California Energy Commission

Alternative and Renewable Fuel and Vehicle Technology Program

FINAL PROJECT REPORT

Tri-Counties Hydrogen Readiness Plan

Encompassing the Counties of: Ventura, Santa Barbara, and San Luis Obispo

Prepared for: **California Energy Commission**

Prepared by: **Santa Barbara County Air Pollution Control District**

Santa Barbara County
Air Pollution Control District

California Energy Commission

Edmund G. Brown Jr., Governor

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PREFACE

Assembly Bill (AB) 118 (Nùñez, Chapter 750, Statutes of 2007), created the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). The statute authorizes the California Energy Commission (Energy Commission) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. AB 8 (Perea, Chapter 401, Statutes of 2013) re-authorizes the ARFVTP through January 1, 2024, and specifies that the Energy Commission allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The ARFVTP has an annual budget of approximately $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and non-road vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

The Energy Commission issued solicitation PON-14-603 to provide funding opportunities under the ARFVT Program to produce a regional Hydrogen Readiness Plan. In response, the Santa Barbara County Air Pollution Control District submitted an application for the central coast Tri-Counties region consisting of Ventura, Santa Barbara, and San Luis Obispo Counties to prepare for the deployment of hydrogen Fuel Cell Electric Vehicles. The application was proposed for funding in the Energy Commission's Notice of Proposed Awards January 16, 2015, and the agreement was executed as ARV-14-038 on July 9, 2015.

ABSTRACT

This report is a hydrogen readiness plan prepared for the Tri-Counties region of Santa Barbara, Ventura and San Luis Obispo. This plan takes advantage of work already performed at the state level and in other areas to prepare communities for the safe use of hydrogen as a clean alternative fuel for transportation. The plan addresses the placement of infrastructure for vehicle refueling by prioritizing favorable locations and identifying potential sites, establishing key public and private stakeholders, and implementing community outreach efforts. The plan also includes selected resources that can be used by planners, permitting staff and first responders to safely and effective prepare for the use of hydrogen and Fuel Cell Electric Vehicles in the Tri-Counties region. The plan addresses the use of FCEVs with retail and municipal fleet users. This planning work was collaborated and coordinated with the existing hierarchy of regional planning documents that are now adopted or in development to foster the use of Alternative Fuels and Alternative Fuel Vehicles in the Tri-Counties Region.

The plan identified three key priorities for ongoing hydrogen readiness planning efforts in the Tri-Counties. These are: (1) to secure funding to support hydrogen infrastructure build-out, vehicle incentives and outreach efforts (for example from public-private partnerships, CEQA mitigation, settlements, enforcement actions, and grants, etc.); (2) to develop a strategy for creating commercial opportunities locally for the production and delivery of low-carbon hydrogen; and (3) increasing public awareness of hydrogen and FCEVs to facilitate early adoption and create a foundation for broader consumer acceptance in the future.

Keywords: California Energy Commission, Hydrogen Readiness Plan, Central Coast, Ventura County, Santa Barbara County, San Luis Obispo County, Fuel Cell Electric Vehicles, Hydrogen Refueling Infrastructure, First Responders

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EXECUTIVE SUMMARY

Hydrogen has long been regarded as a clean alternative fuel for transportation. To this end, California has been promoting hydrogen and Fuel Cell Electric Vehicles (FCEVs), with the consistent support and leadership from the California Energy Commission (CEC), the California Air Resources Board (CARB). Also, together with the California Fuel Cell Partnership (CaFCP), the State has developed a "roadmap" for becoming a world leader in the use of hydrogen as a transportation fuel. Other parties have contributed to the significant progress made to date including Energy Independence Now (EIN), and several leading automobile manufacturers.

While there has been considerable effort to promote and deploy hydrogen and FCEVs in the major cities, there has been less emphasis on developing hydrogen infrastructure in regional communities. However, the Central Coast Tri-Counties were recently funded to develop a hydrogen readiness plan for the Tri-Counties region (Santa Barbara, Ventura and San Luis Obispo).

The objectives of this project were to:

- Develop a Tri-Counties Hydrogen Refueling Infrastructure Plan that includes analysis of hydrogen siting options, a prioritized list of potential sites for hydrogen refueling stations, and assessment of site readiness.
- Develop a list of key public and private stakeholders specific for each municipality and county in the region that need to be included in the hydrogen infrastructure discussion. Many of the key stakeholders have already been identified in the Plug-in Central Coast EV Readiness Plan and the Central Coast Alternative Fuel Vehicles Readiness Plan.
- Assess potential barriers to the efficient and timely permitting and construction of hydrogen stations, and provide recommendations for avoiding or mitigating these barriers.
- Compile a "Tri-Counties Hydrogen Station Permitting Manual" which includes resources to help streamline the Permitting Process for Hydrogen Refueling Stations, including checklists for permitting and safety assessments for hydrogen stations. In addition, city and county planning issues including zoning and CEQA will also be reviewed.
- Summarize the potential for use of FCEVs in local municipal fleets, assess safety concerns at potential refueling sites, and make presentations for the orientation of civic leaders.
- Develop a range of hydrogen refueling technology options that would be candidates for local agencies or private companies to select from, including renewable hydrogen, onsite reforming, and offsite hydrogen transport.
- Compile presentation materials that can be used to train local first responders and technicians at vehicle repair facilities and with emergency towing companies.
- Develop outreach strategies targeted to potential FCEV owners and fleets to promote the use of FCEV vehicles and the benefits of using hydrogen as a fuel.

- Prepare a plan for rolling out the hydrogen fuel infrastructure plan to local communities.
- Develop and track performance metrics for each task included in this preparedness plan to ensure that resources are applied and used effectively.

This planning work was collaborated and coordinated with the existing hierarchy of regional planning documents that are now adopted or in development to foster the use of Alternative Fuels and Alternative Fuel Vehicles in the Tri-Counties Region.

