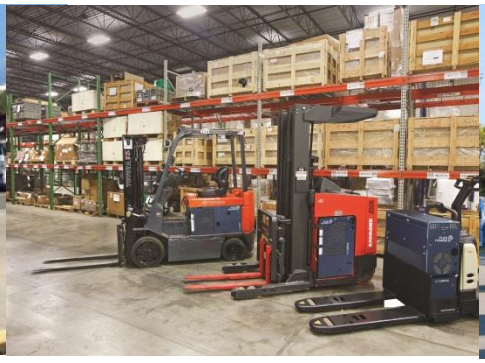


VOLKSWAGEN SETTLEMENT BENEFICIARY MITIGATION PLAN TOOLKIT – FUEL CELLS AND HYDROGEN SUPPLEMENT

FCHEA
Fuel Cell & Hydrogen Energy Association

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Introduction

This Fuel Cell and Hydrogen Energy Association (FCHEA) report supplements the National Association of State Energy Officials (NASEO) Volkswagen Settlement Beneficiary Mitigation Plan Toolkit[1] published in March 2017 as a resource for State Energy Offices, State Environmental Agencies, and others in formulating their Beneficiary Mitigation Plans under the Environmental Mitigation Trust ("Trust").

It provides details on fuel cells and hydrogen applications and by showcasing the environmental benefits and successful implementation of fuel cell and hydrogen technologies for those states that wish to include hydrogen and fuel cell-related actions in their plans.

Plan Considerations for Beneficiaries: Overview of Repower or Replacement Options

As stated in the NASEO toolkit, through the Trust, states will support projects that fall within ten eligible mitigation action categories. Most of the mitigation actions revolve around repowering and replacing vehicles with new vehicles or engines that use a variety of fuels. In this instance, "repower" means "to replace an existing engine with a newer, cleaner engine or power source that is certified by U.S. EPA and, if applicable, CARB, to meet a more stringent set of engine emission standards."[2]

In most eligible mitigation action categories, diesel engines can be replaced with an engine certified for use with the following fuels:

- Diesel, including biodiesel and renewable diesel
- Natural Gas, including CNG (Compressed Natural Gas), LNG (Liquefied Natural Gas) and RNG (Renewable Natural Gas).
- Propane (Liquid Propane Gas)
- Hybrid (a vehicle that combines an internal combustion engine with a battery and electric motor)
- All-Electric (powered exclusively by electricity provided by a battery, fuel cell or the grid)

Fuel cells generate energy through an electrochemical reaction between hydrogen and oxygen, a process that is inherently clean and efficient. The only emissions from fuel cells are water and heat, both of which can be recovered and put to use.

Commercial fuel cells are used today in wide range of applications, with tens of thousands now operating in the U.S. to supply power to on- and off-road vehicles, telecommunications towers, buildings, wastewater treatment plants, and the electric grid. These fuel cells range in power from kilowatts to multi-megawatts with customers that include corporations, municipal governments, and transit agencies.

ABOUT FUEL CELLS

FUEL CELL BENEFITS

- Exceptionally low/zero emissions
- High quality, reliable power
- Durable and rugged
- Efficient – 50%+ electric efficiency, 90%+ electric and thermal efficiency
- Quiet
- Fuel flexible – conventional or renewable fuels

Motive Applications

- Fuel Cell Vehicles (FCVs): Replicates today's driving experience -- range of ~300 miles per fueling, refuel at a pump in 3-5 minutes
- Fuel Cell Electric Buses (FCEBs): Vibration-free, zero-emission, fuel savings compared to diesel buses
- Material Handling Equipment (MHE): Constant power/no lag, reliable operation in refrigerated environments, refuel in minutes

Distributed Generation

- Flexible siting, indoors or outdoors
- Lightweight, enables rooftop siting
- Modular/scalable to meet any need, ranging from a few watts to multi-megawatt systems
- Able to provide primary, supplemental, or backup power
- Can be grid-tied, or can operate independently from the grid
- Compatible with solar, wind, batteries and other renewable/conventional technologies
- Can be used with, or instead of, fossil fuel generators
- Requires less space than solar photovoltaics
- Operates in water balance/uses very little water in operation

Remote/Off-Grid

- Rugged
- Long runtime
- Low operational costs
- Reduced risk of fuel theft

All Electric: Fuel Cell Vehicles

Fuel cell vehicles (FCVs) are electric vehicles, producing energy on-board the vehicle from hydrogen. They do not need to be plugged in to charge, instead fueling with hydrogen from a dispenser, much like fueling a car. Light duty vehicle fueling takes 3 to 5 minutes.

FCVs are twice as efficient as internal combustion vehicles, and have zero tailpipe emissions. Fuel cells also offer high reliability and are scalable, fuel flexible, efficient and quiet.

This scalability in motive applications allows the technology to be integrated into vehicles of all sizes, from material handling equipment such as forklifts, to cars, delivery vans, trucks, buses and locomotives.

Light duty vehicles powered by fuel cell powertrains, called fuel cell vehicles or FCVs, are the only zero-emissions vehicle capable of replicating today's driving experience of 300 – 400 miles range and a refueling time of just three to five minutes.

There are currently three commercially available FCVs for sale or lease in California, with plans to expand to the Northeast market in 2018 and beyond. As pictured below, the vehicles include the Honda Fuel Cell Clarity (left), the Hyundai Tucson Fuel Cell (middle), and the Toyota Mirai (right).

For the off-road vehicle markets, range, fueling time, reliability and power consistency are the impetus for the surge in fuel cell-powered forklift market. Today, there are more than 16,000 fuel cell material handling vehicles deployed or on order by major customers around the country. These customers include Amazon, The Home Depot, Sysco, Walmart, Coca-Cola, and more.

Fuel cell buses are now in revenue service in several states around the U.S., including California, Ohio, Delaware, and Massachusetts.

The success of these early commercial markets shows the maturity of fuel cell and hydrogen technologies and their readiness for local freight truck, drayage truck, bus, marine and other material handling applications.

Current U.S. Fuel Cell and Hydrogen Fueling Snapshot

Type	# Deployed or on Order in the U.S. as of May 2017
Fuel Cell Vehicles (FCVs)	1,700+
Fuel Cell Electric Buses (FCEBs)	25 in operation, 56 planned
Fuel Cell Forklifts	16,000+
Hydrogen Fueling Stations	• California: 27 in retail operation (38 planned) • Northeast U.S.: 12 retail stations planned (Connecticut, Massachusetts, New Jersey, New York, Rhode Island) • Washington, D.C.: 1 non-retail for FCVs operated by federal government and automakers • Non-retail stations for FCEBs are located in California, Connecticut, Delaware, Massachusetts, Michigan, and Ohio • Dozens of non-retail hydrogen stations are located at U.S. warehouses and distribution centers to refuel fuel cell-powered forklifts.

Chart compiled by Fuel Cell and Hydrogen Energy Association

Alternative Fuel: Hydrogen

Hydrogen has been safely produced, stored, transported, and used in the U.S. industrial sector for more than half a century. Millions of metric tons of hydrogen are produced annually for use in the fertilizer, agriculture, food, chemical, and petrochemical industries, and more.

Hydrogen can be extracted from virtually any hydrogen-containing compound, including both renewable and non-renewable resources. Regardless of the fuel source, fuel cells utilize hydrogen with little to no polluting emissions.

Currently, steam reformation, where high-temperature steam with the aid of a catalyst, extracts hydrogen from natural gas, accounts for the majority of the hydrogen produced in the U.S. Some carbon dioxide (CO_2) is emitted in the reforming process, but the emissions of NO_X, sulfur oxide (SO_X), particulates, and other smog producing agents are zero. As shown in various emissions calculations tools, since a fuel cell is more efficient than an internal combustion engine, the overall emissions using natural gas as the hydrogen feedstock are still dramatically less.

Hydrogen can also be produced renewably, from solar or wind-powered electrolysis, as well as from biogas.

Today, hydrogen is being used as a fuel for a range of fuel cell vehicles, as well as to power thousands of stationary and backup systems around the world.

Plan Considerations for Beneficiaries: Emissions Reductions and Other Benefits of Fuel Cells

GREET model

As mentioned in the NASEO toolkit, there are several modeling tools available online at no charge that can serve as resources for states to use in calculating NO_X and other greenhouse gas emissions reductions under the environmental mitigation trust.

The Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model analyzes well-to-wheel (WTW) studies and shows that FCVs are among the cleanest vehicles on the road today, comparable to battery electric vehicles, and at least twice as efficient as traditional gasoline cars. In fact, each conventional gasoline vehicle replaced by an FCV can reduce the amount of carbon emissions on our roads by approximately 12,600 pounds a year. Figures 1 and 2 show some comparisons of FCVs with other vehicles.

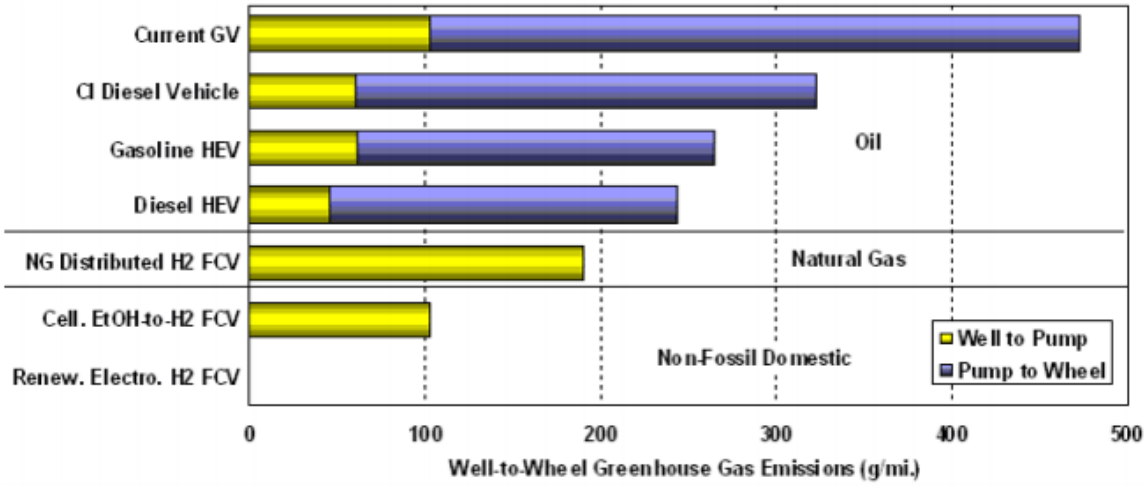


Figure 1 - GREET WTW GHG Emissions[3]

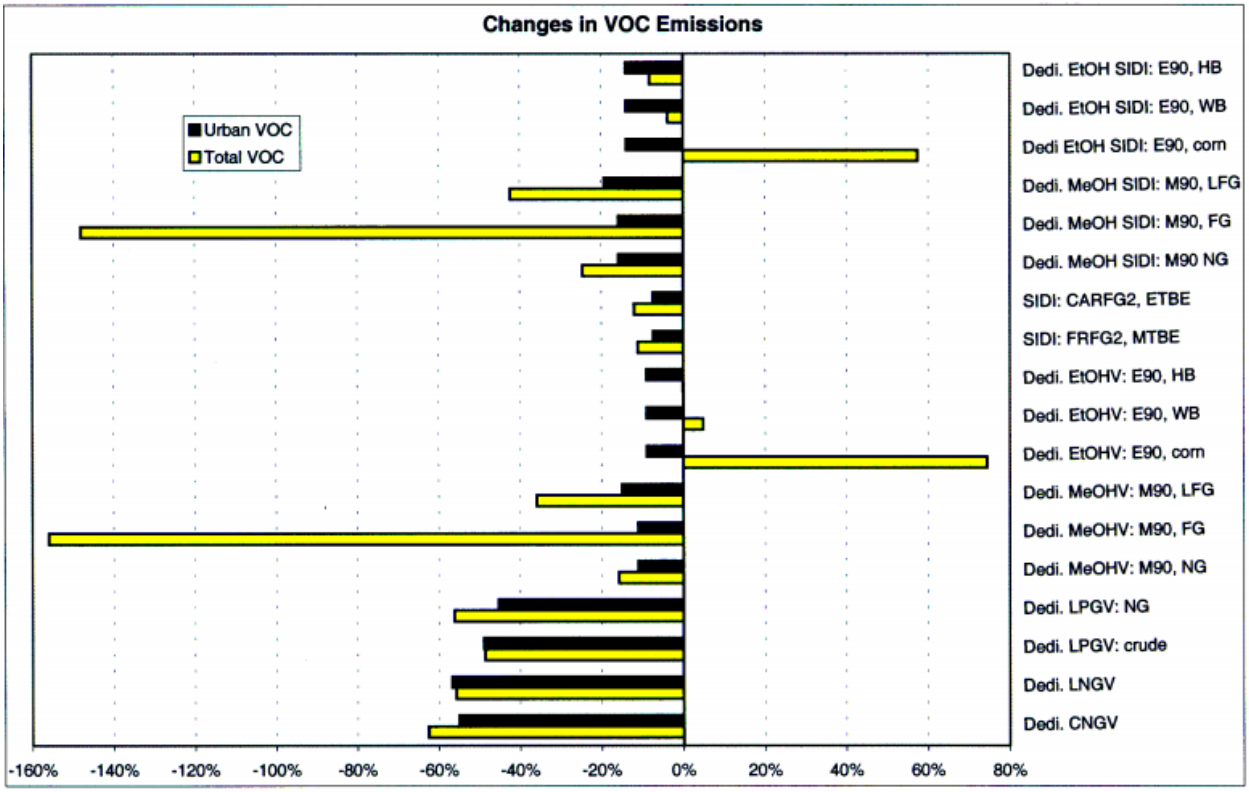


Figure 2 – GREET – Changes in Volatile Organic Compound (VOC) Emissions[4]

Ten Eligible Mitigation Actions from Final Consent Decree

Beneficiaries have the option to spend funds from the Trust on projects that fall within ten eligible mitigation action categories. According to the final consent decree, "the goal of each Eligible Mitigation Action shall be to achieve reductions of NO_X emissions in the United States." The following section provides examples of how fuel cells and hydrogen fueling are compatible with each action category based on feasibility studies, demonstration projects, or actual deployments, with examples of best practices.

1) Class 8 Local Freight Trucks and Port Drayage Trucks (Eligible Large Trucks)

The first eligible mitigation action is the repowering or replacement of Class 8 (over 33,000 pounds) local freight and port drayage trucks. This includes trucks used for hauling cargo to and from ports and intermodal rail yards as well as trucks used for freight or cargo delivery including waste haulers, dump trucks, and concrete mixers.

In 2011, the Ports of Long Beach and Los Angeles began one of the first U.S. demonstrations of a fuel cell-battery hybrid heavy-duty hauling trucks. The technology proved feasible and in the recent year, there has been several companies unveiling heavy-duty trucks with fuel cells, including Nikola Motors, Kenworth, and Toyota.

In April 2017, Toyota unveiled "Project Portal," a new hydrogen fuel cell-powered semi-truck that will take part in a feasibility study examining the potential of fuel cell technology in heavy-duty applications at the Ports of Long Beach and Los Angeles, under the Port's Clean Air Action Plan. The fuel cell truck from Toyota has an estimated driving range is over 200 miles per tank of hydrogen, under normal port drayage operation.[5]

Success Story: San Pedro Bay Ports Zero Emission Cargo Transportation Program (ZECT program) [6]

In an effort to reduce petroleum use, carbon emissions, criteria pollutants, and air pollution at transportation hubs, specifically ports, in 2014, the DOE awarded the South Coast Air Quality Management District (SCAQMD) $9.7 million to fund seven new zero emission truck projects. Three of these projects involved fuel cell-powered drayage trucks.

From this, the San Pedro Bay Ports Zero Emission Cargo Transportation program (ZECT program), co-funded by the California Energy Commission, the Ports of Long Beach and Los Angeles, the Los Angeles Department of Water and Power, and Southern California Gas, brought together three teams of OEMs and vehicle integrators to demonstrate fuel cell-powered drayage trucks. The trucks will operate along major drayage truck corridors including the Terminal Island Freeway, a primary corridor for port cargo travelling between Port of Los Angeles and Port of Long Beach terminals.

One team partners the Center for Transportation and the Environment (CTE), Kenworth (PACCAR), BAE Systems, and Ballard Power Systems. Ballard Power Systems is integrating its 85-kilowatt fuel cell engine into a Class 8 Kenworth drayage truck for a two-year demonstration program. CTE is also installing a hydrogen fueling station near the ports to fuel the CTE truck as well as trucks built by other teams for SCAQMD. Other teams include TransPower, working with fuel cell manufacturer Hydrogenics, and U.S. Hybrid, also working with Kenworth.

