IS HYDROGEN A SOLUTION FOR GREEN ENERGY RESILIENCE IN THE CARIBBEAN?

As energy grids become greener with the rise of renewable energy sources, the need to implement both short and long-term energy storage and grid services has become more apparent. Renewables, such as solar or wind energy, are inherently intermittent. Therefore, storing energy for moments in which demand exceeds supply is key to achieving reliable grids.

With the recent unmatched interruptions in several electricity grids of Caribbean islands impacted by Irma and Maria hurricanes, it becomes even clearer that it is a priority to work towards more resilient energy systems, and hydrogen as a long-term energy storage solution is viable when hybridized with batteries.

Our research shows that under specific circumstances hydrogen storage can be competitive with the more popular battery electric options, and can also have important co-benefits such as providing ancillary grid-services, catering to clean mobility applications for heavy duty vehicles and marine transport, as well as increasing the resiliency of island grids by minimizing power outages over longer time periods than batteries can.

This whitepaper serves as an introduction to hydrogen energy storage in climate sensitive islands, presents a hybrid battery-hydrogen business case yielding positive economic, technical, and environmental results and

Key Takeaways

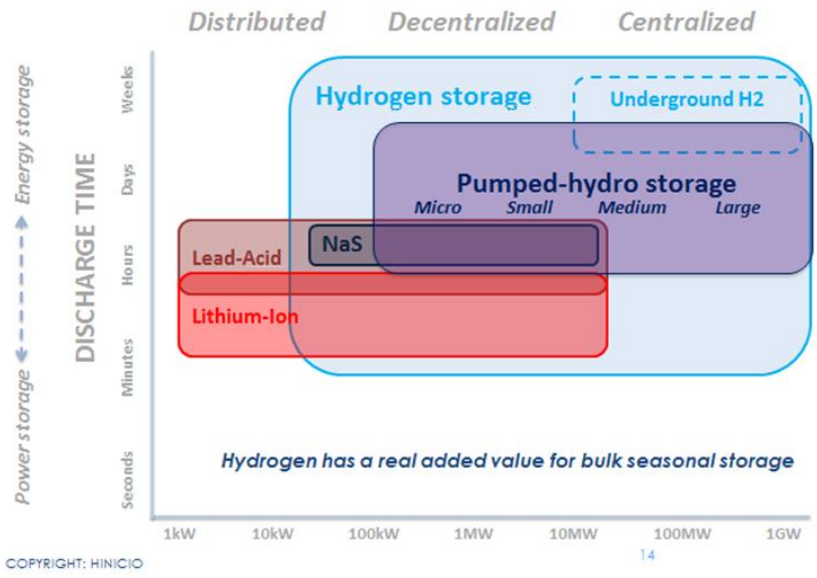
- Energy storage can provide attractive business cases for Caribbean grids, improving grid reliability and resilience towards power shortages and outages
- Hydrogen can provide a solution for long-term storage (everything more than overnight) where batteries are less competitive.
- A hybrid solution (batteries and hydrogen) coupled with solar generation yields an attractive business case for Caribbean grids.
- Other applications such as grid ancillary services and mobility may emerge in the future, creating more opportunities for the adoption of hydrogen technologies.
- Yet, local environments need to create a level playing field for markets to adopt these technologies.

concludes with several actionable recommendations, which local authorities should contemplate to create the necessary space for such technologies to deliver their full potential, and enable further grid resilience in tough whether conditions.

IS HYDROGEN A CREDIBLE ENERGY SOLUTION?

Hydrogen is the most abundant element in the universe. Although hard to find as a pure gas in nature, an established market for hydrogen in industrial applications is well developed, expecting to grow from 118 billion dollars in 2015 to 152 billion by 2021 (Hinicio own research).

Over the last two decades, significant research and economic efforts have been made on promoting hydrogen as an energy carrier. Using fuel cells, hydrogen can be combined with oxygen to produce zero-emission electricity and heat, with the only by-product of the process being clean water.