Key accomplishments of the project were as follows:

- Development of a Tri-Counties Infrastructure Plan that outlines how the region will facilitate the installation of hydrogen refueling stations over time, and determine where those stations will be most effectively sited. This plan was developed through application of UC Irvine's Spatially and Temporally Resolved Energy and Environment Tool (STREET) model at the regional and municipal level, together with extensive work locally to review siting options.
- Analysis of hydrogen production and delivery options, with assessment of cost implications and potential for reducing emissions.
- Development of a Hydrogen Station Permitting Manual for our local municipalities and government agencies to use as a reference document when permitting a range of new hydrogen refueling station types in this region. It is expected that the manual will also be a useful resource for infrastructure providers.
- Compilation of resources that address hydrogen safety issues and provide guidance and training resources for First Responders.
- Establishing a suite of materials for the promotion of FCEVs and the potential for hydrogen as a transportation fuel.
- Assembling an improved database of fleet information for municipal and commercial fleets in the Tri-Counties, and assessment of fleet operator interest in hydrogen as an alternative fuel.

Based on the analyses and information presented in this report, the following recommendations are suggested for ongoing hydrogen readiness activities in the Tri-Counties. Recommendations are sorted into two groups: "Local and Regional Recommendations" and "Suggested Actions for the State".

Local and Regional Recommendations

1. Ensure ongoing local support for hydrogen planning and infrastructure build-out.
2. Set local targets for infrastructure. The immediate target would be for the installation of another station in close proximity to the existing station to entice local dealers to offer vehicles for sale in the region.
3. Support ongoing research and adoption of renewable hydrogen.
4. Keep the plan a living document. One way to do this would be to support an ombudsman for the region.

5. The planning focus going forward should be on making sure permitting and response agencies know where available resources are, and helping them make contact with peers in jurisdictions where hydrogen stations have already been permitted.

6. For first responders, provide access to training resources and support for local trainers. There is a need to recognize the time constraints on first responders' time constraints given the extensive amount of training they need to take.

7. Conduct ongoing outreach to_expand awareness of hydrogen and fuel cell electric vehicles, with a focus on highlighting benefits. FCEV test-drives and vehicle loaner programs should be used when possible since research shows that firsthand experience with new vehicle technologies is effective at increasing acceptance.

8. Obtain testimony on hydrogen safety from an expert authority that is widely trusted, such as local fire official and emergency response personnel. This testimony can be incorporated into broader outreach and education campaigns in communities where hydrogen refueling stations are in operation or planned. Public notifications, community workshops, and information resources should be provided during the planning and permitting process for new hydrogen stations to help ensure that safety concerns are addressed.

Suggested Actions for the State

1. Ensure station construction/funding is informed by the regional plans. CEC grant application criteria could be revised to call for a demonstration of how the grant proposal matches the siting analyses in the plan for the proposed station's region.

2. Develop a central statewide website for regional plans and resources (permitting, safety training, etc.). For example, as hydrogen codes and guidance are revised (such as NFPA-2 or the GoBiz Hydrogen Station Permitting Guidebook), then links should be updated to ensure the resources and guidance materials are current.

Moving forward it is evident that there are three key priorities for ongoing hydrogen readiness planning efforts in the Tri-Counties. These are: (1) to secure funding to support hydrogen infrastructure build-out, vehicle incentives and outreach efforts (for example from public-private partnerships, CEQA mitigation, settlements, enforcement actions, and grants, etc.); (2) to develop a strategy for creating commercial opportunities locally for the production and delivery of low-carbon hydrogen; and (3) increasing public awareness of hydrogen and FCEVs to facilitate early adoption and create a foundation for broader consumer acceptance in the future.

If these three priorities are successfully addressed in the near term, there will be a much greater chance that the Tri-Counties region will become a vibrant new "hub" for clean hydrogen transportation. This, in turn, would have significant secondary benefits for lowering carbon intensity of the local energy infrastructure, also resulting in many environmental co-benefits. This is an audacious goal, but the opportunity is real if the intention is sincere.

CHAPTER 1: Introduction

Hydrogen has long been regarded as a clean alternative fuel for transportation. To this end, California has been promoting hydrogen and Fuel Cell Electric Vehicles (FCEVs), with the consistent support and leadership from the California Energy Commission (CEC) and the California Air Resources Board (CARB). Also, together with the California Fuel Cell Partnership (CaFCP), the State has developed a "roadmap" for becoming a world leader in the use of hydrogen as a transportation fuel. Other parties have contributed to the significant progress made to date including Energy Independence Now (EIN), and several leading automobile manufacturers.

While there has been considerable effort to promote and deploy hydrogen and FCEVs in the major cities, there has been less emphasis on developing hydrogen infrastructure in regional communities. However, the Central Coast Tri-Counties were recently funded to develop a hydrogen readiness plan for the Tri-Counties region (Santa Barbara, Ventura and San Luis Obispo). Through a well-designed and coordinated planning effort, there is a potential to accelerate the introduction and use of hydrogen in the Tri-Counties region, and one with great potential for the adoption of Hydrogen Fuel Cell Electric Vehicles (FCEVs), based on past experience with other forms of advanced vehicle technologies.

The goal of this Final Report is to assess the project's success in achieving the Agreement's goals and objectives, and providing energy-related and other benefits to California. The objectives are to describe the project's purpose, approach, activities performed, and results; to present an objective assessment of the success of the project; to make insightful observations based on results obtained; to draw conclusions; and to make recommendations for further projects and improvements to the Energy Commission's funding process for planning projects.

Project Goals and Objectives

The goal for this grant was to prepare a hydrogen infrastructure readiness plan for the Tri-Counties, which is supported by strong proactive leadership throughout the region. By accomplishing this goal, the intent was to position this region for moving efficiently down a well-planned and synchronized path for introducing hydrogen-fueled transportation.

