Green Hydrogen Production, Transportation, Securitization, and Tokenization

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***Abstract*—HedgeSPA is looking to launch a demonstration project for a green hydrogen production and delivery hub in collaboration with a consortium including the Fraunhofer Institute for Reliability and Microintegration (IZM), part of Germany's leading applied R&D institute Fraunhofer Institute, which will be working with German and EU industrial electronics and process control specialists. The consortium will bring German sensor technology to work with HedgeSPA's AI engine to drive process control to produce green hydrogen. With the validation and support from Amazon Web Services (AWS) and Nvidia, HedgeSPA will deploy its graph-theoretic AI engine on their most advanced hardware to control the hydrogen production processes.**

***Index Terms*—Green Hydrogen; Solar-Thermal Hydrogen Production; Transportation; Securitization; Tokenization**

I. Introduction

While commercial photovoltaic panels have now achieved efficiencies exceeding 20%, such efficiency is typically achieved under optimal radiation conditions. [11] [16] Using them to generate the type of high-voltage, steady-output electricity to produce hydrogen by electrolysis still faces technical unknowns with low efficiency being the biggest hurdle to wider commercialization. [4] The Ashalim Power Station in Israel, [10] the Ivanpah facility in Mojave Desert, California, [13] and the Planta Solar 10 in Andalusia, Spain, [15] have demonstrated the commercial feasibility of solar-thermal electricity production with efficiencies *starting* from the 20s and with the plants being able to operate for up to another 12 hours after sunset. [1] [6] Steam-based turbine generators are proven, reliable, and cost-effective, and minimize inefficient downtime due to photovoltaic panels not being able to operate under optimal solar radiation conditions at all times and after sunset.

The project consortium as shown in Figure 1 is consisted of senior academics in the relevant technical fields, proven professionals in energy project finance, as well as engineering professionals with deep industrial energy and process control experience. While typical solar-thermal installations require 150 hectares (or 1,500,000 square meters) to 320 hectares (or 3,200,000 square meters), we propose to build smaller production sites starting from about 10 hectares (or 100,000 square meters, or 316.2 meters on each side in a square configuration). Such smaller sites are much easier to find, and

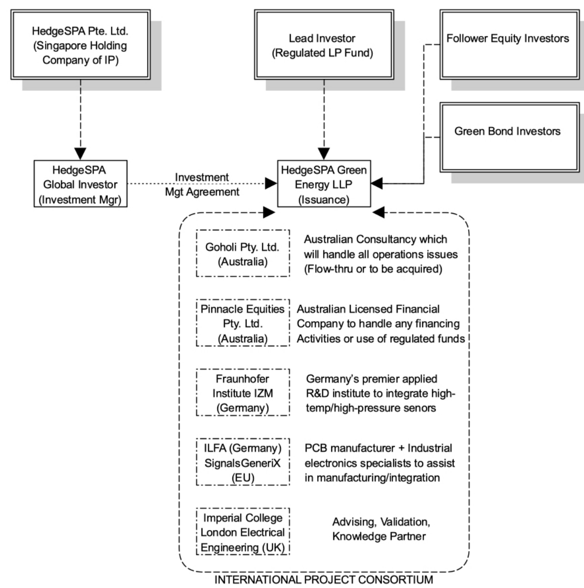

Fig. 1. Consortium Organization Chart

we bring the cost down by economy of scale and improve efficiency with practical designs, e.g. by controlling these production sites on the cloud and servicing a cluster of them with a technical staff centrally-located in an urban city. The following is a 7-point summary of our proposed project:

1) *Demonstration.* The proposed demonstration plant is a 1∼2 metric tonnes per day facility targeted to meet customary demonstration requirements to secure the form of financing that we intend to pursue. We are looking at extraction sites with high solar radiation. The transportation hub will be located near a port.
2) *Production.* The idea is to replicate these extraction sites within reasonable transportation distance from the transportation hub, with access to fresh, mixed, or seawater, so that the produced hydrogen can be shipped to a port for consolidation to ship to its final destination. Once proven, this "hub and spoke" production method shall

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not be limited to one or two locations. We can choose locations such as those with lower cyclone risks.

3) *Financing.* The form of financing will be quite similar to how Tesla uses third-party financing to install photovoltaic panels on roofs across homes in California, but those solar electricity generation units are controlled from the cloud. We are proposing a similar setup because there may be farms, aquafarms, or ranches with at least a few percentages of unused land. Process control will be driven by HedgeSPA's AI engine working with AWS IOT Core to connect to microcontrollers, which has been validated by AWS' technical team. This is intended to be a relatively carefree solution for the landowners, who will benefit from access to cheap renewable energy, and potentially steady income streams while contributing to the global fight against climate change.
4) *End-Consumer.* Our consortium has secured one committed buyer in Asia who runs a fleet of hydrogen vehicles that can take delivery of up to 2 metric tonnes/day, under a highly achievable delivery price target, while we are in conversations with other committed renewable buyers in Asia and the Oceania. Our assessment of current demand is that we can deliver as much green hydrogen to corporate buyers as we can practically produce, provided that we deliver below a very achievable price target per kilogram of hydrogen. Of course, we must account for the cost and logistics of getting the end product to the end-consumer. We plan to use the high-quality cashflows to create asset-backed securities and attach carbon credits to them.
5) *Securitization.* Just like in Tesla's photovoltaic panel use case in California, the smooth financing of the generation units will be the key to the success of the program after our initial demonstration project. We plan to finance these projects with asset-backed securities and issue the securities as digital assets for investors outside the issuance domicile to invest, to be custodied using an independently-verifiable ledger at a brand name custodian. We have discussed the issuance with a government agency outsourced by Hong Kong's central bank to validate the issue's eligibility for the Hong Kong Green bond program, but we are actively exploring other jurisdictions, such as Australia, Japan, and Singapore.
6) *Tokenization.* There is an institutional pool of yield-producing tokens that is interested in switching to these asset-backed securities with carbon tokens attached to support these green energy projects. With economies of scale, we are projecting our costs and required investments to be consistent with industry estimates, which is similar to the numbers published by research from Goldman Sachs [12]. We also plan to attach carbon credit tokens to the digital assets based on the non-fungible feature of tokens. Doing so discourages the prevalence of cheating among issuers of carbon credits today, which often prevents carbon credits in some markets from fetching their fair market values.
7) *Transportation/Delivery.* Shipment and transportation can be done using one or more of the following methods: Cryogenic storage (which may require a significant safety margin due to the very high pressure in the event of any leakage but this is the cheapest over the long run for long-distance delivery), MCH hydrogenation (which requires a plant, and therefore space, for mid-distance delivery) and compressed tanks (for shorter distance delivery, e.g. to the transportation hubs), or via delivering ammonia which is a jet fuel/petrol substitute.

