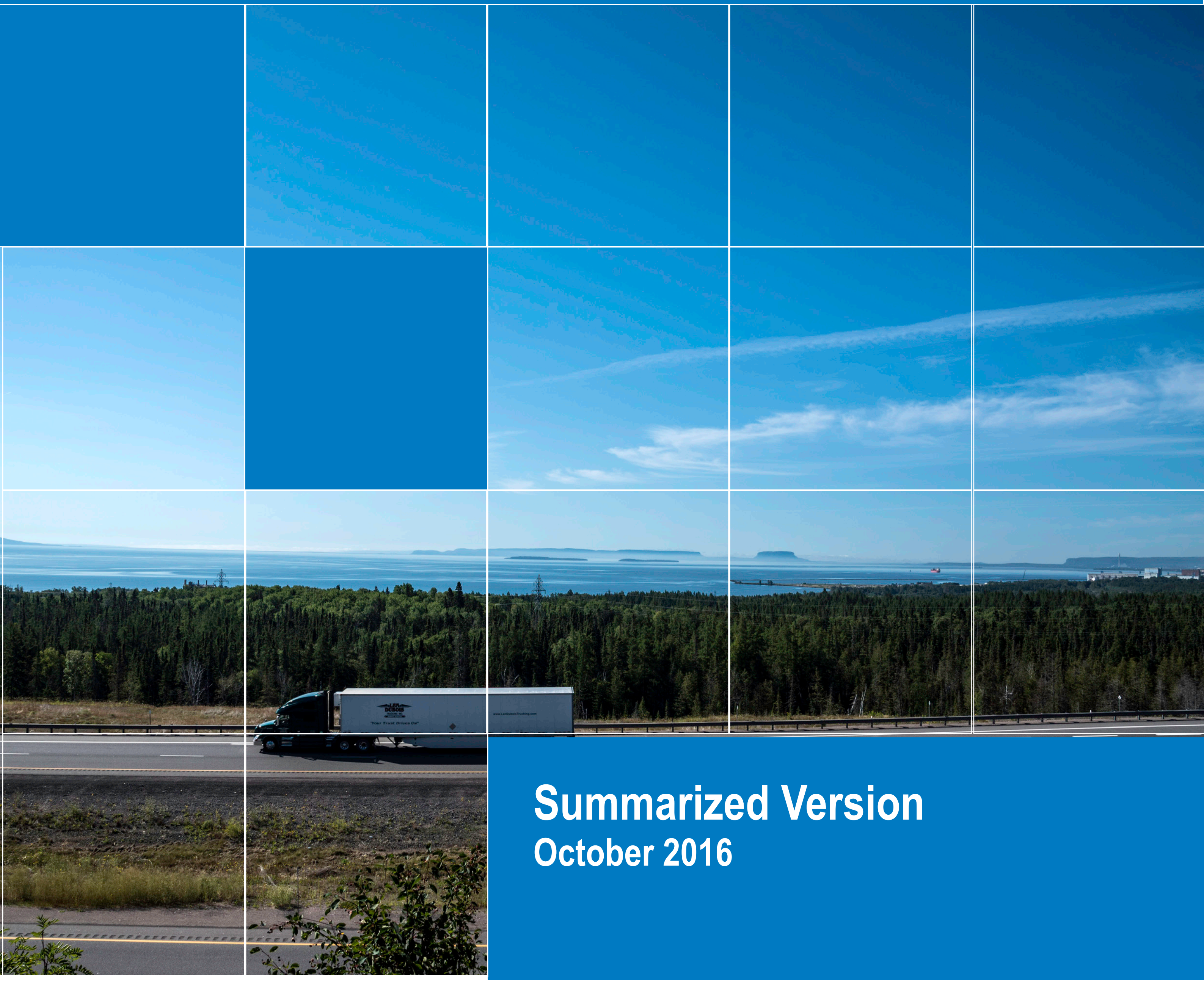
MEDIUM- & HEAVY-DUTY FUEL CELL ELECTRIC TRUCK ACTION PLAN FOR CALIFORNIA



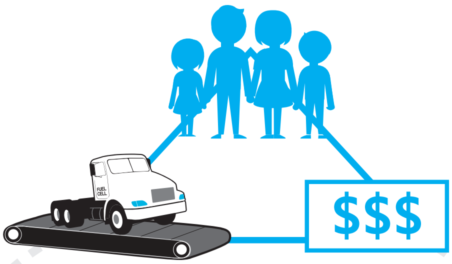
Summarized Version

October 2016

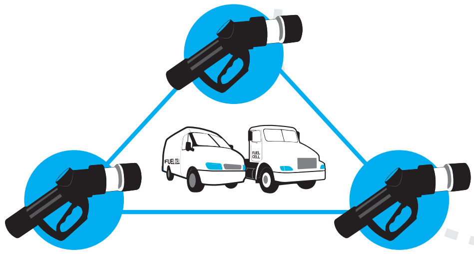
California Fuel Cell Partnership

DRIVING FOR THE FUTURE

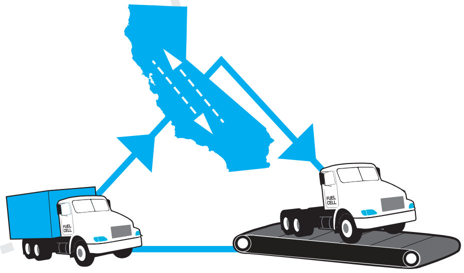
Goals



Help create a sustainable business case to truck manufacturers



Establish the necessary hydrogen infrastructure for trucks



Successfully demonstrate fuel cell trucks to spur more development

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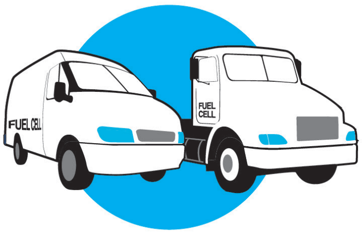
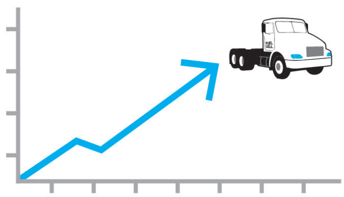
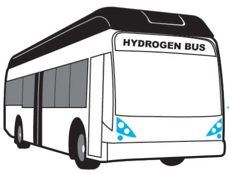
Key Elements



Focus on Class 4 parcel delivery trucks and Class 8 drayage trucks



Establish metrics for measuring progress



20,000+
HOURS CLEAN & GREEN ENERGY

Leverage bus experience

Overview

In California, vehicles are the leading contributors of air pollution and greenhouse gas emissions, and, medium- and heavy-duty vehicles are one of fastest-growing sources of emissions and energy consumption. Transitioning today's trucks from mostly diesel to zero emission fuels can significantly reduce the negative environmental impacts of freight transport.

This paper summarizes the *Medium- and Heavy-Duty Fuel Cell Truck Action Plan for California*, which makes recommendations for three over-arching actions:

1. Help create a sustainable business case to truck manufacturers
2. Establish the necessary hydrogen infrastructure for trucks
3. Successfully demonstrate fuel cell trucks to spur more development.

Demonstration Projects

According to the California Energy Commission, medium- and heavy-duty vehicles with a gross vehicle weight rating above 10,000 pounds represent 3% of registered vehicles, yet produce 23% of on-road greenhouse gas emissions. State incentive programs encourage market introduction of more efficient, low-emission MD and HD vehicle technologies that have largely concentrated on cleaner diesel and natural gas. Zero emission vehicle regulations and incentives have been directed at the passenger vehicle market.

In July 2016, the *California Sustainable Freight Action Plan* was published. Its aim is to improve freight efficiency, transition to zero emission technologies, and increase competitiveness of California's freight system. Among other targets the plan calls for deploying more than 100,000 freight vehicles and equipment capable of zero emission operation and maximizing near-zero emission freight vehicles and equipment powered by renewable energy by 2030.