The challenge to be addressed in the project is how to best extend the network of hydrogen refueling infrastructure out from the major urban clusters to a more regional level. The California Energy Commission (CEC) recognizes the need for hydrogen infrastructure readiness planning in regional communities, as well as the major urban areas. The counties of Ventura, Santa Barbara and San Luis Obispo (Tri-Counties) represent a critical corridor for travel between the Bay Area and Southern California, and the region is a proven location for "early adoption" of alternative fuel technologies.

Existing barriers to successful implementation include market limitations – specifically, the availability of FCEVs and hydrogen infrastructure – and also financial barriers, including vehicle cost and the significant investment needed for reliable refueling stations. To allow FCEVs to be operational in a community, the infrastructure needs to be available at the same time as the vehicles are offered for sale.

The hydrogen readiness work outlined in this plan is a critical first step in this process. In addition to sound technical analyses, the planning effort includes promotional activities in local communities, which will highlight the many environmental benefits of using hydrogen as a fuel compared with traditional fuels. To date, local communities have very little experience with hydrogen, so awareness building, highlighting advantages, and managing concerns will be essential for gaining public acceptance. Training permitting staff and first responders provides another critical need to help communities to become better prepared for this new fuel. Given that hydrogen refueling stations are costly, a readiness plan will provide a regional foundation for the strategic introduction of FCEVs together with the necessary refueling infrastructure.

This plan draws extensively from the existing body of information now available from statewide planning and installation efforts to date (including the annual CARB progress reports on FCEV deployment and hydrogen station development), and also from multiple local sources. This experience-based information will form the foundation for addressing the unique challenges that are anticipated in successfully achieving both an incipient and long-term hydrogen refueling network for the Tri-Counties region. We see this effort as a critical step for expanding the reach of hydrogen infrastructure beyond the main urban centers of California.

The objectives of this project were to:

- Develop a Tri-Counties Hydrogen Refueling Infrastructure Plan that includes analysis of hydrogen siting options, a prioritized list of potential sites for hydrogen refueling stations, and assessment of site readiness.
- Develop a list of key public and private stakeholders specific for each municipality and county in the region that need to be included in the hydrogen infrastructure discussion. Many of the key stakeholders have already been identified in the Plug-in Central Coast EV Readiness Plan and the Central Coast Alternative Fuel Vehicles Readiness Plan.
- Assess potential barriers to the efficient and timely permitting and construction of hydrogen stations, and provide recommendations for avoiding or mitigating these barriers.
- Compile a "Tri-Counties Hydrogen Station Permitting Manual" which includes resources to help streamline the Permitting Process for Hydrogen Refueling Stations, including checklists for permitting and safety assessments for hydrogen stations. In addition, city and county planning issues including zoning and CEQA will also be reviewed.
- Summarize the potential for use of FCEVs in local municipal fleets, assess safety concerns at potential fueling sites, and make presentations for the orientation of civic leaders.

- Develop a range of hydrogen refueling technology options that would be candidates for local agencies or private companies to select from, including renewable hydrogen, onsite reforming, and offsite hydrogen transport.
- Compile presentation materials that can be used to train local first responders and technicians at vehicle repair facilities and with emergency towing companies.
- Develop outreach strategies targeted to potential FCEV owners and fleets to promote the use of FCEV vehicles and the benefits of using hydrogen as a fuel.
- Prepare a plan for rolling out the hydrogen fuel infrastructure plan to local communities.

Develop and track performance metrics for each task included in this preparedness plan to ensure that resources are applied and used effectively.

Project Tasks

The project work tasks were in alignment with the CEC's Program Opportunity Notice which was the basis of funding for this work (PON-14-603), as follows:

Task 3 - Regional Hydrogen Refueling Infrastructure Plan
Task 4 - Streamlining the Permitting Process for Hydrogen Refueling Stations
Task 5 - Promotion of FCEV Use
Task 6 - Training
Task 7 - Safety Assessments
Task 8 - Incorporation of FCEVs in Municipal Fleets

A Work Plan was developed with sections that cover project objectives, project management, detailed work activities, and a section on the schedule and deliverables. The Work Plan addressed each of the tasks listed above with a description of the task, the objective of the task, how the task was to be conducted, who the task lead was, and which parties had a role in performing the task. The Work Plan served as a key reference for monitoring and measuring progress with the project.

This planning work was collaborated and coordinated with the existing hierarchy of regional planning documents that are now adopted or in development to foster the use of Alternative Fuels and Alternative Fuel Vehicles in the Tri-Counties Region. Existing plans are in place in the form of County and City General Plans and Climate Action Plans. A summary of applicable planning documents is provided in Appendix A. The work did not duplicate any activities in the Tri-Counties that have been previously funded by CEC. On the contrary, this work was complementary to and supportive of other plans and projects developed in the Tri-Counties/Central Coast region, including:

- Tri-Counties Alternative Fuels Readiness Plan
- Tri-Counties PEV Readiness Planning

Energy Commission funding for the first hydrogen refueling station constructed in Santa Barbara which opened in May 2016

Chapter 2: Hydrogen Refueling Infrastructure Plan

Statewide Context

To assess the future potential of hydrogen vehicles in the Tri-Counties region, and the actions that regional and local stakeholders can take to support FCEV readiness, it is helpful to provide some context of the statewide policy and planning efforts for hydrogen fuel to date[1]. As such, this chapter gives an overview of the following issues:

- Development of FCEV technology and the California Zero Emission Vehicle (ZEV) mandate
- Overview of California's Hydrogen Infrastructure Strategy
- Statewide hydrogen refueling infrastructure

Development of FCEV Technology and the California ZEV Mandate

Fuel cells have been under development for many years, and over the last twenty years, a vast amount of work has been devoted to making fuel cells commercially viable and cost-effective in vehicles. The California ZEV mandate has played a key role in driving this development, and auto manufacturers have collaborated closely with government agencies in California through the CaFCP.

While manufacturers have been developing the vehicle technologies, the state has begun a diligent program to establish a hydrogen refueling infrastructure across the state, with the initial priority of supporting FCEV clusters in the two primary urban areas – the Bay Area to the north, and the Los Angeles basin to the south. This investment program is discussed in more detail in the next section.

