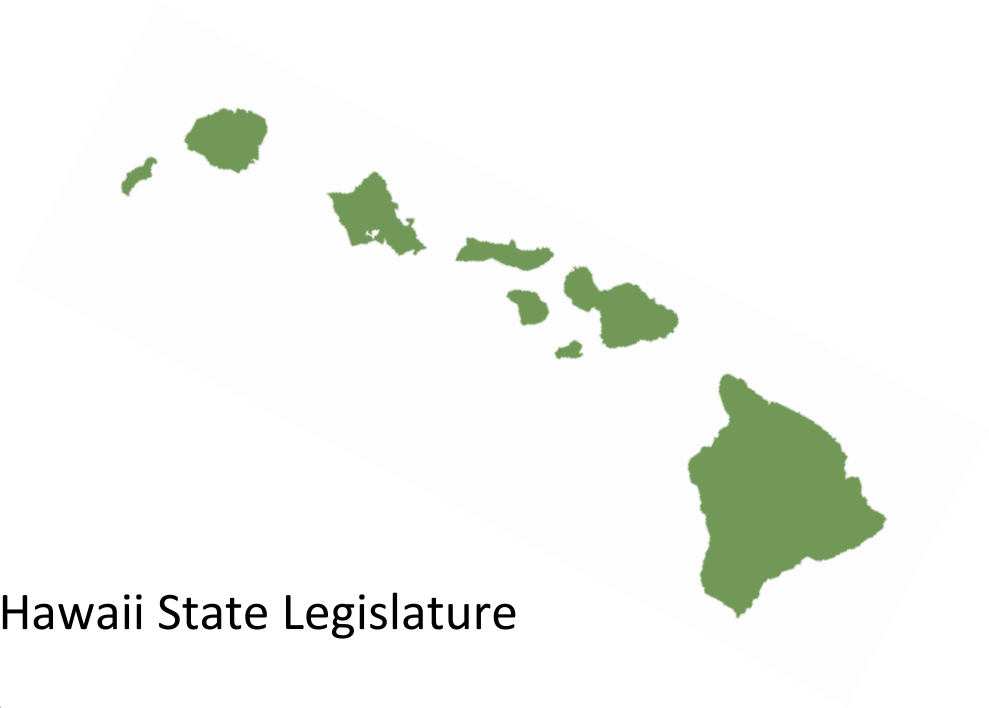
Hawaii + Hydrogen

Implementation Working Group

(H2IWG)



2015 Report to the Hawaii State Legislature

November 30, 2015

REPORT TO THE LEGISLATURE

FROM

Hawaii Hydrogen Implementation Working Group

(H2IWG)

30 November 2015

Working Group:

Mr. Mitch Ewan, Hawaii Natural Energy Institute, UH Manoa

Mr. David Rolf, Hawaii Auto Dealers Association

Mr. Rene Andre DeRosa, Lamplighter Energy

Mr. Dave Rodriguez, State Department of Transportation

Mr. Paul Ponthieux, Blue Planet Research

Coordinator:

Mr. Stan Osserman

Director, Hawaii Center for Advanced Transportation Technologies,
High tech Development Corp., Hawaii Department of Business, Economic Development and Tourism

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I. Background

I -1 This section is designed to give a concise historical perspective of Hawaii's efforts to develop hydrogen technologies as part of the effort to meet the goals of the Hawaii Clean Energy Initiative (HCEI).

I-2 The Hawaii Renewable Hydrogen Program ("Program") was initiated in 2006, 2 years before HCEI, to focus on one over-riding strategic objective - reducing Hawaii's dependence on imported fossil fuels by using hydrogen to increase the utilization of Hawaii's renewable energy sources. The Program is embodied in Hawaii Revised Statute §196-10 and directed the Department of Business, Economic Development, and Tourism ("DBEDT") to manage the State's transition to a renewable hydrogen economy. The Program is required by statute to design, implement, and administer activities that include:

(1) Strategic partnerships for the research, development, testing, and deployment of renewable hydrogen technologies;
(2) Engineering and economic evaluations of Hawaii's potential for renewable hydrogen use and near-term project opportunities for the State's renewable energy resources;
(3) Electric grid reliability and security projects that will enable the integration of a substantial increase of electricity from renewable energy resources on the island of Hawaii;
(4) Hydrogen demonstration projects, including infrastructure for the production, storage, and refueling of hydrogen vehicles;
(5) A statewide hydrogen economy public education and outreach plan focusing on the island of Hawaii, to be developed in coordination with Hawaii's public education institutions;
(6) Promotion of Hawaii's renewable hydrogen resources to potential partners and investors;
(7) Plans to more fully deploy hydrogen technologies and infrastructure capable of supporting the island of Hawaii's energy needs, including:
    (A) Expanded installation of hydrogen production facilities;
    (B) Development of integrated energy systems, including hydrogen vehicles;
    (C) Construction of additional hydrogen refueling stations; and
    (D) Promotion of building design and construction that fully incorporates clean energy assets, including reliance on hydrogen-fueled energy generation;
(8) A plan to transition the island of Hawaii to a hydrogen-fueled economy and to extend the application of the plan throughout the State; and
(9) Evaluation of policy recommendations to:
    (A) Encourage the adoption of hydrogen-fueled vehicles;
    (B) Continually fund the hydrogen investment capital special fund; and
    (C) Support investment in hydrogen infrastructure, including production, storage, and dispensing facilities.

I-3 The plans developed under the Program proposed the legislature establish an Implementation Authority (IA) resident in the State Energy Office and tasked with implementing the necessary actions required to develop a hydrogen economy in Hawaii. The IA would be led by a full time senior manager who would be designated the State Hydrogen Economy Implementation Authority. The Implementation Authority would have an administrative staff for support. The office would be funded by the legislature for a minimum of ten years so that it has the ability to conduct long-term implementation tasks without the uncertainty of losing its funding. There would also be established three additional entities that would provide policies and action plans to the IA for presentation to the legislature. The structure illustrated in Figure 1 provides the input of all stakeholders in developing the plan, implementing it, providing feedback, and making suggestions for changes. The IA would be supported by a Senior Review Committee comprised of senior state government officials representing the various stakeholder agencies that need to be consulted in the implementation process.

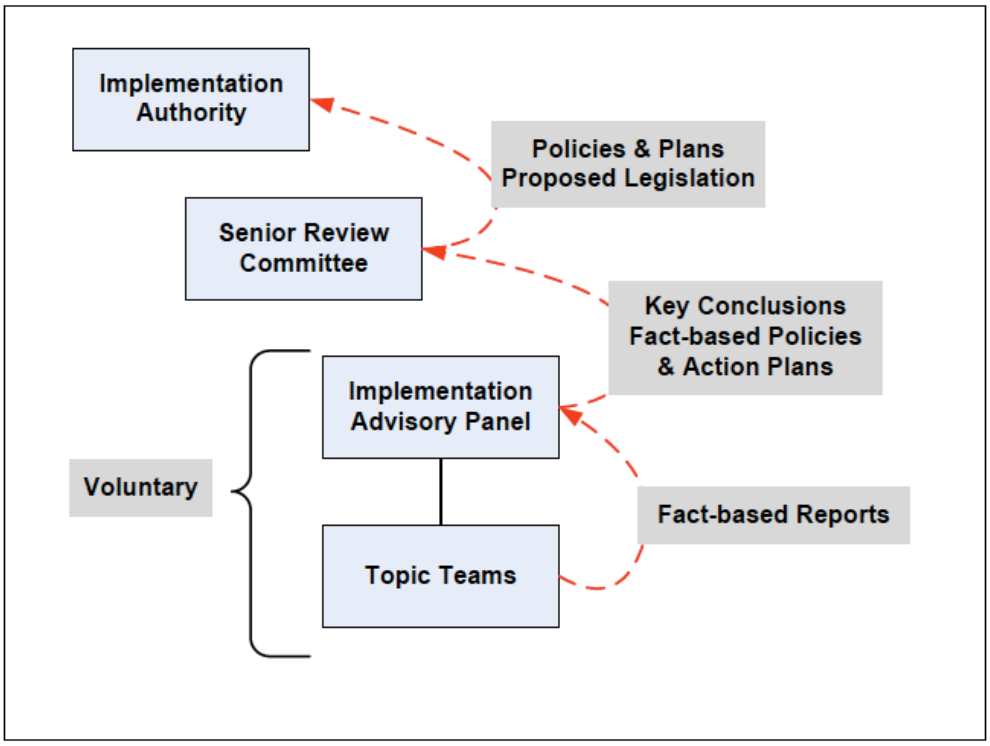


Figure 1: Implementation Organization

Implementation Advisory Panel

I-4 The plan also called for the establishment of an Implementation Advisory Panel, reporting to the Senior Review Committee, comprised of representatives from 1) industry, 2) state agencies, 3) federal agencies, 4) local government agencies, 5) academia, and 6) public advocacy groups. The Advisory Panel would establish Topic Teams to investigate 1) rollout

strategies; 2) the economy; 3) implementation teams; 4) public education; 5) societal benefits; and 6) budgets.

I-5 After the establishment of the Hawaii Clean Energy Initiative in 2008 and in line with Federal efforts to reduce greenhouse gas emissions in transportation, Hawaii embarked on an ambitious effort to promote electric vehicles (EVs). Much of that effort was supported by federal funding through the High Tech Development Corporation ("HTDC"), and its subordinate program, The Hawaii Center for Advanced Transportation Technologies ("HCATT"). HTDC is part of DBEDT.

It is noted that although the Hawaii Renewable Hydrogen Program had the potential to be a significant contributor in meeting the HCEI electricity generation and delivery, transportation, and fuels goals, hydrogen was not represented in the HCEI structure.

"Barrel Tax":

I-6 The Environmental Response, Energy, and Food Security Tax [HRS§ 243-3.5], commonly referred to as the "Barrel Tax", places a $1.05 tax on each barrel of petroleum product sold for non-aviation purposes. Twenty five cents per barrel of the tax revenues are placed into two funds which could be resources for hydrogen-related energy security and energy development programs: Fifteen cents of the tax on each barrel shall be deposited into the energy security special fund established under section 201-12.8; and 10 cents of the tax on each barrel shall be deposited into the energy systems development special fund established under section HRS§ 04A-2169.

I-7 Much of the funding has historically been directed to the General Fund to help with the state's economic recovery. Today, roughly 65% of the "Barrel Tax" (~ $19 million) revenues still go into the state's General Fund.