II. Overview

This section provides an overview of the proposed project:

A. Background Technology

HedgeSPA has a proven graph-theoretic AI engine with a successful track record in application to investment management and related domains. [2] In particular, some of our latest R&D projects have won global recognition by appearing in scientific publications of respected publishers such as Springer-Nature. [5] The plan is to deploy our AI engine to control chemical processes for the green hydrogen demonstration plan.

AWS Greengrass can support Web Sockets and MQTT protocols. HedgeSPA's AI engine, already running on AWS, supports Web Sockets, with plans to integrate with MQTT eventually. The planned collaboration model is for IZM to help with the hardware integration until the point where HedgeSPA programmers can read the signals from the UNIX ports on microcontrollers, and then the HedgeSPA technical team can take care of the rest of the integration from the microcontrollers to the AI engine.

AWS has also reduced the absolute minimum RAM requirements to 1 megabyte for super light microcontrollers such as the ARM Cortex M-class microcontrollers. Based on the sensor design proposed by IZM, we aim to package the sensor and its microcontroller into a single unit. The microcontrollers can initiate orderly shutdowns in the event that connectivity to the AI engine on AWS is lost due to extremely rare events such as peak coronal mass ejections or solar flares which are expected to peak in this decade.

Why will such a setup become an innovative game-changer in producing green hydrogen? In the past, energy plants tended to have a large footprint because it was quite costly to run a data center to control the plants in terms of both equipment and human resources. Reaching a certain economy of scale was the only financially feasible solution. Today, we can offer more agile setups by using an AI engine to control the production process from the cloud. For instance, many commercial farms, aquafarms, and ranches come with easily 5∼10% unused land that can sublease plots with water access starting from 10 hectares (or 100,000 square meters) to build smaller solar-thermal plants, which can be consolidated at a hydrogenation plant for loading hydrogen in a transportation hub for export shipment. The value proposition will be analogous to Tesla installing many photovoltaic units in homes across California. Those units are subsidized by the State of

California and a separate financing unit underwrites meaningful portions of the unsubsidized installation costs for the homeowners, who will end up not only with cheaper energy but also in some cases earned income by feeding electricity back to the power grid. We are targeting roughly the same model for more agile green hydrogen plants.

B. Project Objectives

This proposed project's objectives include the following:

1) Reduction in the cost of renewable energy:
   - We expect our hydrogen production cost to eventually get closer to the Biden Administration's ambitious target of 1 US dollar per kilogram of hydrogen under the economy of scale. The current design is based on the proven technology of Polymer Electrolyte Membrane (PEM) Electrolysis coupled with a Solar-Thermal Steam Turbine and feeding the effluent steam to the electrolysis surface. Both improving the efficiency of the membrane surface using more advanced materials and heating the water (instead of superheating to 2600 degrees to ionize water molecules into their plasma state under High-Temperature Electrolysis, which may not be energy efficient even when the solar-thermal setup is in a location with extreme heat) will allow a steam turbine to produce the electricity to electrolyze heated water molecules. The demonstration plant will allow us to collect experimental data and fine-tune system control parameters to achieve the most efficient temperature/electricity combination given the simulation models and the characteristics of the sites.
   - Active investigation of other safe methods of storage and transportation, such as hydrogenation and dehydrogenation aiming to achieve more practically realizable objectives on such aspects as heat/pressure required in the MCH process and any significant residual, including transportation of hydrogen without the significant amount of energy required to liquefy hydrogen at -253 Celsius to transport it.
2) Increase in the value delivered by renewable energy:
   - The proposed setup can be augmented by other methods to generate green electricity at other non-sunlight hours to maximize usage of the electrolyzer, which is a fixed-cost investment. For example, there can be a higher attitude wind farm feeding green electricity to the electrolyzers to produce hydrogen at night (slopes cool faster, and cool air rushes down), and all such control mechanisms can be driven from the cloud. This is similar to how Tesla chooses to sell more expensive electricity to the State of California grid during peak consumption hours during the day but draws cheaper electricity from the public grid to charge vehicles at night.
   - Part of our testing efforts will fine-tune the most efficient temperature-pressure-source combinations based on physical characteristics such as the topology of the production site. With this kind of dynamic management, we expect our hydrogen production cost to eventually get closer to the Biden Administration's ambitious target of 1 US dollar per kilogram of hydrogen under the economy of scale.
   - Our process control engine will also consider other factors such as access to consolidated distribution units. More effective delivery methods to vehicles based on ammonia are also considered.
3) Improvement in technology readiness and commercial readiness of renewable energy technologies:
   - We will start with proven technology and modify the temperate/electricity mix to achieve higher efficiency. This may include using the demonstration plant to adapt to lower-temperature techniques tested in laboratories before rolling out such technology in new plants:
     - Sulfur Iodine Cycle
     - Cerium (IV) oxide-cerium (III) oxide cycle
     - Copper-chlorine cycle
     - Hybrid sulfur cycle
     - Iron oxide cycle
     - Zinc-zinc oxide cycle
   - The testing of materials that can stand up to 2600 Celsius for the reaction chamber in high-temperature electrolysis (likely candidates are ceramics – with some candidate materials already in use in Japan for hybrid-hydrogen power generation), or more efficient materials for PEM electrolysis. Part of our R&D efforts will fine-tune the most efficient temperature-pressure combinations based on the physical characteristics of each production site. There are modeling solutions available for such temperature optimization. [7]
4) Reduction in or removal of barriers to renewable energy uptake:
   - Integration of our AI engine with solar-thermal mirror and control algorithms to focus solar rays on the reaction chamber and with actual testing of the thermal efficiency on the demonstration plant means that any control software updates can be deployed from the cloud. While we still expect to have support professionals servicing multiple sites around each major delivery center to meet health and safety requirements, these plants should no longer require large data centers and large crews to run. Just like Tesla in California, we are proposing a smart solution that can be deployed flexibly by any cattle station owner with a low barrier of entry.
   - The proposed computational control architecture has already been validated by AWS to work with AWS IOT Core, while our AI engine is already working with Web Sockets as required by AWS. Deploying the control mechanism on the cloud will mean that

