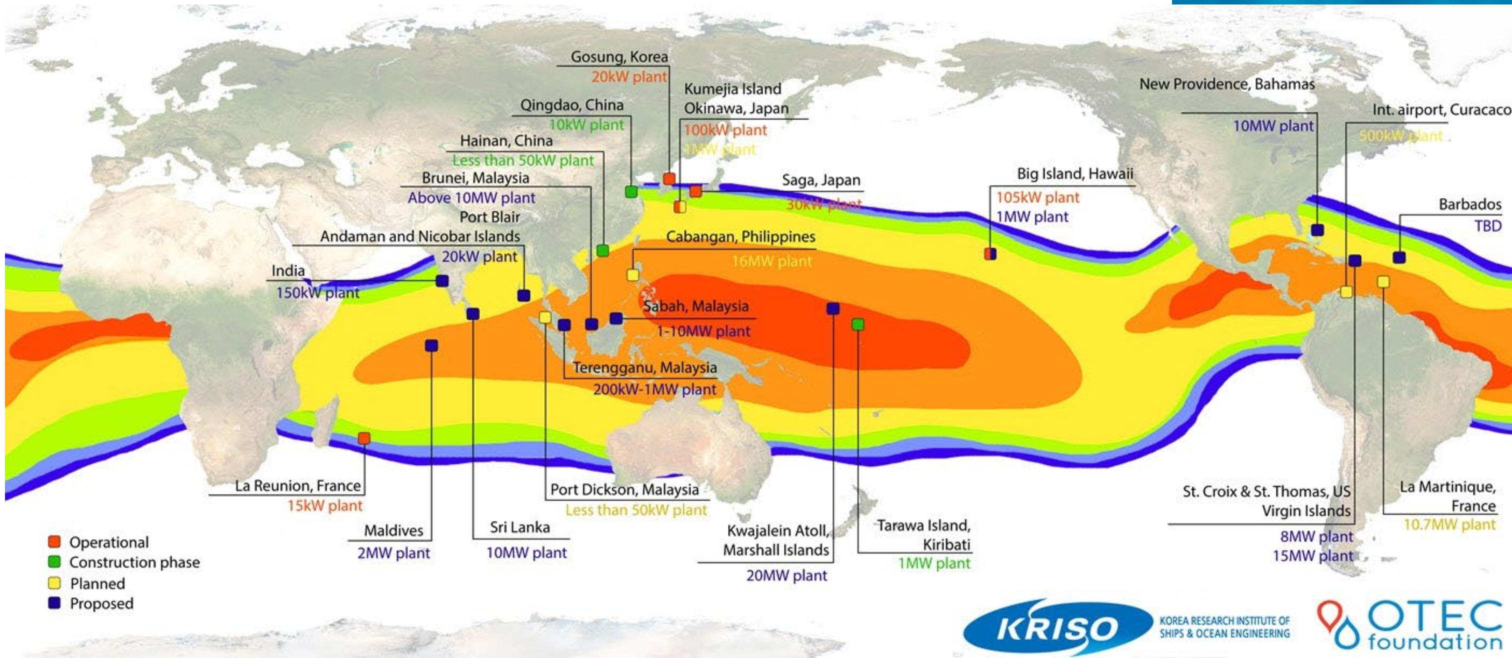
Ocean Thermal Energy Conversion (OTEC)

How it works:

- OTEC uses the temperature difference between surface and deep ocean water to generate power
- Warm water at surface can be pumped through an evaporator with a working fluid. Vaporized fluid drives a turbine.
- Thermal buoyancy engine – changes in temperature change the volume of a system without changing its mass

Types

- Closed cycle: working fluid with a low boiling point (commonly ammonia)
- Open cycle: Seawater is the working fluid. Can result in desalination
- Hybrid: Seawater evaporates into steam which heats a working fluid



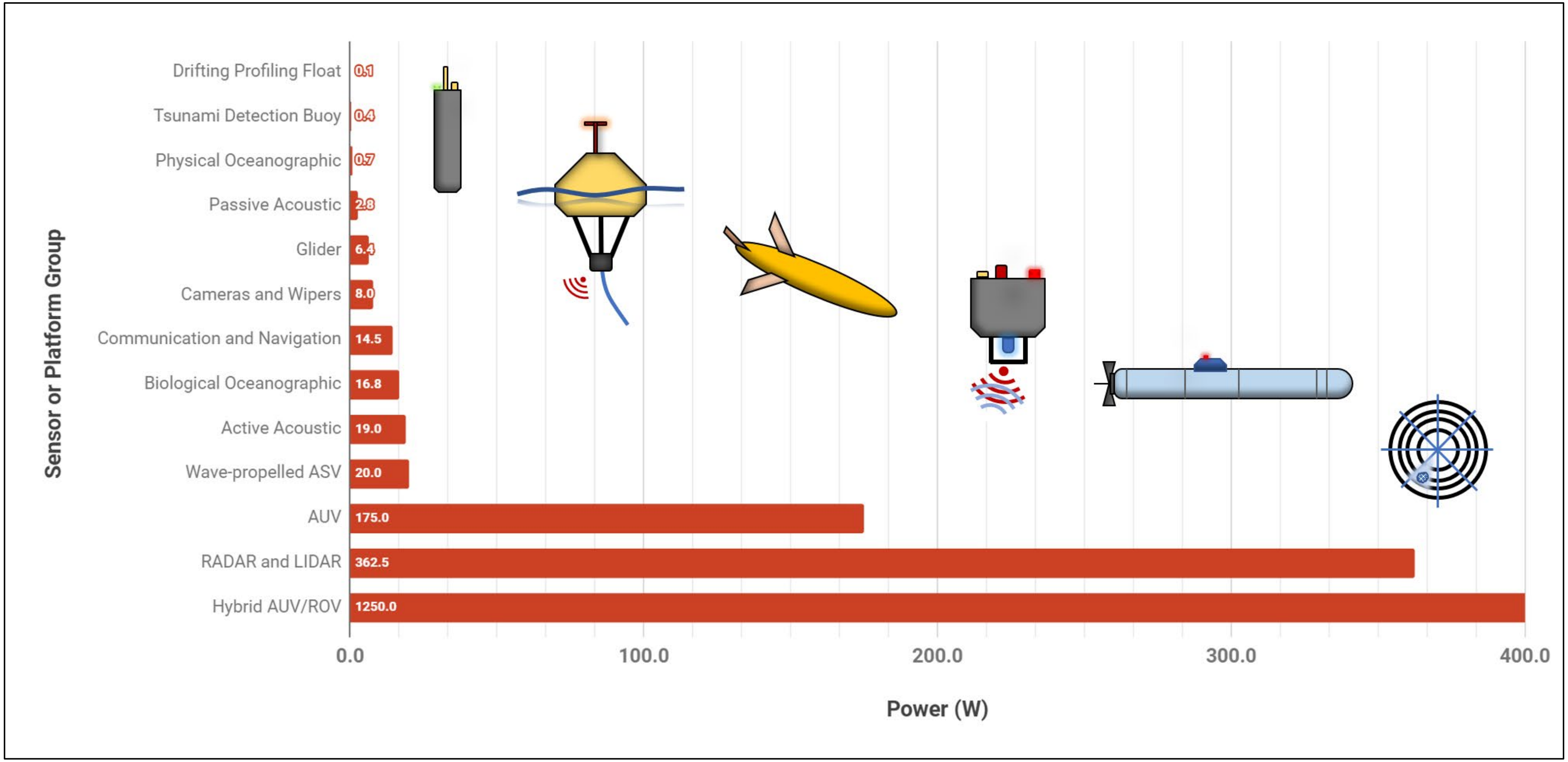
Potential End Uses

DOE
Powering the Blue Economy Report
link

Example: Ocean Observation

Ocean Observation

Potential ocean observation applications and estimated power requirements



[Powering the Blue Economy: Ocean Observing Use Cases]

Example: Offshore Marine Aquaculture

Aquaculture: The cultivation and harvest of fish (salmon, seabass), shellfish, crustaceans and aquatic plants (seaweed).