Hydrogen can provide storage solutions from 10 kW up to above 10MW, where batteries are no longer cost-effective

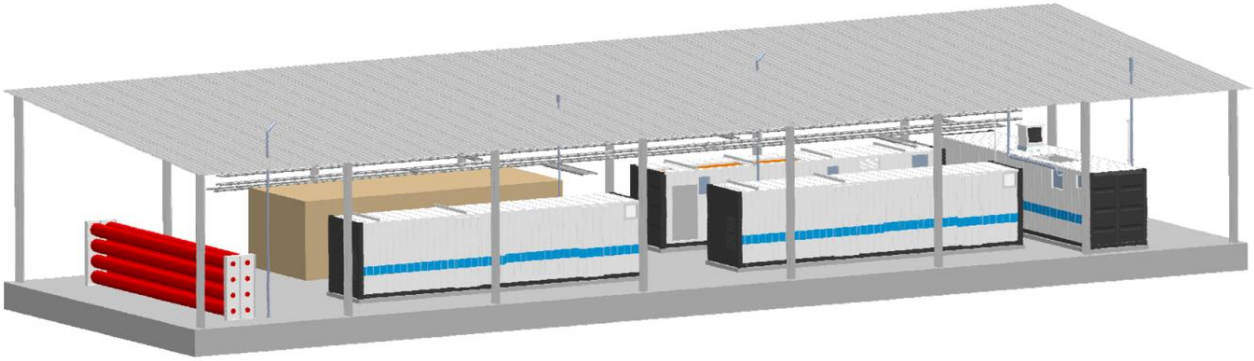
Currently, most hydrogen used by industries is obtained through steam methane reforming, thereby making it difficult to label hydrogen as such as a clean resource. Recently however the steady adoption of electrolysis technology (using electricity to decompose water into hydrogen and oxygen) has made it possible to generate the highly-valuable gas using power from clean

sources, such as wind or solar, **placing hydrogen as a viable 100% clean energy storage option to avoid renewable power curtailment**.

Aside from industrial demand and energy storage applications, the use of electrolyzers coupled to electrical grids has additional benefits. Valuable ancillary services such as frequency regulation, peak-shaving and continuous grid balancing are offered by the hydrogen-based solution while simultaneously generating the valuable fuel. Furthermore, hydrogen can even be used in fuel-cell electric vehicles like heavy duty trucks, buses and passenger cars, or even in ferries.

DOES HYDROGEN MAKE SENSE IN CARIBBEAN ISLANDS?

Due to its equatorial location, **Caribbean islands possess abundant natural resources for harvesting energy**, most notably solar and wind resources. Despite this, adoption of renewables in the region has been slow. According to the World Bank, most Caribbean insular countries are heavily dependent on fossil fuel imports, with **97.6% percent of all energy generated in the islands coming from fossil fuels in 2015**.



Hydrogen based energy storage system consisting of a 1 MW PEM electrolyzer, a 3 MWh hydrogen storage and a 300 kW fuel cell, stabilizing the power grid in Thailand (for EGAT) with high penetration of wind energy (source: Hydrogenics)

Spot and market energy prices in Caribbean islands are susceptible to volatility, associated with international market pricing and availability of import fuels such as diesel, coal, natural gas, and fuel oil. The Petrocaribe alliance (under which Caribbean countries can purchase oil with

preferential conditions from Venezuela) has enabled these countries to maintain fossil-based energy matrixes and acceptable fuel costs for decades, but environmental and energy dependency concerns are influencing governments to look towards pushing for cleaner energy matrixes. **Most insular governments have set ambitious renewable energy targets for 2030**, coupled with the development of public policies and incentives that enable solar photovoltaic systems, wind turbines and marine energy to become competitive with fossil-fuel based generation. **However, as the penetration of renewables in Caribbean grids grows, so will the challenges**. The need for reliable and resilient energy storage solutions to avoid curtailment of these new clean sources, as well as the establishment of a market for grid ancillary services is imminent.