Overview of California's Hydrogen Infrastructure Strategy

The California Hydrogen Highway Network was initiated in April of 2004 by Executive Order S-07-04 under then Governor Arnold Schwarzenegger. The intent of the Order and associated investments in FCEV technology by the California Energy Commission has been to ensure that hydrogen refueling stations will be in place to meet the needs of future FCEV drivers, and to facilitate the advancement of hydrogen vehicles as projected under the ZEV mandate[2]. Over the medium-term (5-10 years), hydrogen technologies also have potential to be deployed in medium and heavy duty vehicle segments, as well as the light-duty sector.

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1 *Note. More detail of the background and context for hydrogen fuel development in California is included in the Central Coast Alternative Fuels Plan.*

2 *ZEVs are vehicles with zero tailpipe emissions*

To provide an overall strategic framework for FCEV deployments across all vehicle types, CaFCP published *A California Road Map: The Commercialization of Hydrogen Fuel Cell Electric Vehicle in 2012*.[3] This Road Map and subsequent updates have articulated the core policy and program framework for FCEV market development, including the all-important development of a new hydrogen refueling infrastructure.

The Road Map in turn served as a basis for Governor Jerry Brown's March 2012 Executive Order that directed California state agencies to support the accelerated deployment of the full range of zero-emission vehicles (ZEVs), including FCEVs.[4] The passage of Assembly Bill 8 (Perea, 2013) was another pivotal step in FCEV development, extending through 2023 the Air Resources Board's Air Quality Incentive Program (AQIP) and the Energy Commission's Alternative and Renewable Fuel & Vehicle Technology Program. The state's comprehensive ZEV Action Plan has provided further guidance on bringing FCEVs to market.[5]

AB 8 included a crucially important provision to fund at least 100 hydrogen stations with up to $20 million a year. Since the passage of AB 8, three automakers (Honda, Toyota, and Hyundai) have moved ahead and introduced FCEVs to the California market, and other automakers are expected to enter the market in the 2017-2022 timeframe. FCEVs have been embraced by key state policy makers because -- once an appropriate refueling infrastructure is in place -- they will combine the convenience and utility of conventional Internal Combustion Engine (ICE) vehicles with the quiet and clean attributes of electric vehicles.

The majority of the hydrogen fuel produced in California is currently derived from natural gas, though current state law mandates that 33% of the hydrogen supplied for FCEVs must be from renewable sources (SB 1505[6]). With the potential to develop a supply chain for renewable and low-carbon hydrogen fuel, the state has produced another key policy document known as the Vision for Clean Air -- developed by several leading air quality management agencies -- to highlight strategies to accelerate the introduction of FCEVs as well as EVs in the context of air quality policy and goals.

While policies for FCEV promotion are developed primarily at the state level, local and regional stakeholders can work together with hydrogen fuel suppliers and the California Fuel Cell Partnership to support and accelerate existing plans for hydrogen refueling station deployment.

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[3] A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles, June 2012 *http://cafcp.org/sites/files/A%20California%20Road%20Map%20June%202012%20%28CaFCP%20technical%20version%29_1.pdf*

[4] *Executive Order B-16-2012, March 23, 2012. http://gov.ca.gov/news.php?id=17472*

[5] ZEV Action Plan A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025, February 2013, and updated in 2016
http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf.
https://www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf
h t t p

6 SB 1505 Environmental Performance Standards for Hydrogen Fuel

Statewide hydrogen refueling Infrastructure

The Road Map and ZEV Action Plan together prescribe a minimum network of hydrogen stations to establish the foundation for robust, commercial-scale FCEV adoption. Focused on "early adopter" areas in Southern California and the San Francisco Bay Area, the FCEV station network includes "connector" and "destination" stations intended to anchor the evolving statewide network and enable north-south travel.

In 2015, the CEC announced funding for 28 new stations, which – when constructed – will result in 51 total stations. Additional stations will be funded by the CEC until there are at least 100 stations across the state by 2020. Current information on the status of stations is provided by the CaFCP and the Governor's Office for Business (GoBiz).

The Hydrogen Progress, Priorities and Opportunities Report was recently published by the CaFCP and its Original Equipment Manufacturers (OEM) Advisory Group – including Honda, General Motors, Hyundai, Mercedes-Benz, Nissan, Toyota and Volkswagen. The report included a consensus list of recommended priority locations for the next 19 hydrogen stations to be built in the state. While these are simply recommendations, it is of relevance to the Tri-Counties in that the city of Thousand Oaks was recommended as a Primary Priority, and the cities of Ventura or Oxnard was recommended as Secondary Priority locations.

The first hydrogen system to be installed in the Tri-Counties is located in Santa Barbara at the Conserv Fuels station at 150 South La Cumbre Road. The system was developed by First Element Fuels with funds awarded by the California Energy Commission in 2014. The station construction was managed by Black and Veatch, and began operating in May 2016.

In its first two years of operation, it is expected that fuel for the station will be sourced by Air Products and Chemicals. As is the case for most early hydrogen refueling stations, the California Energy Commission will also be providing Operations and Maintenance (O&M) funding for at least the first three years of operation, with the expectation that the station will become commercially sustainable in later years as demand for hydrogen grows.

The Santa Barbara station is a starting point for the development of a regional hydrogen network for the region, to be developed in the years to come. It also provides a starting point for north-south connectivity along HWY 101.

Tri-Counties Regional Demand Analysis

As a basis for developing the infrastructure plan for the Tri-Counties region, it is necessary to assess the potential need for hydrogen fuel in the years to come. In turn, for transportation, this is dependent on the FCEVs sales projections for the region, and the anticipated need for hydrogen fuel by vehicles traveling to the region or in-transit through the region. To make this assessment, the ZEV mandate projections for the state were used as a starting point, and pro-rated for the region. Projected sales by the OEMs were also factored into this initial assessment.