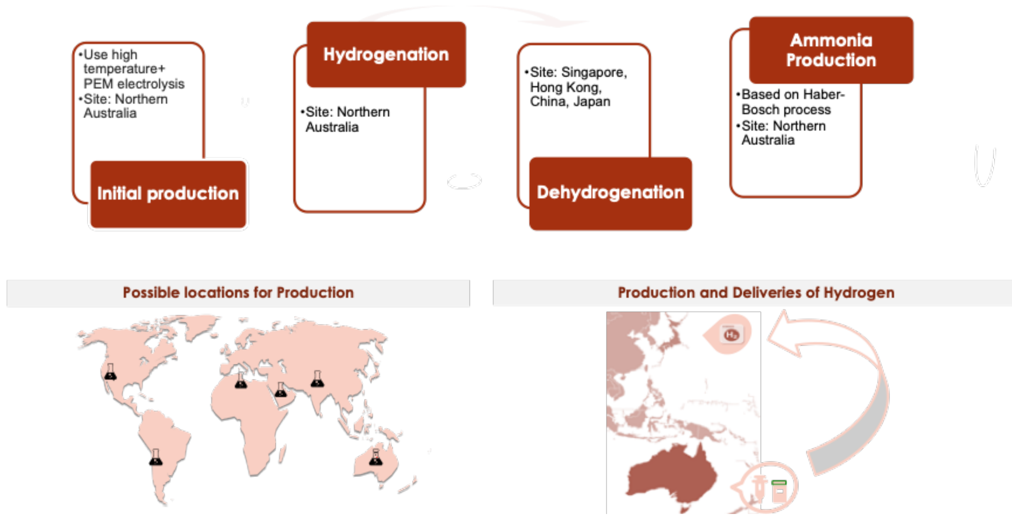

Fig. 2. Demonstration Plant for Green Hydrogen Production in Australia

many cattle stations with at least 5∼10% of unused land will have access to cheap renewable energy as well as income streams while contributing to the global fight against climate change by delivering green hydrogen to a transportation hub for domestic consumption or exporting.
- Finally, one key to success in the world's sustainable energy transformation is financing. We are proposing an innovative way to finance these projects using digital tokens. Once successful, there is an institutional pool of yield-producing stable coins exceeding 1 billion US dollars that is interested in subscribing to these asset-backed securities with carbon tokens to support these green energy projects.

5) Increased skills, capacity, and knowledge relevant to renewable energy technologies:
   - Physical testing of all chemical steps to fine-tune the chemical simulations already completed on the Chem-CAD software ASPEN – In particular, future upgrades will follow the path of simulation to lab-scale testing to demonstration-scale testing. Thus, the demonstration plant will be used to test some of the lower temperature cycles in electrolysis. This will also involve the future construction of lab-scale demonstration units that will allow a continuous flow of chemical processes rather than the hitherto batch mode operations. These activities will include the hiring of scientists, engineers, and technicians.
   - The world cannot migrate away from fossil fuels based on batteries alone because the use of batteries in commercial transportation such as buses and trucks has the known problem of low energy-to-weight ratio with the need to transport the heavy weight of batteries. In fact, batteries finish dead last in an energy density chart published by the top American manufacturer of locomotives. In the same chart, the manufacturer suggests that hydrogen can be one solution to this problem. Hydrogen fuel cell supplement is one attractive solution for mid-distance commercial vehicles with its far more attractive energy-to-weight ratio, but voltage stabilization and heat mitigation are necessary to avoid the overheating of batteries and therefore potential explosions. Moreover, HICE (hydrogen internal combustion engine) or the alternative of mixing fossil fuels with ammonia requires no to extremely simple modifications to the existing gasoline-powered vehicles, e.g. HICE has been deployed on buses in California for over a decade. As we need to target our capacities based on end customer demand, we will also devote resources either to test the downstream technology directly or work collaboratively with relevant R&D institutes.

III. Proposal Implementation

The proposed project will be implemented with the following steps:

A. Proposed Hydrogen Production Technology

The typical consumption rate of hydrogen by a passenger vehicle has been estimated to be slightly above 10 grams/kilometer. Assuming that these vehicles travel 200 kilometers/day, the daily consumption of each vehicle will be ∼2 kilograms of hydrogen. We have identified hydrogen demands from a fleet of 1,000 vehicles, which will consume 2 metric tons per day or about 700 metric tons/year (assuming 350 operating days/year, allowing for downtime due to public holidays and maintenance). The demand volume is expected to increase dramatically over the next few years. We expect the aggregate demand that we can serve can eventually exceed the yield of 2,000 metric tons/day. Based on current financials, the annual yield for the production plant will be roughly 12%.

We propose to produce hydrogen in scale using solar-thermal electrolysis, which can be either based on a) High-Temperature Electrolysis or one of its lower-temperature variants based on a different chemistry cycle, b) Polymer Electrolyte Membrane (PEM) Electrolysis coupled with a Solar-Thermal Steam Turbine and feeding the effluent steam to the electrolysis surface. Part of our R&D efforts will fine-tune the most efficient temperature-pressure combinations based on the physical characteristics of each production site. There are modeling solutions available for temperature optimization. [7]

For high-temperature electrolysis, the most desirable region to run such productions will be hot and dry desert areas with access to water, such as Northern Territory and/or Western Australia, Central Asia, and the Arabian Peninsula. The steam will be extracted by solar-thermal distillation and the high temperature will be generated by AI-controlled solar mirrors.