"Truck" is a broad term that encompasses many vehicles, from Class 8 long-haul tractor/trailers to Class 2 and 3 pick-up trucks and vans. Research for this paper identified Class 4-6 package delivery trucks and Class 8 drayage trucks as the first targets for demonstration vehicles that can lead to on-road vehicles in by 2020 in California.

Small demonstration fleets of drayage and package delivery trucks in California have already been funded and are under development. They will validate technology and provide essential operational data. To be successful in operation and encourage investment in additional fuel cell trucks, permanent hydrogen fueling stations must be installed and operating.

Today's heavy-duty vehicles use dedicated stations, and many package delivery trucks use fleet stations. Heavy-duty fuel cell vehicles will require the same. It is unlikely that trucks will use mobile or temporary fueling due to the cost, and few passenger vehicle stations for any fuel are designed for large vehicles.

The experience gained from demonstrations can transfer to other truck applications and other states, and establish a road map for deploying fuel cells throughout the freight industry.

The *Action Plan's* recommendations for industry and government will help advance and incentivize fuel cell electric trucks and hydrogen infrastructure.

Fuel Cell Electric Vehicles

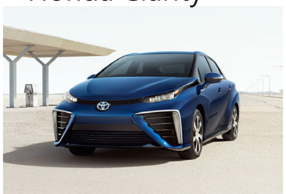
Fuel cells create electricity from hydrogen, stored onboard the vehicle as a compressed gas, and oxygen from the air. When the hydrogen molecules come into contact with a catalyst inside the fuel cell, a chemical reaction converts the energy stored in the hydrogen into an electric current. A fuel cell will create a current as long as it has fuel. When the fuel supply is shut off, the reaction stops and therefore, so does the current.

Light-duty FCEVs are available in California, and more makes and models are coming between 2017 and 2020. Passenger FCEVs travel about 300 miles on a tank of hydrogen and refill in under five minutes. FCEVs are also available in Europe and Asia, and coming to the Northeast U.S. in 2017.

Fuel cell electric buses are in operation with transit agencies and universities around the world. All are demonstration programs that are showing increasing availability and reliability. FCEBs have a range of about 300 miles, which equates to about 16 hours of operation, and refill in about 10 minutes.