2) Class 4-8 School Bus, Shuttle Bus, or Transit Bus

The second eligible mitigation action is the repowering or replacement of Class 4-8 School Buses, Shuttle Buses, or Transit Buses. Vehicles eligible for scrappage and repowering or replacement include those with engine model years prior to 2009.

According to the California Fuel Cell Partnership, every fuel cell transit bus put into service in the U.S. could reduce the carbon released into the atmosphere by 100 tons annually and eliminate the need for 9,000 gallons of fuel every year over the life of the vehicle. For buses running on diesel fuel, that translates into a savings of more than $37,000 per year, per vehicle.[7]

Average fuel economy of fuel cell electric buses (FCEB) from three fleets is about six miles per diesel gallon equivalent (DGE), 1.4 times higher than conventional diesel buses (~4.2 miles per DGE) from one fleet and up to 1.9 times higher than compressed natural gas buses (~3.3 miles per DGE) in another fleet.[8]

Transit Buses

The first fuel cell bus debuted in the U.S. in 2002, operated by SunLine Transit in California's Coachella Valley. Since that initial demonstration, fuel cell technology for buses has matured greatly. The number of buses in the state has grown, with 20 FCEBs now in daily operation and revenue service at California transit agencies. Fuel cell buses are also operating in Flint, Michigan, Columbus, Ohio, and Boston, Massachusetts. Demonstration buses have also operated in Austin, Texas, Columbia, South Carolina, Birmingham, Alabama, and several other sites. Dozens more buses are planned in California and other states.

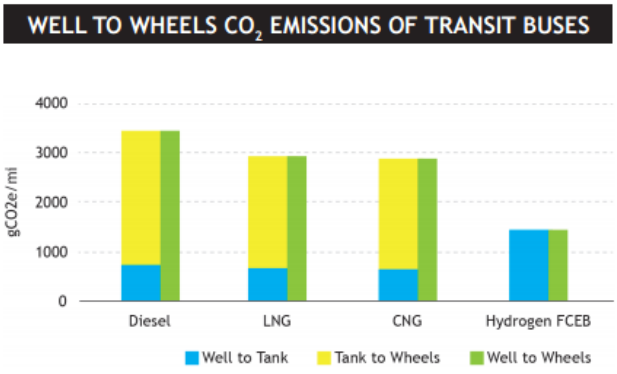
Source: U.S. Department of Transportation

FCEBs achieve an average range of 230 miles per fueling.[9] Fueling time depends on station design, ranging from under 10 minutes to about 20 minutes.

Since fuel cell buses are electric-powered, they are quiet and since there is no combustion, fuel cell buses operate without any emitting pollutants.

Sources: Well to tank from GREET V1 with an assumption of 2015 fuel mix and tank to wheels from EMBARQ's *Exhaust Emissions of Transit Buses* that used actual emissions of 240 buses (model years 1994-2010) in lab and field tests.

www.embarq.org/sites/default/files/Exhaust-Emissions-Transit-Buses-EMBARQ.pdf



$99,792

US EPA estimates that 40 fuel cell buses in a community will reduce particulate matter by 1.2 tons per year compared to 2004 model year diesel buses saving an estimated $99,792 in health costs associated with avoided medical care and sick days in Alameda County. And as much as $2.5 million in LA County.

Figure 3 - California Fuel Cell Partnership[10]

Several of the fuel cell buses in operation today are part of the American Fuel Cell Bus (AFCB) project, which meet or exceed the Federal Transit Administration's (FTA's) "Buy America" Provision that requires more than 60 percent U.S. manufactured content.

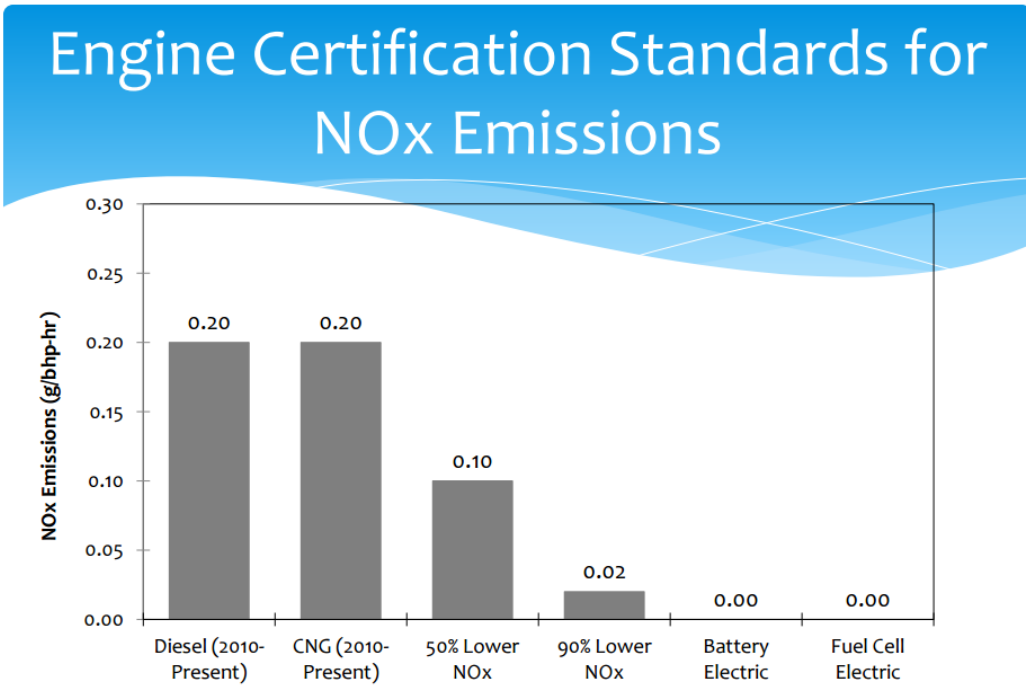


Figure 4 - CARB Engine Certification Standards for NOx Emissions[11]

New and Growing Fleets:

In addition to the success stories outlined below, there are FCEB fleets being introduced or added to across the country.

In an upcoming deployment, Orange County Transportation Authority (OCTA, which serves Anaheim, Santa Ana and surrounding cities) will operate ten new fuel cell buses. In total, 33 new fuel cell buses and four shuttles are planned at several California transit agencies. Twenty of the buses are being manufactured by New Flyer, the largest transit bus manufacturer in North America.[12]

SunLine Transit in Thousand Palms, California, will be the recipient of five of these fuel cell buses, along with an upgraded hydrogen fueling station.[13] Once that upgrade is complete, the publicly-available station will become the largest renewably-sourced hydrogen fueling station in the United States, producing 400 kg of hydrogen daily, and able to fuel 15 buses per day.

By 2018, the Stark Area Regional Transit Authority (SARTA) in Canton, Ohio, will have ten buses, making it the second largest fuel cell bus fleet in the nation behind California.

Manufacturer teams for FCEBs currently operating in the United States

Bus OEM	Length (ft)	Fuel Cell System	Hybrid System	Design Strategy	Energy Storage
Van Hool	40	US Hybrid	Siemens ELFA integrated by Van Hool	Fuel cell dominant	Lithium-based batteries
New Flyer	40	Ballard	Siemens ELFA integrated by Bluways	Fuel cell dominant	Lithium-based batteries
ElDorado	40	Ballard	BAE Systems	Fuel cell dominant	Lithium-based batteries
Proterra	35	Hydrogenics	Proterra integration	Battery dominant	Lithium-titanate batteries
EVAmerica	35	Ballard	Embedded Power	Battery dominant	Lithium-titanate batteries

International bus manufacturers Hyundai, New Flyer, Toyota and Wrightbus are planning to put fuel cell bus models into production, making them available to customers in 2017 and 2018.

Hydrogen stations for U.S. bus refuelings have been supplied by Air Liquide, Air Products, and Nuvera.

Shuttle Buses

The University of Delaware operates two 22-foot, 22-seat shuttle buses and one 40-foot, 42-seat bus that utilize a hydrogen fuel cell/battery hybrid powertrain. They are part of the campus shuttle bus service and are also used for demonstrations and public outreach. The buses also serve as a research platform to study new fuel cell system components and control strategies. Two additional fuel cell shuttle buses are in development for addition to the school's bus fleet.