The generation of hydrogen via electrolysis is well understood by scientists. We will start with a proven setup and explore other alternatives to improve efficiency and lower reactor temperature:

- Sulfur Iodine Cycle
- Cerium (IV) oxide-cerium (III) oxide cycle
- Copper-chlorine cycle
- Hybrid sulfur cycle
- Iron oxide cycle
- Zinc-zinc oxide cycle

The proven design is the decades-old technology of Polymer Electrolyte Membrane (PEM) Electrolysis (as illustrated in Figure 3) coupled with a Solar-Thermal Steam Turbine and feeding the effluent steam to the electrolysis surface. Both modifying the membrane and heating the water (instead of superheating to 2600 degrees to ionize water molecules into its plasma state under High-Temperature Electrolysis, which may not be energy efficient even if the solar-thermal setup is in a desert) will allow a steam turbine to produce electricity to electrolyze vaporized water molecules. In short, we produce steam in a solar-thermal plant, convert the thermal energy into electricity, and then use the effluent to feed steam to the electrolyzer surface to produce hydrogen.

In the future, such a setup can be augmented by wind, photovoltaic or tidal methods to generate green electricity. The currently proposed design will be based on a triple-heat-circuit solar-thermal design, as shown in Figure 4.

B. Transportation and Delivery

The harder technical challenge is the shipping of hydrogen to its final delivery sites, which can be complex and dangerous. Three possible methods of transporting hydrogen are described as follows:

1) For shorter distances (within 3,000 kilometers, we propose that we ship with Type 3 or Type 4 compressed hydrogen tanks.
2) For mid-distance deliveries of about 3,000∼7,000 kilometers, we propose that we use bulk carriers to ship methylcyclohexane (MCH). This method involves the hydrogenation of toluene, a colorless and odorless liquid, into methylcyclohexane. After arriving at a receiver port such as Hong Kong or Kobe, Japan, the MCH can be dehydrogenated (under heat and pressure) to release the hydrogen for local consumption. Currently, hydrogen delivered with this method can be delivered to the Port of Kawasaki in Japan.
3) For future delivery over longer distances, we propose to deploy cryogenic tanks to ship liquified hydrogen. This is potentially the most expensive technology requiring significant upfront investments, but it may turn out to be the cheapest method to ship long-distance to locations as far as Europe at over 10,000 kilometers. Hydrogen has a liquefication point of -253 Celsius. Cryogenic shipments (as is currently done from Japan to Australia) require significant use of energy to achieve this extremely low temperature.
4) We may propose using ammonia as a subsequent-stage solution for transportation fuels, depending on user demand. Ammonia can be deployed as a direct substitute for gasoline and jet fuel, often requiring no to relatively simple modifications to the power plant. Upon combustion, ammonia emits nitrogen and water. Neither of them causes any harm to the environment. Unlike MCH which requires the shipment of toluene back to the production site, ammonia does not require any dehydrogenation at the delivery point and the “return shipment” of toluene, resulting in more cost savings.
5) Certain transportation hubs can be of dual-use in nature, mixing MCH hydrogenation and ammonia conversion

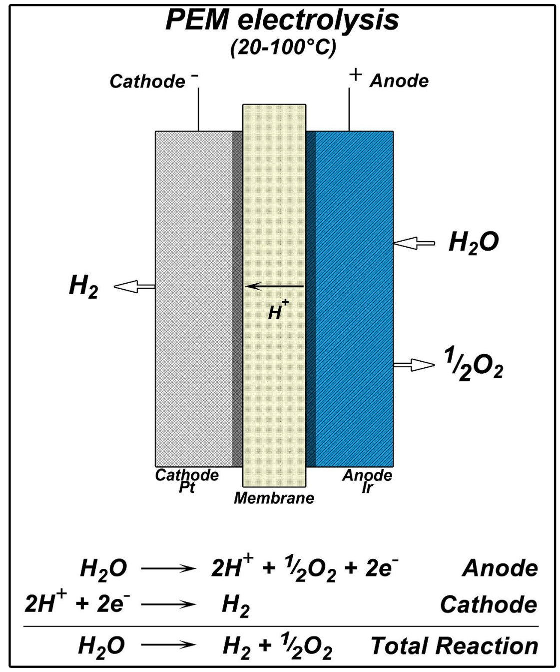

Fig. 3. PEM Electrolysis Process (Wikimedia Commons License).

