Top Hydrogen and Fuel Cell Stories of 2018

California

In 2018, California witnessed several achievements and milestones. Please note that a few of these are featured elsewhere in our list under Hydrogen Infrastructure.

Starting off the year, then Governor Jerry Brown called for a goal of 5,000,000 zero-emission vehicles by 2030 in California, setting a number of ambitious goals for the Golden State. His executive order also called for 200 hydrogen stations by 2025.

The California Fuel Cell Partnership released "The California Fuel Cell Revolution," that calls for, among other things, 1,000 hydrogen stations serving upwards of 1,000,000 fuel cell electric vehicles by 2030. The document also explores the synergies between light-duty and heavy-duty fueling infrastructure, the opportunities for renewable hydrogen and the role of hydrogen in the increasingly renewable electrical grid.

The California Air Resources Board approved a Low Carbon Fuel Standard infrastructure credit for hydrogen fueling and charging infrastructure that is set to be implemented in 2019. It is expected, among other policy measures, to spur infrastructure investment and greater capacity.

California exceeded 5,000 fuel cell electric vehicles-mostly passenger cars-on its roads, more than Japan or Germany which had more hydrogen stations. Hydrogen stations opened in Palo Alto, LAX area, Citrus Heights, Emeryville, Newport Beach, Ontario, Thousand Oaks and Mountain View. Hydrogen station capacity increased in 2018, and more stations with greater capacity will be opening in 2019 and beyond.

California continues to lead in North America in the bus category. The California Air Resources Board approved an Innovative Clean Transit regulation, putting transit agencies on the pathway to zero-emissions, fuel cell and battery electric.

A 60-foot fuel cell electric bus –the first of its size- made by New Flyer, the largest manufacturer of buses in North America, completed federal testing and is destined for AC Transit in the San Francisco East Bay. New Flyer is building 25 more fuel cell electric buses which are destined for AC Transit, Sunline Transit and the Orange County Transportation Authority. And fuel cell electric buses are exceeding national standards set by U.S. Departments of Energy and Transportation.

The California Air Resources Board awarded $41 Million to the Port of Los Angeles to launch a fuel cell freight project that includes partners Toyota, Kenworth and Shell and will include 10

heavy-duty fuel-cell-electric trucks, two new heavy-duty hydrogen stations, and four fuel cell powered cargo handling equipment.

The Horiba Group committed $9 million to the University of California, Irvine for a new institute to focus on better connectivity between transportation and energy sectors.

The California Energy Commission (CEC) funded a renewable hydrogen production road map for California, designating the University of California, Irvine to develop the strategy document. The CEC also funded two renewable hydrogen production projects, one in the Inland Empire and another in the Central Valley. And Energy Independence Now released its renewable hydrogen road map.

And, lastly, one California fuel cell car driver, Tadashi Ogitsu, pushed his Honda Clarity to a range of 502 on one fill up.

Buses, Trucks, Military and Trains

The heavy-duty category saw an increase in activity last year, especially with Nikola Motor and Toyota.

Toyota unveiled its second fuel cell truck, Beta, after having unveiled its first truck, Alpha, in 2017. Lighter, roomier and with longer range, the Beta will soon begin its hauls out of the Long Beach and Los Angeles Ports like its slightly older sibling which has logged more than 10,000 miles so far across the Los Angeles Basin. This year, the California Energy Commission awarded Shell and Toyota $8 million to build the first hydrogen-truck refueling station at the Port of Long Beach. Later in the year, the California Air Resources Board awarded the Port of Los Angeles $41 million to establish a fuel-cell-electric technology network to move goods from "shore to store" in partnership with Shell, Toyota and Kenworth.

Nikola Motor, one of the newest CaFCP members, captured the attention and imaginations of many in 2018 with numerous announcements throughout the year about its Class 8 fuel cell trucks, including the April 2019 launch at its new 500-acre, 1 million square foot facility in Arizona. The launch event will showcase Nikola's first pre-production models of its Class 8 truck and a hydrogen fueling station that is the model of its eventual 700-plus station network built by Nel Hydrogen. Mid-year, Anheuser-Busch ordered 800 trucks, increasing the number of high-profile companies that are customers or partnered with Nikola, including Ryder and Thompson Machinery. Later in the year, Nikola unveiled the Nikola Tre for the European and expects to begin testing the truck in Norway in 2020.

