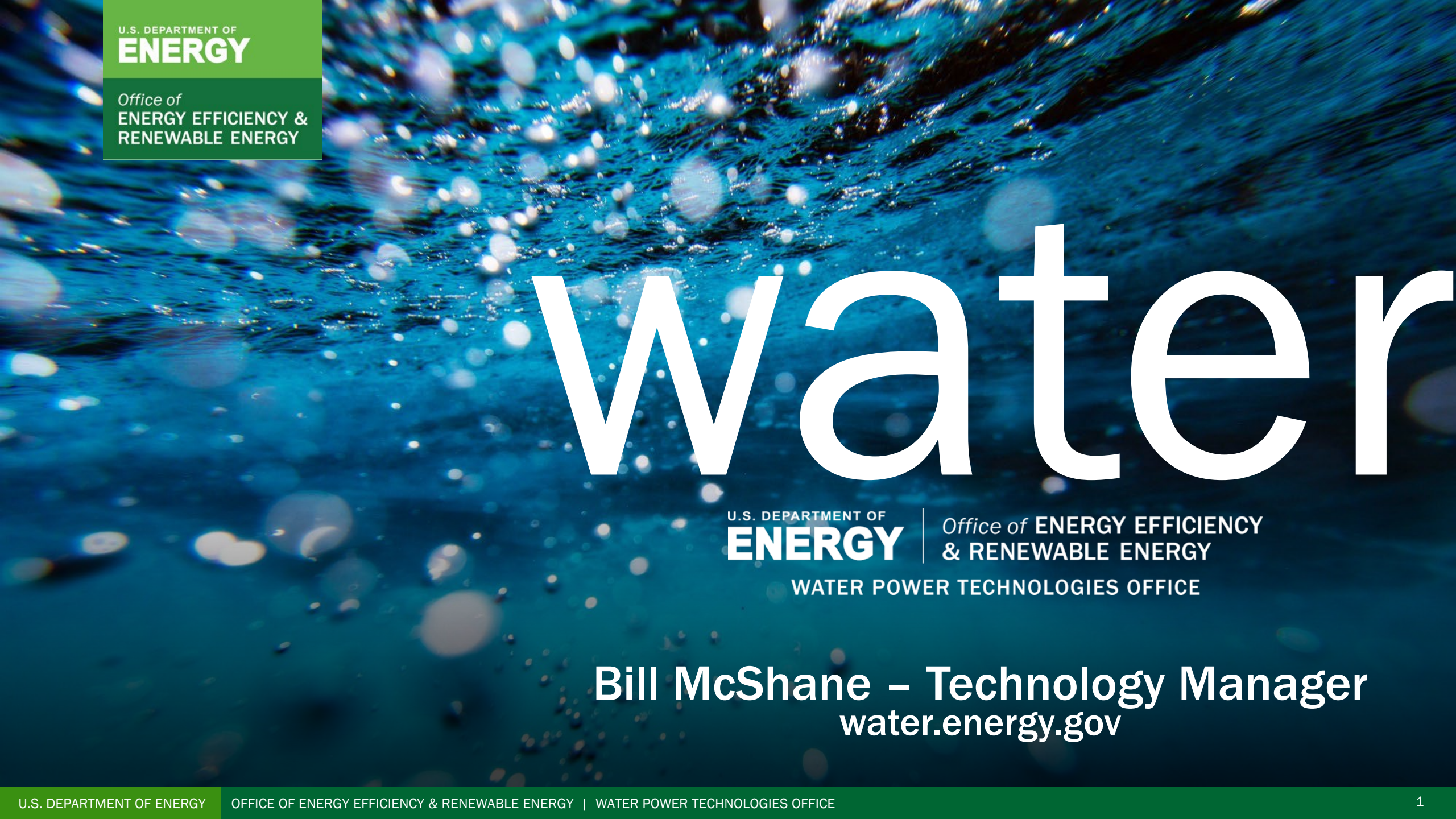
U.S. DEPARTMENT OF
ENERGY
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY
water
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& RENEWABLE ENERGY
WATER POWER TECHNOLOGIES OFFICE
Bill McShane – Technology Manager
water.energy.gov

water power | about the office

WPTO enables research, development, and testing of emerging technologies to advance **marine energy** and **next-generation hydropower** and **pumped storage systems** for a flexible, reliable grid.

WPTO invests in early-stage research to accelerate development of innovative water power technologies, while ensuring that long-term sustainability and environmental issues are addressed.

WPTO supports efforts to validate performance and grid reliability for new technologies, develop and increase accessibility to necessary testing infrastructure, and evaluate systems-level opportunities and risks.

WPTO aggregates, analyzes, and disseminates relevant, objective, and technical information on water power technologies and related issues to stakeholders and decision makers.

Research Priorities in the Water Power Technologies Office (WPTO)

WPTO enables research, development, and testing of emerging technologies to advance marine energy and next-generation hydropower and pumped storage systems for a flexible, reliable grid.

Hydropower Program
FY2023: $59M

Modernizing the Existing Fleet

Pumped Storage Hydropower

New Low-Impact Projects

Marine Energy Program
FY2023: $120M

Wave

Tidal, River and Ocean Current

Ocean Thermal

How We Accomplish Our Mission

Foundational R&D: Invest in the technologies, materials, and approaches to advance the readiness of all water technologies.

Support the Pipeline of Solvers: Through solicitations, fund the solvers, the entrepreneurs, and the technical experts through solicitations to help solve our challenges.

Infrastructure & Access: Fund the infrastructure needed to test technologies and use those assets for more researchers and organizations.

Demonstrations: Fund in-the-water demonstrations of hydro and marine energy research. De-risk technologies for deployment and understand how these technologies work in the field.

Environmental Assessments: Support the analysis, technology development, and partnerships needed to advance water power in rivers and oceans.

Address Regulatory Barriers: Work alongside the partners in the federal and state governments to understand the complexities of deployment.

Partnerships and Community Engagement: Identify the partners critical to work, catalyze the private and public sector partnerships to ensure success, fund the innovation ecosystem and community partnerships, and bring new people and organizations to the table, including a diverse, representative portfolio and programs.