The Hawaii Department of Transportation plans to operate a fleet of eight fuel cell shuttle buses at Honolulu International Airport in 2018. The project is part of an effort to facilitate early heavy users of hydrogen, starting with public fleets, in order to develop a hydrogen market in the state. The project partnership also includes the federal government and industry.

School Buses

In California, a new program announced in 2017, funded by proceeds from the state's greenhouse gas cap-and-trade program aims to encourage the turnover of California's school bus fleet to zero-emission and cleaner-burning school buses. The $10 million program, known as The Rural School Bus Pilot Project, will provide funding for the purchase of new advanced technology zero-emission fuel cell and battery electric school buses and associated vehicle charging equipment, as well as near-zero-emission plug-in hybrid school buses, or new school buses operating on renewable fuels.[14]

Success Story – AC Transit HyRoad Program

Alameda-Contra Costa Transit (AC Transit), serving the East Bay area in California, has operated fuel cell buses for more than a decade. In 2005, AC Transit unveiled its first fleet of three FCEBs via its HyRoad Program. Those buses transported more than 700,000 passengers and clocked more than 270,000

revenue miles. Today, a fleet of 13 zero-emission buses now has more than 1.8 million miles of service and carried more than 15 million passengers. This is currently America's largest fuel cell-powered bus fleet.[15]

AC Transit has two onsite hydrogen stations to fuel its FCEBs. The Emeryville station dispenses hydrogen made both from natural gas and water, and from water and solar electricity. At its Oakland site, AC Transit has implemented an innovative project: a 420-kW stationary fuel cell, using biogas collected from landfills, produces power that supplies clean electricity for the entire facility and also powers an electrolyzer that produces carbon-neutral hydrogen for the site's hydrogen station.

Linde North America operates the two hydrogen production and dispensing stations for AC Transit's hydrogen fleet. The combined fueling stations have produced than 300,000 kilograms of hydrogen fuel, equivalent in energy to nearly 300,000 gallons of diesel.[16]

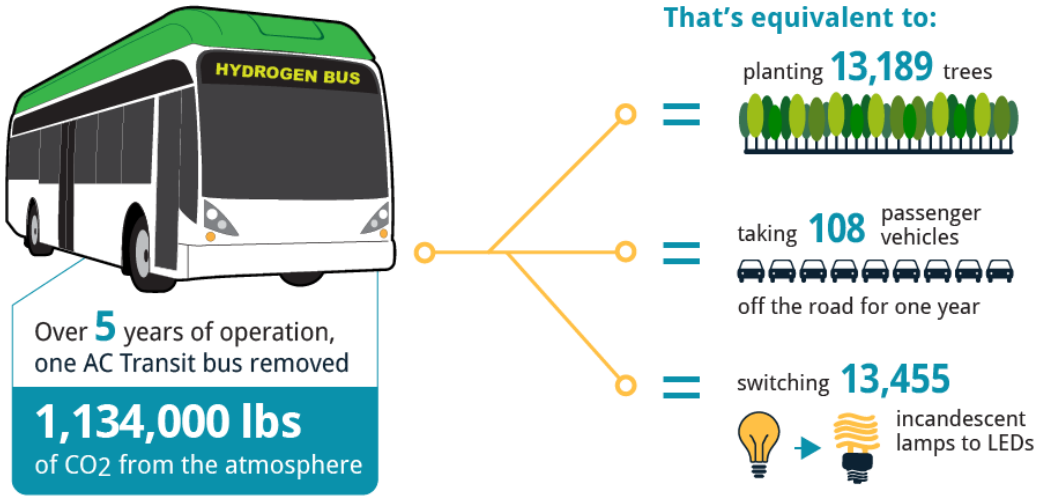


Figure 5 – California Fuel Cell Partnership[17]

Success Story – University of California, Irvine

The University of California, Irvine will become the first college campus in the nation to convert its buses to an all-electric fleet, using battery-powered buses and a fuel cell-powered bus. Going all-electric supports the university's goal to emit net-zero carbon greenhouse gases from buildings and vehicles by 2025.

A demonstration fuel cell bus has been in operation since 2015, covering nearly four thousand miles per month on its assigned route. The school reports that the 40-foot fuel cell bus complies with the Buy American Act that requires more than 60% domestically sourced content. The bus has a range of 260 miles under a typical urban transit cycle, while transporting up to 37 seated and 19 standing passengers.

On its website, the school highlights the benefits of fuel cell electric buses:[18]

- Zero tailpipe pollutant emissions.
- Fuel cell electric buses have better fuel economy than diesel or natural gas buses, and do not have the vibration associated with buses powered by reciprocating engines. As a result, fuel cell buses are quiet and provide a "smoother" riding experience.
- Hydrogen can be produced from several domestic sources (e.g., natural gas, renewable electricity) without dependence on foreign oil.
- Fuel cell electric buses have a significantly longer range than battery-only electric buses.

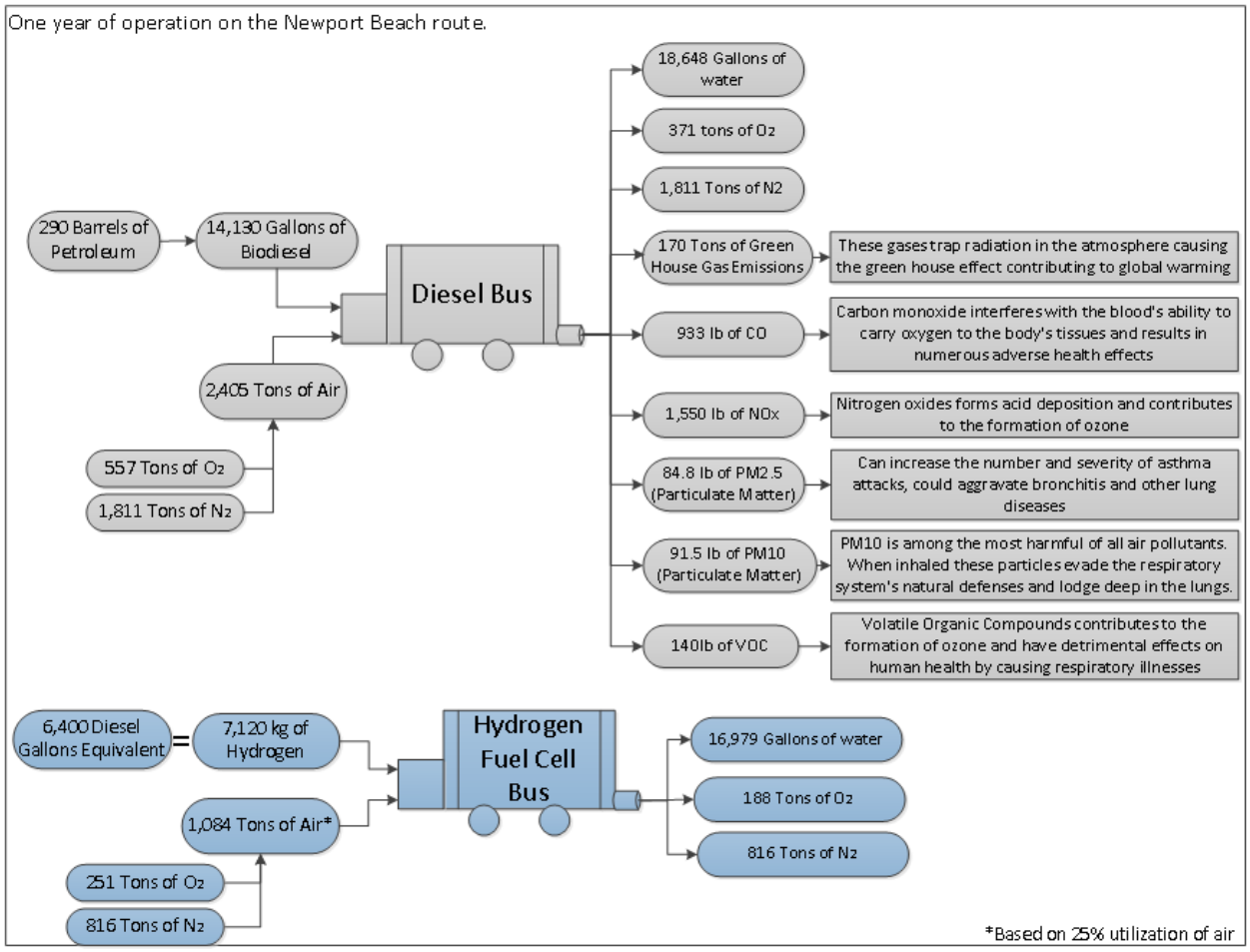


Figure 6 - University of California, Irvine[19]

3) Freight Switchers

The third eligible mitigation action is the repower or replacement of pre-Tier 4 freight switcher locomotives that operate 1,000 or more hours per year. A freight switcher is a locomotive that moves rail cars around a rail yard as compared to a line-haul engine that moves freight long distances.