Hyundai announced it would build 1,000 heavy-duty trucks for a project in Switzerland, all the while keeping their eyes on the U.S., Chinese and larger European market.

With so many entering and expanding their presence in the heavy-duty market, it should not be surprising that companies like Cummins have signaled their intent to participate. Their entrance was marked by the announcement that they had joined the Hydrogen Council. Also, it was not

surprising to learn that Ballard Power Systems created a fuel cell stack for the heavy-duty motive market.

With more than 20,000 fuel cell forklifts operating across the U.S. with companies such as Amazon, Walmart, Coca Cola and BMW, the forklift sector is the most commercialized category of the fuel cell electric vehicles. As a result, it's surprising that Plug Power is looking to increase fuel cell production rates up to 20,000 units per year — a 30 percent increase compared to the current numbers. Last year, Plug acquired American Fuel Cell, hoping to accelerate the company's expansion into the on-road industry, including delivery vehicle fleets.

Fuel cells have increasingly been considered an option for military organizations across the globe. General Motors unveiled its ZH2 military reconnaissance vehicle not too long ago to positive reviews, based on its popular Chevy Colorado. In 2018, it unveiled the Silverado ZH2, shortly after establishing its military subsidiary, GM Defense. The U.S. Department of Defense and Department of Energy signed a memorandum of understanding to develop fuel cell and hydrogen infrastructure-related technologies.

Fuel cell electric buses (FCEBs) – often referred to as "the other electric bus" - saw increased visibility, especially with the year-end decision by the California Air Resources Board to mandate bus agencies transition to zero-emission vehicles. California has 18 years of experience with fuel cell electric buses and millions of miles of service, including production of FCEBs at ElDorado National in the Riverside area. ElDorado fuel cell buses, powered by Ballard fuel cells, completed rigorous testing under a program established by the Federal Transit Administration.

Other FCEB announcements were made by manufacturers and government agencies in the U.S., Japan, Korea, China and Europe. One thousand hydrogen-powered buses are slated to hit the road in South Korea by 2022, manufactured by Hyundai. At least 100 Sora hydrogen buses made by Toyota are expected to ferry attendees around the 2020 Olympics in Tokyo. Chinese manufacturer BYD, in partnership with California-based U.S. Hybrid, announced their intention to develop a fuel cell electric bus for Honolulu Airport. SARTA, a transit agency in Ohio, and its partners ElDorado National and BAE Systems, will lend a fuel cell bus to transit agencies wanting to learn more about the technology.

This last year also saw an increase in activity in the rail sector, include the world's first hydrogen-powered train in Germany, with additional trains planned for other regions.

Hydrogen Production and Infrastructure

Hydrogen fueling infrastructure announcements increased in 2018, reflecting the growth of the vehicle market in California and across the globe.

In California, FirstElement Fuel, developer and operator of the growing True Zero hydrogen fueling network, secured a long-term, renewable hydrogen fuel contract with Air Liquide. Air Liquide, in turn, will build the first world-scale liquid hydrogen production unit dedicated to the hydrogen energy markets, with the capacity to fuel up to 35,000 fuel cell electric vehicles.

Complementing this and other announcements, Hexagon, a manufacturer of cylinders for the storage of gases, received a U.S. Department of Transportation special permit for high-pressure hydrogen transport, enabling higher volume of hydrogen per trip, reducing fuel costs. Nel Hydrogen achieved UL certification for its hydrogen fueling station product – the first in the world.

In a move that will double the retail hydrogen capacity in California, FirstElement Fuel will outfit its newest True Zero stations with Linde's Cryo Pump, enabling the developer to provide more fuel daily and refuel cars simultaneously to reduce customer wait times.

With the commitment to fund hydrogen infrastructure in California, the new Low Carbon Fuel Standard capacity credit, and the call for 1,000 stations by 2030, more infrastructure companies are taking notice and entering the market. Trillium CNG, a provider of alternative fuels systems, changed its name to Trillium, reflecting its work with charging and hydrogen stations, including the development of Orange County Transportation Authority's bus hydrogen fueling station.