Electric Vehicles

I-8 The first alternative fueled vehicles introduced in Hawaii were plug-in electric vehicles of varying sizes. Larger vehicles were converted from diesel to battery electric and eventually passenger car manufacturers began to market EVs to the public. Some 311 plug-in electric vehicles were registered in 2011, the first year of broad public uptake of the vehicles, which were predominantly 4-door sedans, purchased or leased for personal use. In that year, a $4,500 State Rebate program, funded through federal TARP funding, encouraged early adopters. A federal tax credit of up to $7,500 was also available. Today, even without a continuation of the initial rebate offered as a part of the first year's rollout, and with 5 model years of vehicles (2011, 2012, 2013, 2014 and 2015) now on the roadways, EV adoption in Hawaii is more than double the rate of customer uptake of that on the mainland, with total numbers of EVs approaching 4,000 vehicles. The 4,000 uptake mark for EVs is 1/250th of the total approximately 1 million vehicle personal vehicle market in Hawaii but is significant because of the "Rule of 250."

I-9 This marketing axiom holds that a satisfied user of a new product, experiencing a positive product experience will tell 250 others, and with continuing favorable market conditions, increased uptake often follows that point.

I-10 As the plug-in EVs started to gain popularity, the responsibility for coordinating the further adoption of the EV market moved to the State Energy Office (also under DBEDT), and HCATT began exploring hydrogen vehicles by the military. These included fuel cell electric vehicles (FCEVs) and various forms of hybrid vehicles. In 2008, the federal Department of Energy had de-emphasized hydrogen transportation technology, and as a result, federal funding of hydrogen technologies diminished, and the focus at the state level turned to plug-in and hybrid electric vehicles being brought to market by the auto manufacturers. **I-11** HCATT remained focused on the hydrogen related programs as the DoD continued to explore hydrogen technologies in Hawaii across all military components (Army, Navy, Air Force and Marine Corps). Hawaii has an exceptionally good relationship with the U.S. Military, and has long been recognized by the federal government as the logical place to test renewable energy programs due to our abundant and varied renewable energy sources and also our high energy costs. It was often said, regarding Hawaii's suitability as a renewable energy test bed, *"If it can't work in Hawaii, it won't work anyplace in the U.S."*

I-12 Hawaii, for hydrogen fuel cell electric vehicle uptake, provides a so-called "Goldilocks environment" with our islands' favorable ambient air temperatures which help maximize battery operation, our relatively high petroleum prices compared to mainland markets, and our widely-accepted public policy initiative relating to the adoption of renewable fuels in order to reduce petroleum use in vehicles (the transportation component of the HCEI).

I-13 While hydrogen fuel cell electric vehicles, used for transportation—both public and private—will comprise the greatest segment of hydrogen's use, other uses for this clean energy will appear early on, as the hydrogen economy begins to emerge.

Formation of the Hawaii Hydrogen Implementation Working Group (H2IWG)

I-14 The HIWG was established as a result of Act 98 of the Hawaii State Legislature, signed into law on June 8th, 2015. The objective of the H2IWG is to study and examine methods to promote the expansion of hydrogen-based energy in Hawaii. The Hydrogen Implementation Coordinator (HIC) established the H2IWG by establishing a steering committee (which met on June 19, 2015) to help organize the effort. Formal selection of the Working Group members was delayed until consultation with the State Attorney General's office was complete and members were formally named on September 23rd, 2015. Originally the State Energy Office and US Dept. of Energy were invited to be formal working group members, however, after discussion with

those agencies and the State AG's Office, it was determined that those organizations would be restricted in their participation for a variety of reasons, so all participants agreed to exclude those two organizations as "formal members" but invite them to all meetings.

II. Executive Summary

II-1 This report has been drafted to meet the requirement of Act 98 and represents a collaborative effort by the varied stakeholders in Hawaii that have a role in implementing hydrogen infrastructure for Hawaii.

II-2 This report is formatted to make recommendations to stakeholders from the federal government to the private sector, and includes a concise "primer" for those not familiar with hydrogen fuel cell technology. Those recommendations are listed in the second to the last section of this report. In addition, accessing our Working Group web site at www.h2iwg.com will provide additional information and reference materials, plans and reports used by the working group, or referred to in this document.

II-3 No State funds were expended to produce this report, however facilities at the Foreign Trade Zone #9 were used for public meetings and a negligible amount of administrative time and supplies were consumed, primarily from HCATT.

Meetings and Outcomes

II-4 A public meeting was held at Foreign Trade Zone #9 on June 22nd to solicit public opinion. The outcome focused the Working Group's efforts on "Demand Driven" efforts to grow H2 infrastructure and initially identified 18 focus areas. Those efforts were narrowed down to:

1. Shuttle Buses,
2. Rental Vehicles,
3. Aviation Support Equipment,
4. Delivery Trucks,
5. Portable Power - including farm and film industries,
6. Disaster Response,
7. Backup Power and
8. Material Handling.

II-5 Many of these take advantage of "Commercial Off-the-Shelf" (COTS) technology, already in production, which reduces the delivery time and improves the supportability of new hydrogen powered equipment, which should help accelerate Hawaii's hydrogen demand.

Findings

II-6 The Nexus Transportation and Grid Energy Systems

It is crucial to recognize that transportation is no longer autonomous from discussions of grid power. As the world moves towards clean and renewable energy, discussions about "energy" in general must encompass grid power, gas pipelines, transportation energy, energy storage and a variety of new energy generation technologies. All players in the renewable energy discussion need to relook at the changing dynamics impacting all things "energy" in Hawaii. Policy makers and public utilities in particular, need to open their apertures, and explore energy in an entirely new way.

II-7 As Hawaii shifts away from fossil fuels we need to look at the varied applications for new technologies. It is imperative that we recognize the necessity of integrated systems, both in terms of energy as well as programmatic level efforts. For example, efforts toward hydrogen infrastructure development can simultaneously benefit the development of a new private sector energy industry more directly, a stable, resilient and reliable energy system will not be completely dependent upon one energy source. A self-contained, clean and resilient energy system can be anchored in the capacity that hydrogen storage provides.

Leverage

II-8 In application, there are many ways of producing hydrogen, and hydrogen as energy storage in a system precipitates a wide range of benefits and crosslinking markets and systems not traditionally associated (like grid stabilization and transportation for example). Producing hydrogen using electrolysis (the cleanest, but least cost effective means of production) could allow us to reduce/stop importation of things like medical grade oxygen, liquid oxygen, welding oxygen, fertilizers and other agricultural chemicals and CO2 for local consumption in manufacturing and the food and beverage industry. Taking into account the "by-products" of making hydrogen from different types of water (salt water vice fresh water for example) produce additional gases or compounds that have a market application for the production of things like fertilizer, that further reduces the need to import those commodities to Hawaii.

Outreach & Education

II-9 The importance of public outreach and education **cannot be overstated**. Changes in energy generation will affect individual energy use in all industries and business, and the public at large. **In order to make important decisions that face us today, policymakers and community need to understand the fundamentals of this technology. We cannot afford to be bogged down by systems, policies, or public opinion based on mis-information or a lack of understanding.** Public outreach and education is necessary to keep all stakeholders informed, and to encourage relevant dialogue amongst the individuals elected to represent the public interest. As new technologies and ideas are introduced, it will become increasingly

important to dispel myths at their inception - *successful integration will depend on it*. Energy demand will vary as residents and businesses begin to reevaluate their energy use, looking not only at the amount, but the time of use and how self-generated power impacts grid-supported demand.

III. A Technical Primer on Hydrogen (Hydrogen 101)

III-1 Facts About Hydrogen

- The word hydrogen is of Greek origins meaning, "water maker".
- Hydrogen is the most common element in the universe (not just on Earth, in the Universe).
- Hydrogen is number one on the periodic chart of elements.
- Hydrogen can be liquefied, but you need to drop the temperature to -240 degrees C.
- Hydrogen is 14 times lighter than air.
- Hydrogen is typically bonded to other elements forming compounds (like water) and is rarely found in its elemental form. Therefore hydrogen must be separated from compounds to release the hydrogen atoms. The "hydro-carbon" fuels we burn contain significant amounts of hydrogen.
- When hydrogen is released from a storage tank it moves vertically at 45 miles an hour, eventually combining with oxygen in the air to form clouds.
- Hydrogen is flammable when mixed with air between 4% and 74% by volume, however, in practice, hydrogen is very hard to ignite because it moves so quickly through the air without mixing, and that makes it difficult to attain a flammable mixture under normal circumstances. Hydrogen stored onboard vehicles in modern tanks cannot burn because the hydrogen is pure, and until it escapes into the air cannot be ignited.
- When hydrogen burns, it has a light blue color which is difficult to see in daylight, and hydrogen also radiates very little heat due to the lack of carbon. So if you have a hydrogen flame you can put your hand right next to the flame and hold it there for a long time because very little heat move sideways and all of the heat goes directly up. If you hold your hand several feet above the flame you'll feel the moisture in the heat.
- Over 400 firefighters in the state of Hawaii (Federal and Counties) have been trained to deal with hydrogen motor vehicle accidents. After this training, firefighters often find themselves more comfortable dealing with hydrogen after an accident than dealing with a gasoline mishap. The reason for this is that when hydrogen escapes from the tank it's very loud (so even if you cannot see a flame, you know there's a hydrogen leak), and the gas moves away and upward quickly. It's also very hard to ignite so if you just let the tank empty you have nothing to deal with, and there is nothing to clean up afterwards. If there is a fire, the fire is very directional, and will act like torch. So as long as there is