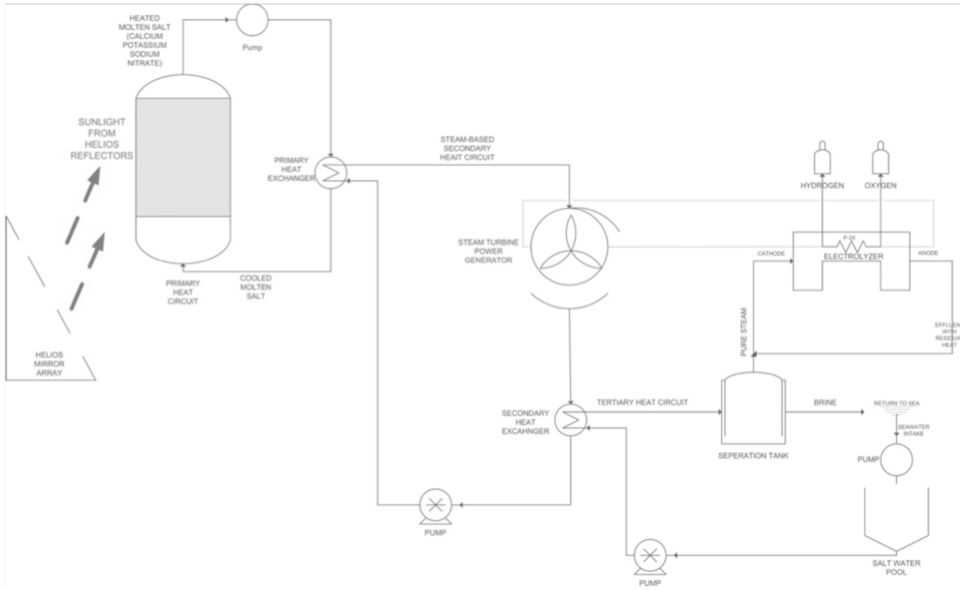

Fig. 4. Solar-Therma Hydrogen Production Plant Schematic

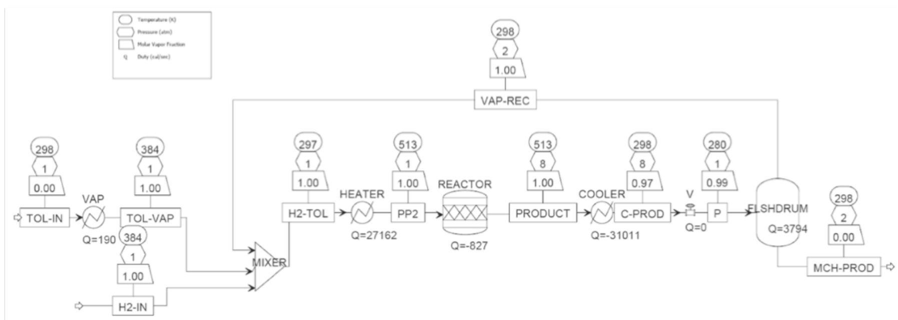

Fig. 5. Hydrogenation Process

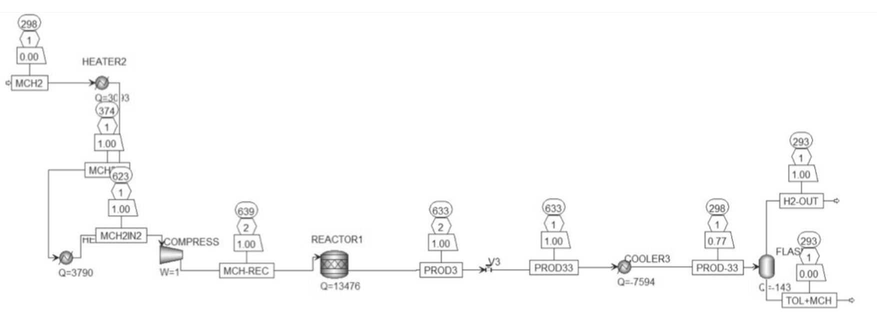

Fig. 6. Dehydrogenation Process

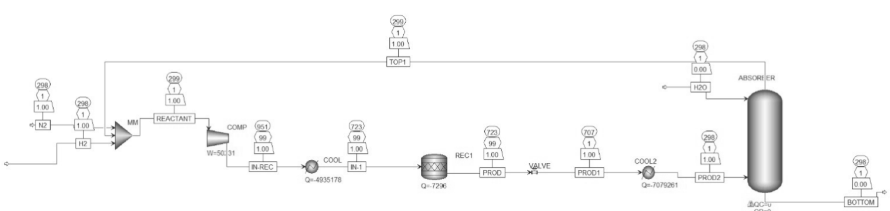

Fig. 7. Hydrogen to Ammonia Conversion

given that the equipment required is not hugely dissimilar. Converting hydrogen to ammonia will be based on the extensively-used Haber-Bosch process. The mixture of Nitrogen and Hydrogen will be compressed to 100 ATM but cooled to 450 Celsius using a cooling coil. The resulting gas will be fed into an absorber column filled with water. The ammonia is extracted from the bottom of the absorber column. Any unreacted gas will be recycled from the top of the absorber column. This will be done as a batch-based process because of the pressure required.

6) The main goal of this project is to complete the full hydrogen supply chain until delivery to end consumers. This is likely to involve a certain “hub and spoke” setup starting from locations where green hydrogen can be generated efficiently. Other future production locations may include say the Middle East. Doing so may balance global demand and supply by generating more green hydrogen in the December months in the Southern Hemisphere and doing so in the June months in Northern Hemisphere.

C. Securitization and Tokenization

This subsection contains the implementation details of the securitization and tokenization piece of the project.

1) Token-based Financing Use Case:

1) Global investors can buy digital assets on renewal energy using an authorized central bank digital currency (CBDC).
2) Their home central bank can confirm the eligibility of the investors to invest (instead of relying on payment apps or commercial banks to do KYC/AML) according to local regulations.
3) The identity of the qualified buyer can be lodged in a “custody” ledger at a brand-name custodian that will be kept under the watchful eyes of the issuance jurisdiction’s central bank.
4) The issuance does not need to be for any specific jurisdiction such as Hong Kong. We are using Hong Kong as one example because of a Green Bond program already in existence, but we may choose to do so under the CBI program in Australia or any other relevant jurisdiction such as Singapore, in the event that Hong Kong may require complicated licensing for issuing digital tokens.
5) If the security is redeemed (either at maturity or by the market maker), the proceeds can be converted back to the CBDC based on the prevailing exchange rate.
6) If working with one specific regulator may take too long, then a similar idea can be applied to another jurisdiction, e.g. Japanese investors provided the tokens comply with ERC-721 requirements. We have been working with one of Japan’s top two securities law firms to work out whether we can meet the exempt status for selling to Japanese investors. For a simpler proof of concept without excessive licensing concerns, another possibility is to issue the paper securities in Singapore while running the digital token ledger in Dubai International Financial Center.
7) The HedgeSPA core investment platform will integrate with R3/Corda and offer the users of our solution a secured way to keep the tokens. There would be no additional security concern from investors in that the actual ledger sits with a brand-name custodian.
8) We also intend to move some of our non-asset-backed securities investment products to such a ledger to create a form of e-ETF. This way, we attract more traditional investors to use digital tokens as an asset class for financing all types of sustainable energy projects. The more precise technical details are given below and further illustrated in Figure 8:

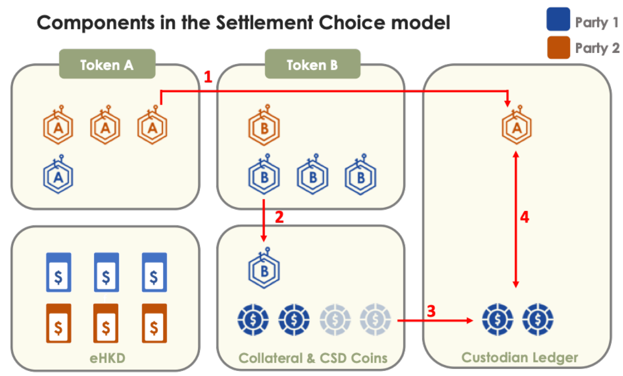

Fig. 8. Asset Tokens in Custodian Ledger

- Construct an investor portal (or API calls to access the R3/Corda blockchain) for an investor to transact on one unit of security.
- API calls working with CBDC portal to buy/subscribe to the asset-backed security:
  - investor transfers the quoted CBDC amount to the CBDC account of the custody bank
  - local regulator allows the custody bank to confirm investor eligibility (preferably by electronic means);
  - log one unit of the security under the investor’s name in the bank ledger;
  - custody bank to issue one token (on the R3/Corda blockchain) to the investor.
- API calls working with CBDC portal to sell/redeem asset-backed security:
  - investor to give instructions to the custody bank to sell one unit of the token on the portal;
  - confirm investor instruction to sell based on the latest bid price quoted by the market maker;
  - confirm account details and double-check that the account has no KYC issues (based on local regulatory requirements);
  - sell or redeem one unit of security; reverse one unit of the security under the investor name in the bank ledger;

  - custody bank to deposit proceeds to CBDC investors.
- API calls to detach carbon token from combined security:
  - investor to surrender token on the portal and give instructions to detach carbon token from security (note - once detached investors cannot reattach based on industry practice, just like detaching a warrant);
  - reverse one unit of the combined security under the investor name in the bank ledger;
  - add one unit of the standalone security and one unit of carbon credit token under the investor name in the bank ledger;
  - sends one unit of the standalone security and one unit of carbon credit back to the investor.

2) Benefits from Token Financing Proposal:

1) Financial Inclusion – CBDC does not receive any interest payment unless it is deposited. Today, inflation is driven heavily by surging energy prices, and the world is getting ready for its expected transformation to adopting renewable energy. The creation of straightforward ways to convert CBDCs into renewable energy-linked securities allows the financially “less involved” population to participate in the upside of adopting renewable energy.
2) Minimize fraud and develop the carbon market – The domestic carbon credit market in Asia is unable to fetch international carbon prices to date due to the (mis)perception of widespread fraud. Attaching non-fungible serial numbers to digitalized carbon credits is one solution since one ton of verified carbon credits cannot be sold more than once under this setup.
3) A mechanism to settle cross-border transactions in securities issued in one jurisdiction for other CBDC investors – This is expected to become a highly credible test case for interoperability with large-value transactions under delivery-versus-payment (DvP) in a shorter settlement timeframe than t+2 via a brand-named custodian in two ways:
   - Settlement on a programmable CBDC can be made as soon as a digital asset is received and the ledger entries are updated. There is no reason for this transaction to require T+2 settlement any longer. As and when both the custodian and the investor agree, this can be settled based on even end-of-day or T+0 settlement. Please note that in a typical setup like this, the paper security will be held by the custodian in “street name”. This mechanism should be done inside the custodian and does not require any designated “oracle” unless there is a specific regulatory requirement to do so.
   - Similarly, a digital bond can release its coupons as programmable CBDC automatically when certain pre-defined conditions (by a designated oracle) are met. Without the need for servicing agents to send out paper checks, digital bonds can be far easier to manage to accommodate more retail investors, especially retirees. Today, one reason for the high minimum on most bond investments is that issuers are unwilling to pay for the high costs of servicing retail investors (e.g. sending coupons, manual corrections of common book entry mistakes).

IV. Project Analysis

This section will discuss expected outcomes, success drivers, and risk and mitigation methods.

A. Expected Outcomes

Our proposal aims to build the demonstration unit of this hydrogen supply chain with German components so that eventually the financing units (e.g. by underwriting asset-backed securities with tokenization of carbon credits) can visualize that our proposed technical setup will work in a demonstration plant.

1) Generator Size: According to one manufacturer’s specifications, [14] a 5-megawatt commercial PEM electrolyzer can yield 83.75 kilograms of 99.999% high-purity hydrogen. Such equipment can be ordered based on a more customized specification. In other words, a 6-megawatt electrolyzer is expected to generate 100.5 kilograms of 99.999% high-purity hydrogen per hour.

Citing the *Weather and Climate* website, [9] the average annual amount of sun hours available in Northern Territory is 3,100 hours or 8.5 hours per day. At over 3,000 sun hours per year, Northern Territory has one of the world’s highest exposure to solar radiation. For comparison, in Taiwan today, solar mirrors and panels are regularly built on top of aquaculture ponds to moderate temperature. Tainan enjoys about 2,200 sun hours per year. Any location with more than 2,000 sun hours per year can be a potentially interesting target site.

While the generators may take 0.5 hour to reach operational efficiency, solar-thermal towers (with the right type of molten salt or thermal oil) have the ability to continue operations for hours after sunset due to the very high temperature already accumulated in the heat circuit to generate steam. Therefore, it is conservative to assume that we have at least 12 hours of production per day, although some literature has suggested that the solar tower can continue to run for up to another 12 hours after sunset, allowing close to 24-hour production during the summer months. [6]

As a result, the yield for a 6-megawatt PEM electrolyzer in one year is 328,599 kilograms or 328.6 metric tonnes of hydrogen if the plant can only run for 12 hours per day on average, but the yield can reach as much as 657,000 kilograms or 657 metric tonnes if the plant can run 24 hours per day. 329$\sim$657 metric tonnes per year is consistent with our production target of 1$\sim$2 metric tonnes per day of hydrogen.