Water Power Matters at All Scales

Watts:

enable a persistent power source to understand the ocean, by powering observing buoys, monitoring for the environment

Kilowatts:

develop deployable systems to provide clean water, power aquaculture, and powering remote communities

Megawatts:

deploy and demonstrate water powered systems for local grids, remote communities, powering dams and agriculture

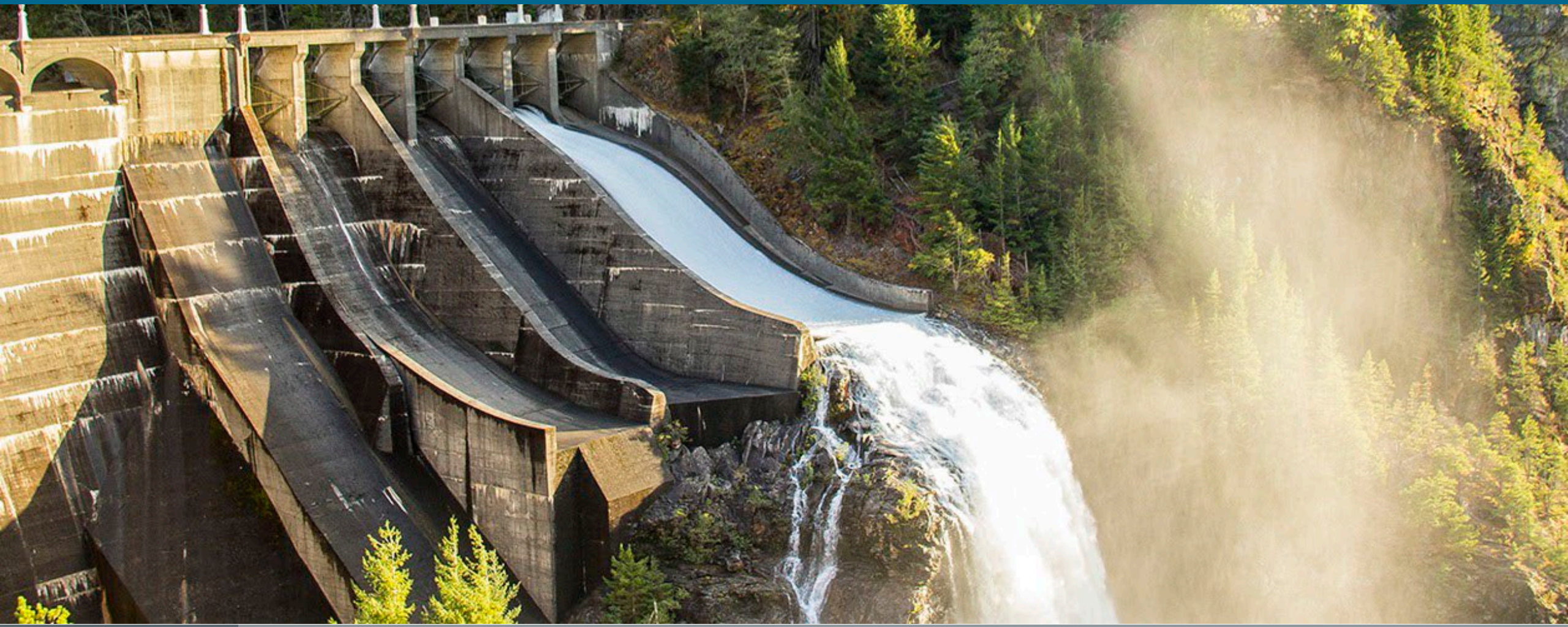
Gigawatts:

deploy and demonstrate seasonal storage, enhance hydro grid flexibility, demonstrate new water power systems

All scales require technical and financial assistance, testing infrastructure, user-centric designs, and a robust innovation ecosystem.

Hydropower

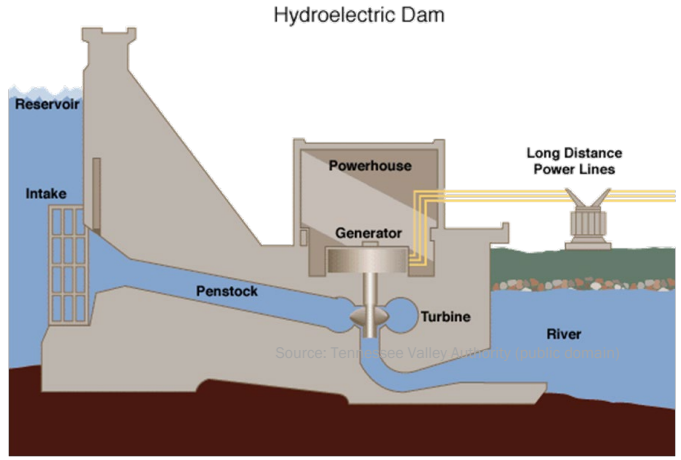
Hydrogen R&D Projects



INL, PNNL, & Idaho Power Hydropower-Based Hydrogen Production Analysis

- There is growing interest in the concept of hydrogen production from the hydropower industry
  - Hydropower plants are a source of clean, reliable electric power, and are co-located with freshwater resources. These are the primary resources required for electrolytic hydrogen production, which is a commercial technology with equipment costs continuing to decrease as a result of ongoing R&D efforts.
  - Idaho Power Company is interested in hydrogen production as a means of diversifying revenue streams. Hydrogen can be used as an energy carrier, fuel source, as well as a chemical feedstock

- Idaho National Laboratory (INL), Pacific Northwest National Laboratory (PNNL), and Idaho Power will collaborate to evaluate the technoeconomic feasibility of adding clean hydrogen production to an Idaho Power Company hydropower plant. This project will identify hydrogen production technologies and the production capacity for prospective facilities with the greatest economic potential to:
  - Enhance electricity generation flexibility, reduce transmission congestion, and increase power sales revenue during periods of peak demand by adding hydrogen production and storage capacity to a hydropower facility
  - Produce clean hydrogen for blending with natural gas as a fuel for a conventional combustion turbine plant to produce electricity
  - Produce hydrogen product to sell to transportation, chemical, manufacturing, and/or industrial markets
  - The oxygen byproduct from electrolytic hydrogen production could also be used to improve water quality associated with hydropower dams