Since fuel cells are able to scale up to virtually any power size, there have been many demonstrations of fuel cell-powered locomotives over the years, The first fuel cell-powered locomotive was an underground mine locomotive successfully completed and demonstrated in a working gold mine by Vehicle Projects Inc in 2002.[20]

Today fuel cell-powered locomotives and trams are operating in China and Aruba and, soon, a commercial fuel cell passenger train made by Alstom will begin operation in Germany.

Success Story: Vehicle Projects/BNSF Switch Locomotive

In November 2009 a switcher locomotive entered operational testing in the Los Angeles Basin. The North American public-private project partnership was comprised of Vehicle Projects Inc., BNSF Railway Company, and the U.S. Army Corps of Engineers (through its Engineer Research and Development Center Construction Engineering Research Laboratory). The prototype fuel cell-powered shunt (switch) locomotive was developed for urban rail applications.

4) Ferries and Tugs

The fourth eligible mitigation action is repowering ferries and tugs with unregulated Tier 1 and Tier 2 marine engines by installing new Tier 3 or Tier 4 marine engines.

Fuel cells have long been demonstrated in various boats and ferries. According to the Office of Naval Research, in naval vessels, fuel cells are 40 percent efficient compared with gas turbine and diesel engines which are 16 percent and 12 percent efficient, respectively.[21]

At the port of Hamburg in 2008, the world's first fuel cell-powered inland tourism ship, the FCS "Alsterwasser" Zemship (zero emissions ship) was put into operation for two years. Linde built a portside refueling station for the 100-passenger ship, which could be refueled in 12 minutes, and a fuel cell-powered forklift that was also part of the demonstration. The Zemship was able to travel throughout the entire network of routes, including the neighboring lake, canals and the port area.

After Hamburg, other countries followed suit with integrating a fuel cell ferry or ship into their fleets to test the feasibility, including the Netherlands, Finland, Turkey, Germany, and Iceland.

In April 2017, Air Liquide announced a partnership with Energy Observer, the world's first seagoing vessel powered by hydrogen and renewable energies.[22] The catamaran left Saint-Malo, in Brittany, France, to make the first-ever trip around the world - a 6-year world tour of 50 countries with 101 stops. Hydrogen will be produced via the electrolysis of seawater, then compressed and stored for use in a fuel cell.

Success Story: San Francisco Bay Renewable Energy Electric Vessel with Zero Emissions[23]

Hundreds of Bay area residents use water vessels as part of their daily commute. The owner of a Bay-area tourist boat fleet approached Sandia National Laboratories with an interest in zero-emission boat transport. This led to development of the project, which has the goal of determining the technical, regulatory, and economic feasibility of a commercial zero-emission vessel.

This led to "Feasibility of the SF-BREEZE: a Zero Emission, Hydrogen Fuel Cell High Speed Passenger Ferry," a report from Sandia National Laboratories funded by the Department of Transportation's Maritime Administration, and with collaboration with the American Bureau of Shipping (ABS), the US Coast Guard, naval architect Elliott Bay Design Group, the Port of San Francisco, and other contributors, found that it was feasible to build and operate a high-speed passenger ferry solely powered by hydrogen fuel cells.

The San Francisco Bay Renewable Energy Electric Vessel with Zero Emissions (SF-Breeze) used conceptual specifications: a 150-passenger commuter ferry that would travel four 50-mile round-trip routes each day at a top speed of 35 knots (roughly 39 miles per hour) about 60 percent of the time. As part of the next phase, the group is working with Red and White Fleet of San Francisco to optimize the vessel design.

Analysis by Sandia National Laboratories found that, using liquid hydrogen made from renewable electricity, the well-to-wheels emissions would be reduced 75.8% compared to a similar, diesel-fueled vessel, and would lead to a 99.1% reduction in NOx, a 99.2% reduction in hydrocarbons, and a 98.6% reduction in particulate matter (PM).

The cost of the one-off vessel would be higher than a comparable diesel vessel, but Sandia determined that the hydrogen-powered vessel would result in an estimated societal economic benefit of $2.6 million to $11 million over the 30-year lifetime of the ferry. Additional benefits would also include superior response time during power changes (such as during maneuvering), less noise and vibration on-board, and elimination of diesel fuel spills, diesel odor, and exhaust odor.

5) Ocean Going Vessels (OGV) Shorepower

The fifth eligible mitigation action is marine shorepower. Eligible marine shorepower systems provide electric auxiliary power from shore while a boat is docked to allow a vessel's engines to turn off and remain off while the vessel is at berth. It is sometimes known as "hoteling" or "cold-ironing."

Auxiliary diesel engines that provide power to docked ships contribute heavily to the pollution levels at ports. Fuel cells are quiet, reliable, with no criteria or greenhouse emissions and can be sited in many different locations around the port: indoors; on roofs; near buildings; giving flexibility to ports that are constrained for space and replacing diesel engines used for shorepower.

In 2013, Sandia National Laboratories published a report, *Vessel Cold-Ironing Using a Barge Mounted PEM Fuel Cell: Project Scoping and Feasibility,*[24] which found that the most technically viable and commercially attractive deployment options for a hydrogen-fueled fuel cell barge were powering container ships at berth, powering tugs at anchorage, and powering refrigerated containers on-board inter-island transport barges.

Success Story: Maritime Fuel Cell Generator Project[25]

The Maritime Fuel Cell Generator Project, co-funded by DOE's Office of Energy Efficiency and Renewable Energy and the U.S. Department of Transportation's Maritime Administration, was launched in 2013. Led by DOE's Sandia National Laboratory, the project tested a fuel cell as a replacement for a diesel generator used to provide power for refrigerated containers on land and on transport barges. Hydrogenics Corp. designed and manufactured a containerized 100-kW hydrogen fuel cell unit (image at right), which includes the fuel cell, a hydrogen storage system, and power-conversion equipment. The system was built into a standard shipping container.

A six-month field trial was hosted by Young Brothers Ltd., a subsidiary of Foss Maritime Co., at its facility in the Honolulu Harbor in Hawaii.

After using the hydrogen fuel cell unit on land, Young Brothers Ltd., deployed the unit to power refrigerated containers onboard barges traveling between the Honolulu and Kahului harbors.

The fuel cell succeeded in reducing emissions, eliminating more than 5,400 kWhr of diesel power generation.[26]

6) Class 4-7 Local Freight Trucks (Medium Trucks)

The sixth eligible mitigation action is the repower or replacement of Class 4-7 local freight trucks.

Fuel cells have proven themselves as a viable powertrain for MHE, light-duty vehicles, buses, and other vehicles, as well as for range extenders in battery-dominant vehicles.

Success Stories: Hydrogen Fuel Cell Extended-Range Battery Electric Vehicles Demonstrations[27]

DOE provided $3 million for the Integration of fuel cell range extenders from Plug Power into 20 FedEx battery electric pickup and delivery vehicles. The vehicles will operate in Memphis, Tennessee, as well as several California locations.

The project is expected to reduce diesel consumption by 100,000 gallons and reduce CO_2 emissions by more than 270 metric tons.

Another DOE-funded project involves UPS.[28] A team consisting of CTE, Hydrogenics and other partners are developing a fuel cell hybrid electric walk-in delivery van with a 150-mile range per fueling. Objectives of the project include substantially increasing the zero emission driving range and commercial viability of electric drive medium-duty trucks. The project will also determine how competitive fuel cell hybrid electric vehicles are to existing technologies by deploying the fuel cell vans on routes that are also served by diesel, natural gas, and battery electric vans. The team will then retrofit 17 UPS delivery vans to test at distribution facilities across California.