2) Water Intake: The amount of water required to produce 100.5 kilograms of hydrogen is 804 kilograms of pure water, which is roughly equivalent to 804 liters at ambient temperate. However, even if pure water is fed into the electrolyzer, there should be an allowance for a 10% loss due to production factors such as evaporation. So, we estimate 893 liters of pure water or roughly 15 liters per minute. This is comparable to the manufacturer's recommendation of 1,000 liters per hour, which typically includes an additional buffer to avoid commercial liabilities.

Do note that the flow rate of 15 liters of water per minute is similar to the intake flow rate of large-capacity washing machines. In the worst case, even taking treated city water at such a flow rate is unlikely to draw significant environmental objections. Besides mixed water, we are exploring using either used industrial water or sewage after primary treatment, since we will perform a distillation step to extract the pure water. If we are allowed to extract 10% of pure water from any mixed water, we will require an intake of 10,000 liters of mixed water per hour to extract 1,000 liters of pure water per hour.

3) Heliostat Mirror Site Size: At the Solar Two Power Plant site near Barstow, California (shown below), a 10-megawatt solar plant requires a field size of 82,750 square meters. For 6-megawatt, we estimate the field size required to be 49,650 square meters.

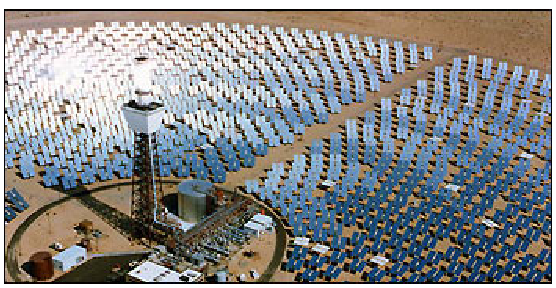

Fig. 9. Solar Two Power Plant (Wikimedia Commons License).

Do note that Solar Two is using older technology from the 1980s. The efficiency of solar-thermal technology has since improved significantly so it is reasonable to treat this as an upper bound on the field size. Moreover, Bartow's latitude is 34.9 degrees north while most target sites are closer to the equator, which means that the solar radiation will be stronger in those locations due to their proximity to the equator. We expect to require fewer mirrors to achieve the same thermal output.

A field size of 49,650 square meters will require 2,758 solar mirrors in a standard 18 square-meter configuration. In a rectangular site configuration, that will take roughly 53 × 52 mirror units. Typical 18 square-meter mirrors come as a pair of 3 meters by 3 meters solar reflectors. Allowing 2 meters of margin for each mirror pair to minimize blockage from each other means that each mirror pair requires 5 meters by 8 meters of space, or roughly 110,240 square meters in total, translating to 332 meters on each side of a square configuration and 374.7 meters in diameter in a circular configuration. In other words, any regularly-shaped demonstration site of 1∼2 square kilometers for both hydrogen production and shipment consolidation will meet the commercial requirements, and still leaves plenty of room for safety margins and other environmental considerations such as settlement and cooling ponds if mixed water is used; typically, we are allowed to extract only 10∼15% of pure water and return the rest to the source "as close to ambient temperate as reasonable". Finally, NASA's Surface meteorology and Solar Energy (SSE) 6.0 provides 1-degree latitude by 1-degree longitude grid-cell data over the globe, which is reasonably accurate as a starting point for the azimuth and elevation angle control software to calibrate the reflecting directions of mirrors.

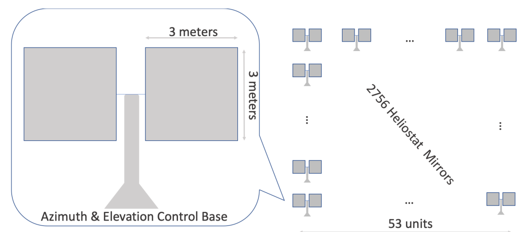

Fig. 10. Heliostat Schematic for Typical 3m×3m Solar Reflector Pairs.

4) Technical Goals of the Demonstration Project: Our primary goal is to fine-tune the optimal production parameters based on physical experiments. For instance, is it better to maintain a higher temperature and aim for 24-hour production? Given that our goal is to implement smaller, self-running plants that may sit on different sites, there may be fewer maintenance issues (e.g. metal fatigue due to continuous high temperatures and pressure) by running the plants at lower temperatures with regular cooling down periods. While there is a large body of similar performance studies based on simulations in the scientific literature, there is no substitute for collecting the empirical physical data to fine-tune our performance models before replicating the plant design *en masse* at other locations.

5) Costs and Benefits: To meet all of our objectives above, our budget worksheet is estimating a total cost of ∼14 million US dollars over 3 years, primarily to pay for the equipment and construction, as well as local costs such as land lease, access rights, and environmental assessments. We target exporting 8∼13 metric tons of green ammonia/day or 1.4∼2.3 metric tons of green hydrogen/day. This is expected to satisfy up to 2 kilograms/day of hydrogen demands per vehicle for a fleet of 1,000 hydrogen vehicles based on a highly achievable delivery price target. We will start with the blueprints based on standard and proven technologies with Technology Readiness Level (TRL) 7 or TRL8. The key innovation is how we put highly proven components together: for instance, by introducing the latest German high-temperature and high-pressure sensor technologies running with the HedgeSPA AI engine to drive the chemical processes to improve efficiencies and yield.

6) Work Packages: The specific collaboration with the Fraunhofer Institute will include the following R&D collabo-

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ration areas to address immediate needs for the initial demonstration facility. In most energy plants, sensors are usually placed at equal distances or in a topologically regular pattern to detect "fault signatures". Our goal for the First Phase is to place the sensors outside the pipelines and reaction chambers. Our goal for the Second Phase is to place some of them inside the pipelines and reaction chambers. Each time we shall start with a lab-scale setup, primarily to avoid unnecessary changes and potential damages to the demonstration plant.