$$2\,H_2O + e^- \rightarrow 2\,H_2 + O_2$$

Project Details

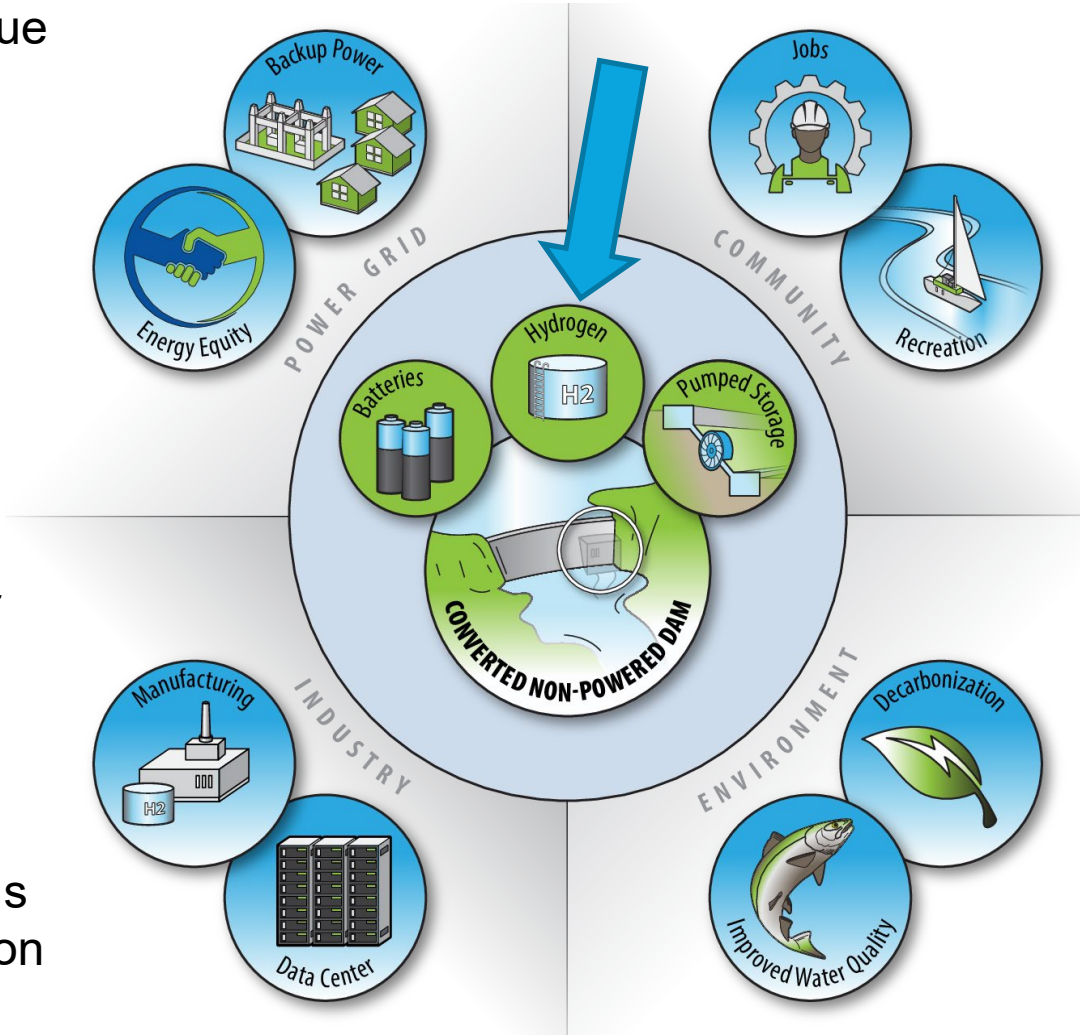
• Collaborators: Idaho National Laboratory, Pacific Northwest National Laboratory, Idaho Power Company

• Principal Investigators:
Dan Wendt, INL (daniel.wendt@inl.gov)
Di Wu, PNNL (di.wu@pnnl.gov)

• Funding Office: DOE Water Power Technologies Office

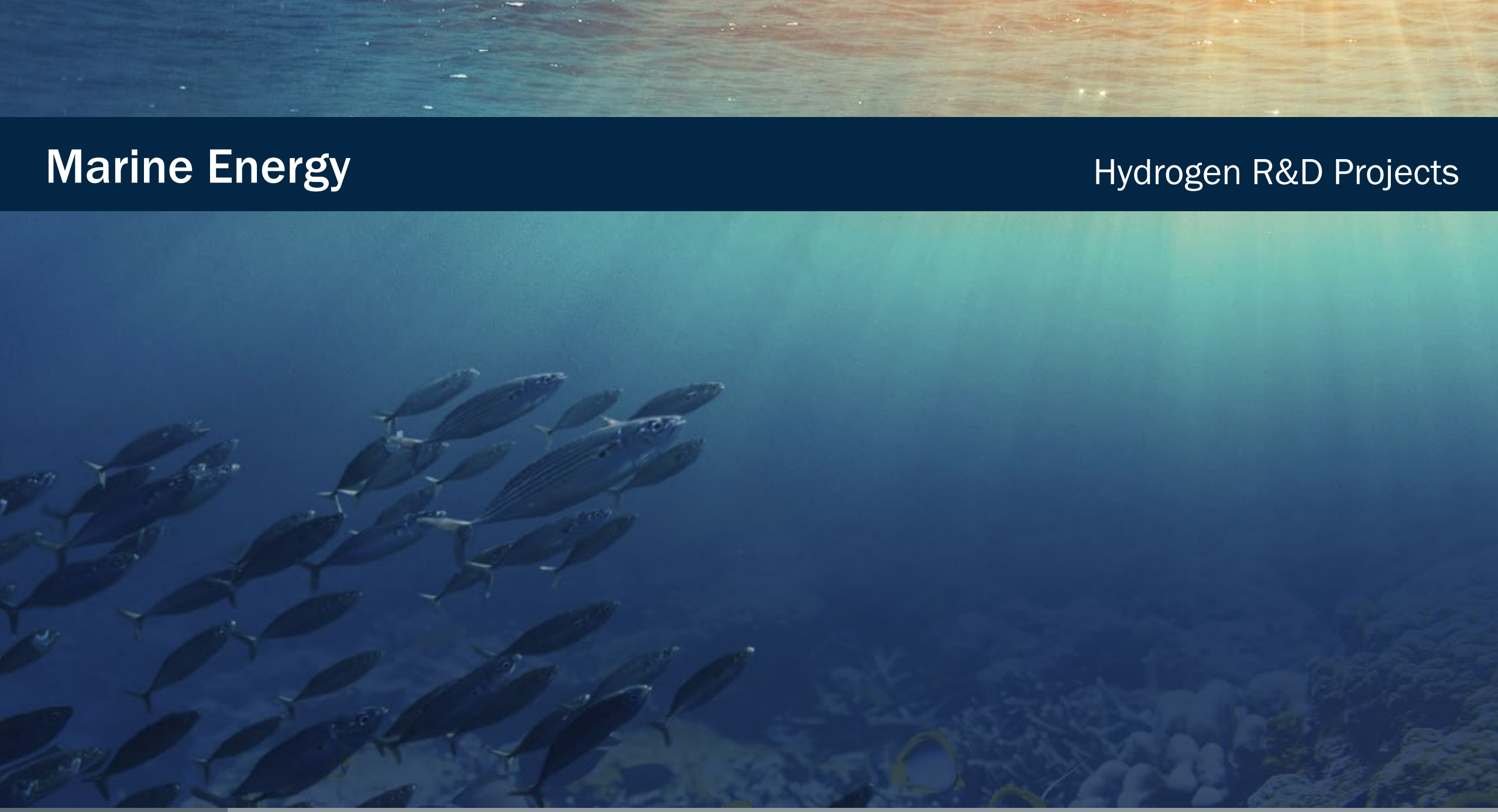
Evaluating Options for Non-Powered Dams (NPD) to Provide Grid, Community, Industry, and Environmental Benefits