Factors affecting energy needs

- Species
- Operation scale
- Geographical location
- Phase of growing cycle (finfish)

Energy Requirements

- Lighting
- Pumps
- Feeding
- Aeration
- Desalination
- Cleaning
- Refrigeration
- Monitoring
- Support (barge) operations

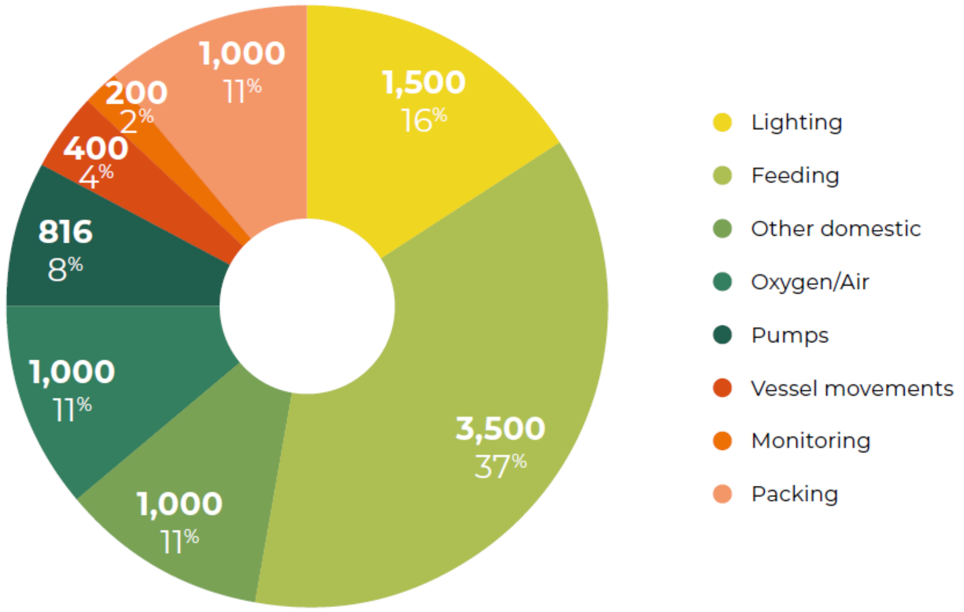


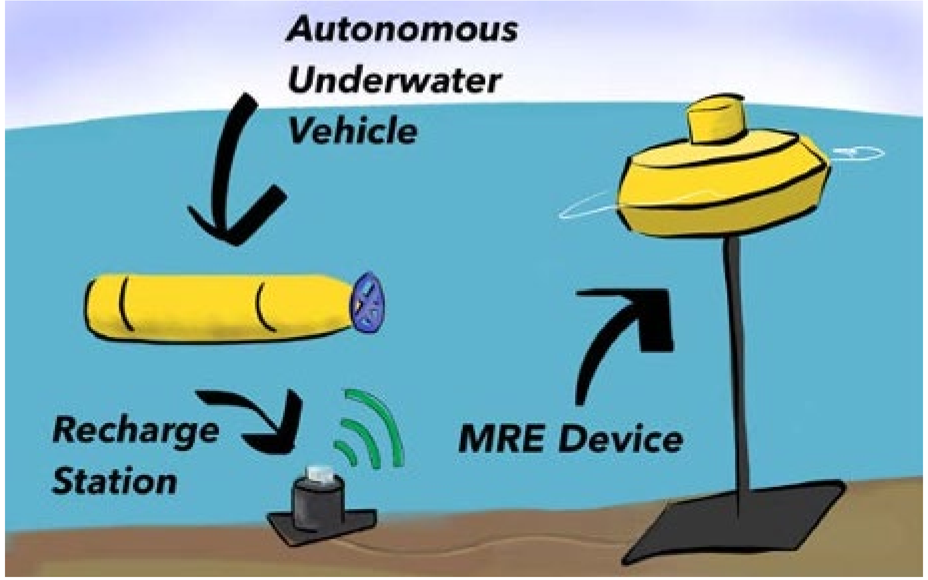
Figure 5. Average daily energy demand profile of the marine-based, enclosed system Asian seabass farm, Eco-Ark, in Singapore in kilowatt-hours (and percentage of total daily energy use) (pers. comms. Ban Tat Leow, October 2, 2021). The energy consumption is based on an annual production capacity of 166 tonnes and a cumulative energy demand of 9,416 kWh/day. The current bulk energy demand per tonne is 21,000 kWh/year (Leow 2021).

Offshore Aquaculture: A market for ocean renewable energy

Example: Underwater Vehicle Charging

Autonomous underwater vehicles (AUVs) and unmanned underwater vehicles (UUVs)

- Useful for:
  - Ocean Observation
  - Underwater Inspections
  - Mine detection
  - Surveillance
- Limited by battery capacity
- Missions may be extended by docking and recharge stations



Marine renewable energy application overview for underwater recharge of vehicles
(Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets, 2019)

Underwater Vehicle Charging

Example: Marine Algae

Marine Algae

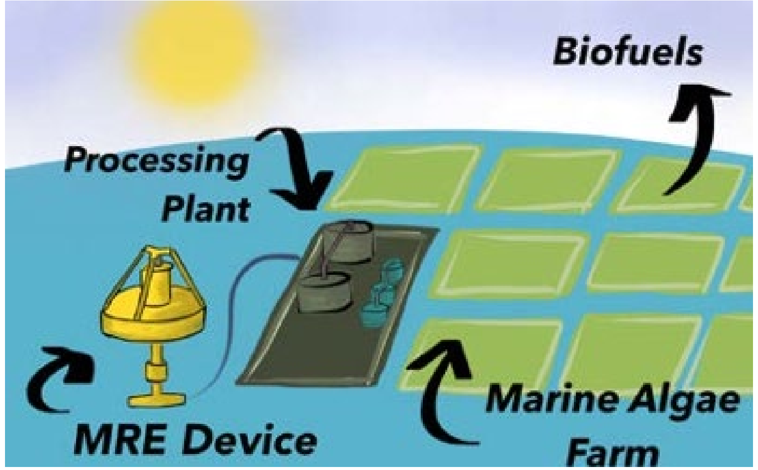
Macroalgae (seaweed) and some microalgae can be grown at commercial scale at sea

Uses

- Biofuels
- Food processing chemicals
- Cosmetics
- Pharmaceuticals
- Soil additives and fertilizers
- Animal fodder

Power Needs

- Navigation lights
- Maintenance equipment
- Pumps for nutrients and ballast control
- Refrigeration and ice production
- Drying operations
- Marine Sensors
- Vessel operations



Marine renewable energy application overview for a macroalgae farm
(Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets, 2019)

Example: Seawater Mining

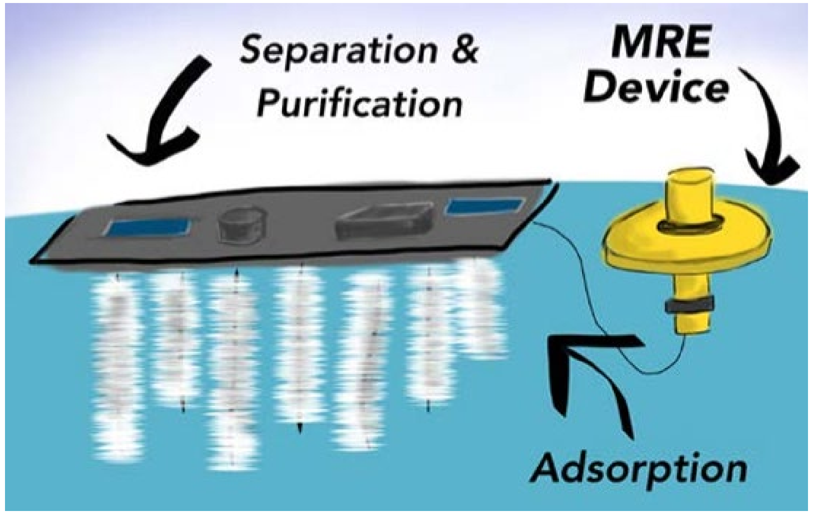
Seawater contains large amounts of minerals, dissolved gases, and specific organic molecules that are more evenly distributed than in terrestrial locations.