Passenger Vehicles

Honda Clarity



Toyota Mirai

Mercedes-Benz GLC

Hyundai Tucson Fuel Cell

Transit Buses

AC Transit

SunLine Transit

Orange County Transit

UC Irvine Student Transportation

Hydrogen Stations

“Hydrogen stations” consist of equipment for storage, compression, and dispensing. All vehicles use hydrogen as a gaseous fuel, although it may be stored on site as a liquid.

Hydrogen stations for light-duty vehicles are usually located at existing gas stations. Transit buses use dedicated hydrogen stations. Most hydrogen is produced at a central facility and transported by truck or pipeline to the station, although hydrogen can also be produced on site from electrolysis of water or from biogas. In California, 33% of hydrogen for transportation must be produced with renewable sources.

Filling a fuel cell passenger vehicle takes about five minutes, and a bus can fill in less than 10 minutes—about the same time as filling a car or bus with a liquid fuel. In every type of fuel cell electric vehicle, hydrogen is two-to-three times more efficient than gasoline or diesel in a conventional vehicle.

La Cañada Flintridge


Emeryville


West Sacramento


Irvine

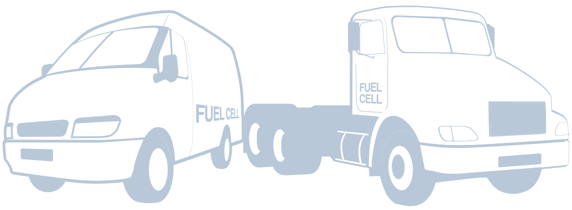
Sustainable Business Case for FCETs

Although truck manufacturers have been investing in electrification to increase fuel economy, no truck manufacturer has plans to build commercial fuel cell trucks. Like most companies, truck OEMs look to recover R&D costs through future volume sales throughout North America. In collaboration with truck OEMs and industry consultants, the *Action Plan* researchers created a diagram that breaks the business case for new vehicle technologies into major elements.

Cost and technology advancement must be addressed at the same time. Based on experience with fuel cell buses, passenger vehicles, and hydrogen stations, the Action Plan recommends:

- Near-term demonstrations to serve as proof of concept and/or for demonstration purposes to collect data, understand gaps, and learn about the long-term feasibility of the technology.
- Vehicle and building codes and standards for integrated medium- and heavy-duty fuel cell electric drive systems and the supporting fueling infrastructure to ensure safety and reduce costs.
- Stable and consistent long-term policies and regulations related to petroleum reduction and air quality improvement.
- Assessments of Technology Readiness Levels, impact of ZEVs in 2031 and 2050, incentives, and market readiness.

In simple terms, near-term vehicle fleet demonstrations are important to provide a basis for setting longer-term goals that can lead to the cost reductions necessary for commercialization.



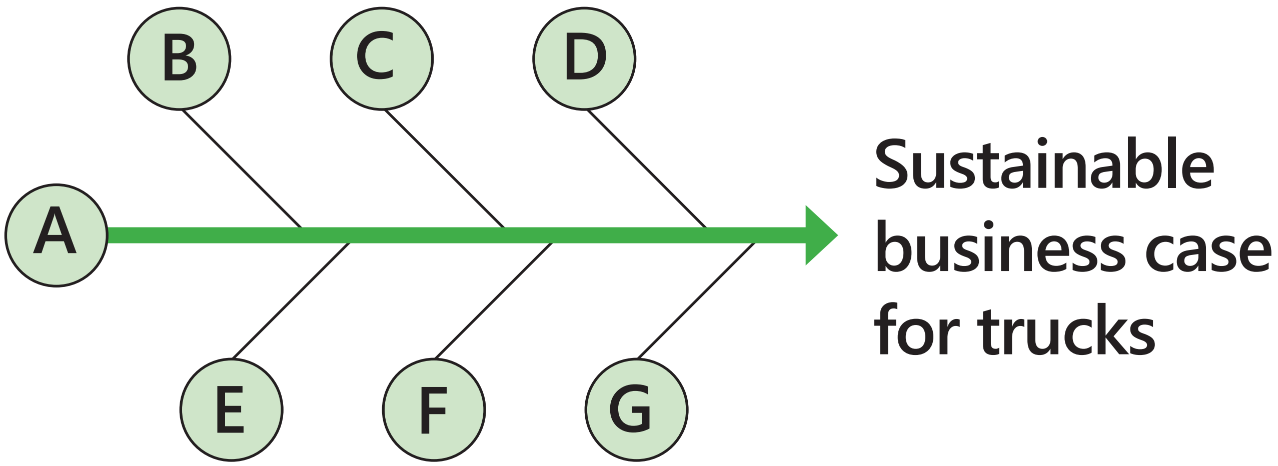
Truck Vocations

CaFCP members recommend focusing near-term (before 2020) efforts on two types of vehicles:

- Medium-duty Class 4-6 “last-mile” delivery trucks that transport packages from a distribution hub to the surrounding community and return to the hub at the end of the operating shift.
- Heavy-duty Class 7-8 drayage trucks[1] in a tractor-trailer configuration that transport freight over a short distance, generally from an ocean port to a rail loading area, warehouse, or other similar destination (or vice-versa).

These vocations align with the needs in the Air Resource Board’s Sustainable Freight and Mobile Source Strategy and will provide stakeholders with operational data and lessons learned to consider expanding demonstration projects to other geographies and other vehicle vocations and classes.