- Adding hydrogen (H_2), batteries, or pumped storage hydropower as part of NPD retrofits can enable diverse value drivers, helping to motivate development of more projects.
- The team is developing frameworks to prioritize potential NPD projects across the U.S. and perform site-specific feasibility analysis. The team is fully implementing the national-level prioritization framework as a tool and developing site specific case studies.
- H_2 is unique and promising technology because it can both act as energy storage and be used directly by off-takers for diverse purposes such as blending with natural gas or serving as a chemical feedstock for fertilizer or steel production.
- Coupling H_2 with NPD retrofits can also make use of surplus hydropower supply, especially if it can support high utilisation factors for electrolysis plants.

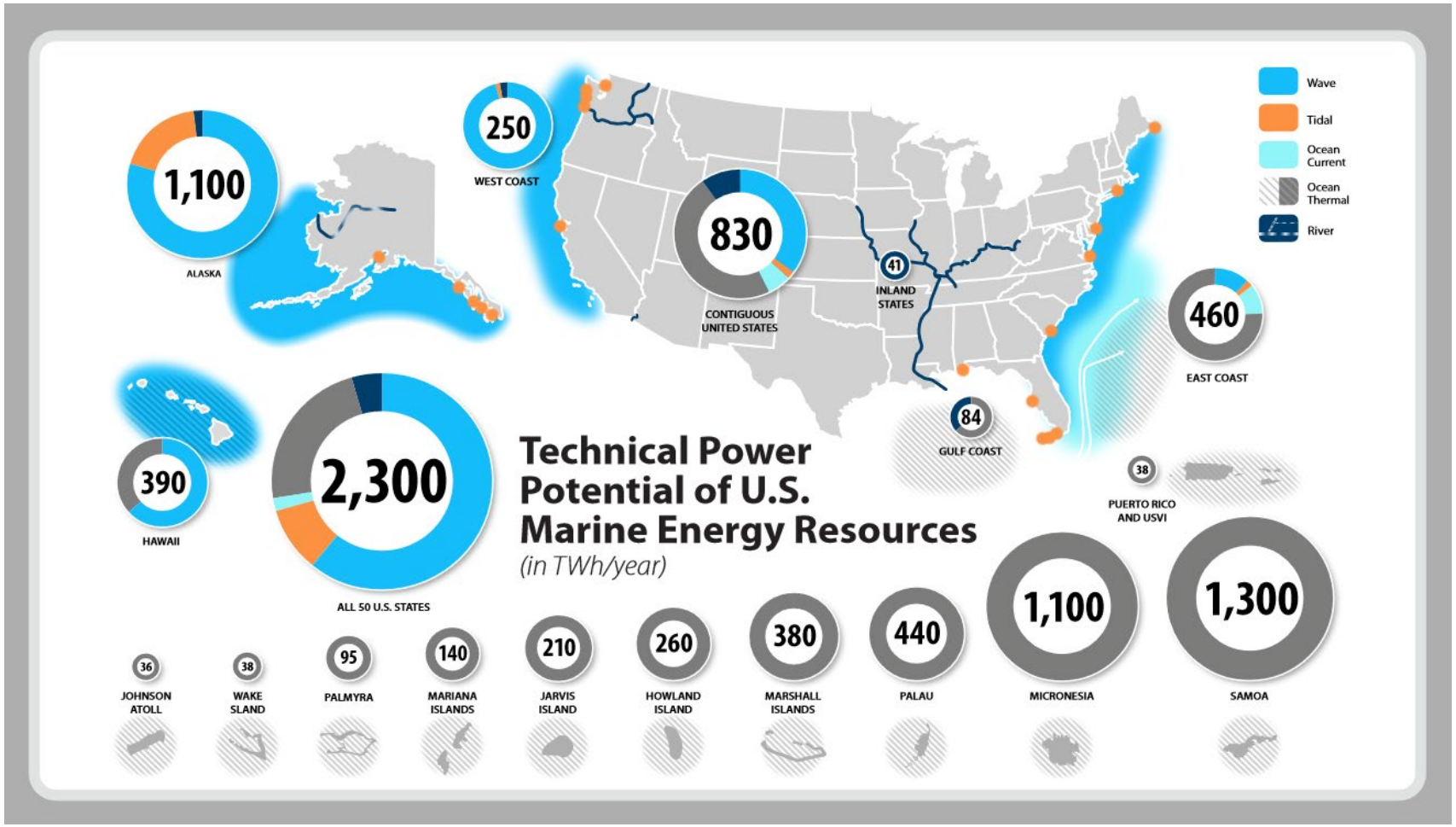


Marine Energy

Hydrogen R&D Projects



Why Combine Marine Energy and Hydrogen Technologies?



Kilcher, Fogarty, and Lawson. 2021. ***Marine Energy in the United States: An Overview of Opportunities.*** Golden, CO: National Renewable Energy Laboratory. NREL/TP-5700-78773. https://www.nrel.gov/docs/fy21osti/78773.pdf