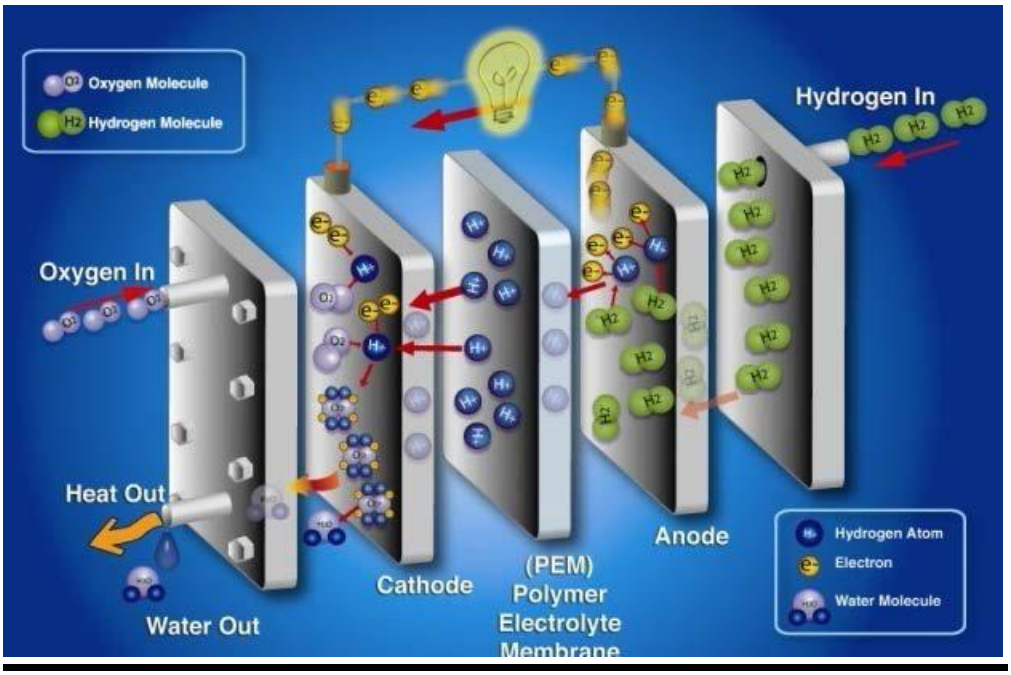
nothing in the path of that torch, the fire department would just let the fire burn until all hydrogen is consumed and then cool down any hotspots. So the main job of firefighters is generally to keep anything in the path of the burning hydrogen cool enough not to catch fire.

III-2 A Typical Transportation Hydrogen Storage Tank

5kg/5000psi truck tank with "roll cage" *5kg tank plumbed to simulate a vehicle.*

- Storage tanks used in the transportation sector today are highly specialized vessels designed to contain hydrogen gas up to 10,000 psi (700 bar), with a substantial safety margin, and many built-in safety features.
- Motor vehicle hydrogen storage tanks are double-walled with the interior wall approximately 3/8 inch thick aluminum alloy wrapped by approximately 5/8 of an inch carbon fiber and epoxy. This double layered system provides exceptional strength, but more importantly keeps the tank from rupturing in a catastrophic way. The valves on the tank are designed to shut down if they sense a vehicle impact. They are also designed to open up if they sense a temperature indicating a fire. The temperature sensing function is designed to release the hydrogen before the overpressure inside the tank gets to a dangerous level (which could cause a serious failure, probably at the valve seam, so releasing the hydrogen and letting it burn controllably is the better option).
- Manufacture of these tanks is highly regulated, and the testing of designs is very mature. Hydrogen storage tanks have been subjected to extreme heat, subject to impact and even perforation by a 50 caliber high powered rifle while fully pressurized. They are designed for many decades of use, making the tanks not only safe, but also very low maintenance and cost-effective.

III-3 How a Hydrogen Fuel Cell Works



Graphic courtesy of the U.S. Department of Energy.

- A hydrogen fuel cell is a lot like a battery, except that instead of having to stop and charge the fuel-cell with energy using electricity, the fuel-cell mixes hydrogen and air to create energy in the form of a DC electric current.
- The fuel-cell is made up of many alternating layers. Just like in a battery there are positive layers (cathode) and negative layers (anode) separated by a special layer the Polymer Electrolyte Membrane (PEM). Hydrogen is introduced on one side where it tries to migrate across the special PEM layer, but to do so, it needs to give up its electrons to the metal anode plate. Those electrons travel through wires to the second metal plate creating an electrical circuit. Once the electron stripped hydrogen passes through the special PEM layer they are met on the cathode plate with oxygen and the returning electrons creating water (H2O). In essence, hydrogen is mixed with oxygen from the air to make water, and this reaction yealds three things; electricity, heat, and water.
- Electric motors using fuel cells in vehicles are roughly twice as efficient as vehicles with internal combustion engines, therefore, although 1 gallon of gasoline contains about the same energy as 1 kg of hydrogen, a fuel-cell vehicle will travel roughly twice the distance that a traditional gasoline powered vehicle would travel using the same amount of energy.
- People often argue that batteries are more efficient than hydrogen fuel cells in terms of power in-to power out. However this is only one comparison point that needs to be considered between these two modes of storing energy. For example many people assume that a fuel-cell, because it produces water, will not work in a very cold climate.

However, if you take a frozen fuel-cell and push hydrogen and air into it, it will start working and generating electricity. Initially the fuel-cell will not be very efficient at a cold temperature, but because it is generating heat as it makes the water, it heats itself up and becomes more efficient the warmer it gets. Because fuel cells operate between about 150-200°F, a fuel-cell will reach peak efficiency relatively quickly. In contrast, if you have a battery in an extremely cold temperature its power output is extremely diminished (directly correlating to the negative temperature) and the battery will not become more efficient as you drain out whatever power it has.

- Batteries are also costly to make and replace, and they virtually begin to lose efficiency as soon as they go into service. So depending on the kind of battery, they need to be replaced every 5 to 10 years, and the components are not easily recyclable. Batteries are also large and heavy.
- Many battery-powered passenger vehicles can travel approximately 100 miles on a fully charged system, but to increase the mileage to the nearly 300 miles before re-charging, it would require more batteries than a passenger vehicle could carry and still have room for people and cargo like most cars today. If you take that same discussion to large trucks, the power required in large trucks is so much greater, and to give a large truck a range of more than 30 or 40 miles it would require more batteries than the axles could legally carry on the road. That's why you may hear of battery-powered cars but you rarely hear of battery-powered heavy trucks.
- Similarly, when we discuss vehicle range, or operating time, it must be pointed out that batteries either need to be charged (which could take several hours) or the need to be changed (swapping batteries means you have to have extra batteries for each vehicle). Hydrogen storage, however, can allow a typical passenger vehicle to attain over 300 miles of range per fill-up by simply connecting to a dispensing station for approximately five minutes. For equipment or vehicles that need to stay in operation more or less continuously, fuel cells meet that requirement and batteries cannot. Continuous operations utilizing only battery power storage requires maintaining an extra set of batteries or necessitate schedule in an appreciable amount of "downtime". The reduced weight of fuel cell systems also increase efficiency and decrease road, brake, and tire wear.
- Hydrogen fuel cell technology is almost **TWO** centuries old (fuel cell technology was invented in 1838), and even though the biggest impediment to fuel cells has been their high cost, modern manufacturing technology and science have reduced the cost, the weight, and the size of fuel cells to the point where they are now very practical for converting hydrogen gas and air into electricity, and can be easily scaled to meet a wide range of power generation requirements.

IV. Role of Government

Federal –

Congressional Delegation

IV-1 Hawaii's Congressional Delegation (CODEL) is critical to securing valuable resources to help Hawaii initiate the growth of hydrogen infrastructure. Our CODEL has expressed great interest in helping Hawaii in its efforts to reach our state's clean energy goals. Leadership in all stakeholder sectors needs to help keep our CODEL informed of progress in our efforts. In doing so the CODEL will be better equipped to address policy and other concerns that can impact the time that it takes our state in its efforts to grow our hydrogen infrastructure.

Grants

IV-2 Grants are valuable tools that can be leveraged to help new technologies and new companies grow to a stage where they can compete in the market place. Government funding should not be looked at as a long term solution, but grants are critical in early stages of adoption. Grants help make new technology competitive until the market fully develops. Hawaii should take advantage of federal funding when the need arises to stimulate private sector growth-to-market.

Equipment from Dept. of Energy projects

IV-3 The Hydrogen Implementation Coordinator (HIC) and the State Energy Office need to keep close contact with the US Department of Energy (US DOE) in order to take advantage of grants and the acquisition of equipment that has been used in research and development projects elsewhere that could be made available for Hawaii at little or no cost. For example HCATT is acquiring two four-wheel-drive hydrogen fuel cell vehicles for use on joint base Pearl Harbor-Hickam and Kaneohe Marine Corps base. We are currently looking into acquiring a tri-generation digester system that produces hydrogen which could be employed in several state projects as part of our effort to expand hydrogen infrastructure in Hawaii.

National Lab Studies

IV-4 The national labs are a valuable resource available to the state for conducting research on specific topics of interest to the state. National labs are also able to fund research with companies in Hawaii seeking to develop renewable energy technologies and manufacturing. In 2013 the National Renewable Energy Lab, (NREL), provided support to HCATT, HNEI, and US DOE for the development of a hydrogen infrastructure plan for Hawaii's transportation sector. In 2014 the Idaho National Laboratory prepared a study that produced the business case for hydrogen

production on federal property using a mix of photovoltaic power and grid power to produce, compress, store and dispense hydrogen to federal fleet vehicles leased from the Government Services Administration (GSA). This study evaluated the possibility of producing hydrogen at a price comparable to that of gasoline in Hawaii. Key to this study was the inclusion of unrelated revenue producing activities to offset capital and other costs. In this case rather than putting photovoltaic systems in a ground array an additional investment was made to elevate the photovoltaics onto a hurricane proof covered parking structure. Using only 75% of occupancy, and $12 a day rental fee the price for hydrogen was calculated between $10 and $12 per kilogram. At that time gasoline prices in Hawaii were in the high four dollar to low five dollar per gallon range. Since that study came out several private-sector investors have taken a harder look at the practicality of investing in hydrogen infrastructure. In 2015, NREL produced a study showing multiple pathways for Hawaii to produce 800 kg of hydrogen per day, and it also provided positive data for investors to consider private undertaking to build hydrogen infrastructure in Hawaii.

Military Collaboration

IV-5 Currently, the United States Navy, specifically the Office of Naval Research ("ONR") invests heavily on research and development in Hawaii. Much of this investment is directed to the Hawaii Natural Energy Institute (HNEI) as well as the not-for-profit Energy Excelerator. In addition, the United States Air Force signed a $20 million cooperative agreement with HCATT. The US Department of Energy and the US Department of Defense lead many federal departments investing in renewable energy research in Hawaii due to the many available renewable energy sources, the cultural respect in Hawaii for clean environment, and the high cost of electricity, produced primarily from fossil fuel. Hawaii needs to continue to attract investment dollars for research, development and demonstration projects in renewable energy fields. In addition, the military enjoys strong community support in Hawaii and has a tradition of reciprocating by supporting state initiatives in clean and renewable energy deployment.