1 Although referred to as “drayage trucks,” OEMs do not manufacture or market truck models identified as such, but as HD trucks that have many applications and can be used by freighting companies for drayage operations.



A. Meets customer cost and operational requirements, including ability to obtain financing and plan for fleet purchasing

B. Favorable operating environment, including broad industry support of technology (including manufacturers and suppliers)

C. Supportive and consistent legislative and regulatory framework

D. OEM "essentials," including the ability to leverage existing manufacturing lines and components, a line of sight to volume sales, and revenue to sustain operations during a demonstration program

E. Incentives that match the development schedule, such as manufacturing incentives in the beginning and customer incentives later on

F. Reliable, accessible, and affordable fueling

G. Go/no-go milestones that identify trucks that may never transition to ZEVs and provide time for iterations to meet minimum requirements.

Recommendations for Technology Advancement

- **Transfer the lessons learned from fuel cell bus programs to truck vocations, especially as they relate to technology and financial risk.**

California hosts the two largest fuel cell electric bus (FCEB) programs in North America at Alameda-Contra Costa Transit Agency (AC Transit) and SunLine Transit Agency. These demonstration programs are showing increasing FCEB availability, reliability and cost reductions. SunLine and AC Transit have on-site, self-provided technician training programs and operate heavy-duty hydrogen fueling stations. These two programs, along with others in the U.S., have already created a wealth of knowledge that transfers to trucks.

- **Collect data using a consistent set of variables for comparison, feasibility assessments, and decision making; this should be a basic requirement for all government-funded truck projects**.
- **Prove reliability of FCETs to show the cost-per-mile of transported freight.**

CaFCP offers the following as minimum operational targets are that can provide clearly-stated national targets for fuel cell demonstration trucks. (The Action Plan has more detail on these proposed metrics.)

Parameter	Medium Duty		Heavy Duty	
	Fuel Cell	Baseline	Fuel Cell	Baseline
Miles between fueling	>125	400	100-200	400
Performance	0-60 in 26 sec	0-60 in 12 sec	1,200-1,800 ft-lbs of torque	1,200-1,800 ft-lbs of torque
Top speed (mph)	65	85	62-65	62-65
Refueling interval	1 day	Multiple days	1-2 days	2-4 days
Operates for	12 hrs	14 hrs	10-14 hrs	10-14 hrs
Route flexibility	95%	100%/full service	"Full service"	"Full service"
Grades	15%	15%	6.5%	6.5%
Durability (miles)	TBD	300,000 miles	~500,000 miles	~500,000 miles
Durability (years)	10-12	22 years	≥8 years	≥10 years
Availability	95%	≥98%	≥90%	≥90%
Warranty	TBD	3 yrs/50,000 miles	TBD	3 yrs/300,000 miles

- **Assume a timeline of 7-15 years for developing new truck platforms with completely new propulsion and power train systems.**

Transit bus fuel cell systems, fuel storage systems, and hybrid drive train systems can be expected to transfer to fuel cell trucks, but buses are not an exact match for trucks. Buses are designed for low-speed, start-and-stop duty cycle while trucks are designed for highway speeds and carrying freight instead of people. Individual components may transfer platforms, but truck manufacturers will need new integration approaches.

The balance between batteries and fuel cells is another important consideration. Most fuel cell vehicles also have batteries to capture energy from breaking and augment power from the fuel cell. Truck manufacturers will also need to test and evaluate hybridizing the drive train.

- **Build a mutual understanding of the truck manufacturing process among all stakeholders.**
- **Establish separate groups (drayage and package delivery) to provide realistic information about baseline requirements for vehicle technology, operational cycles, supplier expectations, etc.**

In 2008, CaFCP started outreach with the gas station industry to better understand their business models, development process, and operational needs that helped form the deployment of today's retail hydrogen stations.

In 2010, the U.S. EPA established the SuperTruck program that provided grants to teams of truck manufacturers to invest in R&D designed to increase the fuel economy of diesel-powered long-haul "18 wheelers."

CaFCP started building relationships with truck OEMs to gather input for the Action Plan, and the relationship needs to continue to build in the coming years. It is important for industry and government to recognize needs, targets, expectations, and processes that can lay the foundation for a sustainable market and address technology advancements that benefit the industry as a whole. This collaboration has worked well within CaFCP to introduce passenger FCEVs and we anticipate similar results for FCETs.

Recommendations for Cost Reduction

- **Support fuel cell electric bus Centers of Excellence to prove infrastructure and fuel cost reduction, and develop expertise and understanding about hydrogen fueling for large fleets.**

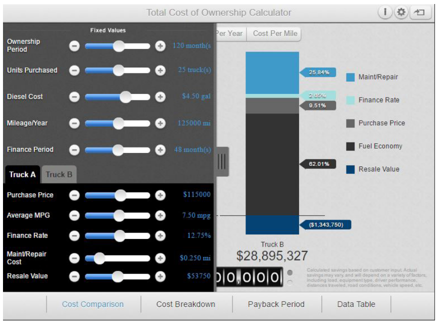
AC Transit and SunLine are becoming Centers of Excellence and will deploy between 20 and 40 buses each, which is a production run large enough to reduce the capital cost per bus at or below $1 million[1] and help achieve fuel costs that are competitive with diesel on a per-mile basis. Funding for both COEs was estimated at $30 to $50 million to purchase buses, build high-capacity hydrogen stations, retrofit maintenance facilities, and provide some O&M costs.[2] Because vehicle and station technology is directly transferrable other heavy-duty vehicles and stations, funding the COEs will help reduce component and fuel costs, leverage the supply chain, and potentially reduce the time needed for product development.

