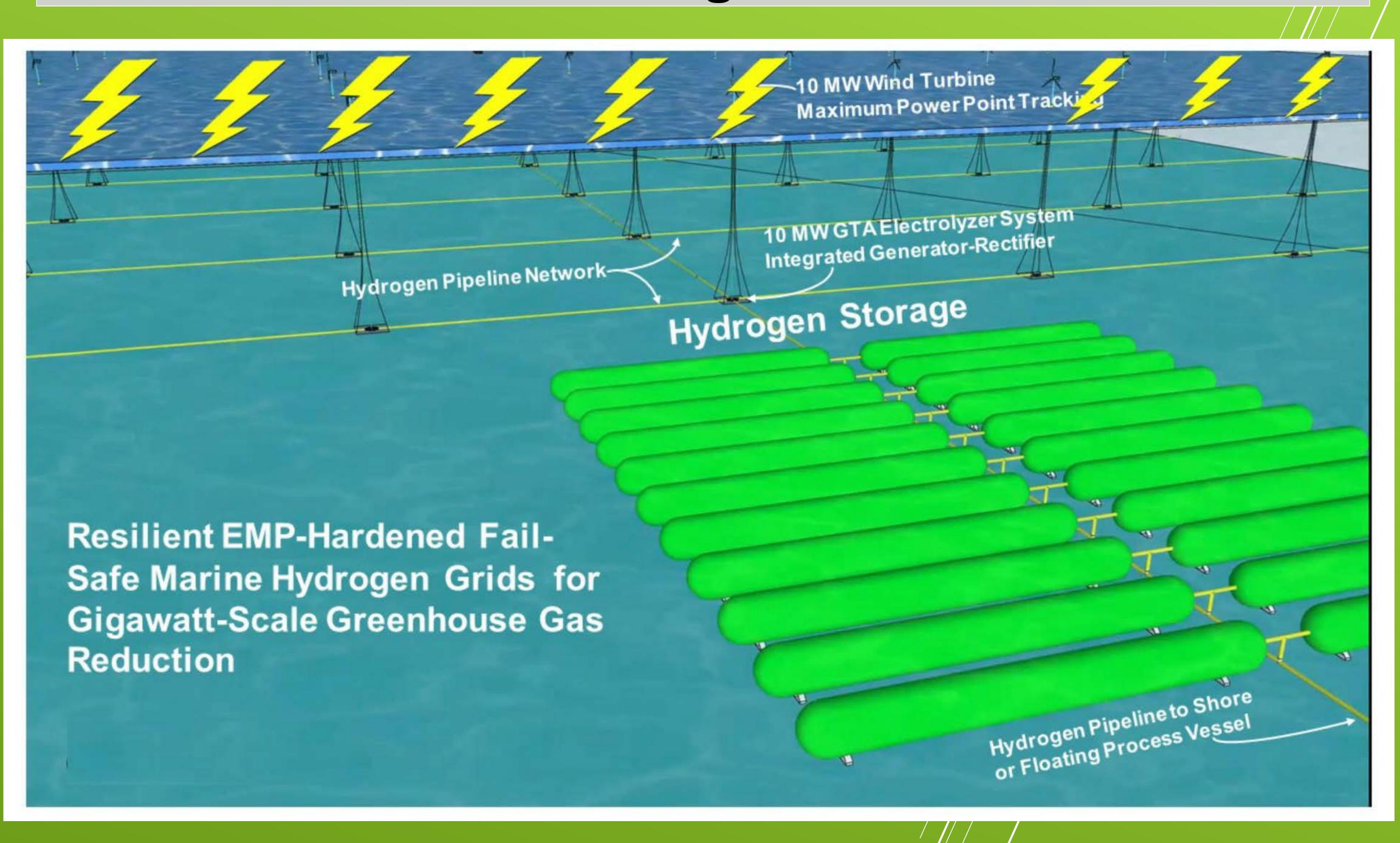


Deep Water Subsea Hydrogen Production by Offshore Floating Wind Turbines



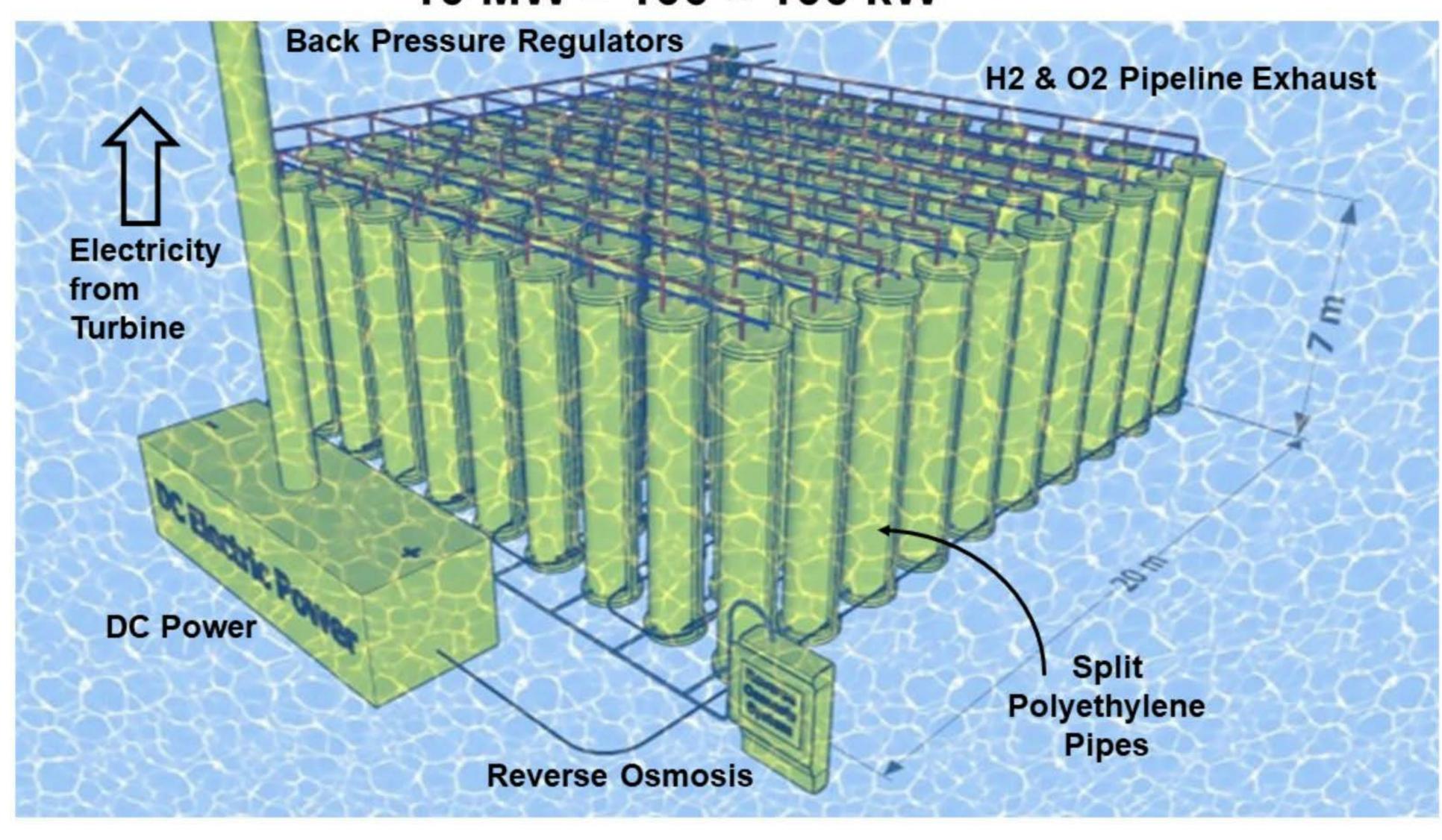
Operation, Materials Compatibility, Subsea Stability, Maintenance/Servicing

- Fail-Safe with respect to sub-freezing weather.
- Polyethylene has virtually 100% stability in sea water [1].
- Potassium hydroxide is a thermal stabilizer for polyethylene [2].
- GTA electrolyzers have no moving parts. Nickel electrode/alkaline electrolyzers rarely need servicing [3]
- [1] International Standard ISO 22404, "Plastics Determination of the aerobic biodegradation of non-floating materials exposed to marine sediment Method by analysis of evolved carbon dioxide", September 2019.
- [2] N. P. Cheremisinoff, Handbook of Engineering Polymeric Materials, p. 84, Marcel Dekker, New York, 1997.
- [3] B. Kroposki, J. Levene, K. Harrison, P.K. Sen and F. Novachek, "Electrolysis: Information and Opportunities for Electric Power Utilities", Technical Report, NREL/TP-581-40605, September 2006.