"Relief from "Non-Attainment" status

IV-6 One area that Hawaii does not compete well for federal funding is in the transportation sector. Most federal programs place a priority on helping cities in non-attainment areas. Hawaii is **not** in a non-attainment area and as a result is **not eligible** for many of these funds. Several stakeholders in the state have petitioned the Congressional delegation over the past two years to have language amended in the laws and policies that contribute to Hawaii's exclusion from these programs. Hawaii has displayed an impressive record of efforts to move away from the use of fossil fuels, to include the high per capita participation rate of Hawaii citizens towards attaining low pollution and greenhouse gas levels. Rather than being excluded from competing for federal transportation funding, Hawaii should be assisted in trying to overcome the high cost of fossil fuel. These and other efforts evidence accomplishments for which we should be given credit and support rather than penalized via exclusion for federal funds.

CODEL add to the Congressional Record a proclamation recognizing Spark Matsunaga's contributions in promoting H2 technology

IV-7 Finally, one of the actions the congressional delegation could undertake that requires very little investment of time or funds would be to recognize the efforts of Senator Spark Matsunaga in the Congressional Record. Sen. Matsunaga was a pioneer in promoting research in hydrogen technology as a way to reduce our nation's dependence on fossil fuel. Similarly Hawaii has been the initiator or originator of so many great initiatives in the world today, and it's important to recognize and remember these efforts particularly as we look backwards in history to seek the origins of great changes for good in our world.

State –

The Governor's Office/ State Legislature

IV-8 Enlist support of Mayors to standardize H2 efforts across all sectors/codes and standards. One of the most critical elements needed to propagate hydrogen infrastructure in the state of Hawaii is a public statement by state and county leadership that collectively they are committed to meeting the state's clean energy goals, and that a hydrogen infrastructure is important to meeting those goals. The commitment by leadership in setting the example costs virtually nothing from the general fund, but is priceless and motivating an already conscientious public.

Support hydrogen energy storage as a synergistic solution of grid stabilization problems and clean transportation goals

IV-9 It is also important for state leadership to understand that the playing field has changed. No longer can we look at energy as strictly gasoline or power grid, we have to look at energy in a whole new way. Transportation energy and public utilities (be they electric or gas) will be interlinked in ways that most people have never thought of, but need to grow in appreciation for. Initially, plug-in electric vehicles were looked at as receivers of electric power but in the modern and sophisticated energy society, plug-in vehicles can also be mobile energy storage. Likewise, hydrogen fuel cell vehicles can also function as an energy storage option, an energy transporter, a portable generator, and as other integral parts of a home system based completely on renewable energy and energy storage. Rural communities are sometimes better serviced by being off the grid and utility companies need to adjust their business model to include providing services to households, farms, and businesses that, logic dictates, are better off providing their own renewable power on-site rather than stringing utility wires or running gas pipelines many yards or miles.

Support interdepartmental efforts to use H2 in clean energy programs

IV-10 Across the state, departments are trying to meet Hawaii Clean Energy Initiative goals, but they are stifled by systems that hinder purchase of, installation, and operation of new clean technologies. The executive branch needs to make it clear to its cabinet members that working together to bring about change is critical if Hawaii intends to meet its clean energy goals. State departments cannot be at odds with each other or, for that matter with County government offices, when it comes to adopting clean energy technologies, including hydrogen.

Direct departments to convert to H2 material handling and transportation when able

IV-11 In the commercial sector across the United States the material handling and logistics sector has proved to be a significant market for hydrogen solutions. Many companies who have around-the-clock operations, particularly warehousing operations and enclosed warehouses, are looking to hydrogen and battery power for their forklifts and powered pallet jacks. In certain cases, battery-powered material handling equipment is superior, particularly when operations have downtime where battery charging can be accomplished without interfering with operations. However, where around-the-clock operations are important to productivity, hydrogen systems have proven to be a superior platform because there is virtually no downtime with the equipment. Although state government has very few round-the-clock requirements for material handling, the functions that do, should be considered priority targets for conversion to hydrogen fuel cell material handling equipment, and the state should consider leading the way in showcasing this technology, so that the private sector can see an example of the advantages and will more readily make capital investment themselves.

Procure H2 power generation for back-up power of critical State functions

IV-12 Besides having a wide range of renewable energy sources available in our state, Hawaii is also vulnerable to a wide range of natural disasters. Once again, if the state government could consider some of the potential advantages of including hydrogen infrastructure as part of their public safety effort, the payback in lives saved, and rapid recovery could be substantial. For example, Hawaii's schools, which are also designated as emergency shelters, could be identified as candidates for early adoption of renewable energy, battery storage, long-term hydrogen storage, and neighborhood micro grid, or "islanded" power capability. Hydrogen production in that area could then be coupled with stationary hydrogen fuel cell power generation. Then, not only could the electric utility absorb more residential photovoltaic energy, but it could help communities recover quickly from a disaster by being able to generate their own power. The electricity needed at the emergency shelter, electricity needed to pump freshwater, and even flammable gas that can be used for cooking could be sourced from within the microgrid without any support from outside. This model could not only help lower energy costs but contribute to the resiliency of neighborhoods across our state.

Promote an H2 future at the Conservation Congress (Sept 2016)

IV-13 In September 2016 Hawaii will host the International Union for the Conservation of Nature (IUCN) World Conservation Congress-the world's largest conservation event. This event presents an once-in-a-lifetime opportunity to showcase the many years of effort Hawaii has put in to promote clean energy and clean transportation. Although there is very little time to actually make significant infrastructure changes by September 2016 we could make a concerted effort to use that event as a kickoff to show Hawaii and the United States as a leader in the effort to adopt clean energy and renewable energy technologies across all sectors of our society. The governor's office should put together a group to spearhead this effort, and hydrogen infrastructure should be one of the focal points of this clean energy initiative.

State should not compete with private sector (providing H2)

IV-14 Although some would argue that large investments by the state government are required to initiate dramatic change, such as building hydrogen infrastructure from scratch, it is becoming apparent that large companies, particularly automobile manufacturers have made a huge commitment. Other private-sector investors see that commitment and are willing to invest in complementary businesses that support these new technologies as well. The actual capital investment by the state need not be monumental, however streamlining state and county processes, and standardizing procedures and policies is critical to facilitating the development and growth of new infrastructure.

Initiate "Study Bills" deemed necessary to help the state move ahead intelligently

IV-15 From time to time, determining the proper course of action for our state regarding new technologies can be beyond the scope of Hawaii's organic research resources. The Legislature should be prepared to fund studies, or match federal funding of studies, to help resolve technical issues impeding sound decision making as we face renewable/clean energy challenges.

Consider H2 "fuel subsidy" to encourage private investment

IV-16 Although the working group appreciates that the majority of effort to bring about hydrogen infrastructure in Hawaii rests with the private sector, there is a role for state government in providing incentives at the onset. The early stages of market development and demand are of particular import. The working group did not identify specific incentives for this legislative session, although other stakeholders may initiate requests for legislation, and in the future we anticipate that the working group will identify specific initiatives to help incentivize hydrogen growth in Hawaii.

Update State H2 plan

IV-17 In 2012 HNEI drafted a hydrogen plan for the state of Hawaii focusing primarily on transportation and limited hydrogen production. The working group recommends that this plan

be updated, and that the calculations included in that plan be updated with current production and other costs.

Develop a solid Transportation education plan and field it (Improve the image of EV's and particularly FCEVs)

IV-18 The working group noted that there appears to be a nascent competition between plug-in electric vehicles and hydrogen fuel cell electric vehicles. It is unclear what drives this conflict, and how deeply it runs, but in certain quarters the conflict is significant enough to derail legislation and fuel heated debates. There are those who feel that battery technology is the key to clean transportation and those who feel that fuel-cell vehicles have a greater potential in reaching our goals and clean transportation. However, most of us who understand both technologies feel that there are applications better suited for both technologies, and in some cases plug-in electric vehicles make more sense and in other cases hydrogen fuel cell vehicles make more sense. What is clear as you observe the disagreements, is that both technologies are fighting for acceptance, infrastructure, and validation by the public. The reality is that both vehicles are electric vehicles, and both vehicles contain batteries, and the rules that apply to plug-in electric vehicles in most cases should also apply to hydrogen fuel cell electric vehicles. It is important to point out, however, that not all hydrogen powered vehicles are fuel-cell electric vehicles.

Investigate opportunities to use "bridging technologies" that may help hydrogen demand grow faster

IV-19 Recent advancements in converting internal combustion engines to run on hydrogen have eliminated many of the shortcomings that plagued earlier conversions to hydrogen internal combustion engines. The advantages to internal combustion hydrogen are: it is a quick and relatively inexpensive conversion and the hydrogen required does not have to be as refined and pure as the hydrogen required for a fuel-cell electric vehicle. The disadvantages include trying to locate places onboard passenger vehicles to accommodate high-pressure hydrogen storage tanks, because these tanks are limited to cylindrical shapes or spheres and generally require 25 or more percent space than gasoline tanks installed at the factory. Additionally internal combustion engines are only about half as efficient as fuel-cell electric vehicles, so although they may spur hydrogen infrastructure, they will most likely be replaced by fuel-cell technology in the long-term.

Look at expanding projects at National Parks (Pearl Harbor, Punchbowl Hale Akala etc.)

IV-20 The federal government has undertaken many initiatives to reduce greenhouse gas emissions, and has instituted many policies and executive orders directing federal agencies to reduce fossil fuel consumption and seek opportunities to use renewable energy resources wherever practicable. Hawaii should leverage these policies and directives and aggressively work with all federal agencies operating in Hawaii in these efforts. Many of these agencies have set aside funding specifically to expedite clean energy initiatives, and Hawaii should capitalize

on the federal resources available in these efforts. Specifically HNEI is working with Volcano National Park, on the Big Island, to build and operate two hydrogen fuel cell shuttle buses that will move visitors between the Visitor's Center and the Thurston Lava Tube. This project includes specialized sensors and scrubbers built into the buses to keep contaminants common in volcanic gas from damaging the fuel cells. But there are several other major national parks in Hawaii visited frequently by tourists. Hydrogen fuel cell technology could be showcased and not only help the National Park Service meet its clean energy goals but also encourage the visiting public to experience these new technologies firsthand, and adopt them in their own hometowns. Examples would be; off - grid park headquarters at 10,000 feet atop Hale Akala on Maui, and a hydrogen fuel cell electric barge service to shuttle tourists to the Arizona memorial in Pearl Harbor.

