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Energy and Environmental Science

SUPPORTING INFORMATION

Solar Hydrogen Production from Seawater Vapor Electrolysis

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A Design for Marine Solar Hydrogen Generation from Ambient Humidity

The results provide a proof-of-concept for a fully integrated system floating at the ocean surface like a system of buoys. The proposed marine solar fuel buoy would work as shown in Figure S1. A low-cost buoyant casing would support the structure at the surface while a ballast maintains the orientation of the top PV component towards the Sun. Laminated, commercial PV would be designed in modules to build photovoltage appropriate to the load such that the electrolyzer operates at the PV maximum power point. As seawater vaporizes, salts and impurities are left behind. Water vapor can diffuse through a reinforced port on the buoy into the anode compartment, passing through a semipermeable material such as Goretex that blocks liquid water but allows the passage of water vapor.[1] As an alternative to this breathable membrane design, an upstream bubbler could saturate air directly through ocean water before feeding it to the anode chamber. The seawater-humidified air would be directed through internal serpentine flow channels to serpentine flow path, the cathode outlet would be directed to a separation platform where a method such as pressure swing adsorption would be used to separate the fuel from the recycled carrier gas. The stored fuel would then be used as needed, directly in a fuel cell utility onshore to provide non-intermittent electricity or as a reactant for hydrocarbon synthesis. The only byproduct of this system is pure water which after treatment can be used in irrigation and other applications. A major advantage of storing solar energy as fuel is that the point of storage and the point of usage can be completely decoupled. Thus, it is possible to make a ship- or platform-based marine solar fuels system deployed on the open ocean, returning full H_2 tanks to shore as needed. In this arrangement, issues such as resistance to visual aesthetics from coastal communities could be avoided, while the solar buoy field could be withdrawn into the ship/platform for protection during a powerful storm.

Undoubtedly there are major technical challenges to overcome to make the envisioned solar buoy system practical. Engineering

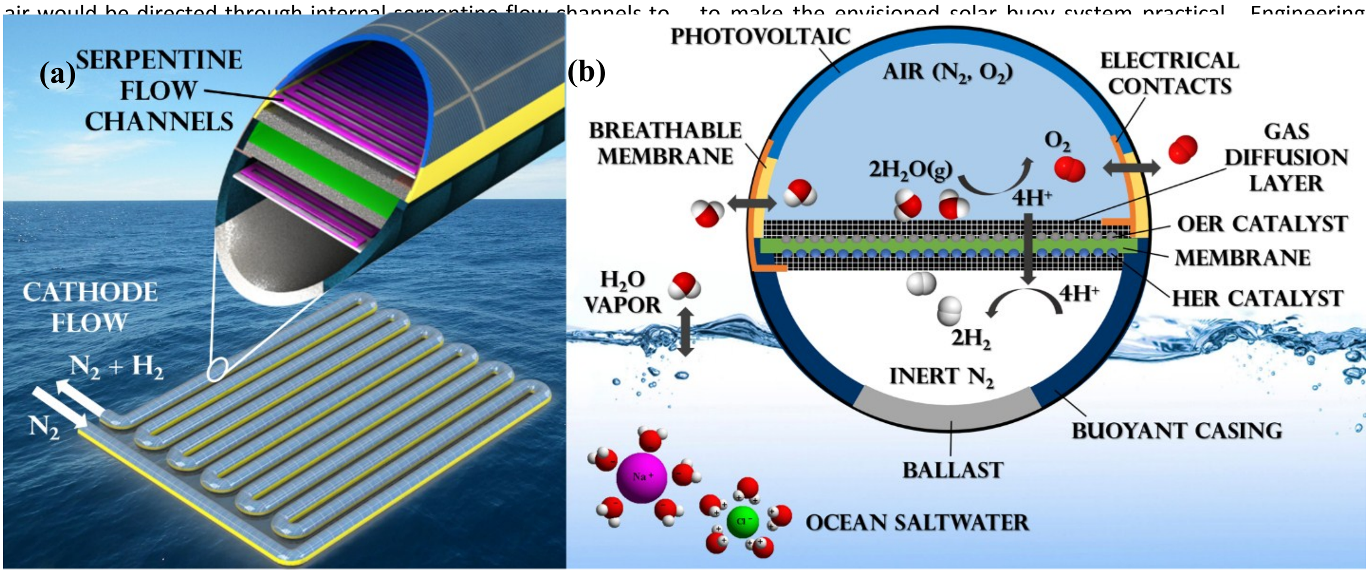

Figure S1. Schematic of a proposed unit of a marine solar hydrogen utility. (a) A solar buoy system could be laid out in a serpentine arrangement to maximize photoactive area per system footprint. The dry N_2 cathode input flow would gain in H_2 concentration before returning to a separation unit. Serpentine anode and cathode gas flow channels (inset cross-section), similar to a fuel cell, would improve performance by uniformly dispersing the reaction across the active membrane area. (b) Cross-sectional schematic of a marine solar fuel buoy, with ballast for orienting the photovoltaics, inert N_2 at the cathode to maximize H_2 faradaic efficiency, and a breathable membrane on the anode side to exclude liquid seawater while permitting passage of water vapor.

obstacles include establishing material and device robustness for deployment on the open ocean, particularly in maintaining a stable seal on the cathode compartment. Besides the standard economic challenges for solar energy, the device would need a cost-effective MEA for use over large areas. As previously mentioned, the low current densities open the possibility of replacing noble metal catalysts with cheaper, less active substitutes and potentially replacing Nafion with a cheaper alternative. A solar marine utility, however, would have significant advantages over a land-based solar fuels utility.[2] Besides the obvious savings in land costs, the vapor fed system would bypass the need for square miles of highly acidic or highly caustic liquid electrolyte and associated environmental/safety concerns, as well as the major capital expense of the metal structures needed to support and orient a photoelectrochemical panel. A solar buoy utility would also produce rather than consume freshwater, increasing its desirability in drought-ridden coastal regions such as California.

Notes and references

1. R. W. Gore and S. B. Allen, 1980.
2. R. Sathre, C. D. Scown, W. R. Morrow, III, J. C. Stevens, I. D. Sharp, J. W. Ager, III, K. Walczak, F. A. Houle and J. B. Greenblatt, *Energy Environ. Sci.*, 2014, **7**, 3264-3278.