Pressure-Balanced Sea Floor Electrolysis $10 \text{ MW} = 100 \times 100 \text{ kW}$



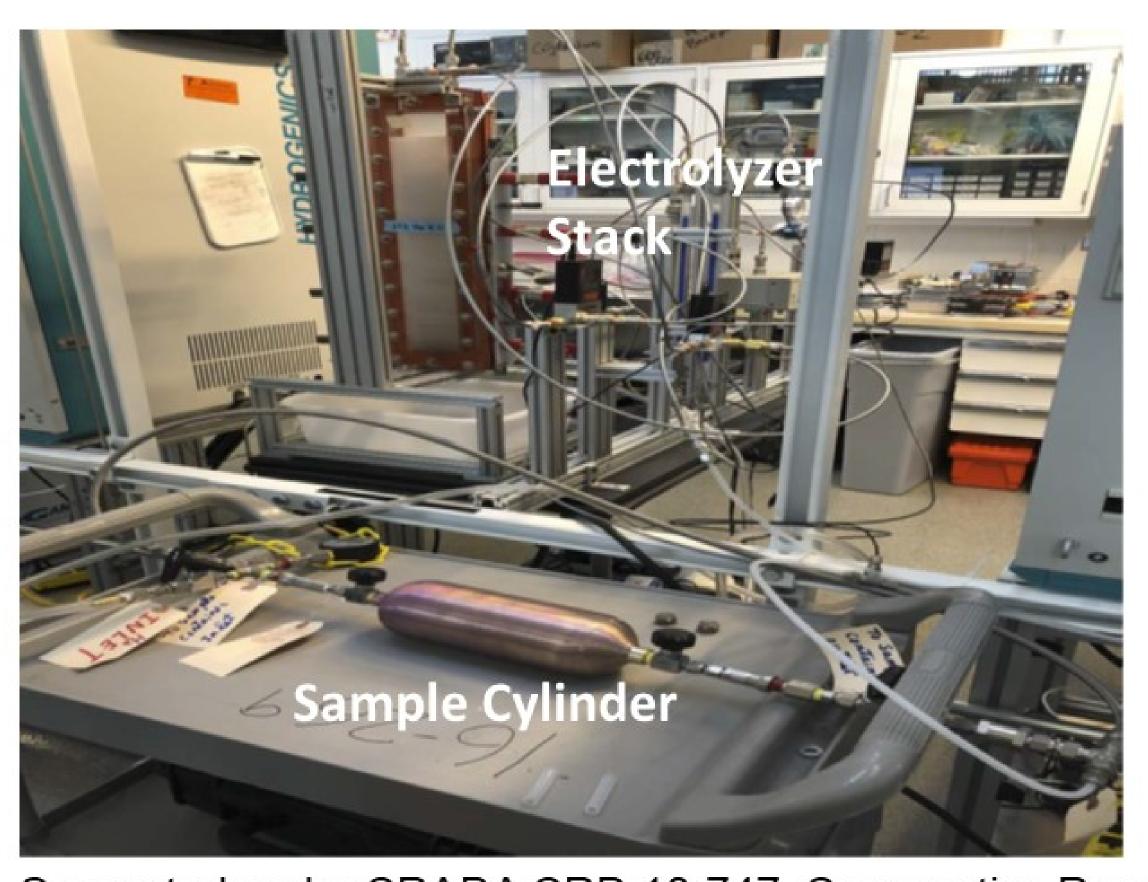
GTA

CO₂: 2.2%

NO_x: 15%

SO_x: 13%

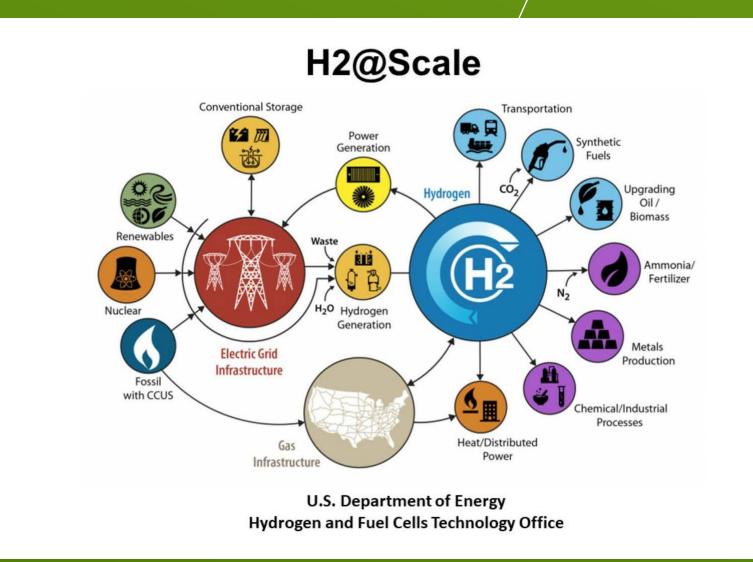
NREL Technology Validation of GTA TRL 4 Prototype



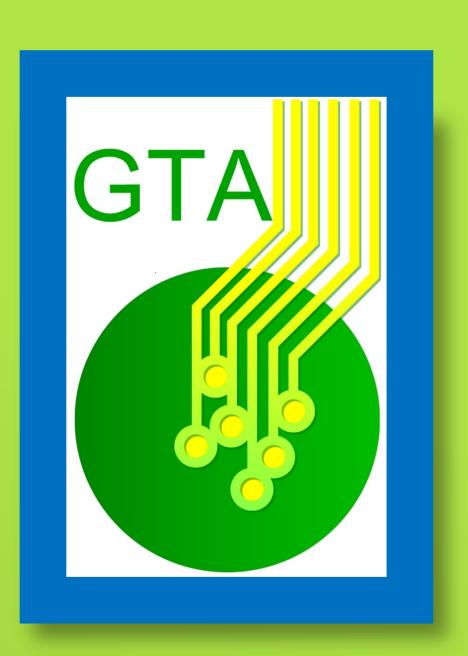
SAE J2719		GTA Floatrolyzor H
Fuel Cell Grade Hydrogen		GTA Electrolyzer H ₂
	SAE J2719 Limits	GTA Sample
	μmole/mole	μmole/mole
H ₂ O (ASTM D7649)	5	279*
Total Hydrocarbons (Methane)	2	0.48
-C ₁ Basis (ASTM D7892)		
O ₂ (ASTM D7649)	5	9.4
with O ₂ getter		
O ₂ (ASTM D7649)	5	3472
native O ₂ content		
He (ASTM D1946)	300	10
N ₂ & Ar (ASTM D7649)	100	40
CO ₂ (ASTM D7649)	2	2.3
CO (ASTM D5466)	0.2	0.023
Total Sulfur	0.004	0.00082
Formaldehyde (ASTM D7892)	0.01	0.0012
Formic Acid (ASTM D5466)	0.2	<0.003
Ammonia (ASTM D5466)	0.1	<0.02