Re-brand hydrogen as "H2" and market it

IV-21 One of the key hurdles of hydrogen technology is the widespread misunderstanding of the technology itself and the misinformation that has been spread over many decades to quell any competition for fossil fuels and related technologies. Powerful lobbying efforts have used negative campaigns in an effort to sway public opinion in favor of their products/industry. This is not a judgement of their motives, but more a fact of life over the past century and a half, as the industrial age rapidly changed the workplace and marketplace, world-wide. Unfortunately some of those practices are still employed and other linger long after their purpose was fulfilled. Hawaii's people and industry professionals need to be provided clear and factual data to help them decide on a way ahead, particularly as our need for energy grows and the shift to renewables changes the way we produce, store and use Hawaii's natural energy resources. These energy demands will necessitate systems integration which will require dissemination of the most accurate data possible to ensure reliable outcomes.

IV-22 Although some may dismiss the claims of misinformation, it is a well-known part of the marketing process. As Hawaii develops a public awareness campaign to counter the misinformation and to raise awareness of hydrogen technology, it may be important to "rebrand" hydrogen. One suggestion was to call it "H2" rather than hydrogen. At any rate, professionals should be consulted as we develop a strategic communications plan for hydrogen implementation.

Introduce an awareness program into schools as part of STEM & Robotics programs

IV-23 As part of the strategic implementation or communications plan, inclusion of hydrogen awareness curriculum through all grades of our education system is needed. One of the critical points to insert hydrogen awareness and education would be in the STEM program, and a natural partnership between school robotics programs and hydrogen fuel cell electric systems seems to be a synergistic choice.

State and Local government support and active leadership is critical

IV-24 Although support for hydrogen infrastructure must take hold of the private sector, the state should also consider building a H2 demonstration station to support state owned and operated fleets. The state may choose to simply purchase hydrogen from commercial sources, but the state should not overlook opportunities that renewable energy and hydrogen energy storage offer in terms of cost savings and resiliency after a disaster. Careful consideration must be given to the fact that government should not compete with the private sector as a matter of principle. Even if the stations that are built by the state are only operated for a few years and then turned over to the private sector (sold) or dismantled at a fixed point in time the process will require some forethought. Failure to thoroughly analyze the state's involvement in building hydrogen infrastructure for the long-term could harm implementation by creating unfair competition and killing the incentive of private investors.

IV-25 Hawaii has an unprecedented opportunity to make a global statement in September 2016 when Honolulu hosts the world conservation congress. Although standing up a complete hydrogen infrastructure by September 2016 is virtually impossible, rolling out an ambitious plan with bold objectives is very much within the realm of the possible. At the same time, highlighting Hawaii's advancements in research and development, demonstration of renewable energy initiatives and work in hydrogen fuel cells are realizable initiatives that can be showcased in September 2016. We must prepare to showcase Hawaii's progress towards HCEI goals at the World Conservation congress (Sept 2016) by establishing the first hydrogen dispensing station in support of public use by a non-ZEV state. Strategic planning at the executive level needs to begin immediately to take advantage of this once-in-a-lifetime opportunity.

IV-26 Several cabinet members have initiated efforts within their departments to implement hydrogen infrastructure and technology into their operations. Other departments are simply not aware of how they can benefit from these technologies, and therefore, they do not have any current plans. These departments are unlikely to reject well-established technologies that would save them funds, improve their operations, and are aligned with the states policies on clean energy. Below are some of the initiatives either currently being discussed in departments of the state of Hawaii, or should be considered by some departments for more development.

HIDOT – Rental Shuttle Project

IV-27 HCATT was approached by the director of the Hawaii Department of Transportation (HIDOT) requesting information on the feasibility of converting a diesel bus fleet to hydrogen fuel cell power at the Honolulu International Airport within five years. Under the proposed project, the HIDOT would like to convert eight large buses (40 foot) and eight, 25 passenger shuttle buses for of the rental car shuttle fleet. Currently each rental car company runs their own shuttles between the airport and their rental car locations. Plans call for a five-year contract to be led by the Hawaii Department of Transportation, Airport Division (DOTA) to consolidate the

shuttle fleet under one common bus system and a single private contractor. This contract will be funded from the customer facility charge (CFC) applied to vehicle rentals originating at the airport locations. As part of the five-year contract the state will be asking the contractor to allow conversion of some of the 40' buses up to two years before the end of the contract, and allow the State to purchase all the 40 foot buses at the end of the contract. In addition the DOTA is considering converting eight, 25 passenger shuttles to complement the 40 foot buses. The HIDOT has asked HCATT to assist in developing plan for hydrogen production from renewal energy on land near the airport currently control by the DOTA. HCATT is developing this plan and is also looking at other options to provide hydrogen for this fleet. Those options include purchase of hydrogen from a local supplier, transporting hydrogen from some other location producing hydrogen from renewable resources with enough capacity to have access hydrogen available to provide other department's transportation needs.

Fleet plans

IV-28 The State of Hawaii is currently organized with single centralized fleet operations through the Department of Accounting and General Services, Motor Pool Division. The State may want to consider transitioning to a model in the future with vehicles operated using renewable energy. As such an effort is undertaken the state Department of Accounting and General Services, Motor Pool Division is a logical place for that effort to reside.

Safety Check

IV-29 The Hawaii Administrative Rules Section 19-133.2 address the Periodic Motor Vehicle Inspection (PMVI) rules for neighborhood electric vehicles. Before attempting to develop rules relating to the inspection of hydrogen fuel cell and other alternative fuel vehicles, information is needed from the manufacturers that identifies items needed for maintenance, inspection and safety to name a few.

EMS Training

IV-30 The Hawaii Department of Health, State Emergency Medical Services and Injury Prevention Systems Branch (EMS) may be the more appropriate agency to train first responders statewide as noted by the National Highway Traffic Safety Administration, "EMS Agenda for the Future" the agenda makes clear that injury prevention is an essential activity for EMS because of EMS' unique role, which involves individual health care, public safety and public health.

NOTES

Reference: http://health.hawaii.gov/ems/home/state-ems-systems-mission/

Based on knowledge and training first responders to an accident or incident involving vehicles with alternative fuel systems is not role performed by HDOT and the Motor Vehicle Safety Office (MVSO)

Movement of H2 (Land/Sea/Air)

IV-31 As the department charged with oversight of Hawaii's ports, the HIDOT will need to be heavily involved in reviewing policies and procedures for handling, storing, and transporting all forms of hydrogen. Hawaii was fortunate this year to be involved with the United States Department of Energy and Sandia National Labs hydrogen fuel cell technology demonstration aboard Young Brothers barges. Specifically, a 20 foot International Standards Organization (ISO) container was modified to hold 75 kg of hydrogen at 5000 psi and also house a 100 kW fuel cell generator and all controlling equipment. This generator was used to power refrigerated containers both dockside, and onboard barges between the islands. This project presented great opportunities for the Honolulu Fire Department, United States Coast Guard, Hawaii Department of Transportation, Harbors Division (HAR), and many other stakeholders to study the impact of this new technology on their operations. It highlighted the critical role that the HIDOT plays when new technology is brought to bear in any transportation sector. The HIDOT has been engaged with the private sector as they invest in these new technologies for business operations and cost efficiencies, and will continue this engagement to stay ahead of these technologies as they appear in Hawaii.

Airport Ground Support Equipment at Honolulu IAP (HNL) and Kona IAP (KOA)

IV-32 Hawaii is fortunate that HCATT was selected over two decades ago to be the national demonstration center for alternative fuel vehicles, and currently is converting and fielding several hydrogen fuel cell electric vehicles at Joint Base Pearl Harbor Hickam, including aviation flight line support vehicles. DOTA has expressed interest in converting vehicles used in our State owned and operated airports to hydrogen fuel cell electric power, and points to the Kona International Airport and Honolulu International Airport as preferred locations to consider implementing fuel cell electric flight line vehicles. HCATT stands ready to support the DOTA in their efforts to field hydrogen fuel cell powered flight line vehicles.

Develop a Tube Trailer Fleet to support H2 Fleets State Wide

IV-33 Whether developed by the private sector or a state agency or department, most stakeholders agree that a fleet of tube trailers will be important during the early stages of hydrogen implementation. As a result the HIDOT, and its federal oversight partners such as the Federal Highways Administration, the United States Coast Guard, and the Federal Aviation Administration will need to address policy and procedural questions regarding hydrogen tube trailers and movement of those tube trailers on Hawaii's roadways, through Hawaii's ports, as well as in and around Hawaii's airports. Hazardous materials endorsement (H) is required for drivers of vehicles transporting hazardous materials requiring placards under subpart F of 49 CFR part 172.

Review Commercial Driver Licensing to include H2 specific training

IV-34 The HDOT should also work with the counties to determine if changes are required for driver's licensing in general, but specifically the certification of those holding commercial driver's licenses.

Pearl Harbor Ferry (Hydrogen? Hybrid Electric?)

IV-35 Considering the ever increasing volume of traffic between West Oahu and downtown serious consideration of improved public transportation should certainly be a priority. Previous efforts to use an oceangoing ferry between West Oahu and downtown were less than satisfactory, primarily due to the complications of operating a vessel in Hawaii's waters which can often be extremely rough and uncomfortable for passenger transport. However, a ferry operated in the sheltered waters of Pearl Harbor could overcome a majority of the shortcomings of previous ferry programs. Aside from remaining in sheltered waters, the transit would take 10 minutes rather than close to an hour, because the distance supported by the ferry is less than a mile round-trip. Working with the county mass transit, and pending approval by the United States Navy and Commander in Chief, Pacific Command, expressed buses could begin by originating in West Oahu, next drive counter flow to traffic, followed by rolling onto a hydrogen powered catamaran ferry near Iroquois point, then proceed directly to Ford Island or the pier just west of the wastewater treatment plant on Hickam, and finally proceeding directly to the freeways and downtown. The feasibility of this concept is solely tied to addressing National Security Concerns, though daunting may not be insurmountable. For example, to address security concerns, individuals disembarking or embarking on the military bases would require credentials approved by the military, all others would remain on the buses which could transit the bases along routes designated by the military. This could potentially remove several thousand cars from Honolulu's roadways for each commute, if allowed. Consider also putting a H2 fuel cell catamaran ferry in Pearl Harbor to move express buses across Ford Island and Joint Base Pearl Harbor, Hickam.