Methods

- Passive adsorption – natural ocean currents deliver fresh seawater to farms resembling a kelp forest. Farms may be deployed and retrieved by a work vessel.
- Electrochemical processes – an electrical current is passed through seawater to extract minerals or dissolved gasses

Power Needs

- Power for an electrolysis
- Deploying and retrieving adsorbent films
- Processing adsorbent films
- Safety and monitoring equipment



Marine renewable energy application overview for mining seawater
(Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets, 2019)

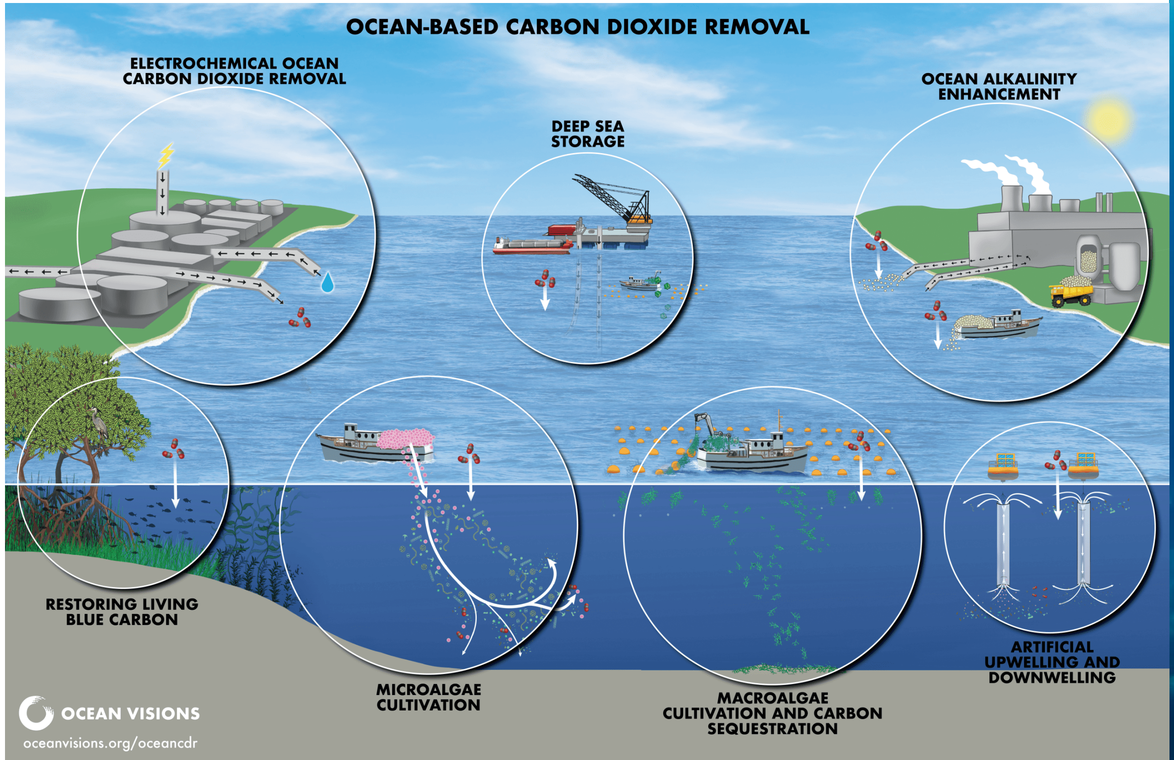
Seawater Mining

Example: mCDR

Marine Carbon Dioxide Removal (mCDR) seeks to remove carbon dioxide from the oceans. Methods are varied, and it is a relatively new field of study

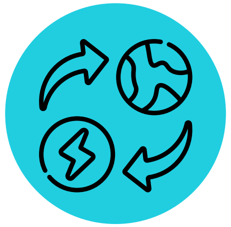
Methods

- Electrochemical ocean capture: Most commonly with bipolar membrane electrodialysis (BMED). Produces an acidic and a basic stream
- Ocean alkalinity enhancement – The basic solution is returned to the ocean where it absorbs more carbon dioxide in the atmosphere
- Deep Sea Storage – carbon dioxide is pumped to depth
- Microalgae/Macroalgae cultivation – Seaweed and microalgae absorb carbon.



Challenge Areas

Access
Deployment Duration
Energy Storage
Environment/Ecological Impact
Harsh Operational Conditions
Hybridization with Other Renewable Energy Resources
Suitability of Power



Access

Blue economy applications are challenged by high cost and limited opportunities for service, maintenance, and/or intervention at-sea

Deployment Duration

Deployment duration is limited by system life-cycle which is affected by available energy and system durability