California Fuel Cell Electric Vehicle Sales Projections

For many years, the California ZEV mandate has played a key role in setting targets for ZEV sales in California. However, the ability to meet those targets has been limited by the challenges of manufacturing vehicles that attain the ZEV standards and, at the same time, meet customer expectations. FCEVs are still in the early stages of commercialization, and there are many barriers to implementation that can impede the speed at which a new technology can be deployed. For this reason, the ZEV mandate targets should be considered targets or goals, rather than projections of actual sales.

An estimate of projected sales numbers can be obtained from the CARB Midterm Review of Advanced Clean Cars Program released in January 2017 which projects at least one million ZEVs by 2025[7]. Specific FCEV projections can also be derived from the OEM survey conducted by CARB in 2014 and discussed in detail in the July 2015 Annual Evaluation of FCEV Deployment and Hydrogen Fuel Station Network Development report (CARB Hydrogen Report 2015). Mandatory surveys were distributed to 16 auto manufacturers requesting information on planned deployment of FCEVs. Data reported back to CARB from the OEMs forecast an acceleration in the number of vehicles made available for sale in California from present to 2021 (the last year included in the survey). CARB has recently projected, from the results of this survey, that the state's fleet of FCEVs is expected to grow to nearly 35,000 vehicles by 2021. (Refer to Table 1.)

The same report stated that a minimum of 51 stations would be needed to service an expected demand of 13,500 vehicles, so the assumption is made here that a single station could serve about 265 vehicles on a consistent basis. Table 1 includes a separate analysis to show that this number is corroborated by a simple projection of station use based on hydrogen consumption data now available for vehicles coming to market.

Analysis of Hydrogen Fuel Demand from Personal Vehicles in Tri-Counties Region

Projections of vehicle numbers, hydrogen fuel demand and refueling infrastructure requirements were made for the Tri-Counties region based upon "best estimates" for the statewide data presented above. Using the CARB survey data, the prorated sales projections would be approximately 1,000 vehicles by 2020 and 3,000 vehicles by 2025. Table 2 provides a summary of these projections. Table 2 also shows that the Tri-Counties would need about four stations (minimum) to meet the projected retail demand in 2020, and about eleven stations by 2025, which assumes that vehicle owners work or live near station sites.

While the projections appear to be very precise, it is simply due to the prorating process that was used to develop the estimates. In reality, it would be prudent to use a range in the projections for planning purposes, with lower and higher estimates of the number of stations needed for planning refueling infrastructure needs.

7 https://www.arb.ca.gov.newsrel/newsrelease.php?id=890

Of course, these demand projections assume that the auto manufacturers promote sales in this region, consistent with other target sales locations. On the contrary, vehicle sales in a region are dependent on the availability of infrastructure, so it could substantially impede sales potential if the infrastructure is not planned and installed.

This emphasizes the need to have redundant and reliable infrastructure in the region so that local dealers are in a position to offer FCEVs for sale. FCEV sales are also likely to be impeded locally if owners have to travel out of the region (100+ miles) for dealer service.

Other Demand for Hydrogen

Other potential demand for hydrogen could arise from fleet operations using FCEVs, heavy duty vehicles (including buses, freight transportation and drayage vehicles), and with turnkey fork lift operations using hydrogen. As and when additional demand occurs for these potential needs, then the fueling equipment and infrastructure would likely be different from that used for FCEV refueling especially for heavy duty vehicles. When the equipment is similar, it may or may not be available to the general public.

The possibility of siting hydrogen stations at auto dealerships that sell FCEVs may be another way to provide hydrogen if and when primary stations go offline. This would provide additional resiliency and redundancy for the local hydrogen refueling network.

Base Case Planning Scenario[8]

This section presents a summary of the FCEV retail sales projections for the Tri-Counties and the infrastructure that will be needed to meet projected demand. Based primarily on the CARB 2015 report and the OEM survey data, it is assumed that there will be a minimum need for an additional three or four hydrogen refueling stations by 2020 to service approximately 500 to 1,000 FCEVs that could be operating in the region by that time. It is anticipated that at least two or three stations will be needed in Ventura County, and one additional station in Santa Barbara County.

Beyond 2020, it is assumed that the number of FCEVs in the Tri-Counties will grow further, and that additional build-out of the refueling infrastructure will be needed. Based on the data available during the planning process, it is reasonable to assume that the number of FCEV sales would increase to about 2,500 or 3,000 by 2025 consistent with a base case (or "business as usual") projection. Overall this would require at least ten to twelve stations in the region by that time.

While there is clearly some uncertainty with this analysis, the projections provide a rationale for local decision-makers to promote this new vehicle technology, and to support the goals of the state for deployment of FCEVs.

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8 *Projections based on OEM survey data reported by ARB. Approach is consistent with analysis by Ogden et al in Joan Ogden, Christopher Yang, Michael Nicholas, Lew Fulton , NextSTEPS White Paper: The Hydrogen Transition, Institute of Transportation Studies University of California, Davis, July 29, 2014, p. 15* *http://steps.ucdavis.edu/files/08-13-2014-08-13-2014-NextSTEPS-White-Paper-Hydrogen-Transition-7.29.2014.pdf*

Table 1 California ARB: 2015 Annual Projection of FCEV Deployment and Hydrogen Fuel Station Network Development

Projected Number of FCEVs in California Fleet

Year End	Vehicles	Source/Derivation
2018	10,500	CARB Hydrogen (AB8) Report 2015, 2nd bullet, page 3
2019	18,433	interpolated
2020	26,367	interpolated
2021	34,300	CARB Hydrogen Report 2015, 2nd bullet, page 3
2022	42,800	extrapolated, assuming additional 8,500 new vehicles per year
2023	51,300	extrapolated, assuming additional 8,500 new vehicles per year
2024	59,800	extrapolated, assuming additional 8,500 new vehicles per year
2025	68,300	extrapolated, assuming additional 8,500 new vehicles per year