Partner with the Port of Long Beach

IV-36 The port of Long Beach is leading the maritime world in developing clean port operations, including the use of hydrogen technologies. DOTH should consider establishing communications with that port authority to gain insight into how Hawaii ports could adopt some of this cutting edge clean technology.

DBEDT –

Photovoltaic Roof on Foreign Trade Zone #9 with H2 Storage and Material Handling

IV-37 The director of the foreign trade zone is currently seeking proposals to install photovoltaic solar panels on 5 acres of rooftop at Pier Two, Foreign Trade Zone (FTZ) # 9. This amount of PV is more than enough to provide 100% of the daytime electrical power used by the FTZ. They are also considering installing electrolyzer equipment to convert excess electricity into hydrogen and oxygen, using the hydrogen to operate forklifts and other material handling equipment within the foreign trade zone, and potentially providing oxygen for state agencies that require it (including medical facilities, and others), and making excess hydrogen available to be trailered to other state locations to support state fleet vehicles.

HTDC Focus on H2 manufacturing Tech

IV-38 As hydrogen infrastructure grows in Hawaii, opportunity arises for new high-tech industries, and manufacturing to take root here. The High Tech Development Corporation (HTDC) should focus some of their efforts on seeking out these opportunities and encouraging entrepreneurs, inventors, and even existing businesses, to expand into these new markets.

Expand GEMS Infrastructure to include H2 infrastructure funding

IV-39 Currently, the Green Energy Market Securitization (GEMS) program is focused strictly on assisting not-for-profit and low income entities in procuring photovoltaic systems. However the program, as written, should be available to help expand hydrogen infrastructure as well. Consideration should be given to expand the program to support hydrogen infrastructure implementation.

Synchronize county efforts to adopt H2 technology across all sectors (HCATT)

IV-40 Develop a public messaging strategy towards meeting HCEI goals. Currently the Hawaii Clean Energy Initiative does not give clear metrics for transportation energy. Likewise certain metrics, that could be useful, do not seem to be collected, such as, number and type of battery electric vehicles sold/on the road, hybrid electric vehicles sold/on the road, vehicle miles travelled, or average fuel economy for cars sold each year. Making this data available and visible could help Hawaii zero in on establishing transportation goals (i.e., 14,000 EV/FCEVs by 2020) and monitoring progress in achieving them.

IV-41 Several options for developing hydrogen infrastructure in Hawaii include installing hydrogen stations on public land that can subsequently be leased or moved to private land in the future. Current studies by the US Department of Energy and NREL indicate that between three and six hydrogen stations are required on Oahu. HCATT can help develop H2 station requirements so DLNR can determine lands available for State owned Fleets.

H2 stations in October 2015

IV-42 The California fuel cell partnership published a guide to assist in the construction of hydrogen infrastructure, specifically fueling stations. Each of the county agencies have a role in permitting or certifying the construction of hydrogen dispensing stations or other hydrogen production equipment, storage and transportation should consider reviewing this document.

IV-43 DBEDT should develop an "Off the Grid" Model (PV, Battery, H2 production/storage, FCEV), and look for opportunities for the state to incorporate that model that could be adopted or adapted somewhere within the state system.

IV-44 DBEDT should develop a simple handout listing consumer comparisons for different fuels to aid is side-by-side consumer comparisons.

Other suggestions for DBEDT consideration

IV-45 Develop a H2 timeline for hydrogen implementation.

IV-46 Publish an alternative Fueling Station locator cell phone application.

IV-47 Produce a hydrogen video for community awareness.

IV-48 Consider hiring at least one permanent staff member to manage administrative duties related to the Hawaii Hydrogen Implementation Working Group.

IV-49 Develop financing advisors to help H2 infrastructure builders with financing and tax advice.

State Dept. of Education –

IV-50 The State DoE should develop curriculum for primary and secondary education in public schools that provides information on hydrogen technologies. They should also consider installation of PV on school roofs to reduce heating classrooms, produce electricity, including surplus electricity that could be placed into H2 storage. In addition, fuel cell power generation, and some battery storage could greatly reduce the school's dependence on commercial power and possibly take that school "off the grid". Ideally public schools that are also designated as emergency shelters should be considered for early adoption of this technology. This would

essentially make grid recovery a little bit simpler but also provide many communities with resilient infrastructure following a disaster.

IV-51 Develop school curriculum in H2 technology (All grades),

University of Hawaii –

IV-52 The UH should begin curriculum development for community colleges to support H2 system maintenance,

State Dept. of Ag. –

IV-53 State Department of Agriculture should work with the Federal Department of Agriculture (USDA) on sustainable agriculture to develop anH2 "off grid" model for Hawaii's typical 40 acre homesteads. Currently, Hawaii not only imports too much fossil fuel, but also food products, many of which should be produced here in Hawaii. The state Department of Agriculture should take the lead in developing some standard agricultural models that can help farmers and other small businesses related to agriculture, begin to operate independently from the Hawaiian Electric grid. Once developed, these models could be used across the Asia-Pacific region to help promote sustainable renewable energy systems, while simultaneously demonstrating an improved financial model for farmers.

IV-54 Currently, the State Department of Agriculture is responsible for certifying gasoline and diesel dispensers across the state, however, gaseous hydrogen dispensing is somewhat more complicated to dispense than liquid fuels. The state Department of Agriculture should work with NREL and NIST to adopt standard certification of H2 measurement at the pump.

IV-55 Hydrogen for transportation use can be made many different ways. Incorporating Gasifier-to-H2 [and power] technology, as we're doing a joint base Pearl Harbor Hickam, can also be employed to eliminate invasive species, like Albesia, and vegetation infested with rhinoceros beetles. This could provide revenue to support the eradication of invasive species, while at the same time helping Hawaii meet its clean transportation energy goals by providing hydrogen across a wide variety of communities.

IV-56 Different methods of producing hydrogen can also produce other useful compounds and elements. Some of the processes for producing hydrogen also produce ammonia that could be used to manufacture fertilizers and oxygen produced from electrolysis could be used to enhance farm-raised fish growth rates. The Hawaii Department of Agriculture should explore the different methods of producing hydrogen to determine if there are advantages to producing hydrogen in specific ways that can make available important agricultural products so Hawaii can avoid those import costs as well.

State Department of Defense and State Civil Defense –

IV-57 Because renewable energy is a domestically produced product that requires the ability to store that energy, adopting hydrogen as one of the principal storage methods for excess electricity provides an added layer of energy security and resiliency to Hawaii's population after disaster. Hydrogen cannot only be used in fuel cells to produce electricity, it can also be burned much like compressed natural gas or propane for direct cooking and heating use, and should be considered as a possible standard emergency power for disaster response facilities across the state.

Department of Commerce and Consumer Affairs –

IV-58 DCCA should begin to look at licensing requirements related to new careers in the technology and energy sectors, as well as update current licensing standards to include new technology and energy duties and requirements (i.e. look at how plumbing certification may need updating to cover very high pressure tubing materials and fabrication in the hydrogen industry).

Department of Health –

IV-59 Familiarize appropriate offices with hydrogen related properties, so they are ready to handle questions from the public regarding a new energy element in our communities.

Department of Labor and Industrial Relations –

IV-60 Update inspectors to be familiar with safety issues related to hydrogen systems so that appropriate Occupational Safety and Health standards can be maintained in the workplace.

The PUC

IV-61 The PUC needs to make a concerted effort to review current policies and consider changes that promote synergistic solutions across the regulated utility sectors. Due to the changes in technologies and relationships between traditional grid and gas utilities, their customers, and the transportation sector, the policies of the Public Utilities Commission should be reviewed to make sure that those policies do not unnecessarily stifle the adoption of more complex business models for all utilities and limit the role of hydrogen technologies as energy storage, dispatch-able power and clean transportation energy in Hawaii.

IV-62 Power/Grid Utility - The power utilities on all islands need to evaluate not only at their grid structure and how they could use new technologies to help balance the power on their grids, but also support hydrogen for transportation use. Public utilities also need to look at their business models, and include the design and regular servicing of off-grid communities and individuals as part of their normal operations. The modern power grid was designed to deliver power from one or more central sources to users. However, today, with the increasing quantity of

renewable power from solar, wind, and any number of other renewable sources, combined with scattered rural communities still connected to the grid, a huge problem has developed for the power utility. As we move towards more renewable energy resources on the grid (while operating the grid under the same rules and designs it was originally created), the current grid requires up to 30% more power generation than is generally needed for consumption at any given time, just to guarantee quality power to all customers under all conditions. When distributed generation technologies (including hydrogen storage and fuel cell power generation) are included in a dispatch-able power mode out closer to the demand, the requirement for spinning reserves, and the power lost in resistance during transmission over long distances is eliminated, resulting in more efficient operations, and cost avoidance for the power provider.

IV-63 Hawaii Gas - As Hawaii's public utility for gas products, Hawaii Gas could take the lead in making hydrogen available for the transportation sector. As a company designed to produce, store, and distribute (in their low and high pressure pipelines) a wide range of gas products, they are perfectly positioned to take the lead for hydrogen distribution as well. If the oil refineries in the state are closed, Hawaii Gas will lose its raw materials to manufacture SNG to fill its current market. This may drive them to not only use all of the locally produced methane from landfills and wastewater treatment facilities, but also necessitate import significant quantities of Liquid Natural Gas (LNG). The compressed Natural Gas (CNG) that Hawaii Gas would convert from LNG could also transport hydrogen to hydrogen dispensing stations equipped to reform CNG into pure hydrogen across the state. On site, these stations could purify and compress hydrogen at a very competitive price for dispensing into vehicles, farm equipment and water craft that operate on hydrogen fuel cell technology.

IV-64 Regulated transporters (cabs, truck fleets etc.) need to be encouraged to adopt hydrogen fuel cell technologies. This would include a regular review of policies set forth by the government which may inhibit the adoption of hydrogen fuel cell technology.

IV-65 As we researched the topic, it was unclear why curtailed power could not be sold to other businesses, particularly if the curtailed power was not transmitted on the grid. This appears to be a topic that needs further investigation, discussion and resolution, so we can use curtailed power to produce hydrogen for the transportation sector.