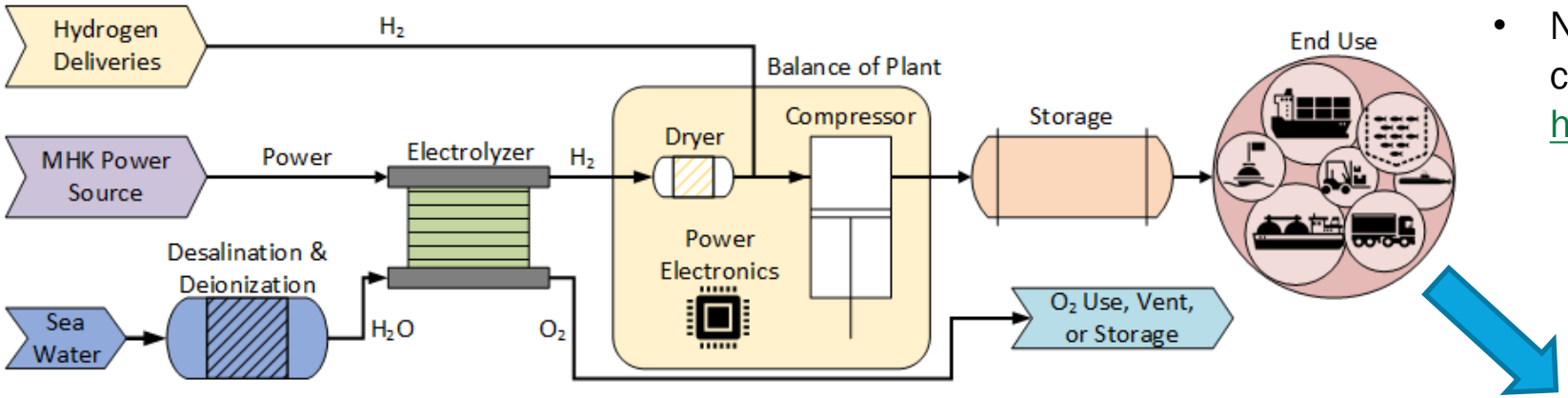
Marine energy

- A vast and untapped resource
- Has the potential to provide energy for utility-scale, remote and distributed applications, and rapidly expanding maritime industries
- Significant amount of the resource is located far from load centers and transmission

- To unlock the potential of marine energy, <u>efficient methods of storing and transporting captured marine energy are needed</u>

- A <u>promising solution</u> to these energy storage and transportation challenges is to <u>combine marine energy and hydrogen generation technologies</u>

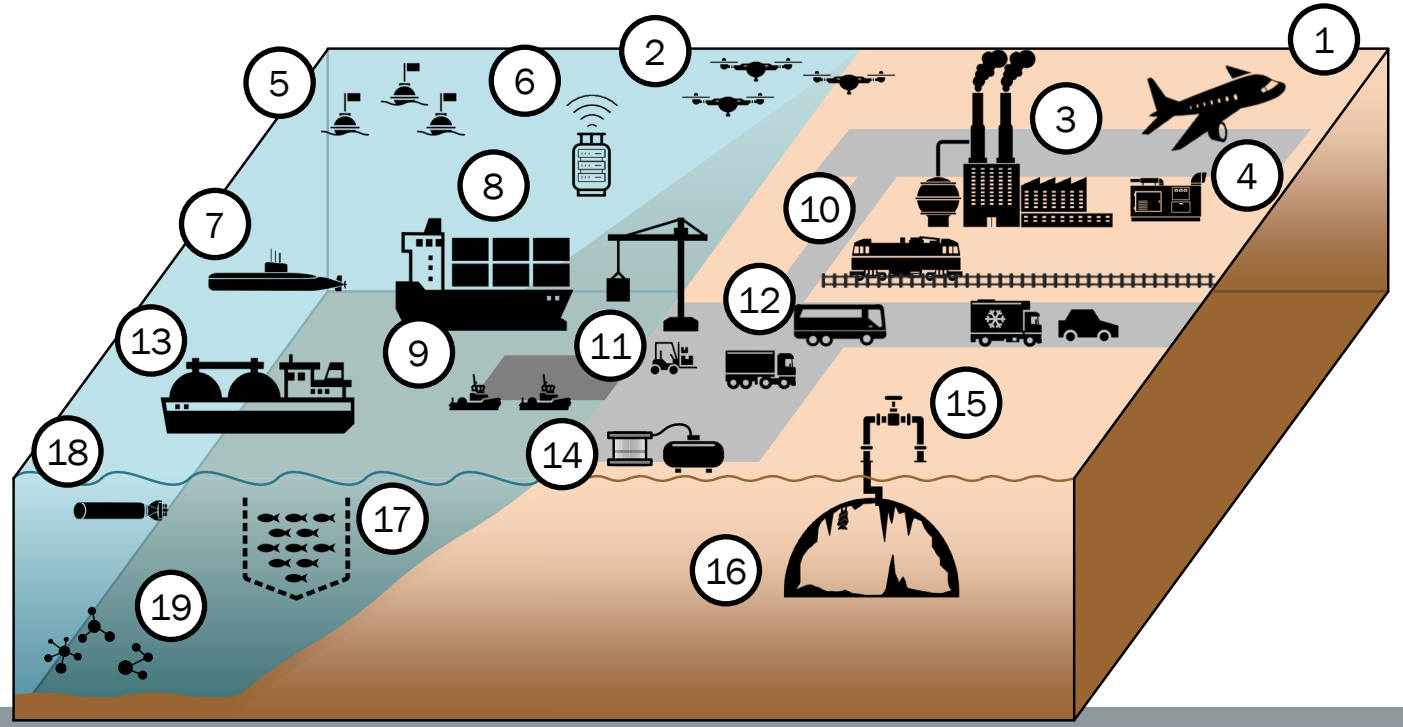
How are Marine Energy and Hydrogen Systems Combined and How do They Integrate Into a Larger Hydrogen Economy?



Technical Report:

- NREL Report Exploring the opportunities for combining ME and hydrogen technologies: https://www.nrel.gov/docs/fy22osti/82538.pdf

1. Air transport
2. Unmanned vehicles
3. Chemical processing
4. Backup/Auxiliary power
5. Navigational aids
6. Underwater computing
7. Military applications
8. Marine vessel aux. power
9. Marine vessel primary power
10. Rail transport
11. Material handling
12. Heavy duty vehicles
13. Liquid fuel production
14. Local H2 production
15. Pipeline injection
16. Underground storage
17. Aquaculture
18. Remote monitoring
19. Ocean mineral extraction



Lab Projects on Marine Energy and H2

Seedlings Small ($50k-$100k) lab awards **:**

- Extraction of H2 from seawater for MHK power storage and element recovery.
- Green Hydrogen from Seawater Splitting Integrating Marine Renewable Power Source

Unique materials challenges of seawater electrolysis:

- Direct conversion of ocean energy to hydrogen: avoids challenges of electrical connection
- Freshwater not available in sufficient quantities at seas
- Chlorine in seawater can react to cause corrosion of fuel cell anode

PNNL and ORNL Solutions:

- Fabricate and tests corrosion-resistant electrodes with using a simulated power supply from marine energy devices