Hydrogen Stations Operational by Year-End 2016

51	stations	CARB Hydrogen (AB8) Report 2015, 3rd bullet, page 3
9,400	kg per day	CARB Hydrogen (AB8) Report 2015, 3rd bullet, page 3
13,500	vehicles	CARB Hydrogen (AB8) Report 2015, 3rd bullet, page 3
254	kg/vehicle/year	derived from information provided
265	vehicles per stn	derived from information provided
184	kg/station/day	derived from information provided

Vehicle-Station Projection

Check

15000		Vehicle miles per year
300	mi	Range (Toyota Mirai)
50		Fuel stops per year (once per week)
20	Min	Time to refuel (conservative estimate, more likely to be 5-10 min)
3	veh/hr	Single station capacity
12	Hr	Time actively used each day
36		Vehicles filled per day
252		Vehicles per week (Vehicles per Station)

Compares well with CARB report which indicates an average of 265 vehicles per station

Footnote – California Fleet Projection numbers are based on CARB Hydrogen (AB8) Report 2015 issued in July 2015. Numbers changed only slightly in the next annual report issued in July 2016, but would not change these projections in a material way.

Table 2 Tri-Counties Regional Projections (Minimum Requirements)

Population Data for Pro-rating			
	Population (2015 est)		
California	38,000,000	100%	(1)
Santa Barbara County	450,000	1.2%	
Ventura County	840,000	2.2%	
San Luis Obispo County	280,000	0.7%	
Tri-Counties	1,570,000	4.1%	
FCEV Numbers Pro-rated based on Population			
	2020	2025	
California	26,367	68,300	(2)
Santa Barbara County	312	809	
Ventura County	583	1,510	
San Luis Obispo County	194	503	
Tri-Counties	1,089	2,822	
Pro-rated Number of Stations			
	2020	2025	
California	100	258	(2)
Santa Barbara County	1	3	
Ventura County	2	6	
San Luis Obispo County	1	2	
Tri-Counties	4	11	
Annual Fuel Use (kg)			
	2020	2025	
California	6,701,040	17,358,319	(2), (3), (4)
Santa Barbara County	79,354	205,559	
Ventura County	148,128	383,710	
San Luis Obispo County	49,376	127,903	
Tri-Counties	276,859	717,173	

Notes:

1. *Population estimates based on Census data 2010, projected to 2015*
2. *Estimate from CARB FCEV Annual Evaluation Report, July 2015*
3. *Consistent with FCEV driven 15,000 miles per year, 5kg tank, 300 mile range*
4. *Each vehicle filled about once per week, on average*

Accelerated FCEV Adoption Scenario

With increased promotion locally and support from the auto manufacturers, an option available to local decision makers in the Tri-Counties could be to implement actions that will accelerate the FCEV adoption rate. If the planned adoption rate increased by a factor of three times, the opportunity for further growth in the near term would be stimulated, along with the many environmental benefits of ZEVs. In this case, there could be about 2,500 vehicles in the region by 2020 (needing about 10 stations), and 7,500 or more by 2025 (needing about 30 stations). To accomplish this would require an investment of about $20 million by 2020 and about $60 million by 2025, split among the three counties (prorated by population).

Assuming a conventional car driven 12,000 miles per year would emit about 5 tonnes of carbon dioxide, replacing 1,000 vehicles with hydrogen would reduce tailpipe emissions by 5,000 tonnes per year, or about 60,000 tonnes over the life of the vehicle (12 years). With an accelerated adoption scenario and a total of 7,500 FCEVs (by 2025), the yearly carbon dioxide emissions reduction would be 38,000 tonnes, or about 450,000 tonnes over 12 years. Further benefits would accrue as hydrogen becomes commercially viable and attractive to private sector investment.

Studies indicate that an alternative fuel like hydrogen would need to be available at about 5-10% of the existing gasoline stations to alleviate driver concerns about fuel availability. With about 540 gasoline stations in the Tri-Counties, this suggests that about 25-50 stations would need to have hydrogen to achieve this.[9] [10] Other research indicates that take 15% or more for successful penetration.[11] With this latter basis, the number of stations with hydrogen in the Tri-Counties would likely have to increase to 70 or more to support a mature hydrogen fuel transportation system.

While these are rather speculative projections, they do present a starting point for decision makers to determine how many stations are likely to be needed to follow in line with the state growth projections for FCEVs over the next five to ten years, and also an idea of the additional investment needed to accelerate the adoption rate if desired.

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9 M. Nicholas, S. Handy, and D. Sperling, "Using Geographic Information Systems to Evaluate Siting and Networks of Hydrogen Stations," Transp. Res. Rec. J. Transp. Res. Board, vol. 1880, pp. 126–134, Jan. 2004.

10 *M. W. Melaina, "Initiating hydrogen infrastructures: preliminary analysis of a sufficient number of initial hydrogen stations in the US," Int. J. Hydrogen Energy, vol. 28, no. 7, pp. 743–755, 2003.*

11 https://www.researchgate.net/publication/222697006_Initiating_hydrogen_infrastructures_Preliminary_analysis_of_a_sufficient_number_of_initial_hydrogen_stations_in_the_US

Tri-Counties Siting Analysis

Introduction

Section 2 (above) includes a summary of the statewide strategy for FCEV deployment with the initial effort focused on vehicle sales and infrastructure development in the two primary urban areas of the state – the Bay Area in the north, and the Los Angeles basin in the south. In the initial “roadmap analysis”, Santa Barbara was identified as a “destination station”, primarily for FCEVs traveling north or south between Los Angeles and the Bay Area.

With this initial station now in operation in Santa Barbara, there is potential to build out a local infrastructure to support additional FCEV deployment in the Tri-Counties region. The strategy for local infrastructure development is principally driven by the availability and demand for passenger vehicles, but also to increase the reliability of supply in the local area for destination travelers, and also for establishing north-south connectivity along the Highway 101 corridor. At this time, the station in Santa Barbara theoretically allows for hydrogen vehicles to travel north to San Jose – the next nearest station to the north along the 101 – but the distance is about 280 miles, which is close to the maximum range for most early FCEVs.