United Hydrogen expanded its operations to produce more hydrogen in anticipation of increased demand from FCEVs and industry. And Ivys Energy Systems announced the first commercial deployment of its SimpleFuel® hydrogen refueling appliance in Japan.

At the Global Climate Action Summit in San Francisco, the Hydrogen Council committed to 100% decarbonized hydogen fuel by 2030.

Passenger Vehicles

Fuel cell electric passenger vehicles saw increased visibility and interest globally, with numerous announcements pointing to the commitment of many automakers to the technology, including the annual KMPG automotive executive survey that found "fuel cell electric mobility is this year's #1 key trend, having grown in importance from its #5 ranking in 2016."

Hyundai released the 2019 NEXO fuel cell SUV to its first customer in California, after releasing its 2030 vision which calls for the production of 700,000 fuel-cell systems annually by 2030 including 500,000 units for fuel cell electric vehicles.

Hyundai also entered into a multi-year patent cross-licensing agreement with Audi, covering a broad range of FCEV components and technologies. That followed a 3.5-year extension inked by Ballard with Audi, and indications that Audi is planning a small series production launch for 2020.

Daimler rolled out its Mercedes-Benz GLC F-Cell in the German market, offering for the first-ever electric vehicle featuring fuel cell and plug-in hybrid technology, with nearly 300 miles of range. Daimler changed the name of fuel cell subsidiary, NuCellSys, in part to send "a clear signal and emphasizing the future relevance of fuel cell technology."

Honda and Toyota, early leaders in the launch of the FCEV passenger market, continue to support the technology and push for more infrastructure, with indications that Toyota may bring a fuel cell Lexus to market.

In France, the Automobile Club de l'Ouest announced that there will be a hydrogen fuel cell class at the 24hr de Le Mans race in 2024, stating that the technology is "the next objective" in decarbonizing motorsport. In Paris, the fuel cell taxi fleet Hype reached 100 vehicles with the addition of 25 Toyota Mirai cars, in addition to the Hyundai Tucsons already on the streets. Hype is expected to grow to 600 by 2020.

China

While in previous years, many were focused on Germany, Japan, California, South Korea and other countries, in 2018 all eyes turned toward China and its efforts to expand hydrogen infrastructure and grow fuel cell electric vehicle production, including passenger cars, buses and trucks. One senior Chinese official, regarded as the father of China's EV industry, urged a shift towards FCEVs.

And many companies are collaborating with their Chinese counterparts. Ballard Power Systems entered into a strategic collaboration with Weichai Power, with Weichai's investment of $163 million; the company also saw increased investment from partner Broad-Ocean Motors.

Hydrogen, Renewables and Energy Storage

Hydrogen as energy storage, a grid balancer and an industrial input took on greater prominence during the year. Most notable was the UN Intergovernmental Panel on Climate Change's report, Global Warming of 1.5 ºC. The Summary for Policy Makers noted that carbon reductions "can be achieved through combinations of new and existing technologies and practices, including electrification, **hydrogen**" and other means.

European Union members agreed to explore the potential for hydrogen use in energy storage, transport, power and heating, and a World Energy Council report found that creating an affordable and reliable energy supply from North Sea wind power in North West Europe would require a hybrid system of (green) power and (green) hydrogen.

The United Kingdom continued exploring the role of green hydrogen, including heating industry and homes. In Leeds, one of the largest UK cities, they are studying the feasibility, from both a technical and economic viewpoint, of converting the existing natural gas network to 100% hydrogen.

In Australia, policy makers, industry and others are looking at hydrogen as a key component of the energy transition and a renewable export. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), the independent Australian federal government agency responsible for scientific research, released a hydrogen road map and the Coalition of Australian Government's Energy Council established a Hydrogen Working Group to further these efforts. Australia's chief scientist, Dr Alan Finkel, believes hydrogen exports could be a $1.22 (US) billion opportunity for Australia by 2030. Already, $20 million is being invested to develop and commercialize new hydrogen technologies to support the creation of a new hydrogen industry.

In North America, the policy makers and others are just beginning to explore and understand the possible role that hydrogen could play in the energy transition. The Electric Power Research Institute (EPRI) released its national electrification assessment and called for, among other things, exploration of the role of hydrogen as a clean carrier of energy. Massachusetts funded a study that will assess the potential for power-to-gas energy storage and hydrogen fuel for the Massachusetts region in collaboration with Holyoke Gas and Electric, a local gas and electricity utility. British Columbia funded a study to evaluate the large-scale production and use of renewable hydrogen in the province and its export to Japan and California. ITM Power will participate in both studies.