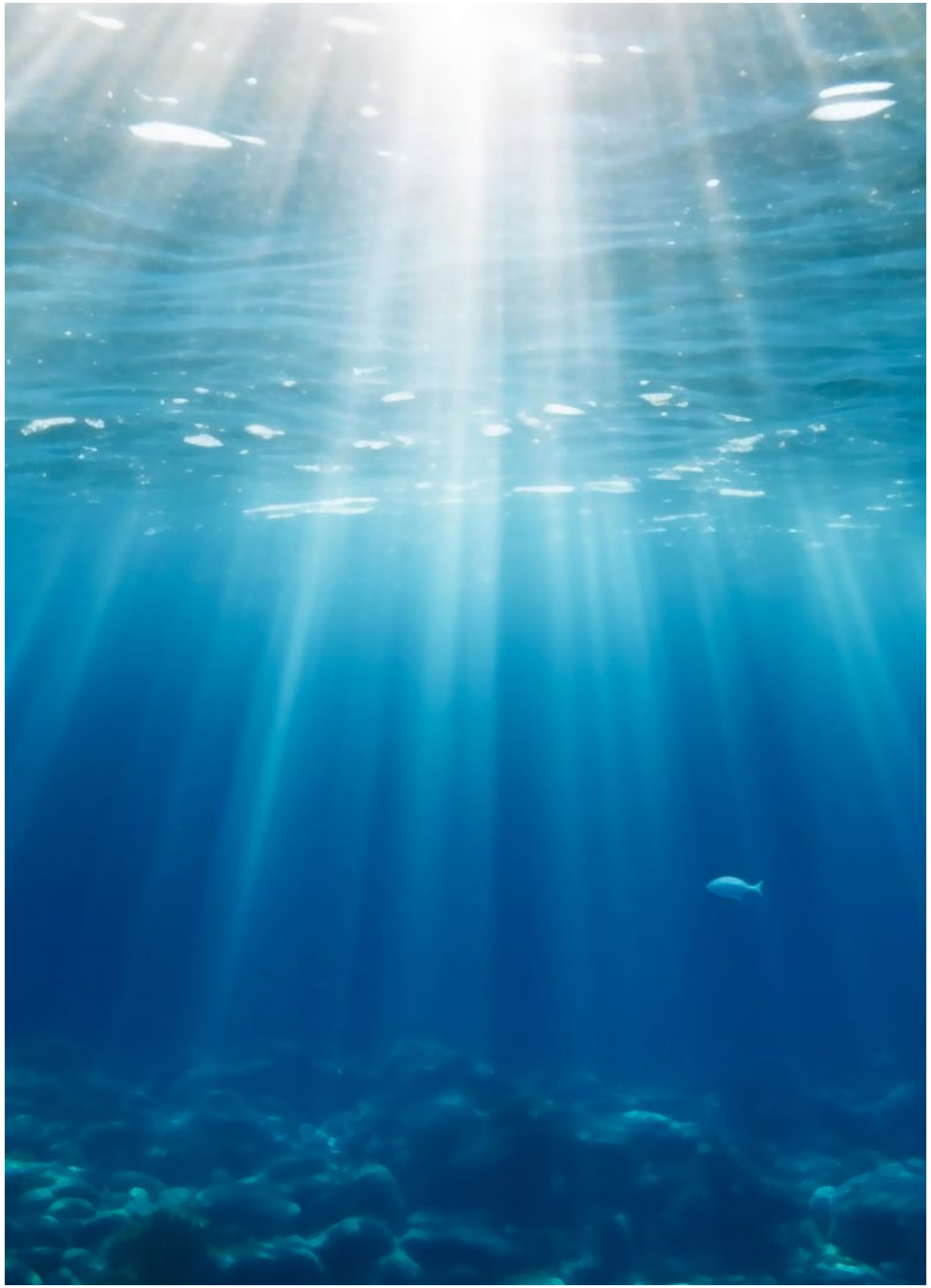


Figure 2.1 in the *2020 State of the Science* Report

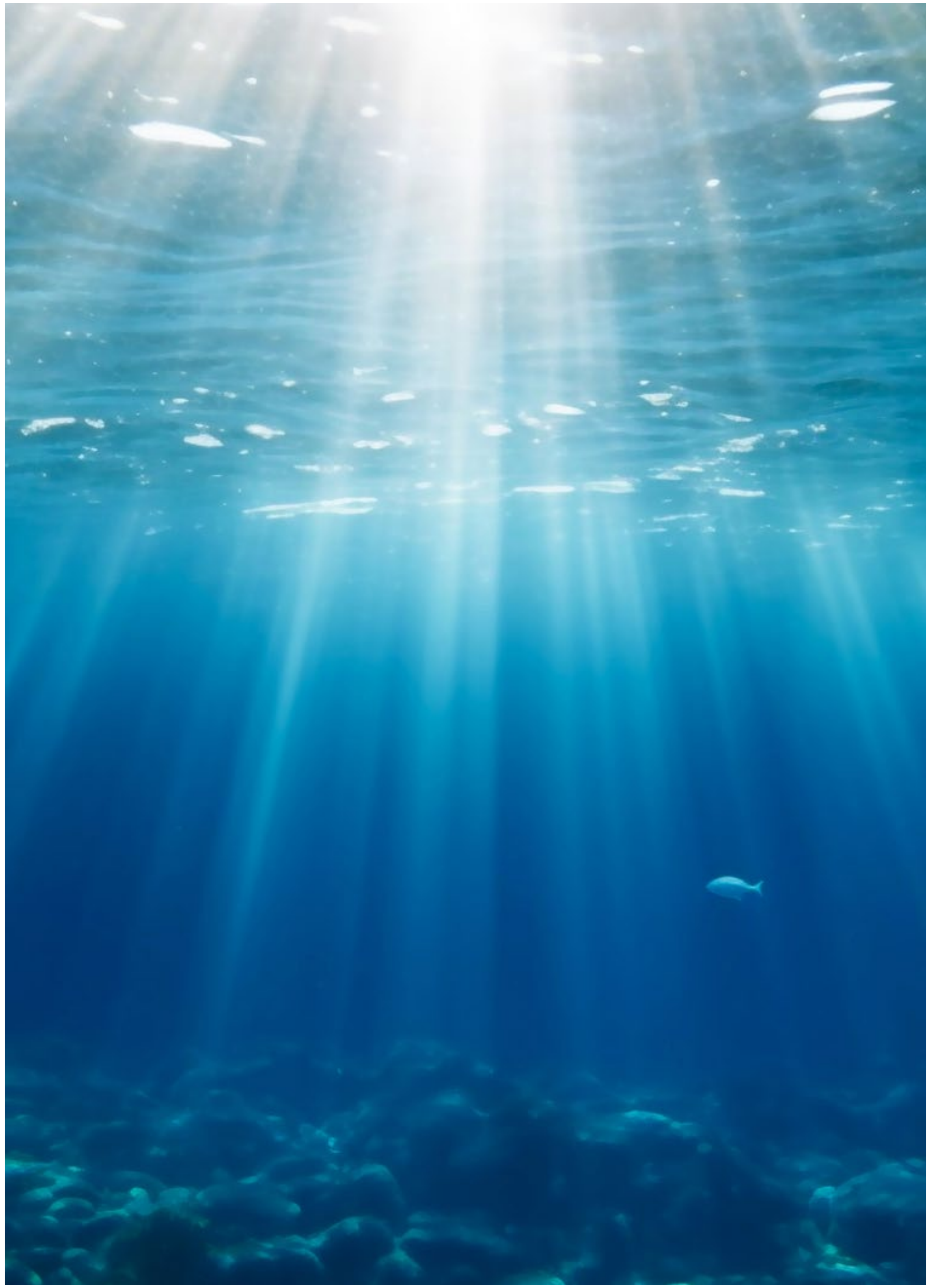
Environmental/Ecological Impact

It is important to minimize negative effects of marine energy solutions interacting with local flora and fauna

Energy Storage

Battery capacity limits capabilities and duty cycles, and battery volume often accounts for most of sensor volume and weight

NexSens data buoy in Lake Erie



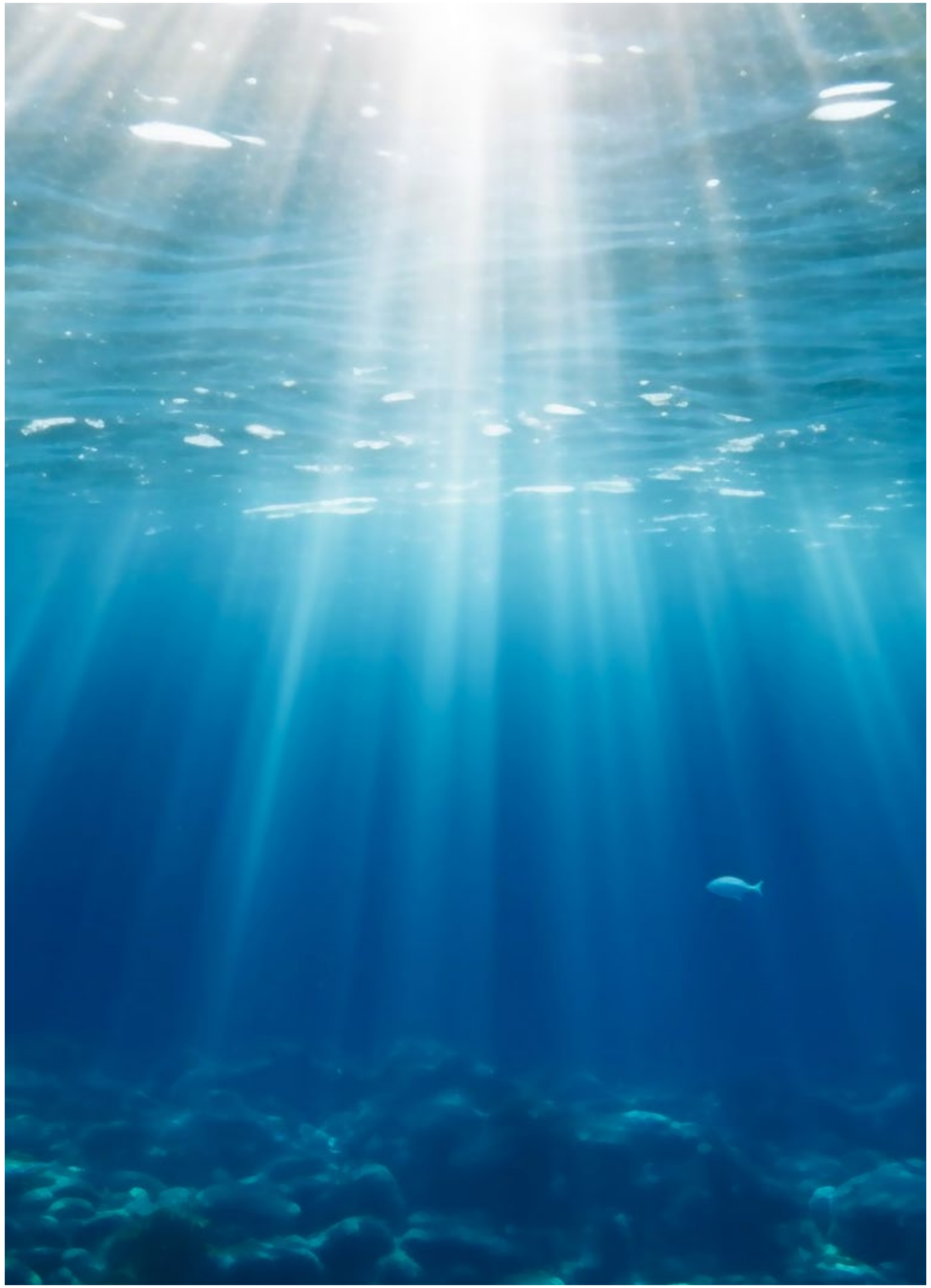
Watch for video series exploring these challenges further!