County

All Counties

IV-66 Plan on converting any sources of Methane to H2 (Biogas, Wastewater Treatment, Landfill, Food Waste, Agricultural Green-waste). Converting Waste Collection and other County

fleets (like material handling, Handy Van, Mass Transit) fleets to H2 could result in infrastructure to produce hydrogen that pays for itself by offsetting fuel prices for these fleets. Standardize all permitting for H2 Infrastructure using California fuel cell partnership guidelines. Streamlining the permitting process has been identified as a critical feature of hydrogen infrastructure implementation. Safety training and purchase of any specialized equipment for first responders (Fire/Police/Paramedics) and permitting officials is essential as the use of hydrogen for energy storage and transportation becomes more widespread in our state. Most of the state's first responder assets reside within the counties, thus the training and equipping of those responders should be anticipated, and funding made available by the counties to accomplish their training and equipping.

Oahu

IV-67 Emphasize H2 in mass transit fleets, synchronize county and State Civil Defense efforts towards H2,

Maui

IV-68 Look at curtailed wind power to produce and store transportation H2,

IV-69 Relook at Ag waste-to-energy with H2 for energy storage,

IV-70 Support Dept. of Ag. with research into developing a model for sustainable 40 acre H2 farms on Molokai, and encourage an all renewable power grid on Lanai.

Hawaii

IV-71 Expand UH Hilo Engineering Dept. to focus on renewable energy at the Natural Energy Laboratory, Hawaii (NELHA) and make NELHA a tech park for renewable energy study for the State,

IV-72 Build H2 infrastructure to support mass transit (including working with Army to create a self-sustaining off-grid" base infrastructure at Pohakuloa Training Area [PTA] to make one of the "Hele-On Bus" hydrogen refueling stops.) A gasification system located there with the proper mix of batteries and hydrogen storage and a stationary fuel cell could provide all electrical requirements at PTA, cooking gas, and fuel for forklifts and other equipment, while also assisting the County in eliminating invasive species (using the green waste as feedstock for the gasifier.

IV-73 Plan to develop mass production of H2 in Kona to support liquefied H2 production (from Geothermal or Ocean Thermal and others) to support mass storage and "export" of State energy needs, particularly to Oahu) and potentially export to Mainland and Asia.

IV-74 Conduct a Volcanic Fumaroles-to-H2 study.

IV-75 Put central H2 Firefighting training at Kona ARFF. Currently plans are under way to make the Kona International "campus" the central firefighting school for aviation responders. Adding a certified training curriculum for hydrogen first responders, could actually become a revenue producing opportunity for the State, as other states send their fire fighters here for training.

Kauai

IV-76 Dedicate one hydroelectric source to H2 production in support of Kauai county fleet vehicles.

V. Role of Not-for-Profit Sector

Universities

V-1 CC Curriculum Development, UH – Curriculum Development for CCs to support H2 system maintenance, See UH Hilo Engineering focus under Hawaii County,

Business Incubators & Accelerators

V-2 Tech Opportunities abound as utilities redesign their operations and new businesses fill demand for new types of services. Incubators and accelerators need to prepare the energy entrepreneurs to meet the new demand. As part of the DBEDT/HTDC "80/80 Initiative", the shift to a hydrogen-based energy system provides great opportunities for Hawaii to capitalize not only on new jobs and new businesses, but the move away from importing fossil fuels provides the economic stimulus to actually grow Hawaii's economy.

Individuals

V-3 Much like the Incubators/Accelerators above, individuals looking to step into a growing market need to look at hydrogen technologies and the wide range of business opportunities they generate. Individuals should focus a portion of their efforts on developing H2 related industry and business in Hawaii.

VI. Role of Private Sector

For Profit

VI-1 The private sector will provide the long-term sustainment and growth of the hydrogen infrastructure in Hawaii. State and federal agencies are critical to lead the community from the "early adopter" stage to the "competitive business stage", and they can influence markets to a degree with policy and other changes, but, the private sector can realistically only function in a positive cash flow situation. That situation generally cannot be successfully dictated by government. Therefore, the list below is just the H2IWG's initial look at the work to be done in the sectors to promote hydrogen infrastructure.

H2 Production

VI-2 Electrolysis – The cleanest method of "making" hydrogen is electrolysis, which involves applying electrical current to water in a controlled system that splits the water (H2O) into H2 and O2. As a rule of thumb we estimate 45-65 kWh of electricity is required to make 1 kilogram of pure, pressurized hydrogen.

VI-3 Reformation- Reformation is one of the least expensive methods of "making" hydrogen, and involves steam applied to any of a number of forms of natural gas to release the hydrogen atoms. While this is one of the "dirtiest" ways to make hydrogen (because it also produces CO2), it will consistently produce hydrogen at costs less than an equivalent amount of gasoline for comparable energy/mileage.

VI-4 Bio Gas to H2 - Usually steam reformation making hydrogen from bio methane.

VI-5 Syngas to H2 – Processing a wide variety of solid waste material through a gasifier produces "syngas" which in turn can be used to make electricity and run electrolysis to make hydrogen, or the syngas can be cleaned up and hydrogen separated from the rest of the syngas by steam reformation to make pure hydrogen.

VI-6 Chemical to H2 – A variety of chemical reactions (usually a metal and an acid) can be combined to make hydrogen.

VI-7 Photo electrochemical production of H2 – Several groups (including HNEI at the University of Hawaii) are working on a process to make hydrogen directly from water and sunlight, but this technology is not mature enough for commercial scale applications at this time.

VI-8 Algae off-gas to H2 – A local "startup" company at HTDC has discovered a specific algae on the Big Island that produces pure hydrogen from water in the absence of sunlight. This technology is very new and not ready for commercial applications, but shows great promise and may be part of the HCATT micro-Grid project at Joint base Pearl harbor-Hickam (JBPHH) in 2017.

VI-9 Other emerging technologies - There are other technologies emerging that the working group will monitor.

Electric Utility Companies

H2 Production

VI-10 Using excess power from rooftop solar and commercial solar or wind, the electric utility companies could turn that clean energy into hydrogen and store it for later use. This creates the needed "load" for the power utility when there is too much electricity being made. When there is not enough electricity being made, stored hydrogen can be turned back into electricity quickly, quietly and rather efficiently using "fuel cell" technology. This takes care of the problem of too little power being made to service customers. Using this concept, a system can be designed to absorb excess residential solar power (where it's produced), store it (and charge some batteries as well) to provide smooth, clean power with less "line loss" and less requirement for "spinning reserves" by the power utility. This system has the ability to not only provide safe, reliable and clean power to customers, it provides that power more quickly after a disaster that disables main grid trunk lines, sub stations or transformers. Also, excess hydrogen is also available for sale to the transportation or agricultural residents in that community, **and all of this with zero carbon emissions!**

Service Provider (On and Off Grid)

VI-11 Maintaining a grid is expensive, particularly when there are few customers and those customers are spread over a wide area. The power utility should modify its business model to include providing design, installation and support services to customers who could be better served "off the grid" This retains skilled labor and is more efficient than operating a large grid with few customers.

H2 Dispenser

VI-12 The electric utility company could also become the transportation fuel provider under any scenario that uses electricity and water to produce hydrogen.

Hawaii GAS

H2 Production

VI-13 Hawaii Gas may be positioned to produce hydrogen gas (along with compressed natural gas and propane, to help reduce transportation carbon emissions. Ideally they could produce hydrogen using any of variety of technologies, and has the pipelines and surface transportation and storage technologies down to a science…they just need customers.

Provide at least three "renewable fuel" stations between Aiea and Diamond Head

VI-14 Provide at least three "renewable fuel" stations between Aiea and Diamond Head to dispense Compressed Natural Gas, Propane, & H2 from renewable sources. Hawaii Gas needs

to make it public that they are actively and immediately offering alternative fuels that are cleaner than gasoline or diesel to those who want to convert now. As demand grows, Hawaii Gas is perfectly positioned to scale up as demand increases.

Look at feasibility of bringing in LH2–

VI-15 A recent report from the national Renewable Energy Lab indicates that the cheapest way to start the hydrogen delivery system in Hawaii is for Hawaii Gas to bring in liquid hydrogen (LH2), convert it to high pressure hydrogen gas and take it to stations for dispensing.

Fleet Operators

Tour Companies

VI-16 Several Hawaii based tour companies have test driven hydrogen fuel cell buses of various sizes and unanimously agree that the technology is perfect for their Hawaii operations, but they need a reliable source of hydrogen and they need the price of the vehicles to be lower. The tour companies are most impressed by the fact that the passenger compartment can be air conditioned constantly whereas currently their diesel fleet must shut down when not moving due to "anti-idling" ordnances. They are also impressed with the quietness, torque and overall performance of the vehicles at all speeds, even fully loaded.

GSA/State/County

VI-17 The role that government fleets play in the early adoption phase of hydrogen implementation cannot be over stated. Public transportation in particular can provide the initial push to bring about public acceptance and spur private sector markets for hydrogen Fuel Cell transportation.

Car Rental

VI-18 Many people rent cars as part of their decision process before buying new cars. The large volume of visitors to Hawaii could expose large numbers of visitors from around the world to hydrogen technology before it is even available in their own home town.

Car-pool

VI-19 Another example of how public awareness can be raised while also reducing "vehicle miles traveled" statistics.

Utility Companies

VI-20 Utility companies using hydrogen material handling equipment or producing hydrogen as part of their business could save substantial amounts of operating costs by using hydrogen in place of gas or diesel fuel in their fleets.

Taxi Cabs

VI-21 Eco-Cabs are already popular. Hydrogen fuel cell eco cabs could be better.

Auto Dealers

VI-22 Most major auto manufacturers are planning to offer hydrogen fuel cell vehicles for sale by 2020. Members of the Hawaii Auto Dealers Association are anticipating these vehicles and are making plans to maintain, and repair and even provide hydrogen to their own initial models until infrastructure grows.

Develop Maintenance Support Teams

VI-23 Even though hydrogen fuel cell electric vehicles (and other equipment) require less maintenance than internal combustion engine (ICE) vehicles, there will always be maintenance required and dealers and community colleges need to prepare to train the current and future workforces to work on this new technology.

H2 Production

VI-24 Hydrogen production by electrolysis is easily scalable from home owner appliance scale, to megawatt scale, so many companies will be able to use solar power and small hydrogen production units to provide at least a portion of their transportation energy for their fleet.

