Chapter 34

Using Hydrokinetic Energy for Green Hydrogen and Green Oxygen Production

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Abstract

The College of the Florida Keys (CFK) and Hydrokinetic Energy Corp (HEC) developed a one-of-a-kind pilot project for sustainable fuel production with zero carbon dioxide (CO_2) emissions. The project will deploy a floating platform equipped with four patented HEC hydrokinetic turbines fortified with: (1) flow-acceleration technology, which increases energy extraction up to 300%, and (2) wildlife/debris excluders, which protect marine life and turbines, while increasing energy extraction for an additional 5-10%. Located 35 km south of Key West in the Gulfstream, this innovative project will demonstrate the most efficient extraction of energy from one of the world's most powerful oceanic currents. The turbines will produce 48 kW of continuous electrical current, powering onboard reverse osmosis (RO) desalination units and feeding freshwater into onboard electrolyser units that split water molecules (H_2O) into "green" hydrogen (H_2 atoms) and "green" oxygen (O_2 atoms). The term "green" is used because the power source splitting the molecules is a renewable energy source, as opposed to "black" or "grey" hydrogen made from burning fossil fuels. Daily production of green H_2 is calculated at 19.8 kg of H_2 and 159 kg of O_2. Gases will be shipped onshore for energy production at CFK. Green H_2 will be used to power aquaculture operations at CFK, and green O_2 will be used to sustain marine organisms cultured for education, research, and environmental restoration (e.g., coral restoration). This pioneering pilot project will be a model for employing clean energy production to support environmental education, conservation, and restoration efforts in the Florida Keys and beyond.

Keywords: *Hydrokinetic, Green Hydrogen, Green Oxygen, Energy, Sustainable*

Introduction

To realize the Paris Agreement[1] goal for net-zero CO_2 emissions by 2050, it is critical to transition energy production towards clean, reliable, predictable, and sustainable renewable energy production for all forms of transportation (i.e., cars, trucks, aviation, and shipping) as well as other industries that currently rely on fossil fuels.

Recent advances in hydrogen fuel cell technology and hydrogen internal combustion engines (H_2ICE), combined with advances in water electrolysis technology and H_2 fuel production/storage, foster a

[1]The Paris Agreement, United Nations Climate Change, https://unfccc.int/process-and-meetings/the-paris-agreement.

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realistic pathway for green H_2 to be used for energy production to support transportation and industrial energy needs[2]. It represents the best technology available to achieve the Paris Agreement goal.

The US Department of Energy (DOE) Hydrogen and Fuel Cell Technologies Office, and other global organisations consider hydrogen as the fuel of the future. To achieve net-zero CO_2 emissions by 2050, it is critical to convert all forms of transportation to hydrogen. Regardless of whether hydrogen is being used to power a fuel cell or as a fuel in an H_2ICE, the only emissions are water vapor. Because H_2O can be recycled and split into H_2 and O_2 repeatedly, it is the perfect solution for a carbon-free future if we use green electricity to split the molecules.

On June 5, 2023, the DOE released the National Clean Hydrogen Strategy and Roadmap[3]; a comprehensive framework for accelerating the production, processing, delivery, storage, and use of clean hydrogen. It intends to reduce US greenhouse gas emissions to half of 2005 levels by 2030, achieve 100% carbon-free electricity by 2035, and achieve net-zero CO_2 emissions by 2050.

Recognising the need for clean energy, the U.S.-based company, Hydrokinetic Energy Corp (HEC) designed, developed, analysed, optimised, and patented a high-efficiency marine electrical energy generation hydrokinetic turbine. This patented technology received the "Patents for Humanity" award from the United States Patent and Trademark Office (USPTO) on 3rd December 2024.

The College of the Florida Keys (CFK) partnered with HEC to develop a pilot project that utilises HEC's patented hydrokinetic turbine technology to demonstrate sustainable fuel production with zero carbon dioxide (CO_2) emissions and uses that clean fuel to power educational and research facilities at CFK. This one-of-a-kind pilot project intends to provide “proof of concept” for an innovative clean energy pathway directly from the producer to the end user.