1) First Phase – Classic approach to set Project baseline:
   - Ready-made components
   - Some microcontrollers outside reaction chambers (already from the AWS approved list)
   - Aiming for 4-pin connections with insulated connections
   - Liquid/air cooling of microcontrollers and connections
   - Ensure that the combination of sensors/actuators (pressure, temperature, viscosity, movements) can meet the AI control and safety shutdown requirements.
2) Second Phase – R&D approach to improve efficiency and reliability:
   - More specialized, bespoke components
   - Microcontroller embedded into the sensor package
   - Insulate the entire unit with insulation materials
   - Study temperature/failure characteristics as well as heat mitigation procedures
   - Where feasible, upgrade specific components in the overall design with the more advanced sensor packages.

This project is exciting to the Fraunhofer Institute in that we will be a good showcase to deploy IOT-style sensors and actuators controlled by our AI engine on AWS using Web Sockets or MQTT protocols. With a solid collaboration model, we may explore further collaboration with the Fraunhofer Institute on advanced high-temperature coating materials for solar-thermal applications and the use of their Graph Neural Network library to enhance the HedgeSPA AI engine.

7) Post-Demonstration Phase: After the demonstration phase, the financiers are interested in funding the full-scale production to meet the over 1 gigawatt in expected green energy demands that we have already identified and can begin delivery as soon as possible. As one example, we have identified a significant pool of institutional assets that will be interested in placing meaningful AUM into this project.

B. Success Drivers

We anticipate the success of this demonstration project due to one or more of these drivers:

1) Our team starts with a fully functional AI investment platform that has generated outperformance (positive returns and positive skewness) across 5 different markets, or an outcome with less than 0.1% probability based on pure luck. That means users of our attractive fintech platform can be natural investors in our private investment projects in sustainable energy.
2) Scientific research linked to our AI algorithm has appeared at and was validated by top academic venues such as American Statistical Association and Association for Computing Machinery and will be published by the venerable scientific publisher Springer-Nature. In particular, we are known for advanced research on predicting "tail loss". These extremely sophisticated risk management tools should give additional confidence to future consumers of any cross-border payment mechanisms.
3) The team has experience in energy investment projects at BlackRock and energy majors such as Chevron-Texaco. A few regulators have indicated that they are ready to approve digital assets related to sustainable energy faster than other asset classes, increasing the chance of project success.
4) We have several seasoned and proven investors in sustainable energy acting as our investors and advisors. The tokenization piece was a finalist in the Tokenized Assets and Digital Securities (TADS) award in 2020 and named for similar awards in 2022. These awards and name recognitions should help increase the confidence of future cross-border investors.
5) We work with identified investor demand (of Asian investors interested in our sustainability projects) and customer demand (of renewable energy users keen to take delivery at or below a certain highly achievable price target). Investors are keen to invest in sustainability projects, and consumers are required by their own regulator(s) to have a portion of their energy supply coming from renewables. These facts lend credibility to how our green bonds will be issued which will be sweetened by a tokenization mechanism to accept cross-border payments, increasing the chances of project success.

C. Risk and Mitigation

The technical processes involved are hazardous by nature. Considering this, our team members have identified the risks expected and possible risk management solutions as well as areas of minimum casualties during operation to be:

1) Solar-thermal electrolysis – No known challenges, except for finding suitable sites with high solar radiation that are not too far from a delivery hub and without unmanageable cyclone risks.
2) Similarly, while Polymer Electrolyte Membrane (PEM) is a proven technology, there may be issues gaining access to state-of-the-art polymer membrane currently manufactured by primarily Western companies for a plant targeting certain Asian buyers. Efficient production is the key to project success. Due to the current geopolitical environment, we must account for a non-zero probability that this project can be denied access to the most advanced electrode materials unless we agree not to deliver to customers in certain countries.

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3) Alternative to cryogenic tanks for hydrogen transportation – We are looking at potentially using Methylcyclohexane as the transfer agent. Successful delivery will depend on a solution to transport/store hydrogen at reasonable costs.
4) Green-bond Issuance – As mentioned, we do not have to issue in Hong Kong if the regulatory process is too slow. There is plenty of interest in such issuance in other jurisdictions, such as Australia, Singapore, or Japan.
5) R3/Corda Tokenization with carbon credits – No known challenges except for the need to deploy time/resources. R3/Corda is public domain.

V. Conclusions

The key takeaways of our proposal are as follows:

1) Einstein once said that "Insanity is doing the same thing over and over and expecting different results." Global organizations have been driving green energy solutions for at least 2 decades. Adoption is often driven by former bureaucrats and project engineers from the energy majors, who are naturally biased toward doing things in the traditional way that they are comfortable with. We present a disruptive, fresh approach that will hopefully drive adoption faster to reverse worrisome trends.
2) We do not need to wait for ground-breaking green technologies to emerge to make an impact. Instead, the most obvious bottlenecks are integration and financing. We can start with proven components and put them together in innovative ways. Our engineers work side by side with financiers to work out the most innovative way to remove each and every roadblock. There is now a once-in-a-lifetime opportunity to pull this off due to the dramatic change in attitudes among heavy users of fossil fuels as a result of global geopolitical developments.
3) Our consortium consists of senior academics in the relevant technical fields, proven professionals in energy project finance, as well as engineering professionals with industrial energy and system control experience getting together, to throw "not completely crazy" ideas against the wall and see "which one sticks" after technical validation.
4) Instead of demanding large equity investments upfront, one alternative is that a third-party issuer or a comparable mechanism can issue a 5-year principal-protected note. Upon the success of the demonstration project, the note will be converted into asset-backed securities backing our plants along with some equity upside. This way, major users of green energy have the alternative to use their strong balance sheets to help drive adoption without making large equity investments upfront.
5) Finally, the carbon market in Asia failed due to a (mis)perception of widespread fraud. We can try the traditional way of fixing such a problem with heavy-handed regulations, which may kill off the nascent carbon market completely, or we can try to address this "trust issue" by using smarter technologies. We have chosen the second approach and welcome other aspiring financial technology professionals to share any related and perhaps even better suggestions.

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