Total Halogenates	0.05	0.015
*No attempt was made to remove water vapor or CO ₂ .		

Supported under CRADA CRD 18-747, Cooperative Research and Development Agreement between GTA, Inc. and the National Renewable Energy Laboratory.









Techno-Economic Features

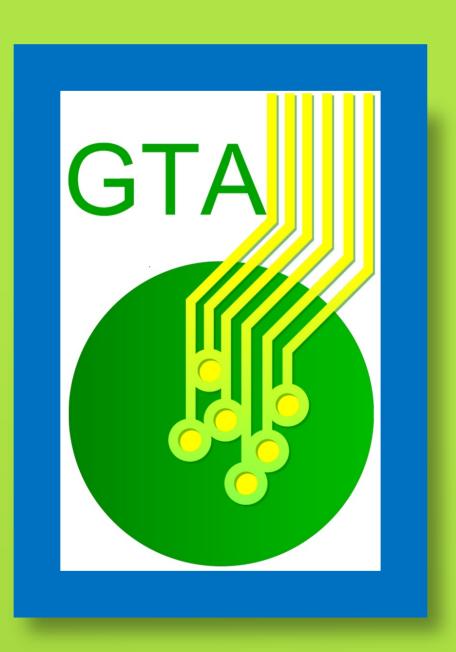
- Electrolyzers that are anchored at the sea floor are shielded from lighting strikes, falling ice from the wind turbine blades, ice floe impacts, the destructive power of high waves, and electromagnetic pulse also known as EMP.
- Subsea electrolysis systems do not need lift pumps to bring water out of the ocean and transport it to elevated decks that are positioned above the splash zone.
- Subsea electrolysis is simpler and safer than the operations of the offshore gas and oil industry. An international trained workforce is already in place.