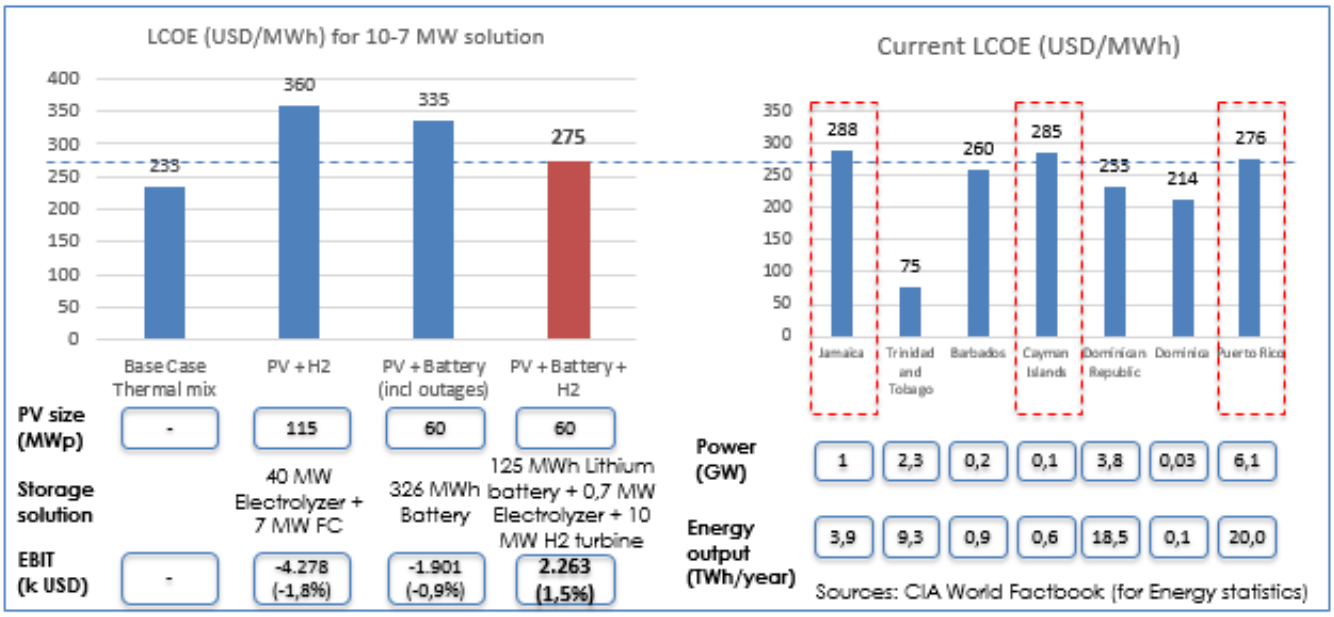
There is little doubt that allowing the incorporation of renewable energy in Caribbean grids will lead in the long term to lower energy prices and higher energy independency, while also allowing islands to achieve their environmental, independence and conservation goals. **Hydrogen can serve as an excellent partner adding further resilience to the grid, and a solid business case may be found behind this statement**.

A BUSINESS CASE FOR HYBRID HYDROGEN-BATTERY STORAGE

Evaluation of the technical and economic feasibility of using hydrogen as an energy storage medium was performed via modelling of a hybrid system consisting of: a solar photovoltaic system, an electrolyzer, a hydrogen storage unit, a fuel cell (or hydrogen turbine) for re-electrification and a lithium-ion battery system.

To assess the competitiveness of a hydrogen storage solution **a benchmark levelized cost of electricity (LCOE) of 233 USD/MWh was established**. It was calculated as a simple average from the LCOE of seven different Caribbean matrices: Jamaica, Trinidad and Tobago, Barbados, Cayman Islands, Dominican Republic, Dominica and Puerto Rico.