Harsh Operational Conditions

Operations face challenging conditions like violent storms, strong currents, strong pressure, corrosive media, and unwanted growth of marine organisms

Hybridization with other Renewable Energy Resources

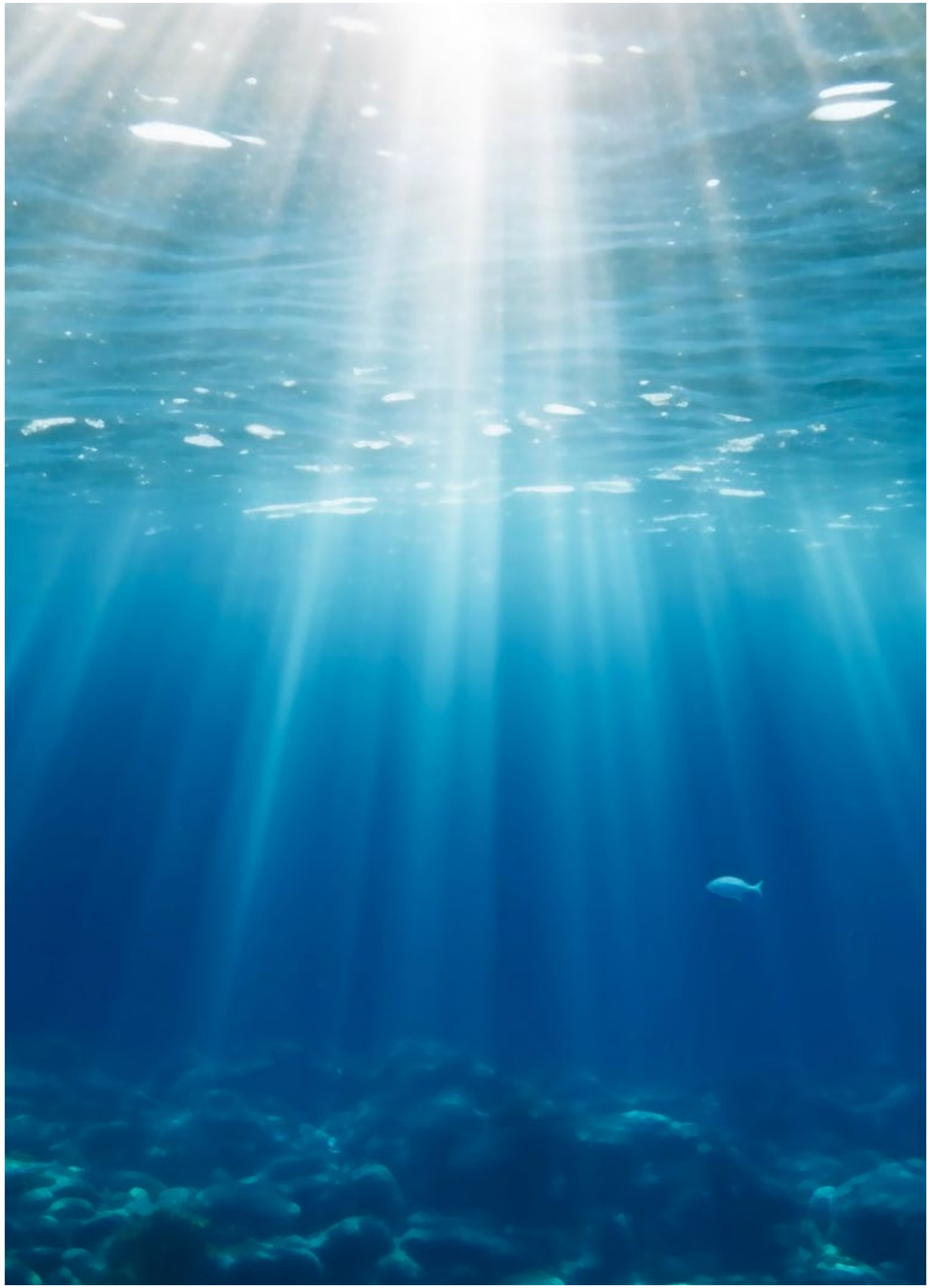
Marine energy may address power gaps caused by intermittency of other non-marine renewable energy sources like solar and wind power




Conductivity, temperature, depth sensor, NOAA

Suitability of Power

Sensors, instrumentation, and automation require specific power at specific times. Marine energy solutions must match power generation to power needs to maximize efficiency



Power at Sea Prize

Prize Goals

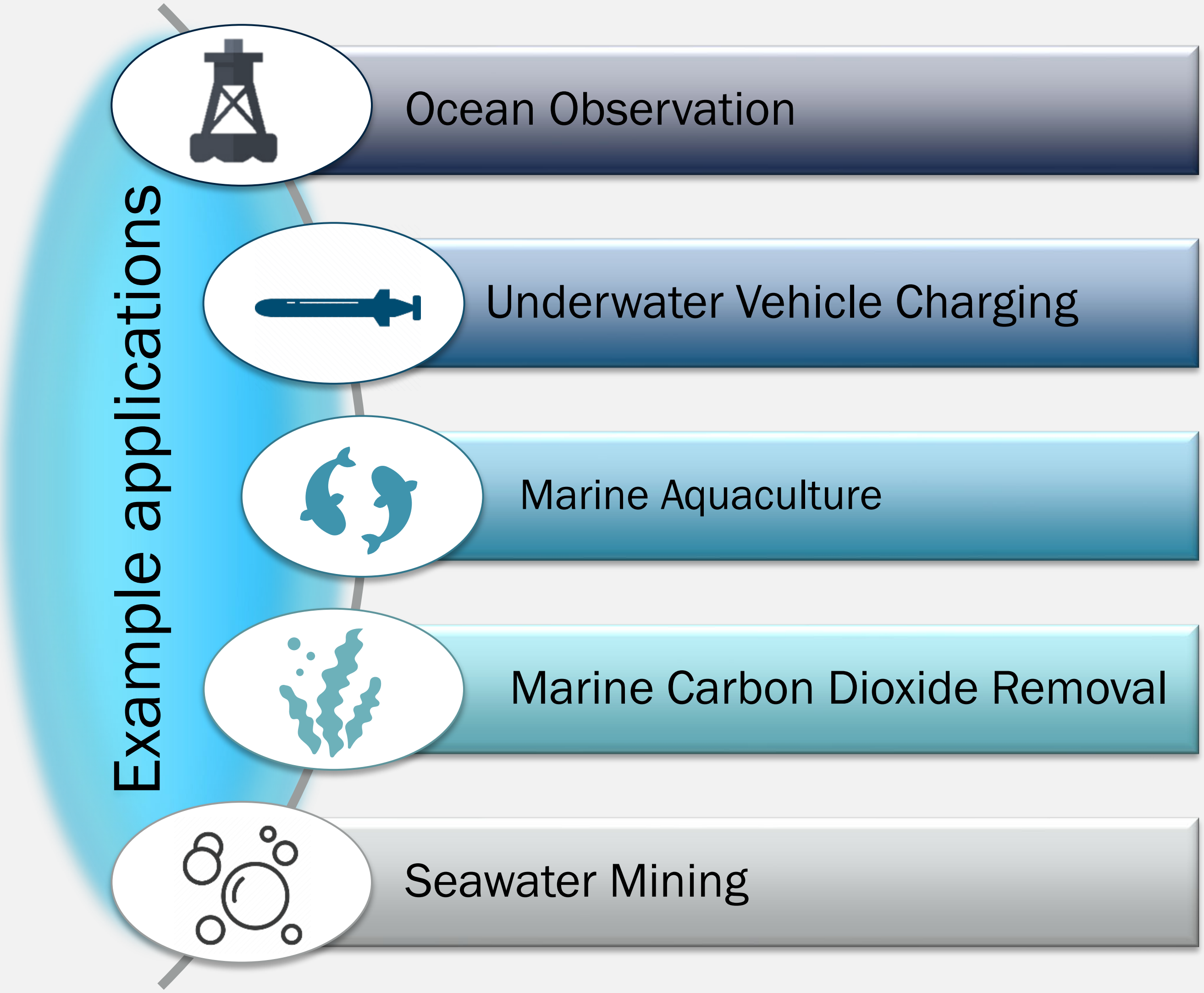
Engage and cultivate a community of **new and existing participants in marine energy** to introduce new, creative minds to Powering the Blue Economy and the marine energy field, fostering the development of new concepts and lessons learned.