7) Airport Ground Support Equipment

The seventh eligible mitigation action is the repower or replacement of ground support equipment (GSE), including vehicles and equipment used to service aircraft between flights and supporing infrastrcuture.

Ground-based airport GHG emissions are caused by gasoline and diesel fuel use in the facility's GSE. Fuel cells are proving themselves as a viable alternative to batteries in forklifts and lift trucks operating in warehouses and distribution centers, and in Europe, demonstrated in a range of utility vehicles, so expanding to ground support equipment at airports is a logical extension.

Compared to a diesel tow tractor, which is typically 20% efficient, a fuel cell-powered tow tractor is 45% efficient. One of the additional advantages is the regenerative aspect of using an electric vehicle – to stop a diesel tractor, mechanical brakes are applied which releases energy as heat and requires costs and maintenance to change worn or burnt out brake pads. In an electric vehicle, the electric motor can stop the vehicle while changing a portion of that kinetic energy to stored electrical energy.[29]

Success Story: Airport Ground Support Equipment at Memphis International Airport[30]

In order to help reduce consumption of diesel fuels, reduce U.S. demand for petroleum, and lower airport emissions, DOE launched a two-year demonstration of fuel cell-powered cargo tractor was launched at the Federal Express facility at Memphis International Airport in Tennessee in April 2015.

DOE provided $2.5 million, with $2.5 million in cost share from partners electric airport ramp vehicle manufacturer Charlatte America and fuel cell manufacturer Plug Power. Fifteen cargo tractors are being tested at the airport and are expected to save more than 175,000 gallons of diesel fuel over two years, as well as reduce the airport's carbon dioxide emissions by more than 1,700 metric tons.[31] DOE reports

that as of June 2016, the fleet had logged more than 1,800 hydrogen fuelings, 41,100 starts, and 22,000 runtime hours.[32]

8) Forklifts and Port Cargo Handling Equipment

The eighth eligible mitigation action is the repower or replacement of forklifts and port cargo handling equipment.

Over the past half-decade, fuel cells have proven themselves in logistics applications centers as a drop-in replacement for batteries. More than 16,000 fuel cell forklifts are now in operation at warehouse and distribution facilities in 26+ states and in several European countries. End users include major corporations, such as Amazon, Coca-Cola, BMW, Home Depot, Kroger, Sysco, Walmart and Whole Foods Market, as well as smaller companies, such as the Newark Farmers Market. Many are repeat customers with multiple facilities.

Fuel cell inherent attributes have made them a go-to technology with proven value in this application. Users are seeing a host of benefits. These include:

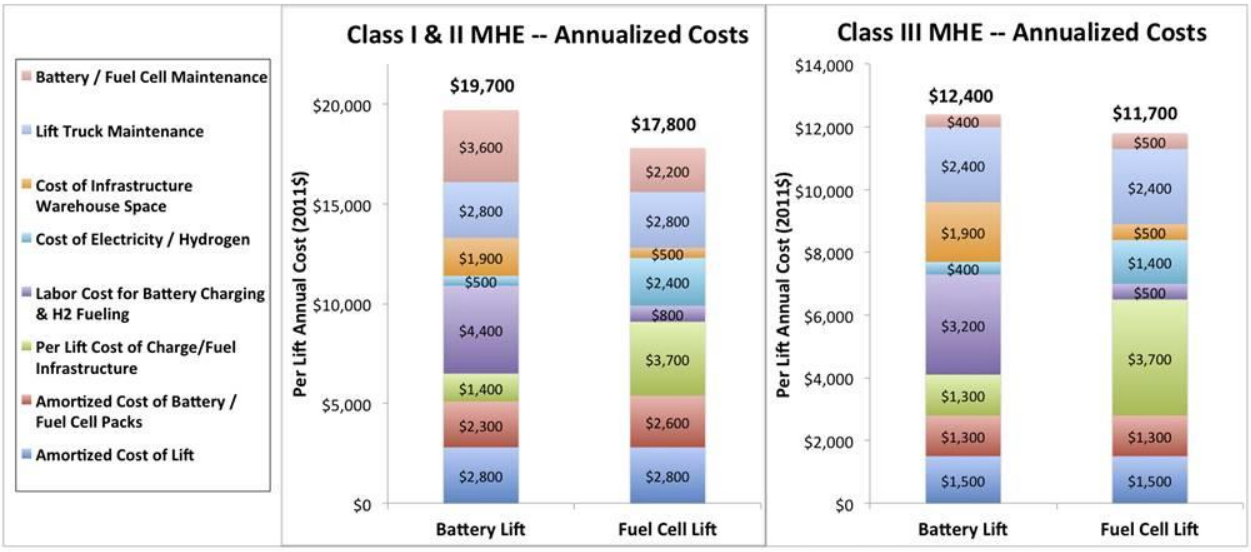
- ***Improved efficiency.*** By using fuel cell-powered forklifts - which are fueled with hydrogen in just two minutes, compared to 13 minutes to change a forklift's depleted battery – Automaker BMW, with its fuel cell forklift fleet in South Carolina, has regained over 156 hours of lost productivity over its three-shift operation, which has an economic value of more than $65 million annually.[33]

- ***Constant, reliable power.*** Fuel cells provide continuous power for material handling equipment throughout the entire shift, with no sag in power generation as is experienced by battery units losing their charge. Fuel cells also operate reliably in cold storage facilities and in sub-zero freezer environments.

- ***Cost savings.*** In large, multi-shift operations, fuel cell forklifts cost 59% less to operate and maintain than battery forklifts.[34] By eliminating the electricity costs for charging hundreds of batteries, businesses can save $75,000 to $225,000 per year.[35]

- ***Space savings.*** Hydrogen infrastructure takes significantly less space than a battery room, recouping around 5,000 square-feet in valuable storage space.[36]

Total Cost of Ownership for Class I, II & III Forklifts[1]



(1) Total cost represents the annualized cost of ownership of Class I, II, and III forklifts on a net present value basis, accounting for capital, operating, and maintenance costs of forklifts, power packs, and infrastructure (labor costs for maintenance and for charging or fueling are included, but labor costs of forklift material handling operations are excluded). Costs are calculated assuming that the material handling operations are ongoing, with equipment replacements made as necessary. Capital, operating, and maintenance costs are assumed to remain constant in real-dollar terms, and capital purchases are discounted using a discount rate representing the time value of money. Fuel cell system costs reflect the current fuel cell tax credit of $3,000/kW or 30% of purchase price. Analysis does not consider the potential productivity increases resulting from the constant power output of fuel cell systems, which may be significant. Costs of ownership of Class II forklifts are expected to be similar for Class I forklifts, though the cost of the lift itself is expected to be higher.

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Costs are based on information provided by deployment host partners (end-users) based on a questionnaire developed by NREL, supplemented with data provided by project partners, and are reflective of the material handling operations of these deployments. Where appropriate, fuel cell deployment data were used in place of end-user questionnaire data; in particular, data from CDPs 1, 6, 8, 14, and 22 were used. Cost assessment will be further refined as additional data are available.

Success Stories – Kroger and Newark Farmers Market

Kroger

After a successful pilot demonstration in Ohio in 2010, in 2012, grocery retailer Kroger ordered 174 Plug Power GenDrive units to replace the lead-acid batteries in class-1, -2, and -3 lift and reach trucks and three hydrogen fueling stations for its Compton, California, distribution center. This facility supplies groceries for Ralphs markets.

Kroger reports that the Compton site has experienced decreasing maintenance costs and a return on investment (ROI) of approximately 20% to date. The fuel cells are running longer (1.5 times more operational time and two times more for class-3 vehicles) than lead-acid batteries and operate at consistent speed and power with quick refueling.[37]

In 2014, Kroger expanded its fleet and deployed additional fuel cells at other distribution centers, including Stapleton, Colorado (120) and Louisville, Kentucky (185). According to the company's 2015 Sustainability Report, Kroger now has more than 1,000 fuel cells powering forklifts and pallet jacks at six locations throughout the U.S.[38]

Newark Farmers Market

Newark Farmers Market has used fuel cell-powered forklifts since 2011, with its original fleet of more than 100 vehicles accumulating more than 625,000 hours of run time.

In November 2014, Newark Farmers Market expanded its fuel cell material handling fleet by purchasing an additional 110 GenDrive units for a new refrigerated food distribution building at its Newark, New Jersey, site. The 25 class-2 standup reach truck units and 85 class-3 pallet jack units that will operate in temperatures kept at a constant 28 degrees F.