GTA Pressure-Balanced Offshore Hydrogen Wind Farm

- Offshore hydrogen wind farms comprise fields of multigigawatt offshore wind turbines that power <u>pressure-</u> balanced electrolyzers that are anchored at the sea floor.
- The turbines are not necessarily electrically connected to the utility grid, thereby eliminating high-voltage cables and large power transformers.
- Hydrogen stored at the sea floor may be sent to a utility company for grid balancing or sold in the H2@Scale market.





Injection Molding: Mass Production of GTA Electrolyzers

- GTA electrolyzers exclude platinum group metals.
- Components are fabricated from thermoplastic polymers such as polyethylene plus nickel, silicone rubber and steel.
- The components possess simple geometric shapes with few cavities.
- Fewer cavities require less tooling that lowers injection mold costs.
- Accurate parts with pristine surfaces can be rapidly produced.
- No additional finishing steps are needed.





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INNOVATION SUMMIT

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Company or Organization: Technology/Solution Name:

Website URL: Country:

Brief Description of Technology in layman's terms:

Track:

Technology Keywords:
Market Keywords:
Technology Readiness Number:
Technology Development Status:
Organization Type:

GTA, Inc.

A Resilient EMP-Hardened Offshore Wind Gigawatt-Scale Grid for Electricity and Hydrogen Fuel

https://www.gtaH2.com

United States

A gigawatt-scale array of resilient subsea pressure-balanced electrolyzers is anchored at the seafloor beneath a corresponding array of offshore wind turbines. The turbines power the electrolyzers that produce renewable hydrogen. The electrolysis array is hardened against EMP by the ocean's electrical conductivity. The wind turbines are EMP-protected by conductive housings.

Energy/Mobility/Logistics

EMP, electric grid, attack tolerance

electromagnetic pulse, electricity grid, continuous service

TRL 4 Prototype

Early-stage Startup (Seed)

Submission form for Ocean-Shot Concepts-Round 2

Response ID:3 Data

1. (untitled)

1. Ocean-Shot Contact Information: *Note - This information will be shared with the National Committee for the Ocean Decade in order to receive feedback. It will also be made publicly available if the Ocean-Shot concept is accepted into the Ocean-Shot Directory.

Primary Contact Name (First & Last): Elias Greenbaum

Organization: GTA, Inc.

Email address: greenbaum@gtah2.com

2. Ocean-Shot Title

Seafloor Hydrostatic Pressure-Assisted Green Hydrogen Production and Storage by Offshore Wind and Ocean Energy

3. Author(s): *Please list contributors to the submitted Ocean-Shot concept with first and last names in the order you wish them to be referenced for *potential* use in the Ocean-Shot Directory. Examples can be found here:

Elias Greenbaum

Ocean-Shot Directory Summary (Please provide a short introduction/description of the Ocean-Shot concept for *potential* use in the Ocean-Shot Directory, 100 word limit. Examples can be found here.):

4. Abstract (describe hypothesis, scientific and/or technological objective, 200 word limit):

GTA is an R&D technology company focused on the development of resilient, EMP-hardened gigawatt subsea hydrogen grids for large-scale reduction of greenhouse gases. Our innovation is development of pressure-balanced electrolyzers, fabricated mostly from polyethylene, that are anchored at the seafloor. With the exception of cleaning external marine growth, the electrolyzers will rarely require maintenance because (1) they have no moving parts; (2) polyethylene, the electrolyzer housing, has excellent stability in seawater; (3) alkaline electrolyzers rarely need servicing. GTA electrolyzers are fail-safe from subfreezing weather. They do not need backup or standby power to address periods of unscheduled downtime during subfreezing weather. The most common cause of unscheduled downtime is unfavorable weather conditions that prevent power generation by the wind turbine generator. GTA's value proposition is that, contrary to competing approaches, large power transformers, offshore platforms, and high voltage cables are eliminated. These are large CAPEX and OPEX items. Using GTA's subsea electrolyzers, the hydrogen is produced and stored safely at the sea floor, away from population centers, via a network of hydrogen pipelines. Transport of energy as hydrogen in pipelines is eight times less expensive than transport of energy as electricity in metal cables.