The Pilot Project: Overview

The project will deploy a floating platform equipped with four patented HEC hydrokinetic turbines each with a 1.5 m rotor diameter and fortified with: (1) flow acceleration technology that increases energy extraction by up to 300%, and (2) wildlife and debris excluders (WDE) that not only protects marine life and the turbines but also increase energy extraction by an additional 5-10%. Located approximately 35 km south of Key West, Florida (USA) in the Gulfstream, these innovative hydrokinetic turbines will revolutionise the hydrokinetic energy industry by allowing the most efficient extraction of energy from one of the world’s most powerful ocean currents. The four HEC turbines combined will produce approximately 48 kW of continuous electrical energy that will power two reverse osmosis (RO) desalination units. The RO units will feed freshwater into two onboard electrolysis units that split water (H_2O) molecules into “green” hydrogen (H_2) and “green” oxygen (O_2). The term “green” is used because the power source used to split the molecules is hydrokinetic (i.e., a green renewable energy) as opposed to “black” or “grey” hydrogen made from burning fossil fuels. The production of green H_2 fuel also fosters offshore energy production by circumventing the deployment of subsurface

[2]Turner, J.W.G. Future technological directions for hydrogen internal combustion engines in transport applications. Applications in Energy and Combustion Science, 2, no. 100302 (2025), https://doi.org/j.jaecs.2024.100302.

[3]U.S. National Clean Hydrogen Strategy and Roadmap, U.S. Department of Energy, 2023, https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap.

electric power cables to transfer energy to the end user. The green H_2 fuel will be shipped onshore to CFK to be used as fuel for commercially available hydrogen power generation, producing pure H_2O as the only exhaust. The green O_2 will be used to oxygenate aquaculture facilities to sustain marine organisms being grown for education, research, and environmental restoration (i.e., coral restoration) at the Southernmost Marine Aquaculture Research & Training (SMART) Centre at CFK (Figure **1**).

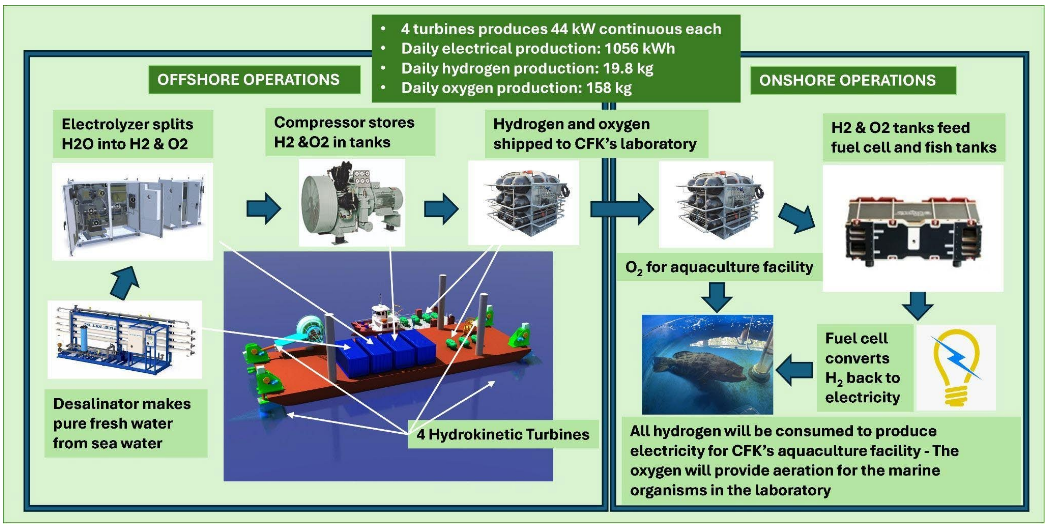

Figure 1: A flow chart of offshore energy production and conversion to transportable green hydrogen and oxygen to be utilized for onshore energy consumption and aquaculture.

This pilot project is intended to be a pioneering effort and model for employing clean energy production to support environmental education, conservation, and restoration efforts in the Florida Keys and beyond.

The Pioneering Turbine Technology

Although the Gulf Stream is one of the most powerful oceanic currents on earth, it flows relatively slowly (6.4 kph or 1.8 m/s). This makes it unsuitable for traditional hydrokinetic current-energy-converters (CECs) because the density, viscosity, and frictional forces of seawater inhibit the speed at which the blades spin and limits the effective length of the turbine blade designs. This is why most traditional CECs are shaped like wind turbines with short, stout hydrofoil blades (Figure **2**) and deployed in very fast ocean currents (e.g., Orkney Scottland at 14.4 kph or 4 m/s).

Figure 2: An image of a traditional hydrokinetic CEC array. Notice the short turbine blades relative to a traditional terrestrial wind turbine.