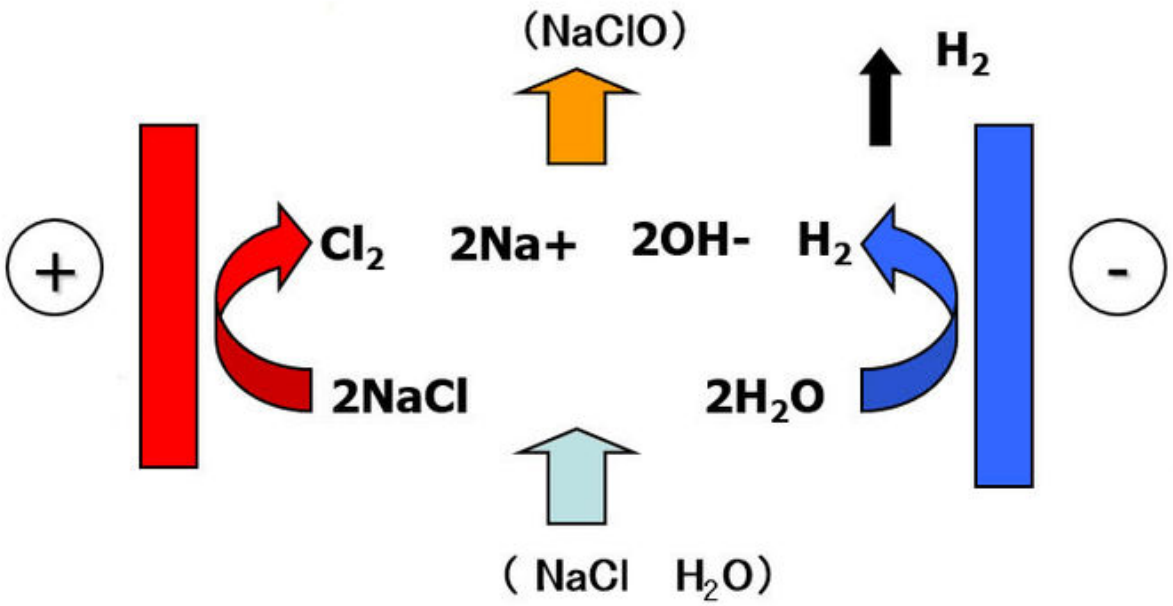
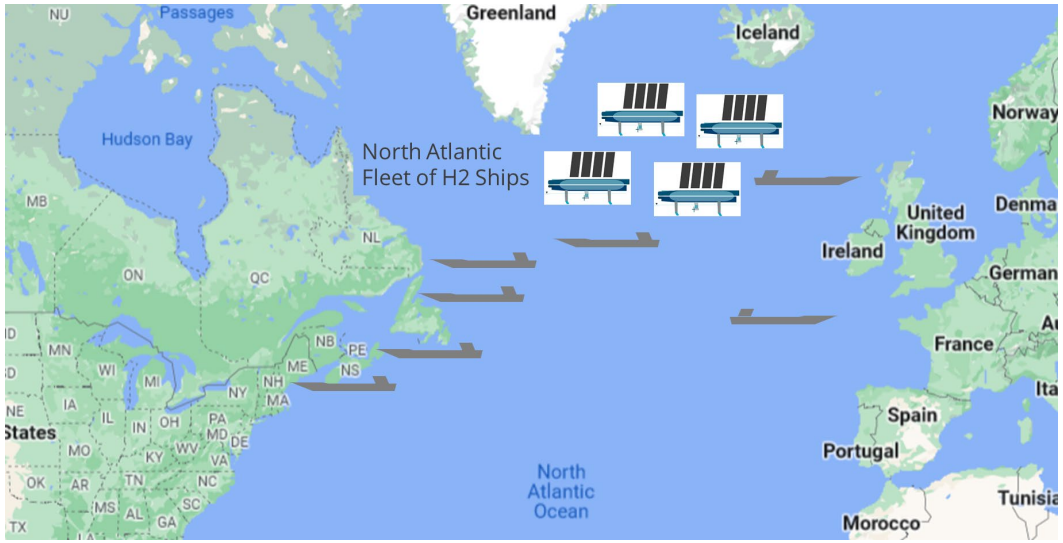


Image source: https://www.sodiumhypochloritegenerator.com/

Energy Ships – Value Proposition

Energy Ships convert ocean wind energy to power manufacturing and storage of sustainable fuels, like green hydrogen, that can power remote island communities, and remote ocean industries (aquaculture, mining) far offshore, or transported to ports and distributed to power land-based energy demands.



Hydro-foiling Hydrogen (H2) Ship

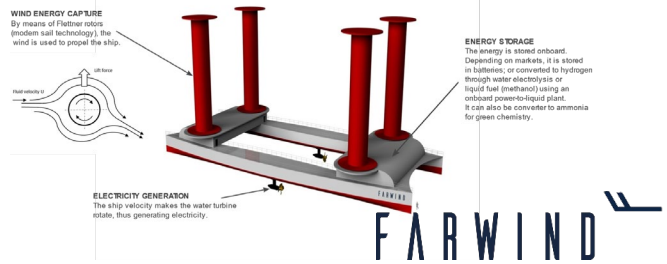
Green Energy Ship LLC

University of Tokyo /
Mitsui O.S.K Lines

Ouchi & Henzie (2017)