Identify **new, innovative, and feasible marine energy concepts** that have a high likelihood of providing power at sea in the near term to accelerate the commercialization of the nascent marine energy industry.

Introduce competitors to WPTO and government funding mechanisms and prepare them to compete technically and financially for future funding opportunities both within and beyond DOE

Power at Sea Prize Scope

- Competitors must propose a tangible system, subsystem, or component that receives **more than or equal to 50% of energy needs** from one of the following marine energy resources: wave, tidal, ocean current, river, salinity gradients, or thermal gradients to power systems at sea
- The proposed system must address one challenge area:
  - Access
  - Deployment duration
  - Energy storage
  - Environmental/ecological impact
  - Harsh operational conditions
  - Hybridization with other renewable energy resources
  - Suitability of power



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CONCEPT PHASE

Up to $200,000 Cash Prize Pool

Up to $10,000 for up to 20 teams

November 13, 2023
CONCEPT Phase Submission Open

July 26, 2024, at 5 p.m. ET
CONCEPT Phase Submission Close

August 2024
CONCEPT Phase Winner Announcement

Join the Competition!

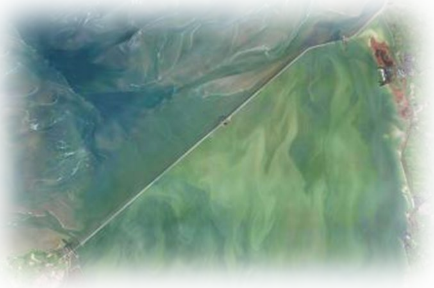
Concept Phase Submissions due

July 26, 2024

HeroX.com/poweratseaprize

Backup Slides

Salinity Gradient Energy Harvesting



How it works: Power can be generated from salinity gradients via mixing or osmosis

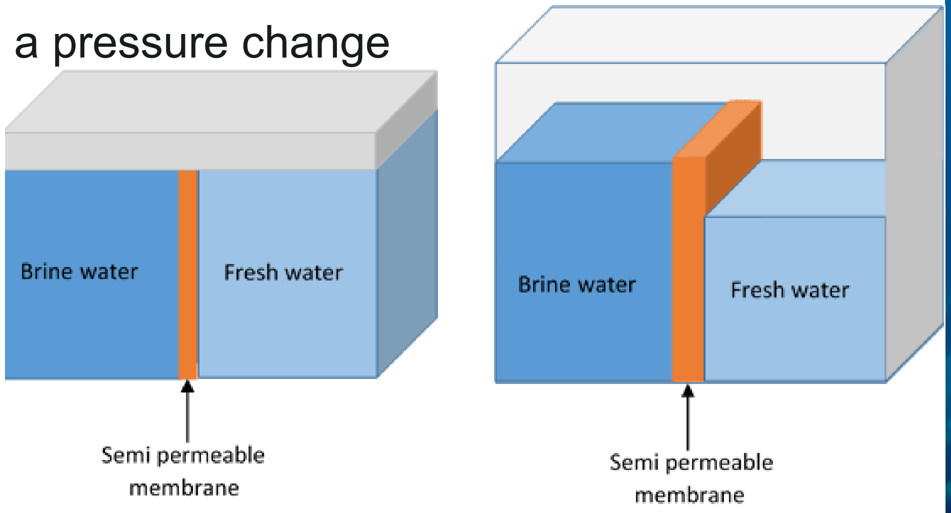
Mixing:

- Liquids with different salinities, such as fresh riverine water and salty ocean water, mix and produce energy ("Gibbs free energy")
- This energy is collected via porous electrodes immersed in the solution

Osmosis:

- Liquids with different salinities are separated with a semi-permeable membrane
- Natural ion movement is amplified with either pressure or electrical current on the low-salt side
- Water movement (from low-salinity to high) results in a pressure change that drives a turbine

Paper highlight: [Hsu et al., 2021]



Engineering Challenges

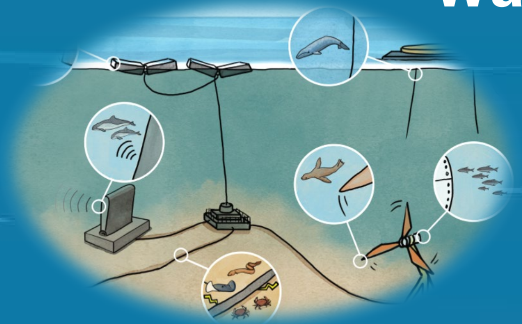
Water Intrusion

Galvanic Corrosion

Biofouling

Understanding Environmental Effects

Watch for: Video series addressing these in detail!



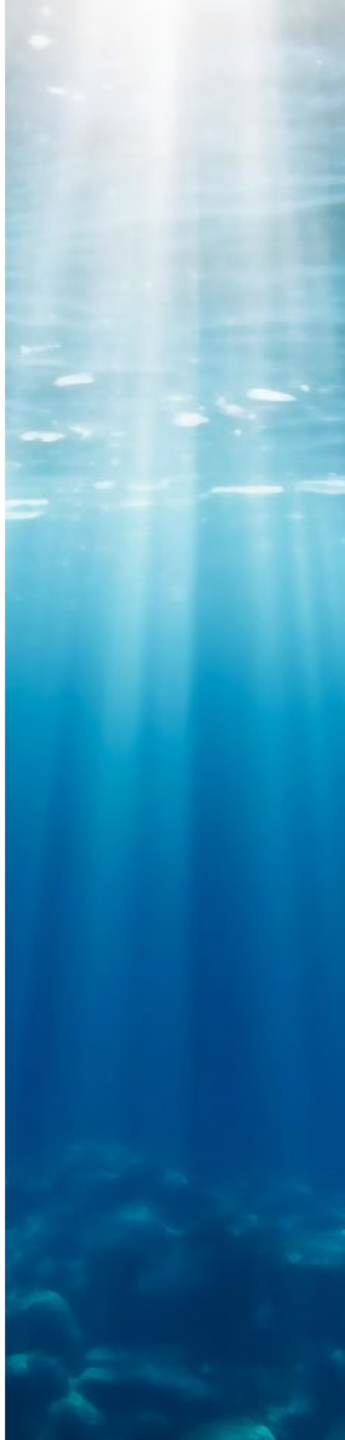
Water Intrusion into Enclosures

Why does it occur? Hydrostatic pressure ($P = \rho g h$) exerts force on a pressure vessel due to the weight of water above the vessel