- **Establish targets and priorities for future fuel cell electric truck funding programs**.

According to established truck OEMS, stable and consistent long-term policy, regulations, and expected return on investment are directly related to the potential for cost reduction and the decision to invest in new vehicle technology development.

- **Initiate, expand, and direct national efforts to perform in-depth studies of fuel cell technology in trucks to understand the components of the total cost of ownership and opportunities for cost reduction.**

The total cost of ownership (TCO) is a primary long-term driver for new technology adoption. The TCO for conventional vehicles is well known, but not for fuel cell trucks. NREL created a framework for calculating the TCO of fuel cell buses and identifying areas for R&D to reduce costs. It's important for government and industry to work together to establish a similar TCO model for trucks. The first demonstration vehicles will provide important data, but will be owned by the manufacturer. A TCO model for trucks will need to include the entire value chain, from parts manufacturer to end operator.



Freightliner TCO calcuator

- **Assess options for developing a zero emission vehicle credit or long-term incentive strategy to encourage truck integrators and manufacturers to invest in fuel cell research, development and deployment.**

Currently, fuel cell trucks are at TRL 3.[3] Once deployed, the currently funded demonstration projects could advance the selected vocations to TRL 4 or 5, which is the point at which the investment in technology needs to increase. Incentives at all parts of the value chain can help manufacturers invest in research and development, and through the "valley of death" of initial deployment.

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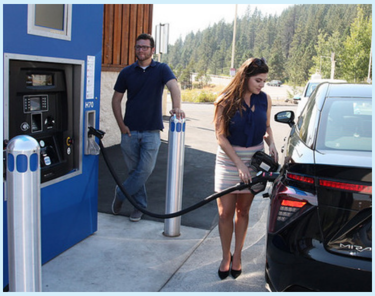
1 According to the American Public Transportation Association, diesel buses can cost up to $600,000. Hybrid buses range from $500,000 to $725,000 per bus. CNG buses are about $675,000. A Columbia University study shows that zero-emission buses are cost competitive at an incremental cost of $300k-$400k above the price of a diesel bus when factoring in carbon and health care costs.
2 The 2013 CaFCP Fuel Cell Bus Road Map called for 40 buses per COE to reduce the costs to $1million per bus. Newer data shows that 20 buses per COE may achieve the same cost reduction. At 20 buses per COE, the total cost needed is $28 million instead of $50 million.
3 CaFCP assessment

Establish Hydrogen Stations for Trucks



Why not use the existing hydrogen stations?

Retail hydrogen stations are most often in the parking lot of a retail gas station. They are designed for vehicles that hold less than 10 kilograms of hydrogen. The storage, compression, and fueling protocol are not designed for trucks.

With a few exceptions, retail hydrogen stations do not have canopies high enough for a truck to drive under. In addition, retail hydrogen stations don't have sufficient space for a truck to maneuver around the dispenser islands.

It may be possible to add storage and a dispenser to an existing station to fuel trucks, which could maximize the investment in hydrogen stations.

Experience from the planning and rollout of passenger fuel cell electric vehicles and hydrogen stations shows that development of fuel cell electric trucks and fueling infrastructure must occur in parallel. Demonstrations of two-to-three fuel cell package delivery trucks or a single drayage truck may be able to use an existing retail hydrogen station, but larger truck fleets will need dedicated fueling islands comparable to current diesel stations. Medium-duty vehicles will need “behind-the-fence” fleet stations.

For the FCET business case to be successful, hydrogen must be equivalent in cost to diesel on a per-mile basis. Initially, hydrogen will cost more than conventional fuels due to low demand and high capital costs of hydrogen stations. For example, the heavy-duty hydrogen station at Emeryville has a capital cost of about $8 million. AC Transit's second station cost slightly under $6 million. A new station in Southern California that will serve twice as many vehicles is under $5 million. Station operation and maintenance costs are expected to be $200,000 per year and the cost of fuel delivered to be $4-to-$7 per kilogram (equivalent to $2.26 to $4.75 per gallon of diesel excluding capital costs).

Because a fuel cell drayage truck will need 20-30 kilograms of fuel at H35 pressure, its needs are similar to a bus, although the fueling logistics of the fleet is likely to be different than a bus fleet. A medium-duty parcel delivery truck will need approximately 10 kilograms of hydrogen; more than twice the capacity of a passenger vehicle. Ideally, fuel cell electric trucks will use the same fueling stations, which will help reduce the cost of building several small capacity stations.

Fuel cell trucks will need high-capacity stations, meaning that they store 500/kg or more of hydrogen and can fill vehicles back-to-back in less than 10 minutes per vehicle. The stations will like have liquid hydrogen delivered by truck or make hydrogen on site from natural gas or renewables.