To complement these activities and exports, Japan and others are exploring ammonia as a means of storing and transporting large amounts of hydrogen.

Shell and ITM will build the world's largest hydrogen electrolysis plant at Shell's refinery in Rhineland, Germany. With a peak capacity of 10 megawatts, the plant is expected to begin operations in 2020.

In Denmark, Air Liquide and other partners inaugurated HyBalance, a pilot for the production of renewable hydrogen, utilizing electrolysis technology that will enable operators to grid balancing and energy storage. Industry representatives in Germany, including Shell and Siemens, have come forward to call for tying renewables to hydrogen production for energy storage and transport. And with increased business activities (ie, Nikola Motor) and increasing opportunities for hydrogen production by electrolysis, Nel Hydrogen will construct the world's largest electrolyzer manufacturing plant in Norway.

Investment

Behind many of the activities listed through our 2018 top stories is the investment being made by private industry and governments around the globe. Last year's various investment announcements are tied to the understanding that the next stage of development is increased production. Air Liquide's Ole Hoefelmann (and CaFCP's board chair for 2019), when asked by Gasworld about the biggest challenge in the near future, said "H2 solutions are technologically mature. The challenge now is their large-scale deployment."

Among private industry, Anglo American stands out for its increased investment in hydrogen and fuel cell technology, with the creation of an investment fund that includes other investors.

Hyundai set up a $100 million fund with a partner to fund Chinese local investments in hydrogen technologies and related industrial infrastructure. And the Korean government will support hydrogen energy companies with several hundred million dollars in funding to develop a sustainable ecosystem surrounding the use, storage and transportation of the clean and alternative energy.

France unveiled an ambitious US$100 million plan for the deployment of hydrogen, with one minister indicating that he wanted to "make France a world leader in this technology". French

industry reacted positively to Plan Hydrogèn. The plan was preceded by a study published by 13 industry partners on the role of carbon-free hydrogen in the energy transition in France.

In Japan, the commitment to a hydrogen society continues, and the 2020 Tokyo Olympics are expected to be a high-tech showcase, with more than 100 Toyota fuel cell electric buses, thousands of fuel cell electric cars, an athlete's village powered by hydrogen and fuel cells, and a torch fueled by hydrogen. Tokyo is expected to invest more than $300 million to showcase fuels and hydrogen.

Maritime

Another sector that saw a dramatic increase in fuel cell and hydrogen visibility and activity was the maritime category, with its push to carbonize shipping. Danish shipping giant Maersk announced its intention to eliminate carbon emissions by 2050. Norway, with a number of battery and fuel cell-related maritime projects in the works and policy discussions well under way, committed to zero-emission shipping. And others see advantages to using fuel cells and hydrogen fuel on ferries, cruise ships and other vessels.

In California's San Francisco Bay Area, work has begun on what will likely be the world's first fuel cell ferry, a project whose partners include SF's Red & White Fleet, Sandi National Labs, the California Air Resources Board, Golden Gate Zero Emission Marine and others. The ferry is expected to be completed late next year.

A Scripps Institution of Oceanography research trimaran will be powered by fuel cells and liquid hydrogen for its trips from San Diego to Hawai'i.

After a year and a half at sea, Energy Observer, the renewable energy-hydrogen ship, shows great promise. Its goal is to visit 50 countries, and 1010 ports of call around the world in six years.

Siemens and Power Cell Sweden entered into a partnership that will integrate fuel cell modules in shipping, possibly for ferries, yachts, cruise ships and research vessels. Similarly, ABB and Ballard Power systems agreed to develop a next-generation fuel cell power system for marine e-mobility.

A consortium that includes Ballard Power Systems and McPhy has received European funding to design and build HySeas III, the world's first sea-going renewables-powered car and passenger ferry. It will operate in the Orkney Archipelago where the BIG HIT project ('Building Innovative Green Hydrogen Systems in an Isolated Territory') uses local renewables to generate hydrogen and fuel vehicles.

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