Sizing of the key system components was performed using an optimizer integrated in the model, with a target function of maximizing project EBIT.



The business case reveals that *the LCOE of the hybrid* ***fully renewable solution of battery and a small H2 solution for long-term storage can compete LCOE wise in Jamaica, Cayman and Puerto Rico, as well as in other islands whose LCOE is in the 280 USD/MWh range.*** This LCOE is achieved by combining a 60MWp solar PV array, a 700kW electrolyzer producing H2 throughout the year, a 10 MW hydrogen turbine (to be used on the occasions where overnight battery capacity is not sufficient) and 125MWh of battery energy storage mainly for overnight storage, which in turn can meet the demand curve of 10MW day / 7MW night load.

Furthermore, there are important co-benefits to be gained from shifting towards a renewable solution with hybrid storage. Implementing the hybrid system described above results in net CO_2 savings of 53.000 tons per year, and avoids the import of 1.700.000 liters per year of fuel oil or 15.000 cubic meters of natural gas for the island.

SHIFTING POLICIES FACILITATES THE CLEAN ENERGY TRANSITION

Clean energy technologies can more easily penetrate national energy markets via the support of governments via public policy that facilitates their adoption for economic, environmental and energy independency reasons. While well-established renewables like solar and wind energy are already cost-competitive with traditional sources of electricity generation, new sources such as marine energy and storage solutions such as batteries and hydrogen require stronger public support.

Regarding the hydrogen hybrid storage solution presented in this document, the following policy recommendations may help strengthening the business case:

- In the business case, the main driver for the relatively high LCOE of the hybrid solution is the CAPEX of the components. **Establishing incentives for the acquisition of clean technologies** that cover components such as solar PV systems, electrolyzers, fuel cells, turbines for self or cogeneration, batteries and similar elements will increase the EBIT of the business case and make investing in clean grids more attractive for public and private developers. Typically, incentives include tax and credit benefits, reduction of import tariffs, preferential financing and loan schemes and support from multilateral organizations. More specifically resilient technologies offering more than overnight storage potential should be given extra incentives for the extra value they bring in terms of system resilience.
- The **market for ancillary grid services and for reserve power is new in Caribbean islands and is foreseen to grow** and create potential for storage solutions to enter in the next decade as renewable penetration increases to meet ambitious commitments by individual islands to meet their Nationally Determined Contributions and comply with their energy planning goals (in most cases with a 2030 horizon). The regulation of this emerging market and establishment of injection tariffs and penalties would drive demand and open the opportunity for new business cases around both battery electric storage and hydrogen storage.
- **Valorizing seasonal storage and setting up solutions for backup power at a premium** in case of power shortages or outages would in turn increase foreseen revenue streams for long-term energy storage that hydrogen can provide. Thus, the recommendation is for local

governments to incentivize **the differentiation of energy tariffs for (a) stable grid conditions, (b) 12-hour scarcity storage price and (c) long-term storage price for over three days of scarcity.**

- **The environmental benefits of shifting towards clean storage coupled with renewable generation cannot be ignored,** and it is in the best interest of Caribbean islands to encourage utilities to invest in said solutions. Coupling clean generation sources with energy storage leads to sustainable grids, which are also as reliable as conventional grids with fossil-based energy matrixes.
- **Internalizing carbon costs** in both the energy and transportation sectors is key towards making cleaner solutions cost-competitive with fossil-fuel intensive activities, which is usually done via carbon taxation to fuels.

ABOUT HINICIO

Hinicio is a strategy consulting firm specialized in sustainable energy and transport. Our areas of expertise include renewable energies, energy storage, energy efficiency and sustainable transport. Furthermore, since 2007 Hinicio has been developing and consolidating a unique level competence center in the field of hydrogen energy.

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