For these reasons, the refueling station siting analysis for the Tri-Counties region has accounted for three main factors when considering spatial distribution of sites:

- To serve the projected growth of retail sales (discussed in Section 2);
- To increase the appeal of the region as a destination for FCEV drivers (mainly from the Los Angeles area initially); and
- To provide reliable connectivity between Los Angeles and the Bay Area along the 101 corridor[12].

Market Demand for FCEVs and hydrogen refueling Infrastructure

As part of the planning effort, a detailed analysis was conducted of the current situation in the Tri-Counties region relative to population and economic demographics, and sales potential for FCEVs in the region. This analysis was used to develop hydrogen infrastructure “build-out” scenarios for the next five to ten years. The approach used is described below.

Projecting market demand for FCEVs is essential for assessing the need for refueling stations in the region over the near term. To assess this, staff at the University of California Irvine (UCI) Advanced Power and Energy Program (UCI-APEP) were asked to adapt their STREET model to the Tri-Counties region. The STREET model (Spatially and Temporally Resolved Energy and Environment Tool) was developed by UCI-APEP to provide insight and information to help decision-makers plan for infrastructure investments related to alternative fuels transportation. The primary objective for applying the STREET model was to develop a strategic approach to the siting of hydrogen refueling stations across the Tri-Counties using FCEV market proxy data.

12 *To fully utilize a station takes about 250 fueling events per week, so this would require 125 round trips per week by FCEVs with no additional local demand (assuming they fill at this location both ways).*

The STREET model was used to identify 20 "high priority" gasoline stations in the Tri-County area. The analysis was based on several different sets of Alternative Fuel Vehicle (AFV) sales registration data that serve as proxies for FCEVs. Connectivity between northern California and southern California was also analyzed. The STREET results were then compared to the Station Coverage Value given by the California Hydrogen Infrastructure Tool (CHIT). The CHIT Station Coverage Value is the ability of the proposed station to fill an identified gap in refueling coverage.

Three different sets of AFV sales registration data were used: (1) battery electric vehicles (BEVs), (2) plug-in hybrid electric vehicles (PHEVs) combined with hybrid electric vehicles (HEVs), and (3) BEVs combined with PHEVs and HEVs. The AFV sales registration data, obtained from IHS Automotive, show the number of a type of vehicle registered in a zip code tabulation area (ZCTA). The spatial resolution of this data set is rather coarse, so it was combined with high resolution population data (1km x 1km) to evaluate potential station locations. In essence, this approach allows for counting potential vehicle sales (demand points) in each grid cell. Existing gasoline refueling stations were used as candidate locations for siting future hydrogen refueling stations. Station addresses were obtained from the APCDs in the three counties.

The final "demand weight" for each cell is the product of the cell population weight and the number of registrations in the ZCTA.

$$Demand\ Weight = ZCTA\ AFVs * Cell\ Weight = ZCTA\ AFVs * \frac{Cell\ Population}{ZCTA\ Population}$$

The "demand point" for each cell is represented by the point location of its centroid. Potential hydrogen refueling stations are then identified using a Maximize Market Share algorithm in the GIS system. This algorithm seeks to place a given number of stations (set at 20) to maximize the demand (i.e., FCEV proxy) on the stations within a given service coverage area. This is the area that is served by a station and can be defined by drive time or distance. In these analyses, drive time was used, and based on previous studies, this was chosen to be six minutes. It appears to be a good compromise between parity with the convenience of gasoline service, and minimization of infrastructure investment.

Once the station locations are allocated using the Maximize Market Share algorithm, they are ranked according to the total demand points (FCEV proxy) covered by a six minute drive time from the gasoline station.

A detailed report of the STREET modeling analysis is included in Appendix B.1, and this includes results for the three different sets of AFV registration data. In general, there was not much difference between the results using the different data sets (HEV+PHEV) and (HEV+PHEV+BEV) data sets, since the number of HEVs and PHEVs is larger than the number of BEVs. However, using BEV sales alone, as the proxy shows slightly different results than for the other two data sets, with more demand indicated for San Luis Obispo County. The results – expressed as the number of stations by county – are summarized below:

	Ventura	Santa Barbara	San Luis Obispo
HEV + PHEV	13	5	3
HEV + PHEV + BEV	13	5	3
BEV	11	5	5

With 21 stations (20 additional stations plus the existing La Cumbre station) these would cover 80% of total sales within the 6 minute radius (i.e., 7,386 out of 9,223 in the Tri-Counties). These are shown in Table 3 below. The California Hydrogen Infrastructure Tool (CHIT) coverage gap scores are also shown for each suggested station. The CHIT Station Coverage Value is the ability of the proposed station to fill an identified gap in refueling coverage.

The spatial distribution of proxy demand and possible station locations are shown for the Tri-Counties in Figure 1. (Note that these results are based on modelling analysis of potential FCEV sales based on proxy data, and not guaranteed to reflect actual sales that may occur.)

Further Assessment of Candidate Stations

Given that the STREET model projects the best locations for hydrogen refueling infrastructure using a theoretical analysis and mathematical algorithms, it does not account for physical characteristics of the existing stations, such as space availability (for the hydrogen refueling system), access and curb-appeal. For this reason, the project team used the modelling results presented in Table 3 to develop a more realistic assessment of station alternatives.

The intent of this assessment was to reconcile the “preferred” station locations from the model with real-world options, thus giving options to decision makers for identifying stations, while staying consistent with the projections of market demand from the STREET analysis. For example, the STREET model may have selected a specific station on a given street based on the allocation algorithm, yet there may be an alternative station in close proximity with more space, better access and with less permitting constraints. This alternative would satisfy the intent to site a hydrogen station within that general location, and at the same time offer a more suitable site alternative.