DRIFT ENERGY LTD, UK

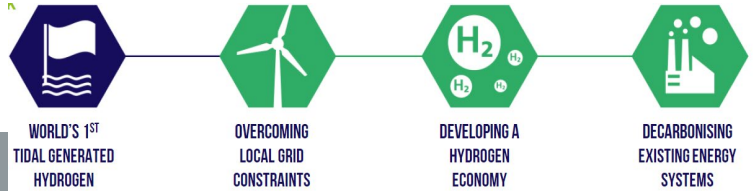
OCEANENERGY

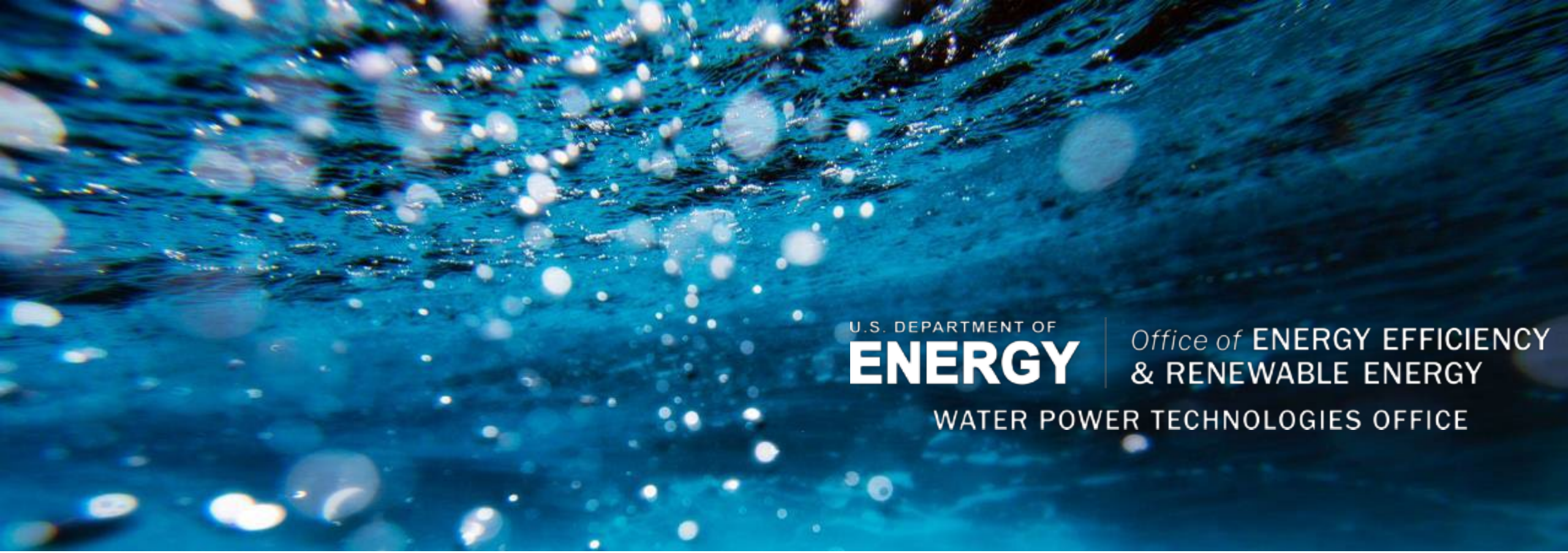


European Marine Energy Center (EMEC) Hydrogen Projects

- Surf ‘n’ Turf harness wind and tidal power for hydrogen production www.surfnturf.org.uk
- BIG HIT (Building Innovative Green Hydrogen Systems in an Isolated Territory a pilot for Europe) www.bighit.eu
- Powering Isolated Territories with Hydrogen Energy (PITCHES) demonstrate the feasibility of using hydrogen to meet the energy needs of remote communities www.emec.org.uk/projects/hydrogen-projects/pitches/
- Integrating Tidal Energy into the European Grid (ITEG) www.nweurope.eu/ITEG
- Hydrogen Diesel Injection in a Marine Environment (HyDIME) www.hydime.co.uk
- Hyflyer - decarbonize medium range small passenger aircraft by demonstrating hydrogen fuel cell www.hyflyer.co.uk
- HYSPIRITS - enable the Orkney Distillery to use hydrogen as a fuel and decarbonise the distilling process www.emec.org.uk/projects/hydrogen-projects/hyspirits/
- FORWARD2030 - This system will combine predictable floating tidal energy, wind generation, grid export, battery storage and green hydrogen production. https://www.marei.ie/project/forward2030/

https://www.emec.org.uk/projects/hydrogen-projects/





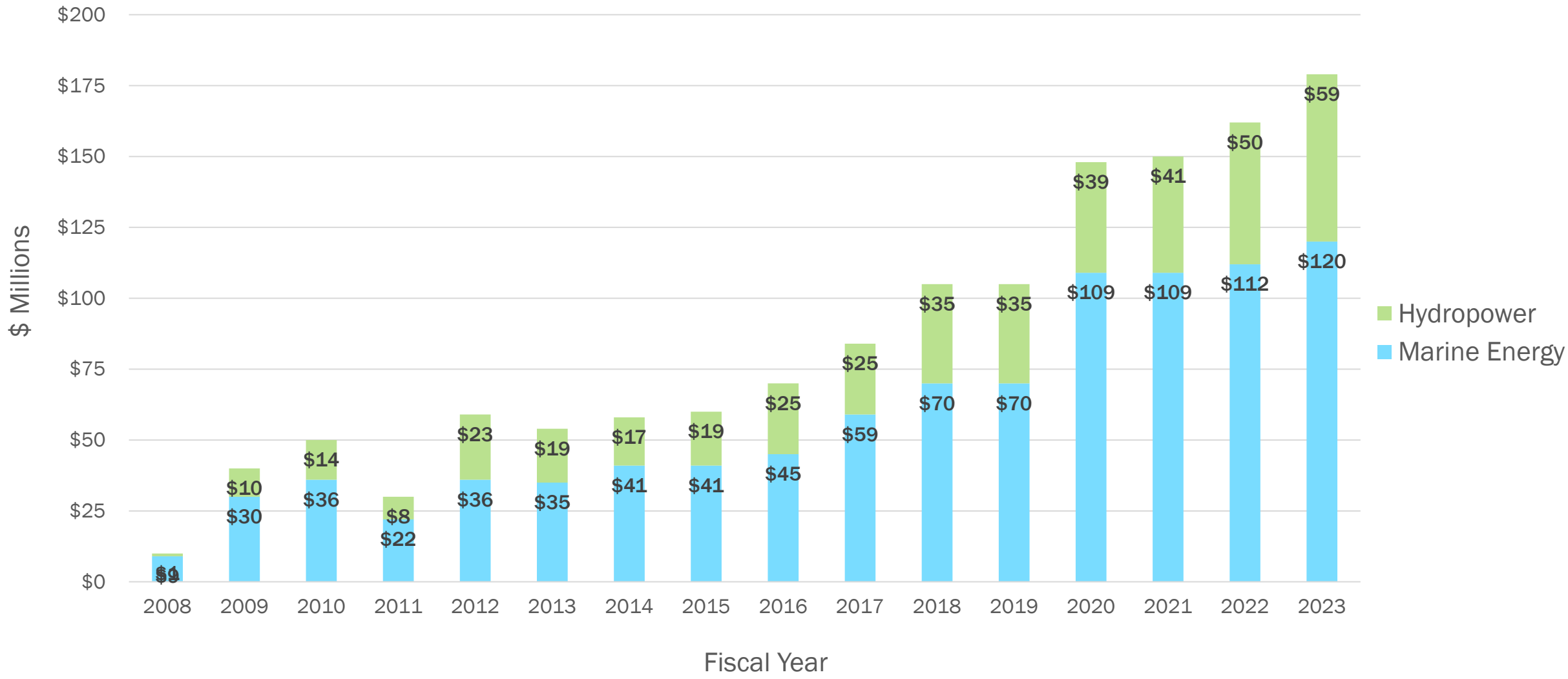
For more information, visit
www.energy.gov/water

WaterPowerTechnologiesOffice@ee.doe.gov

Sign up for our newsletters!