HEC's innovative hydrokinetic turbine overcomes this flow velocity limitation by focusing the horizontal axial hydrodynamic flow and features several novel design elements NOT found in other state-of-the-art hydrokinetic turbines, including:

1. Flow acceleration technology (FAT) enabled by the synergistic effect between the hydrofoil-shaped rotor blades attached to a hydrofoil-shaped centre hub encased in a hydrofoil-shaped accelerator shroud and surrounded by a hydrofoil-shaped diffuser. This design increases the flow-through velocity up to 300%, resulting in up to 8x increase in turbine power output (calculated using the formula $KE = \frac{1}{2} mv^2$, where KE is kinetic energy).
2. Low-cost construction by employing additive/subtractive manufacturing using the newest 3-D printing materials in very large robotic 3-D printers. This eliminates 70% of labour cost, resulting in the lowest cost per turbine on the market with the lowest Levelized Cost of Electricity (LCOE). Carbon fibre reinforced polyethylene terephthalate glycol (PETG) is used to manufacture the turbines. This material is 100% recyclable at the end of the 25-year life cycle.
3. Low-cost operation and maintenance because of floating installation, which allows the turbines to be brought to the surface quickly and easily for cleaning, maintenance, or repair.
4. Unidirectional flow feature that provides up to 30% higher efficiency than bidirectional turbines.
5. No shaft or gears because of an annular generator, which reduces friction losses during power take-off (PTO),
6. A flow-through accelerating wildlife and debris excluder (WDE) (Figure **3**A - CAD drawing with WDE, Figure **3**B - prototype CEC with WDE in the lab, Figure **3**C and Figure **3**D - prototype with WDE being tested from a vessel in the ocean):
    a. protects wildlife from being harmed
    b. protects the turbine from debris
    c. induces a pre-swirl of the water, enhancing performance by increasing flow-through velocity and energy output by 5-10%
    d. constitutes a transformational solution that positively impacts the capability of extracting energy at low-flow velocities.

To date HEC tested and validated 6 reduced scale prototypes, including a turbine with 0.375 m rotor (Prototype No.6) capable of producing 1.78 kW continuous electrical power. *In-situ* ocean testing of these prototypes confirmed results obtained during computational fluid dynamic (CFD) modelling and demonstrated that the design is scalable and works equally efficiently at all sizes tested. Prototype No.7 (.075 m rotor) is currently in production and scheduled for testing and validation during fall 2025. It can produce 7.1 kW of continuous electrical power. Finally, the HEC turbine proposed for the pilot project (Prototype No.8) will have a 1.5 m rotor and be capable of 12 kW of continuous electrical power. For the pilot project, four of these turbines are proposed with an estimated gross power output of 48 kW continuous electrical power.