Recommendation for Infrastructure

- **Fund initial private or commercial hydrogen fueling infrastructure, with consideration of public funding for station O&M in early years.**

Planning for hydrogen infrastructure needs to begin immediately. Providers of conventional fuels and hydrogen need to be included in planning for capacity, distribution, and siting of fueling infrastructure for medium- and heavy-duty fuel cell electric trucks.

Planning should take into account the already-funded demonstration projects, and the market potential for larger demonstration fleets and early commercialization.

While some limited sharing of existing fueling infrastructure may be possible to advance early small demonstration projects, deployment of FCETs will require dedicated fueling stations. The Action Plan advocates development of commercial HD fueling infrastructure beginning with one or two stations that can serve multiple demonstration projects in a region. Initial private or commercial hydrogen fueling infrastructure for FCETs should receive support from public funding sources, with consideration given to providing public funding for station O&M in the early years.

Bus Fueling Experience

SunLine Transit's hydrogen station in Thousand Palms, which opened in April 2000 and is the longest operating hydrogen transit bus fueling station in the United States. The station has on-site production of hydrogen through the use of an auto-thermal reformer with a capacity of 212 kilograms per day. The five FCEBs currently in service are filled daily with 25-35 kilograms of 35 MPa hydrogen in about 25 minutes per bus. Excluding the capital cost for hydrogen station implementation, the combined cost of O&M and hydrogen is approximately $8.00/kg dispensed.

SunLine is in the process up upgrading its station with a larger electrolyzer, additional storage, and a dispenser for passenger vehicles.

AC Transit's hydrogen station in Emeryville is one of the largest and most modern heavy-duty vehicle fueling stations in the United States. Starting operation in 2011, the dual-use station serves buses at a dedicated dispenser inside the yard and passenger vehicles at a public dispenser outside the yard. Hydrogen is delivered as a liquid for buses and produced on site by electrolysis for passenger cars. Both dispensers use the same bulk storage system.

For buses, the baseline capacity is 360 kilograms a day—enough to fill 12 buses—and can be expanded to accommodate up to 24 buses. The station uses fast-fuel technology and can fill multiple buses consecutively at a 6-to-8 minutes per fill—a rate equivalent to diesel bus fueling.

AC Transit opened a second station in Oakland in 2014 with a design capacity to fuel 12 buses rapidly and in succession. This station can also be expanded to fuel 24 buses.

Excluding the capital cost and hydrogen station implementation, the combined cost of O&M and hydrogen to fuel buses is approximately $8.62/kg dispensed.