VI-25 Demo fleets/test drives – Vehicle manufacturers might consider being part of a "transportation tech park" set up by HTDC, or may want to operate an "Echo-tour" operation where they offer race driving, and maintenance experiences to tourists as part of a fly-hotel-rental car package here in Hawaii.

Material Handling

VI-26 Material handling is one of the areas identified by the working group as a prime "demand" for hydrogen energy due to the many operations that use this type of equipment and the fact that COTS hydrogen fuel cell models are already in production and in service worldwide. Retail, Wholesale, Government, Maritime, Baggage handling, manufacturing, freight forwarding are just a few of the typical users, and many of these could bring the "chicken and the egg" to their operation due to the scalability of hydrogen production.

Agriculture

Co-op

VI-27 Co-ops, homesteads, guilds and similar communities offer the leverage of pooled funding and shared resources that could make hydrogen equipment affordable.

Farm Equip

VI-28 Farm equipment is another area where there is already a building selection of COTS hydrogen fuel cell powered equipment in production and used worldwide. Like material handling, farming was identified by the working group as one of the key market sectors in Hawaii that should consider hydrogen fuel cell equipment as well as "off-grid" sustainability options.

Hospitals

VI-29 Aside from benefiting from high quality oxygen produced locally, hospitals may even choose to produce their own oxygen and hydrogen "on-site" to support daily operations, emergency power outages and cooking fuel.

Community Outreach

VI-30 The working group unanimously agreed that public outreach and a State led strategic communications effort are necessary to successfully roll out hydrogen infrastructure in Hawaii. From a multimedia campaign, to school curriculum, to vehicle demonstrations, and much more this is the area needing immediate attention.

VII. Recommendations

Government

VII-1 The state needs to pursue favorable policies from the federal government to allow us to compete for federal dollars. As an example, Hawaii is not considered a "Non-Attainment" state under Federal guidelines and is therefore not eligible for Federal Clean Transportation grants and funding because we do not have polluted air quality due to our trade winds. The State also needs to continue its efforts to garner Military Research and Dept. of Energy funding form the Office of Naval Research and the Air Force Research Lab. These efforts require ongoing attention by DBEDT (HTDC/HCATT) and the University of Hawaii (HNEI), as well as the Hawaii Congressional Delegation.

VII-2 The State needs to lead the way, set the example One of the first things that the private sector looks for before making an investment in a new location or new technology, is the support that they can anticipate from the full spectrum of government agencies. Everything from simple policy desires by the executive branch to tax incentives and other monetary relief options, to establishment of clean fleets and taking the first steps to be the example of what the

policymakers have declared has a huge impact on moving any change forward. Moving Hawaii forward in clean transportation is no different, and the policies, incentives and examples provided by the State and counties is critical if we are to expect the businesses and general population to follow.

VII-3 The State needs to streamline outdated policies and processes. Hawaii has historically placed poorly on the lists of business friendly states. In conjunction with our efforts to attain the Hawaii Clean Energy Initiative, we are also given an opportunity to improve our governmental administrative practices. We need to take a hard look at streamline permitting, updating policies and laws that are needlessly slowing business start-ups, and retain only "value added" policies that benefit all without sacrificing safety or values. Permitting and vague policies, often arbitrarily enforced, can eat up so much time that the start-up investors run out of funding before they can even start building. This is unacceptable. Hawaii can take advantage of much of the work already accomplished by the State of California. The California Fuel Cell Partnership has outstanding standards and check-lists, and curriculum for all levels. Other resources are available as well, and should be considered before starting from scratch.

VII-4 The State needs to make proper use of the "Barrel Tax". The 2014 legislature extended the "Barrel Tax" in order to make those funds available to help the state meet HCEI goals by 2030. The Legislature should periodically review the application of "Barrel Tax" expenditures to validate that they meet the spirit and intent of the statute.

VII-5 The State needs to designate a hydrogen infrastructure representative in the executive branch (accessible to public, but with direct access to the governor's office as well as the mayors offices), to help remove administrative roadblocks as policies and standards are updated. This could be someone in the State Energy Office or in HCATT, but that individual needs to be able to speak with the authority to get the attention of cabinet level directors if needed. This recommendation is modeled after the state of California, where there is one individual in the governor's office whose sole function is to remove unnecessary barriers in any state or county process.

VII-6 After appropriate analysis the legislature should consider specific tax incentives to encourage early adoption of hydrogen technology. Much like the incentives offered in support of adopting solar panels, tax credits for purchasing COTS hydrogen fuel cell equipment for material handling, agricultural equipment and other industries/Mfg.

VII-7 The list of proposed legislation from the Hawaii energy Policy Forum for the 2016 Legislative session is attached and should be considered as law makers undertake the upcoming session.

VII-8 The State needs to leverage the extensive work done in renewable energy by the U.S. military in Hawaii. Organizations like HNEI and HCATT provide valuable information to the

DoD, but that knowledge is also extremely valuable to the people of Hawaii, and Hawaii's efforts to reduce importation of fossil fuels.

Not-for-Profit Sector

VII-9 Continue to support research and provide philanthropic support of individuals and companies that are working to make Hawaii a cleaner and better place

Private Sectors

VII-10 The private sector is where we expect the sustaining implementation activity to occur. How much and how fast is directly related to the effort that the state puts in to streamlining permitting processes and facilitating growth of new business.

VII-11 Stay abreast of new technology using State Energy Office and H2IWG websites and social media. Advances in the hydrogen industry have resulted in a dramatic increase in sales and production improvements resulting in reduction in capital costs for hydrogen production and fuel cell hardware. The obvious result has been lower costs and higher performance as well as increased performance of electrolyzers and fuel cell powered equipment. The hydrogen power marked continues to grow worldwide and the future looks bright for continued trends in higher quality and lower prices, and in spite of the lower prices of fossil fuel (and the prediction of those prices remaining fairly stable) analysts project a steady adoption of hydrogen technology in both the transportation and public utility sectors.

VII-12 Be the "chicken" or be the "egg", or even better "the chicken and the egg" but don't just sit there waiting for someone else to lead the way. Currently SERVCO opted to be the "chicken **and** the egg", and has made Hawaii the second state in the nation to take delivery of Toyota's first production fuel cell electric vehicle, the Mirai, while also installing its own "clean" hydrogen production facility in Mapunapuna. This is unprecedented in the auto industry! The only states currently slated to get these new production FCEVs were Zero Emission Vehicle (ZEV) states, and Hawaii is not a ZEV state. But Toyota's decision to bring the Mirai to Hawaii is based on the likelihood of Hawaii building hydrogen infrastructure ahead of many other ZEV states based on our geography, our market and our efforts towards installing hydrogen infrastructure over the next two years. Several food distribution companies are interested in moving to hydrogen fuel cell material handling equipment (forklifts and powered pallet jacks) as part of a system where hydrogen provides not only their forklift power, but is also energy storage for emergency situations where grid power is not available, and making their own hydrogen using PV and grid power. Hawaii's private sector can lead, step up and do it!

VII-13 We not only import too much fossil fuel, we import too much food! Hawaii needs to leverage hydrogen technology to improve the business model for local farmers. The Agricultural

sector offers a wide range of opportunities for farmers in Hawaii to reduce energy costs and increase productivity using hydrogen technology. As an example, Lamplighter Energy is working with farmers in Kunia to make hydrogen from renewable sources (primarily solar), and using that hydrogen to power remote refrigerated shipping containers, allowing the farmers to keep their crops fresh and hydrated and bringing them higher yields at market. In addition, forklifts and other equipment will replace existing conventional powered equipment (like tractors) over time greatly reducing daily operating costs. As a byproduct of hydrogen production, pure oxygen will be pumped into the aquaculture tanks of farm raised Tilapia to boost their growth rate (by an estimated 25-30%). All of this while upgrading the plantation era wastewater treatment and well service to modern standards and providing reasonable priced housing for farm families in refurbished plantation dwellings.

VII-14 Hawaii's energy markets are in major transition; Recognize it; Adapt to it; or be made irrelevant by it! Hawaii Gas has redoubled it efforts to provide alternative fuels (including hydrogen) for the transportation sector on Oahu and is considering plans to modify its business model to include large scale hydrogen production on the Big Island to provide hydrogen for markets in the rest of the state, and converting the state's methane off-gas (from landfills, wastewater treatment, and potentially agricultural waste) into hydrogen using steam reformation (a relatively inexpensive way to produce hydrogen). With oil refineries potentially being shut down in Hawaii, Hawaii Gas will lose its raw materials to produce propane, and domestic off-gas methane cannot offset the lost feedstock, so Hawaii Gas will most likely need to consider continuing importing LNG, at least in the short term to keep up with demand for natural gas. This will benefit Hawaii's efforts to produce inexpensive hydrogen in the near term as the market matures, and possibly converts from LNG to hydrogen. Long term, Hawaii Gas could produce hydrogen in sufficient quantities using local renewable energy only (primarily geothermal) in large quantities at a very reasonable price and become a net exporter of energy to Asia, the Mainland US and Pacific Island nations.

VIII. Summary

VIII-1 Hawaii is poised to move ahead in renewable energy like no other state in the nation. With our abundance of renewable energy available, the significant amount of federal funding historically invested here to study renewable energy technologies, and the cultural values our people place on a clean and healthy lifestyle and environment, now is the time to commit to a clean future and show the world how to do what is right, what is responsible, what is Pono. Working together across all levels of government, the private sector and with the support of "not-for-profit" organizations, Hawaii can lead the way for many nations struggling for a solution to importing energy, particularly fossil fuel energy. The detrimental economic impact of importing oil cannot be over stated, and if Hawaii expects to grow its job market for our children, and be

able to weather changes in tourism or military spending here, we need to reduce the money we throw away purchasing fossil fuel, when we have the energy resource that we need at hand.

VIII-2 The move to renewable sources, particularly wind and solar PV, drives a demand for energy storage. The portability of stored energy between our islands (or possibly even as an export product!) is critical to efficiently get local energy from places with excess energy to locations with high demand. Hydrogen is recognized worldwide as one of the best, safest and most cost effective energy storage solutions, and if properly developed in Hawaii, hydrogen offers huge benefits across all sectors of our economy. With a relatively small investment by the State, Hawaii could gain economic growth on a scale that few can imagine, a much cleaner environment, stable energy resources/prices (Energy security), and resilience after manmade or natural disasters. It was apparent as the H2IWG held its public forums, that the people of Hawaii are ready to move ahead and they are expecting Hawaii's leaders to do the same.