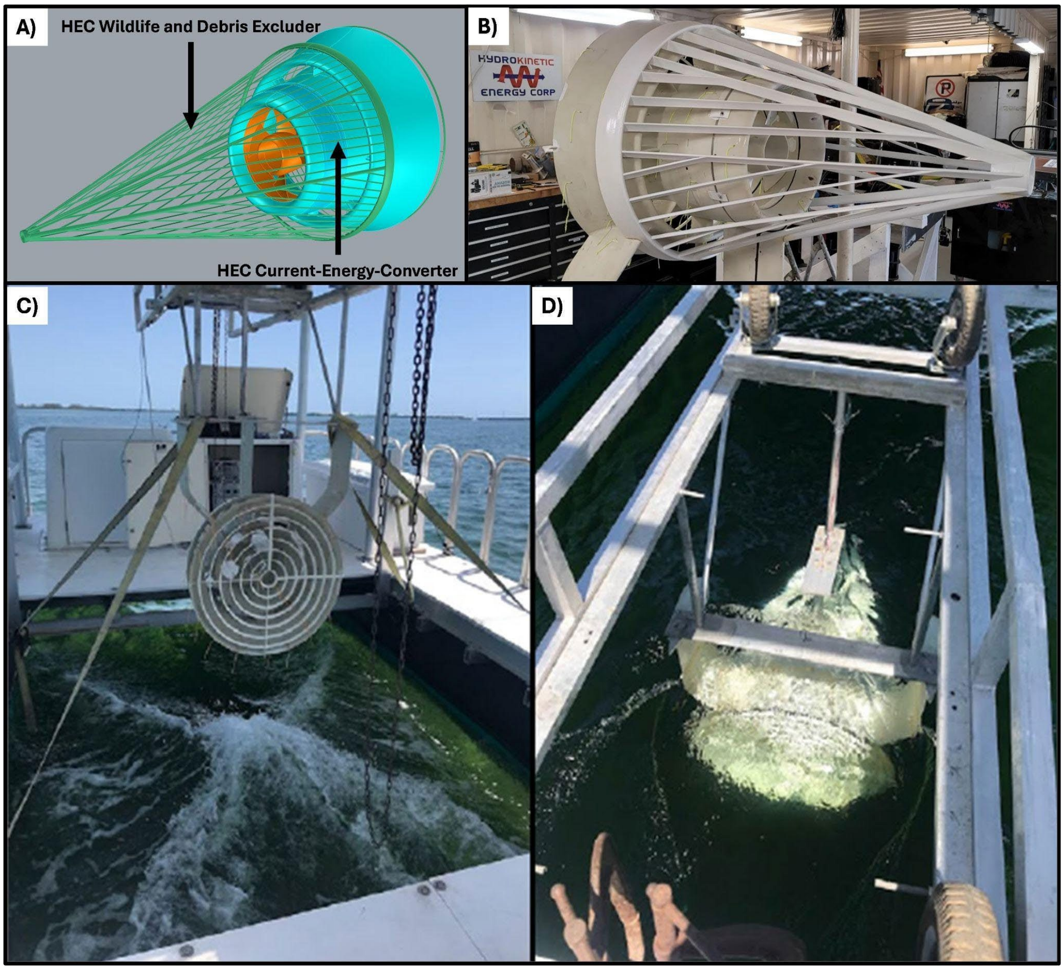

Figure 3: (A) CAD rendering of the HEC current-energy-converter (CEC) with wildlife and debris excluder (WDE), (B) prototype No.6 CEC with the WDE in the lab at HEC, (C) HEC prototype No.6 ready for testing at sea, (D) HEC prototype #6 deployed during sea trials.

The Pilot Project: Offshore Production

The primary objective focuses on the production of green H_2 and green O_2 utilising renewable hydrokinetic electric power harvested from one of the most powerful, reliable, and predictable renewable energy resources on earth, the Gulfstream.

The pilot project incorporates a large floating platform equipped with four HEC hydrokinetic turbines. All HEC turbines (Prototype No.8) combined will produce 48 kW gross continuous electrical output, of which 4 kW of electricity will be used to desalinate the seawater for electrolysis and compress the green H_2 and green O_2 into storage tanks at 700 bar or 10,152 psi. The remaining 44 kW of electric power will be used for the electrolysis of water, producing 19.8 kg green H_2/day (enough fuel to power approximately 20 average U.S. households per day) and 158.8 kg green O_2/day. The gases will be shipped to CFK for energy production (green H_2) and providing life support (green O_2) for organisms at the SMART Centre. H_2 fuel can also be stored for future electric generation in the event of a power outage (e.g., a hurricane).

Pilot Project: End User

CFK has a robust marine aquaculture research and training program at the SMART Centre. The SMART Centre currently uses electricity provided by the local energy grid and powers infrastructure to support aquaculture operations. The green H_2 produced offshore will be used to offset the grid energy, while the green O_2 will be used for life-support systems at the SMART Centre. CFK intends to incorporate the pilot project into the renewable energy training program and establish a Centre of Excellence for Additive Manufacturing using 3-D printers that will manufacture the HEC Prototype No. 8 turbines.

Future Markets and Broader Impacts

Liquid oxygen (LOX) is the primary component in rocket fuel (73%) to launch spacecraft into orbit. NASA, SpaceX, and Blue Origin use tremendous amounts of LOX. Therefore, green O_2 will help to reduce the carbon footprint of space exploration.

Conclusion

This pilot project demonstrates a transformative proof of concept for a next-generation approach to marine renewable energy. By integrating advanced current energy converter (CEC) design with proprietary flow acceleration technology, this system is capable of harnessing mechanical energy from powerful ocean currents—such as the Gulf Stream—to produce clean, renewable hydrogen (H_2) fuel at scale.

Unlike conventional CEC systems, which are limited by low-velocity currents and inconsistent performance, HEC turbine technology is specifically engineered to operate efficiently in a broader range of ocean conditions. This breakthrough significantly expands the viable geographic footprint for marine energy deployment and unlocks previously inaccessible energy resources.

Equally important, on-site hydrogen production eliminates the need for subsea power transmission cables, reducing infrastructure costs while minimizing environmental disruption to sensitive marine ecosystems. The result is a more scalable, cost-effective, and environmentally responsible pathway to offshore energy generation.

This project represents a critical first step toward establishing a new, sustainable energy industry—particularly in the Florida Keys—with the potential for global replication. By enabling the large-scale production of zero-carbon fuel, this technology directly supports the transition away from fossil fuels, contributes to meaningful reductions in CO_2 emissions, and advances progress toward meeting the goals of the Paris Agreement.

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