Successfully demonstrate FCETs

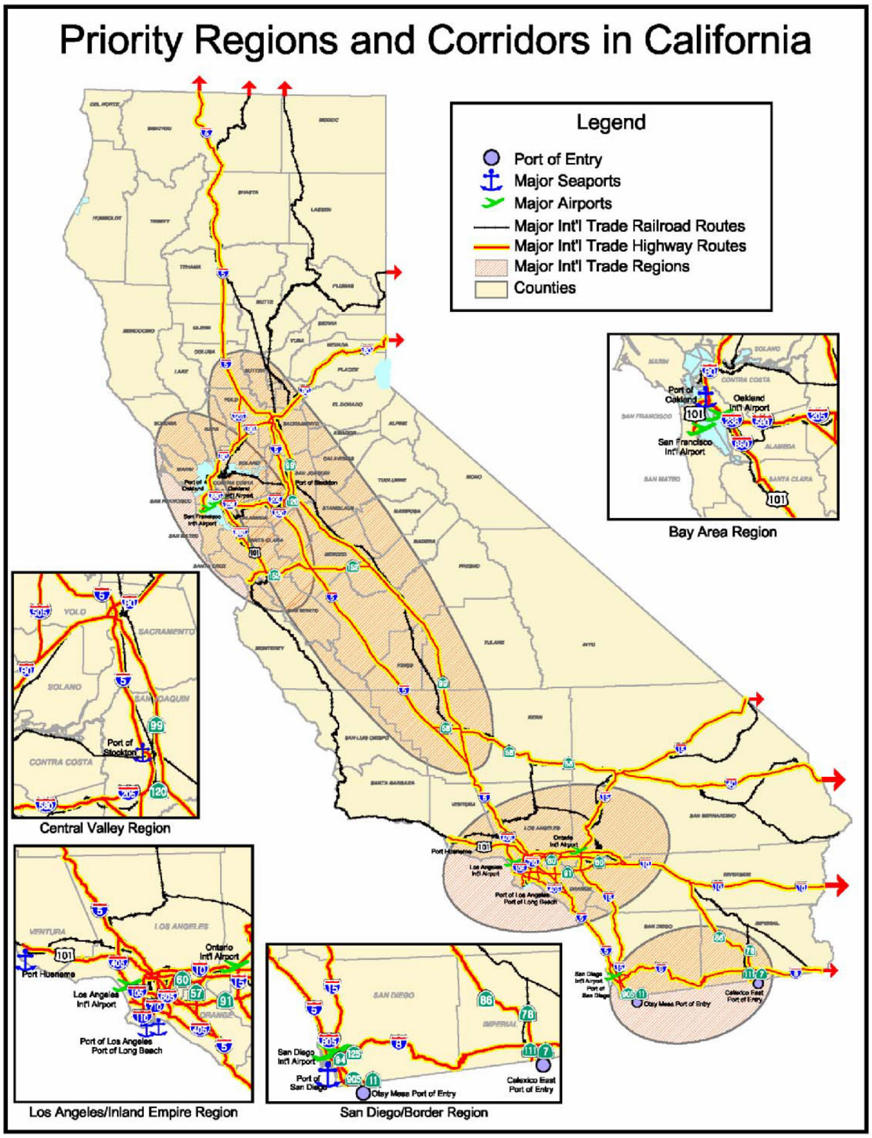
Heavy-Duty Drayage Trucks

In California, the areas of greatest freight activity overlap with the regions with the state's poorest air quality: the South Coast air basin, the San Francisco Bay Area, and the San Joaquin Valley. The Action Plan identifies these as "priority areas" for demonstrations because they provide a co-benefit of improving the environment.

In the South Coast air basin, drayage truck demonstrations should center on the Ports of Los Angeles and Long Beach and the I-710 Corridor that connects ports to warehouses and rail yards. According to a 2011 Tiax report, these facilities can be found as far east as the Inland Empire and as far north as Bakersfield.

Within the San Francisco Bay Area air basin, FCET drayage truck demonstrations should focus on the Port of Oakland and the I-580, I-880, and I-80 corridors that connect the Bay Area to the Sacramento and San Joaquin Valley regions.

In the San Joaquin Valley air basin, drayage demonstrations should focus on short hauls between agricultural sources and warehouses, or around distribution centers using HD yard tractors in Fresno, Bakersfield and Stockton. A demonstration showcasing fuel cell drayage trucks operating between Bakersfield and the ports in the South Coast basin may provide significant lessons learned about FCET operation on the demanding routes that include long, steep grades.



By locating hydrogen stations at the Ports of Long Beach and Los Angeles and within a 100-to-200 mile range of the ports, fuel cell drayage trucks can reach the Inland Empire and Bakersfield. Stations in Sacramento and the South San Francisco peninsula will provide range for FCETs at the Port of Oakland and could support future truck demonstration projects.

Duty Cycles of Drayage Trucks at the Port of Los Angeles

Nearly 40% of all containerized goods entering the U.S. move through the Port of Long Beach and/or Port of Los Angeles. The majority of these containers move by drayage truck to a variety of businesses, terminals, warehouses, trans-loading facilities, and container yards in Southern California. Once at these facilities, these goods may then be sent out for delivery to local businesses, loaded onto rail cars, repacked into dry vans, etc. While these facilities are spread out around Southern California, drayage operations are often grouped into three categories based on the first-move distance

Near-dock Operation: This type of operation involves very short cargo moves from two to six miles in length, generally originating at the marine terminal. Cargo moves to the Intermodal Container Transfer Facility, which functions as the Union Pacific rail terminal, or nearby container yards.

Local Operation: This type of operation involves trips between the port and a one of the warehouses, truck terminals, or the major rail yard that exist within 20 miles of the ports. These terminals include distribution centers in downtown Los Angeles, Compton, and Rancho Dominguez.

Regional Operation: At distances greater than twenty miles from the ports, large warehouse facilities are common and may be used to transfer goods for interstate delivery. Regional operation is described as cargo moves between 20 and 120 miles in length and effectively covers drayage operations to the Mexico border to the south, Coachella Valley to the east, and Bakersfield to the north.

Characterization of Drayage Truck Duty Cycles at the Port of Long Beach and Port of Los Angeles, TIAX

Medium-duty Package Delivery Trucks

For fuel cell package delivery truck demonstrations, the focus should be Los Angeles, San Francisco, and San Diego. These are the locations where UPS, FexEd and DHL have large distribution centers and fleets, and are non-attainment regions (as identified by US EPA and CARB). Package distribution centers are also in a variety of locations throughout the South Coast basin, San Joaquin Valley, Sacramento, San Diego, and on the San Francisco peninsula. Ultimately, the operator will choose the demonstration location.

Motivated operators will consider the ability to use existing hydrogen stations. Retail hydrogen stations in Coalinga, West Sacramento, Burbank, Thousand Palms, and San Juan Capistrano have sufficient space and capacity for a medium-duty vehicle and may be able to fuel two or three FCETs in addition to serving passenger FCEVs.

UPS Package Cars

UPS is an international shipping company with 1,800 operating facilities in every part of the world. Its fleet of 104,926 package cars, vans, tractors, and motorcycles, and 237 airplanes delivers 18.3 million packages a day.

Package delivery trucks (which UPS calls "package cars") all have a home base at a distribution hub. Vehicles typically leave the hub with a full tank of fuel and operate for 10 hours a day. On the Brown Cafe forum, drivers described three basic routes:

Commercial only: Drivers drop off and pick up at businesses only. Businesses tend to be close together, have more than one package delivered or picked up, and have a person available to sign for a package. They drive less than 100 miles a day, make 120 to 180 stops, and handle 350 to 500 parcels a 10-hour day.