- Water Column (monthly marine energy news)
- Hydro Headlines (monthly hydropower news)
- Water Wire (monthly marine energy and hydropower news)

WPTO Budget Over Time



Note: This graph shows annual appropriations and enacted funding only. This graph does not reflect the nearly $1B of funding from the Bipartisan Infrastructure Law for DOE-led hydropower and marine energy programs.

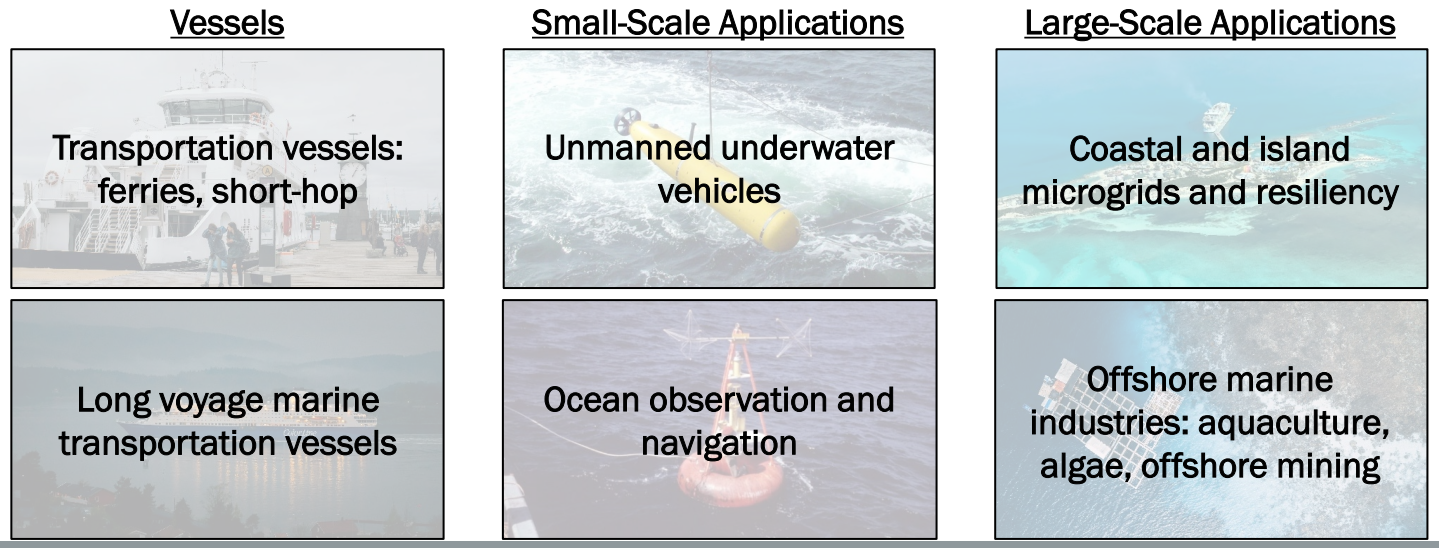
Resources for Additional Information

Technical Report:

- NREL Report Exploring the opportunities for combining ME and hydrogen technologies: https://www.nrel.gov/docs/fy22osti/82538.pdf

2021 Marine Energy-Hydrogen Workshop:

- NREL hosted a workshop that was attended by marine energy and hydrogen technology experts from industry, academia, national labs, and government entities to explore the technical challenges and opportunities for combined marine energy and hydrogen generation systems.
- The workshop proceedings are described in the workshop report - https://www.nrel.gov/docs/fy22osti/79711.pdf
- Activities identified as possible end users of hydrogen produced by marine energy are illustrated below
- These share the common requirements of remote operations, high reliability and/or uptime, high energy storage



The Energy Ship – Key Attributes

MORE POWER

Scalable to satisfy the global energy demand (up to 30 MW per ship, millions of ships)

Windsail power significantly increases hydrokinetic turbine inflow speeds between 5 to 15 m/s

MORE OF THE TIME

Mobility provides high capacity factors, 70-80% avoids hazards, and reduces market barriers and costs

IN MORE PLACES

Oceans with steady powerful Tradewinds cover 72% of the globe, with no exclusion zones or "land-use" constraints

MORE QUICKLY

Operation in high seas (international waters) avoids extensive and costly project permitting process & NIMBY resistance causing extensive delays

Most subsystems at TRL 9

MORE ACCEPTABLE

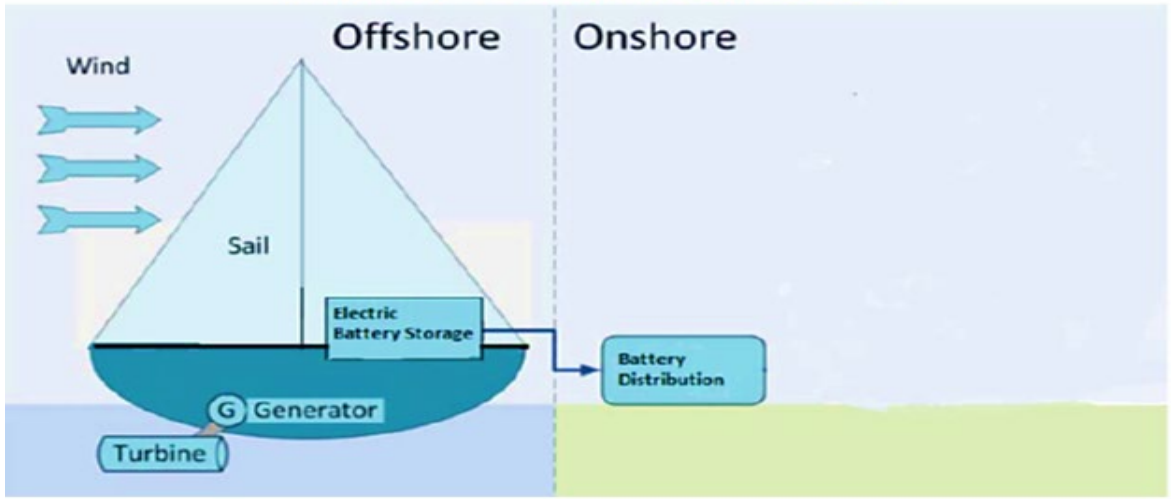
Autonomous system reduces safety risks and operational costs

Relatively minimal environmental impacts with autonomous collision avoidance systems

VERSATILE

A variety of energy storage options, e.g., battery-stored electrical energy, sustainable liquid fuels, compressed or liquefied hydrogen

(a) Electric Battery Energy Storage



(b) Hydrogen Production and Delivery