5. [OLD VERSION] Relevant Ocean Decade Challenge(s) (see below):

Challenge 4: Generate knowledge, support innovation, and develop solutions for equitable and sustainable development of the ocean economy under changing environmental, social and climate conditions.

Challenge 3: Generate knowledge, support innovation, and develop solutions to optimize the role of the ocean in sustainably feeding the world's population under changing environmental, social and climate conditions.

Please select the challenges (no more than 3) that are most relevant to your concept (Expanded reference below):

Describe how your Ocean-Shot addresses the selected challenges (150 word limit).

6. Vision and potential transformative impact (200 word limit):

GTA's vision is to make a significant contribution to worldwide reduction of greenhouse gas emissions by applying renewable ocean energy to power the production of 100% green hydrogen. Ocean energy includes offshore wind and the movement of waves, currents, tides and thermal energy. GTA has developed a game-changing technology that will produce green

hydrogen by electrolyzers that are anchored at the seafloor. Electrolyzers are devices that use electricity to split water into hydrogen and oxygen. The transformative impact of GTA's work is that multi-gigawatts of renewable hydrogen for utility grid-balancing, transportation fuel, green manufacturing, including fertilizer production, will be powered by offshore wind and ocean energy. This will benefit peoples of the world that live at or adjacent to coastal areas, a significant fraction of the world's population. GTA electrolyzers will be fabricated locally from readily available commodity materials. The new green manufacturing industries will provide international employment and new career opportunities. A working prototype of GTA's game-changing technology has been validated at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). GTA's entry, "A Resilient EMP-Hardened Offshore Wind Gigawatt-Scale Grid for Electricity and Hydrogen Fuel" won an Innovation Award at the 2020 Defense TechConnect Innovation Summit & Expo.

7. Realizable, with connections to existing U.S. scientific infrastructure, technology development, and public-private partnerships (150 word limit):

The proposed technology is realizable because GTA assumed and eliminated all early-stage risk. Subsequent technology validation data at NREL showed the native GTA electrolyzer hydrogen purity is 99.65% and that a single purification step elevated the purity to 99.999%. Staff scientists at the Pacific Northwest National Laboratory Marine and Coastal Research Laboratory have expressed interest in using their facilities to advance realization of GTA technology. Significantly, all the unit operations that will be required to realize GTA subsea electrolytic hydrogen production technology is already being performed by the subsea gas and oil industry, albeit in a different context.

8. Scientific/technological sectors engaged outside of traditional ocean sciences (100 word limit):

The phrase/idea "blue economy" was introduced by Gunter Pauli in 2010 and later discussed at the United Nations Conference on Sustainable Development, Rio + 20 in 2012. The Blue Economy is an evolving concept that generally promotes better stewardship of our ocean resources. It aims for improvement of human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities, activities that are outside traditional ocean sciences. GTA President, Elias Greenbaum is a Member of the Board of Directors, California Hydrogen Business Council, a leading organization that promotes science and technology for large-scale hydrogen production by ocean energy.

9. Opportunities for international participation and collaboration (100 word limit):

GTA Inc. is a regular participant and collaborator with professional colleagues at international conferences on ocean science and technology. Elias Greenbaum was an invited speaker at the International Conference on Maritime Hydrogen and Marine Energy, 14 - 15 October 2020, sponsored by GCE Ocean Technology, Norway. He organized and moderated the panel session "Large-Scale Hydrogen Production Powered by Offshore Wind" at the 2019 International Partnering Forum for Offshore Wind, New York, NY. Elias Greenbaum is a Member, Board of Directors, California Hydrogen Business Council which, despite its name, is an international organization that includes members in Europe and Asia.

10. Develops global capacity and encourages the development of the next generation of ocean scientists (100 word limit):

Elias Greenbaum regularly meets and has discussions with students at professional conferences. At the 2019 Offshore Technology Conference in Houston, Texas students visited GTA's exhibit booth. They were from Texas A&M University, Texas Tech, and University of Texas at Austin. They learned the principles of converting offshore wind energy to renewable hydrogen. Elias Greenbaum was a staff scientist and group leader at the Oak Ridge National Laboratory. He mentored more than 100 undergraduate and graduate students over a period of 30 years. He received a 2008 Outstanding Mentor Award from the Office of Science, U.S. Department of Energy.

2. Thank You!

Thank You Email

Mar 05, 2021 16:30:54 Success: Email Sent to: greenbaum@gtah2.com