Commercial and residential: Drivers have business stops in the morning and residential in the afternoon. Miles between houses are greater, and fewer people are home to sign for packages. In a 10-hour day, drivers cover 120 to 160 miles with 95-160 stops and handle 200 to 350 parcels.

Rural routes: Drivers can travel up to 200 miles away from the distribution hub and make as few as 30 stops to deliver parcels to businesses and residents. UPS often uses vans on rural routes that have fewer parcels to deliver.

After the shift, all package cars return to a hub where maintenance staff clean and refuel the vehicles at a fleet station. Afterward, loaders fill the car with parcels for the next day's deliveries.

UPS Pressroom Fact Sheet

BrownCafe Forum at www.browncafe.com

Recommendations for Demonstrations

- **Develop SAE J2601/2 TIR "Fueling Protocol for Gaseous Hydrogen Powered Heavy Duty Vehicles" to a full standard and generate data to address the gaps in fueling protocol-related codes and standards.**

"Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles" is the standard that establishes safety limits and performance requirements for gaseous hydrogen fuel dispensers. According to SAE, "This document applies to light duty vehicle fueling for vehicles with storage capacity from 1 to 10 kg for 70 MPa and 1 to 7.5 kg for 35 MPa. It is intended to be revised in the next two years to include separate requirements for fueling heavy-duty vehicles and motorcycles, forklifts and also for residential hydrogen fueling appliances. Since there is a significant difference between the onboard storage capacity of heavy-duty and light-duty vehicles, the performance specifications could be different."

Currently, medium-duty fuel cell trucks can fuel at passenger hydrogen stations without assistance if the truck uses the same protocol as a car. If the truck stores more fuel than the standard specifies, an operator must fuel the vehicle, which adds cost. To close the gap in the standard, vehicle developers and station operators will need to work together to generate, verify, and assess a sufficiently large fueling test data set.

- **Consolidate funded truck projects and development of commercial HD fueling infrastructure reduce capital expenses and reduce fuel costs by creating higher fuel throughput.**

Several fuel cell truck demonstration projects are funded and under development in California. Ensuring that these small programs operate in similar regions can eliminate the need to build a station for each project.

Project	By	Location(s)	# of trucks
Package delivery trucks	CTE with UPS	California (TBD)	1 + 17
Package delivery trucks	PlugPower with FedEx	California and Tennessee	20
Refuse truck	US Hybrid	TBD	1
Drayage truck	Hydrogenics	Ports of Los Angeles and Long Beach	1
Shuttle buses	US Hybrid/CALSTART	Coachella Valley and Los Angeles	4
Drayage truck	CTE/BAE/Ballard/Kenworth	South Coast air basin	1
Drayage trucks	Transpower/Hydrogenics	South Coast air basin	2
Drayage truck	US Hybrid	South Coast air basin	2
Short-haul truck	Transpower	San Joaquin Valley	1
Shuttle bus	US Hybrid	Fresno County	1

- **Assess corporate operating structure options to create economic benefits for fuel cell electric truck operators and initiate within the next five to 10 years.**

The Action Plan focuses on the near term—the period before 2020—to establish a foundational understanding so that truck manufacturers can make decisions about fuel cell electric truck commercialization. Each manufacturer has its own strategy for ZEV-enabling technologies based on their product mix, plans for fuel economy, and global market considerations. They factor in truck demand and supply, future profitability, and regulatory requirements.

Although full ZEV technology is not central to their current product plans, several manufacturers have begun internal development efforts. Clear, consistent regulatory compliance timelines could encourage ZEV product planning.

It is unlikely that truck manufacturers will finance R&D for fuel cells in the same manner they finance R&D for improving existing technology. It may require new business models or ownership structures that can create economic benefits for truck operators so that they create demand for FCETs. Whatever this structure is, it will ideally be initiated within the next five to 10 years.

Conclusion

One of the lessons learned from previous clean truck programs is to sufficiently test and verify new vehicle technology before replacing a trusted and proven technology. Introducing fuel cell technology will have to be done in a manner that instills confidence in operators who must rely on this technology for their business.

The Action Plan makes recommendations for steps that government and industry can take between now and 2020 to establish a foundation for fuel cell truck development, and leads to continued market investments. If enacted in a timely fashion, CaFCP expects to see FCETs entering the early commercial market by 2031. By 2050, product planning by truck OEMs and hydrogen infrastructure can be fully commercialized in all truck vocations for which a business case exists.

Fuel cell electric bus programs are an important source of data and lessons learned that can be applied to FCETs and hydrogen fueling infrastructure. Because buses are further along in their technical readiness level than trucks, it is vital to continue supporting these programs. They can bring needed cost reductions to the vehicle and fueling technology. The recently funded FCET demonstration projects will help validate the technology, and if deployed in a thoughtful manner, help seed a hydrogen station network for trucks.

California is well positioned to encourage the introduction of fuel cell technology in trucks as a means to reduce air pollution and greenhouse gas emissions, and at the same time support a vital part of the state’s economy.

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Please read the full
MEDIUM- & HEAVY-DUTY FUEL CELL ELECTRIC TRUCK ACTION PLAN FOR CALIFORNIA
at www.cafcp.org

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