The site uses a hydrogen infrastructure that includes indoor dispensers and outdoor fuel storage. The outdoor infrastructure includes a 15,000 gallon hydrogen tank with dual redundant pumps and gas compressor.

Port Cargo Handling Equipment

Fuel cell-powered material handling equipment has also been test in port and other maritime applications. Port managers are seeking to reduce localized emissions and have been investigating fuel cells and hydrogen as a possible solution.

In 2008, the port of Hamburg (Germany) was one of the first to showcase the potential of fuel cells in port logistics, conducting a two-year trial of a fuel cell-powered forklift in the port's warehouse.

Vuosaari Harbor at the Port of Helsinki, Finland, has also demonstrated fuel cells in a variety of port applications aiding electricity delivery, cargo handling, communications, and logistics. In addition, a 50-kilowatt solid oxide fuel cell (SOFC) system, portable fuel cells and metal hydride storage for boats, and a hydrogen fueling station were all part of the demonstration at Vuosaari Harbor.

9) Light Duty Zero Emission Vehicle Supply Equipment

The ninth eligible mitigation action is light-duty Zero Emission Vehicle supply equipment.

Beneficiaries may use up to 15 percent of their allocation of trust funds for the acquisition, installation, operation and maintenance of new light duty zero emission vehicle supply equipment. Eligible equipment includes light duty hydrogen fuel cell vehicle supply equipment, and hydrogen dispensing equipment capable of dispensing hydrogen at a pressure of 70 megapascals (or analogous successor technologies) that is located in a public place.

Currently, more than two dozen retail hydrogen stations operate in California, a state encouraging greater deployment of zero-emission vehicles (ZEVs), including FCVs. California's Assembly Bill 8 (2013) dedicates up to $20 million per year to support continued construction of at least 100 hydrogen fuel stations. About 50 stations are anticipated to be open by the end of 2017. Stations are developed through a cost-share arrangement with industry, with competitive grants awarded to bidders through

periodic California Energy Commission solicitations. California projects that FCVs in the state will grow to more than 13,000 vehicles in 2019 and more than 43,000 by 2022.
Industry is also funding the expansion of hydrogen stations in northeastern states, with Toyota and Air Liquide set to open the first six of twelve initial retail stations in Connecticut, Massachusetts and New York in 2017 and 2018.[39]

There are many other hydrogen stations and dispensing units located around the country, fueling FCEBs, material handling vehicles, and more.

Hydrogen dispensers fuel vehicles in a manner similar to fueling a vehicle with gasoline, by attaching the nozzle to the vehicle. Fueling is accomplished in three-to-five minutes for light duty vehicles. Hydrogen is delivered to stations (the U.S. produces about 10 million metric tons of hydrogen annually) or can be produced onsite by electrolysis of water. California requires that at least a third of hydrogen at stations be sourced from renewables.

DOE's hydrogen cost target is less than $4/gallon gas equivalent in high volume. The National Renewable Energy Laboratory reports that, with FCV volume (400,000-800,000 vehicles), station capital cost reductions may be on the order of 70% below current costs.

Success Story: California Energy Commission Alternative and Renewable Fuel and Vehicle Technology Program[40]

The California Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) is a competitive grant program that provides as much as $100 million annually towards innovative transportation and fuel technologies that help California meet its energy, clean air, and climate-change goals. Hydrogen fueling is included.

In 2013, Governor Brown signed AB 8 that extended ARFVTP until 2024 and designated up to $20 million a year for hydrogen stations through 2023 with the aim of having 100 hydrogen stations statewide. It also required an annual evaluation to ensure that infrastructure and vehicles keep pace, and provided flexibility to adjust the funding in any given year as recommended in the evaluation. Between 2010 and 2015, the Energy Commission granted more than $64 million to support the building or upgrading of 47 hydrogen fueling stations.

The program has significant investment from industry, with a range of companies providing matching funds for awarded projects.

10) Diesel Emission Reduction Act (DERA) Option

The tenth eligible mitigation action is use of Trust funds for a Beneficiary's non-federal voluntary matching fund contribution to Diesel Emission Reduction Act (DERA) DERA-funded projects.

DERA provides funding for projects that reduce emissions from existing diesel engines. Authorized under the Energy Policy Act of 2005 and administered by U.S. EPA, DERA is designed to help replace or retrofit older, dirtier engines still in use with clean diesel or alternative fuel engines, reducing exposure to diesel exhaust and improving human health and the environment.

The DERA option under the Volkswagen Settlement provides states with an opportunity to increase their funding by using environmental mitigation trust funds as a voluntary match. For example, if State X receives $100,000 in formula DERA funds this year, the state can use environmental mitigation trust funds to provide a $100,000 voluntary match. Because State X provided a 1-1 voluntary match, they are eligible to receive an additional $50,000 from DERA, bringing the project total to $250,000.

The DERA option also allows beneficiaries to use trust funds for actions not specifically enumerated in the consent decree, but otherwise eligible under DERA pursuant to all DERA guidance documents available through U.S. EPA. Table 23: Vehicles Eligible for Emission Reduction Actions under DERA34, in NASEO's Volkswagen Settlement Beneficiary Mitigation Plan Toolkit compares the actions covered under the VW mitigation trust compared to the actions covered under the DERA option.

It shows that included in VW settlement under "Port Cargo Handling Equipment" are rubber-tired gantry cranes, straddle carriers, shuttle carriers, and terminal tractors, including yard hostlers and yard tractors that operate within ports. There are additional technologies included in DERA that are not listed in the VW settlement, including:

- Non-road engines equipment or vehicles used for handling of cargo at port or airport
- Non-road engines equipment or vehicles used for Construction
- Non-road engines equipment or vehicles used for Agriculture non-road engines equipment or vehicles used for Mining
- Non-road engines equipment or vehicles used for Energy Production including stationary generators or pumps

Since the DERA Option allows for use of Trust Funds for actions not specifically listed but otherwise eligible under DERA, this opens up opportunities for fuel cells to replace diesel equipment or vehicles at ports, airports, construction, mining and energy production.

There are already thousands of fuel cell systems replacing diesel generators across the United States at a variety of sites – telecommunications towers, railroad switching and signal stations, government facilities and utility networks – to provide constant power in case of weather or other outages to the grid or communications lines. Customers include major telecommunications companies such as AT&T, T-Mobile, and Sprint, and railroad companies BNSF, CSX, and Union Pacific Railroad. Fuel cells can operate independently of the electric grid and can be sited in remote areas, helping keep customers connected and keep critical communications running smoothly. Forty-one states have fuel cells installed in at least one of these sectors.

Fuel cells are also increasing being deployed in construction, mining and energy production/exploration, providing off-grid power to remote monitoring equipment, chemical injection pumps at oil and natural gas well head sites, cathode protection, mobile lighting, and surveillance. Benefits of the technology in these applications include longer operation between fuelings, running for days or weeks at a time, reducing trips to deliver fuel to diesel or propane generators or to replace spent batteries. The fuel cell's higher efficiency adds up to savings. One fuel cell manufacturer serving this market predicts cost savings on propane to equal $2,790 per site per year. Fuel cells are also rugged and able to operate in harsh terrain and cold or hot climates.

At ports, the offloading of cargo from docked ships is typically powered by a diesel engine generator near the top of the crane or, more commonly, by electric power onshore. Currently there are more than 16,000 fuel cell-powered forklifts moving goods in distribution centers and warehouses across the country, which could easily be replicated at ports and/or airports for cargo handling, reducing trips to deliver fuel to diesel or propane generators or to replace spent batteries.

Success Story: Fuel Cell Mobile Lighting at Alcatraz Island National Park Embarkation Dock[41]

A portable fuel cell-powered mobile light tower successfully provided light in an overnight barge exchange operation at the Alcatraz Island National Park in San Francisco, California. The 'Zero-Set Lite' from Luxfer-GTM Technologies uses a Plug Power fuel cell and is able to provide up to 36 hours of continuous LED lighting.

The operation was part of a planned maintenance period for the Island's embarkation dock, which serves approximately 5,000 visitors per day, and was undertaken by Alcatraz Cruises, official National Park Service concessioner for ferry service to Alcatraz Island.