Best practices to ensure enclosure integrity:

- Redundant o-rings (silicone grease is your best friend)
- Sub-sea connectors: pass-through, bulkhead
    - Dry-mate vs wet-mate

Connector images from MacArtney



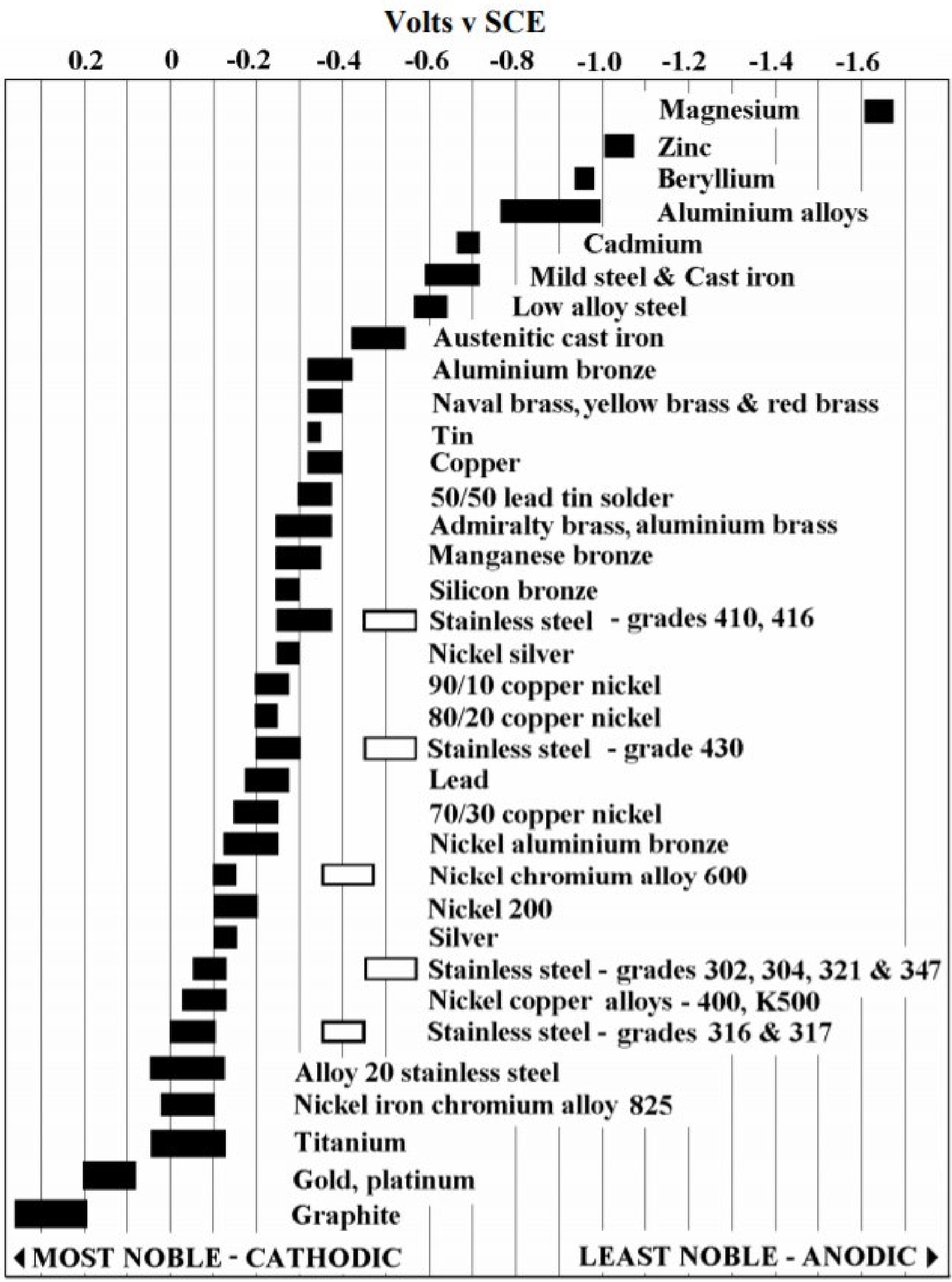
Galvanic Corrosion

What is it? When two dissimilar metals are combined in a corrosive medium (i.e., seawater), corrosion rates change.

Why does it happen? One metal becomes an anode while the other becomes the cathode. The potential difference (voltage) between materials causes a corrosive electrical current. The anode loses material due to current discharge.

Solutions:

- Use a single metal when possible (commonly 316 stainless, titanium, galvanized steel)
- Insulate dissimilar metals
- Sacrificial anode – Zinc
- Rinse equipment with fresh water after deployment and recovery



Biofouling

What is it?

- Growth of marine organisms on objects in the ocean (algae, mussels, barnacles, biofilms)

Factors influencing rate of growth

- Temperature
- Solar irradiation
- Species diversity

Best practices

- Anti-biofouling coatings (those containing copper are closely regulated)
- Frequent maintenance intervals

Environmental Effects of MRE

Stressors: MRE devices and systems that may cause harm

Receptors: marine animals, habitats, ecosystem processes

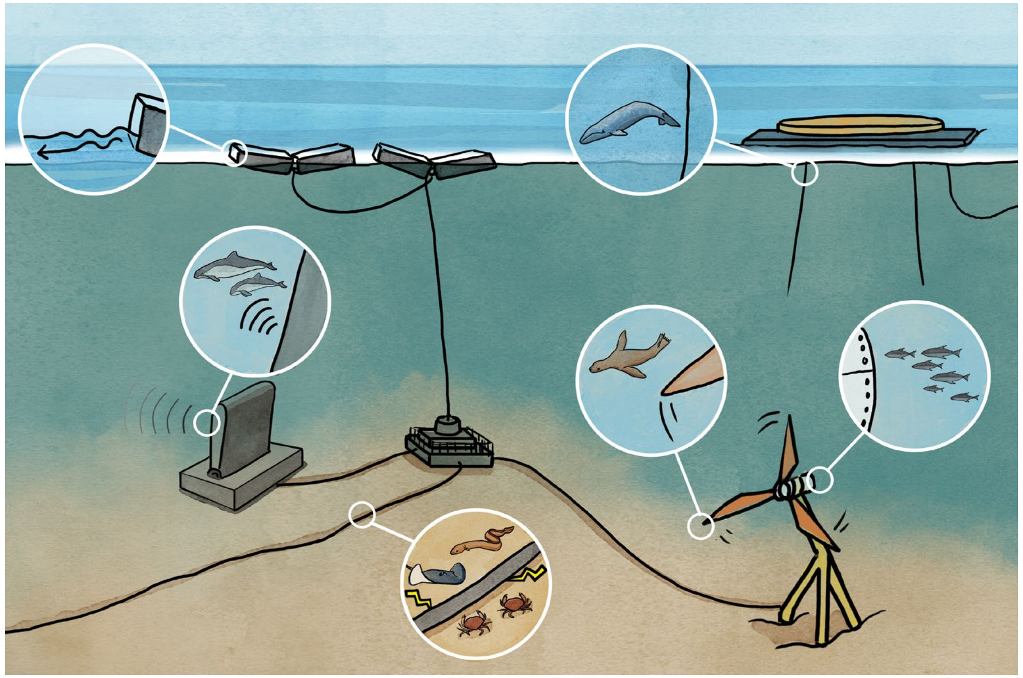


Figure 2.1 in the *2020 State of the Science* Report

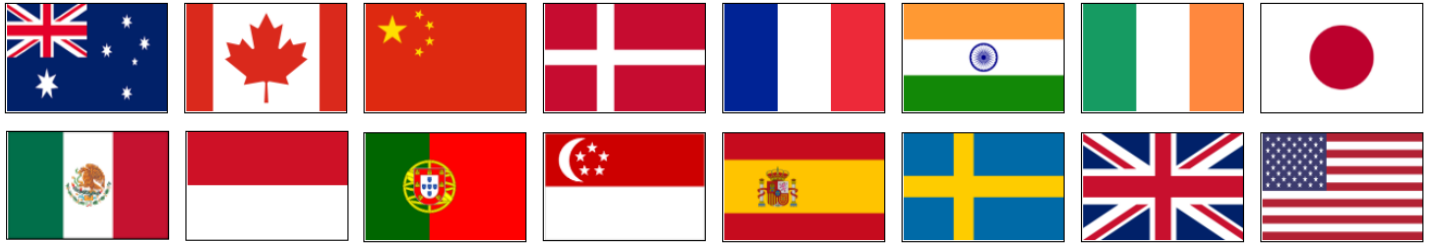
Key stressor-receptor interactions:

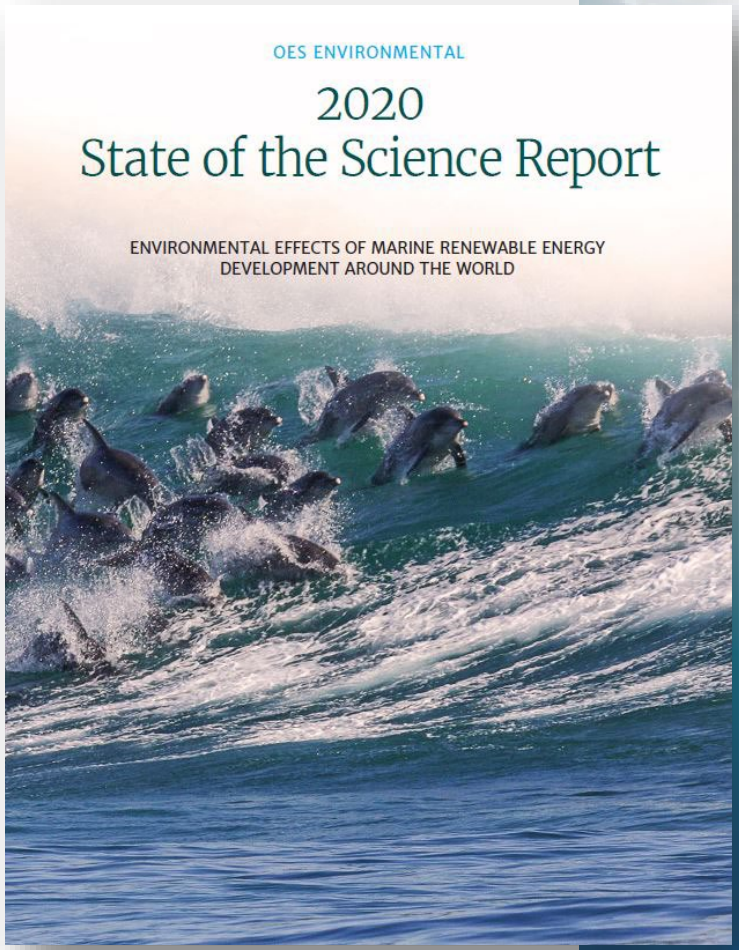
- Collision risk
- Entanglement risk
- Underwater noise*
- Changes in oceanographic systems*
- Electromagnetic fields*
- Displacement
- Habitat changes*

* Retired for small numbers of devices

Ocean Energy Systems (OES) - Enviromental

- Established by the IEA-Ocean Energy Systems in 2010
- Examines environmental effects of marine renewable energy (MRE) development to advance the industry in a responsible manner
- Led by the US DOE Water Power Technologies Office and implemented by Pacific Northwest National Laboratory
- 16 member countries
- 2024 State of the Science Report to be release in the Fall





OES ENVIRONMENTAL

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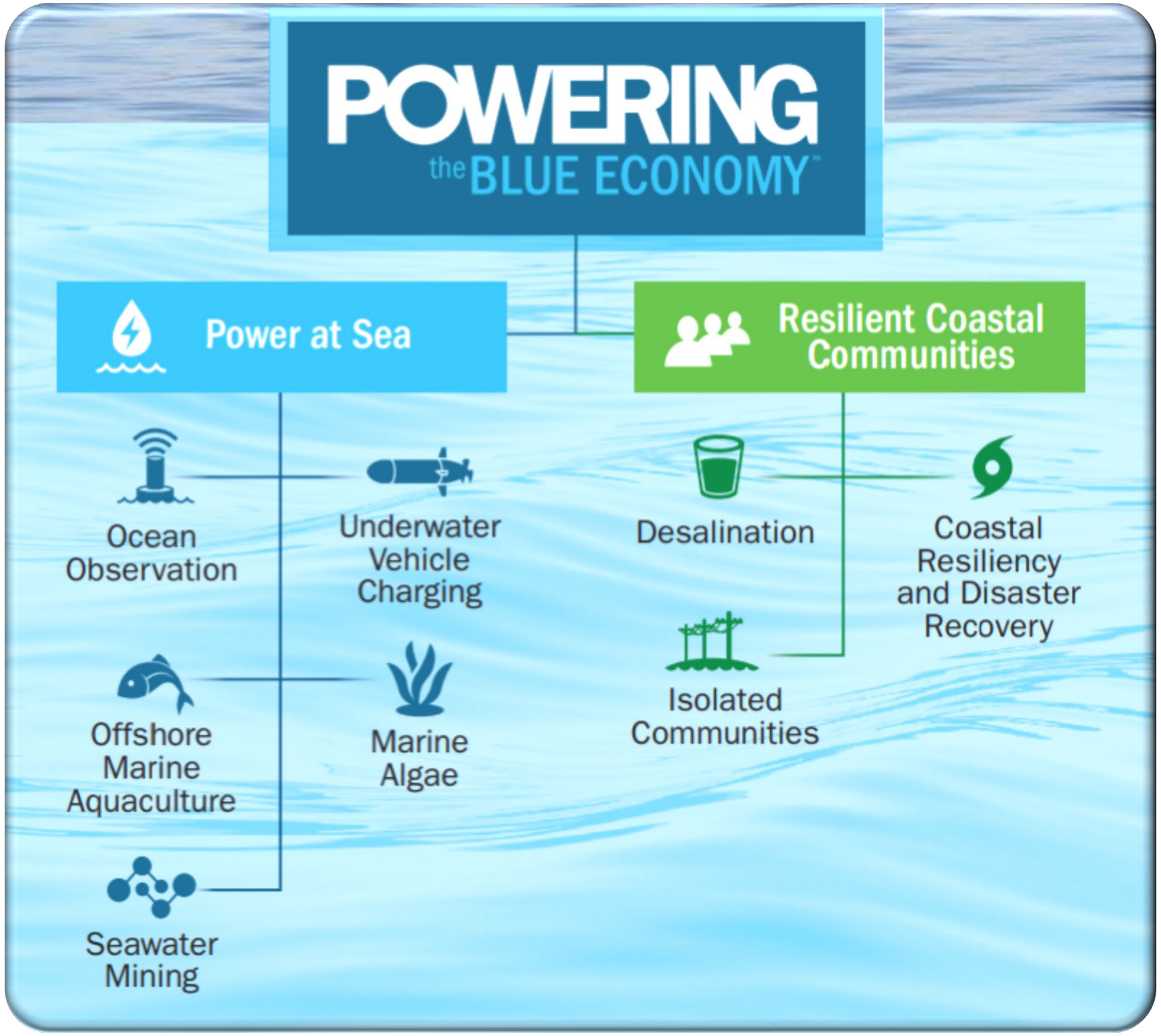
Subtitle


POWERING
the BLUE ECONOMY
Power at Sea
Resilient Coastal Communities
Ocean Observation
Underwater Vehicle Charging
Offshore Marine Aquaculture
Marine Algae
Seawater Mining
Desalination
Coastal Resiliency and Disaster Recovery
Isolated Communities

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Thank you