Alcatraz Cruises crew and subcontractors were able to work throughout the night in inclement weather. The fuel cell-powered lighting system operated quietly throughout the night in inclement weather, allowing crews to see and hear each other clearly with no noise, diesel fumes, or chance of fuel spills.

Conclusion

The Trust is a unique opportunity for states, tribes and territories to significantly reduce NO_X emissions from the transportation sector while also achieving complementary energy, environmental, health and economic development goals. To access allocated funds, states must apply to become a beneficiary and develop a Beneficiary Mitigation Plan that provides a high-level summary of how they intend to use their allocated funds.

As outlined in this supplemental toolkit, fuel cell and hydrogen technologies are being developed, deployed and utilized in each of the ten eligible mitigation action categories and should be considered by states to be included in their plans.

The combination of benefits fuel cells provide is helping customers and early adopters reduce emissions while improving efficiency and reliability. The market sectors where the technology is making the most impact are directly related to action categories.

- In material handling, the increased productivity resulting from faster refueling and full-power operation throughout the shift, is also translating into cost savings. The experience of more than 16,000 fuel cell-powered MHE in warehouses, distribution centers, and cold storage facilities across the country and around the world, is being used to expand the market into ports and airport logistics to power MHE, utility vehicles and GSE.

- Telecommunications companies, utilities, and railroads worldwide are turning to fuel cells to expand networks and provide reliable primary or backup power and longer run times, while simultaneously benefitting from lower emissions and quiet operation. The technology's high reliability, plus the reduced maintenance and fueling trips at remote locations make fuel cells a competitive technology, especially to replace diesel generators.

- Fuel cell vehicles are now commercially available in California, with the supporting hydrogen fueling network growing. Since fuel cells are scalable, the technology is being integrated into larger vehicles such as buses, trains, ferries, delivery vans, and heavy-duty trucks.

Fuel cells, in vehicles and other applications, and hydrogen can bring transformational innovation, economic and job growth to states, while reducing emissions and helping meet goals set in Beneficiary Mitigation Plans and other state initiatives.

Appendix 1: List of Resources:

Assessment of Fuel Cell Technologies to Address Power Requirements at the Port of Long Beach
http://www.polb.com/civica/filebank/blobdload.asp?BlobID=13597
This report describes the potential application of fuel cells to meet the electric power generation and vehicle power requirements of the Port in the context of high efficiency and environmental sensitivity.

California Fuel Cell Partnership Hydrogen Station Map
http://cafcp.org/stationmap
The California Fuel Cell Partnership, industry/government collaboration, has created a map tracking the deployment of hydrogen stations across the state.

Economic Impact of Fuel Cell Deployment in Forklifts and for Backup Power under the American Recovery and Reinvestment Act
https://energy.gov/sites/prod/files/2014/03/f12/economic_impacts_of_arra_fc.pdf
This report by Argonne National Laboratory presents estimates of economic impacts associated with expenditures under the American Recovery and Reinvestment Act, also known as the Recovery Act, by the U.S. Department of Energy for the deployment of fuel cells in forklift and backup power applications.

Fuel Cell and Hydrogen Energy Association
http://www.fchea.org
The Fuel Cell and Hydrogen Energy Association (FCHEA) represents the leading companies and organizations that are advancing fuel cell and hydrogen energy technologies.

Fuel Cell Buses in U.S. Transit Fleets: Current Status 2016
https://energy.gov/sites/prod/files/2017/02/f34/fcto_fceb_status_2016.pdf
This report by the National Renewable Energy Laboratory (NREL), published annually, summarizes the progress of fuel cell electric bus development in the United States and discusses the achievements and challenges of introducing fuel cell propulsion in transit. The 2016 summary results primarily focus on the most recent year for each demonstration, from August 2015 through July 2016. The results for these buses account for more than 550,000 miles traveled and 59,500 hours of fuel cell power system operation.

Fuel Cell Technology for Backup and Supplemental Power Applications
https://www.arema.org/files/library/2014_Conference_Proceedings/Fuel_Cell_Technology_For_Backup_And_Supplemental_Power_Applications.pdf
This 2014 report, prepared for CSX by Aroma, explores the fuel cell development and application in the railroad environment. It addresses the similarities and differences of traditional battery and generator backups. It addresses some of the myths surrounding fuel cell technology and discusses CSX's experience with fuel cells, including both the challenges and the opportunities for the present and future.

Hydrogen Station Cost Estimates: Comparing Hydrogen Station Cost Calculator Results with other Recent Estimates

http://www.nrel.gov/docs/fy13osti/56412.pdf

This report, from National Renewable Energy Laboratory (NREL), compares hydrogen station cost estimates conveyed by expert stakeholders through the Hydrogen Station Cost Calculation (HSCC) to a select number of other cost estimates.

Maritime Hydrogen & SF-BREEZE

http://energy.sandia.gov/transportation-energy/hydrogen/market-transformation/maritime-fuel-cells/

Sandia National Laboratories webpage highlighting all of its maritime fuel cell projects including the San Francisco Bay Renewable Energy Electric vessel with Zero Emissions (SF-BREEZE), Maritime Hydrogen Fuel Cell Project, and the Zero Emissions Research Oceanographic Vessel (ZERO/V).

National Renewable Energy Laboratory (NREL) Fuel Cell and Hydrogen Technology Validation

http://www.nrel.gov/hydrogen/proj_tech_validation.html

The NREL technology validation team works on validating hydrogen fuel cell vehicles; hydrogen fueling infrastructure; hydrogen system components; and fuel cell use in early market applications such as material handling, backup power, and prime-power applications. Technology validation projects involve gathering extensive data from the systems and components under real-world conditions, analyzing this detailed data, and then comparing results to technical targets.

Port of the Future

http://hfcarchive.org/fuelcells/uploads/Port-of-the-Future.pdf

Highlights various applications at ports where fuel cells could be integrated. Includes historical references of past demonstrations.

Appendix 2: List of Companies

Examples of Fuel Cell and Hydrogen Companies with Commercially Available Products			
Company	Website	Product (s)	Mitigation Action Served
Air Liquide	https://www.airliquide.com/connected-innovation/hydrogen-quiet-revolution	F Series, B200, C Series	All
Air Products and Chemicals, Inc.	http://www.airproducts.com/industries/Energy/Hydrogen-Energy.aspx	SmartFuel®	All
Altergy Systems	http://www.altergy.com/	Freedom Power™	10
Altrex Energy	http://www.atrexenergy.com/	RP Series, ARP Series	10
Ballard Power Systems	http://www.ballard.com	FCveloCity®, FCgen®-H2PM	1, 2, 10
FirstElement Fuel	http://www.truezero.com/, http://www.firstelementfuel.com/	True Zero	All
Hydrogenics	http://www.hydrogenics.com	Celerity, CelerityPlus, HD90, HD180, HyPM™, HyPM™-XR	1, 2, 3, 5, 6, 7, 8, 9
ITM Power	http://www.itm-power.com/	HGas, HPac, HFuel	All
Linde	http://www.the-linde-group.com/en/clean_technology/clean_technology_portfolio/hydrogen_energy_h2/experience_h2/index.html	Large, small and mobile hydrogen fueling stations, HYDROPRIME	All
Luxfer-GTM	http://www.luxfergtm.com/	G-Pak, Zero-Set	4, 5, 6, 7, 8, 9
Nel Hydrogen	http://nelhydrogen.com/	H2Station®, Nel A Electrolyzers	All
Nuvera Fuel Cells	http://www.nuvera.com/	Nuvera® Fuel Cell System for forklift trucks, Nuvera® Fuel Cell Engine, Nuvera® Hydrogen Generator, Nuvera® Hydrogen Fueling Station	2, 6, 7, 8. 9
Oorja Fuel Cells	https://oorjafuelcells.com/	Model 3, Model T-1, Stationary Refueling Station, Mobile Refueling Station	7, 8
Plug Power	http://www.plugpower.com	GenDrive, GenSure, GenFuel	6, 7, 8, 9, 10
Proton OnSite	http://www.protononsite.com/	G Series, G4800, S Series, H Series, C Series, M Series	All
US Fuel Cell/US Hybrid	https://www.usfuelcell.com/, http://www.ushybrid.com/	FCe™80, FCe™150	1, 2, 6

Endnotes

[1] https://www.naseo.org/Data/Sites/1/03-27-17_naseo-vw-beneficiary-mitigation-plan-toolkit-final.pdf
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