To accomplish this, the team looked at station alternatives in the high market potential areas and conducted a screening analysis to assess site characteristics. The local Air Districts provided addresses of the active-permit gasoline fueling stations in the three counties – Ventura (259), Santa Barbara (154), and San Luis Obispo (127) – with a total of 540 stations in the Tri-Counties. Non-commercial fueling stations (e.g. golf course fueling stations, city fleets, water districts, Cal-trans, fire stations etc., about 130 facilities) were disregarded (for retail sales potential), and remaining retail fueling station locations were retained.

Stations within the high market potential areas and in close proximity to the primary freeways (Hwy 101 and Hwy 118) were visited. UCI data showed high FCEV sales potential around Thousand Oaks, Simi Valley, Camarillo, Ventura and Oxnard (in Ventura County), and along the south coast of Santa Barbara County. In San Luis Obispo, the higher sales potential areas are along Highway 101 from Arroyo Grande through the City of San Luis Obispo and on to Atascadero. As such, stations in these areas were carefully reviewed, and multiple high-scoring stations were identified for these areas. In total, 183 stations were visited, 92 in Ventura, 60 in Santa Barbara and 31 in San Luis Obispo.

These stations were numerically rated, using five qualitative criteria as follows:

- Space available on the forecourt (maximum of 6)
- Appearance (6)
- Neighborhood (3)
- Ease of Access (3)
- Proximity to Freeway (3)

These criteria and weight factors were established subjectively by the project team, based on discussions with manufacturers and station installers. With this approach, space and appearance carried twice the weight of other criteria. Stations that ranked low in these two primary criteria were not closely investigated.

Stations north of Atascadero were not visited at this time, but they are nonetheless areas where connectivity could be relevant in the final analysis. Stations identified in the UCI report in these areas were reviewed via satellite imagery for size and freeway accessibility. Nipomo stations were not considered due to the town's small size, and proximity to larger population centers in Santa Maria and Arroyo Grande, both communities with high-ranking viable station options.

Stations that had a total rating score of 17 or higher were identified as good potential alternatives to those identified by UCI. The results are summarized in Tables 4, 5 and 6, for Ventura, Santa Barbara and San Luis Obispo counties, respectively. Complete results of the field assessment are included in Appendix B.2.

It should be emphasized that the station prioritization shown in Tables 4-6 is not meant to imply that the highest ranked stations would necessarily be the first for hydrogen refueling placement, nor does it imply that only the stations shown would be considered. The qualitative assessment and prioritization does, however, indicate that there are good options for siting hydrogen refueling systems at existing gasoline stations in all three counties. Also, this analysis does not preclude entirely new locations in these priority locations, such as within retail parking lots, though this may be more complicated and costly because of zoning and permitting requirements.

Reliability and Redundancy

The initial experience with FCEV refueling in California has raised concerns about the reliability of the refueling infrastructure while it is still in its embryonic stages. This fragility is a concern for potential vehicle owners if there is complete dependency on a single station in a given area. Even with optimal reliability, there are going to be times when stations are out of service for one reason or another.

This draws attention to the need for incorporating a "reliability strategy" into the analysis. While this can be most simply established by offering redundant stations in reasonable proximity, this, by itself, can be uneconomic when funding for new stations is limited. That said, the placement of initial stations in growth areas should be clustered if feasible to account for this as well as supporting expansion of the market.

Some of the other factors considered in this plan as possible ways for dealing with the reliability issue are as follows:

- Support the efforts of station manufacturers and installers in technology improvement to further enhance the dispensing technology to increase station reliability.
- Incorporate a limited number of lower pressure stations – at lower cost – when there are other reasons for pursuing this. For example, at dealerships or fleet locations where there could be other fuel cell vehicle types with additional demand.
- Consider supporting pilot projects for emerging technologies for hydrogen production where it makes sense to design for lower demand.

Continue to support online applications and communication systems that provide FCEV owners current and very specific information about station status. This would allow them to plan carefully for their refueling needs when there are system limitations. For example, this could include an interactive capability that could be implemented when an owner expresses intent to use a station during an extended trip, so that if the station does go down there is clear information available about the repair plan, or if the stations are networked provide real time availability information via smartphone apps.

Table 3 Results of UCI-APEP Spatial Modeling (grouped by cluster)[13]

Group	Rank	Street Address	City	County	Zip Code	AFVs Covered	Total AFVs Covered	CHIT Coverage Gap Score [x100]	Total CHIT Score
1	2	45 N. REINO RD	Thousand Oaks	Ventura	91320	607	2308	1.78	7.00
1	4	1152 E AVENIDA DE LOS ARBOLES	Thousand Oaks	Ventura	91360	571		1.90	
1	3	293 S MOORPARK RD	Thousand Oaks	Ventura	91361	596		1.45	
1	*5*	*4500 E THOUSAND OAKS BLVD*	*Thousand Oaks*	Ventura	*91362*	*534*		*1.87*	
2	17	507 E THOMPSON BLVD	Ventura	Ventura	93001	173	1403	0.39	6.15
2	15	7700 TELEGRAPH RD	Ventura	Ventura	93004	266		1.56	
2	13	522 N LAS POSAS RD	Camarillo	Ventura	93010	303		0.97	
2	8	4870 SANTA ROSA RD	Camarillo	Ventura	93012	419		0.84	
2	20	246 W EL ROBLAR DR	Meiners Oaks, Ojai	Ventura	93023	106		0.27	
2	18	655 S VENTURA RD	Oxnard	Ventura	93030	136		2.13	
3	11	50 W NEW LOS ANGELES AVE	Moorpark	Ventura	93021	339	1363	0.35	2.36
3	10	2627 YOSEMITE AVE	Simi Valley	Ventura	93063	346		0.84	
3	1	1196 E LOS ANGELES AVE	Simi Valley	Ventura	93065	678		1.17	
4	21	4401 VIA REAL	Carpinteria	Santa Barbara	93013	102	1706	0.54	2.73
4	6	101 W CARRILLO ST	Santa Barbara	Santa Barbara	93101	505		1.24	
4	*7*	*150 S LA CUMBRE RD*	*Santa Barbara*	*Santa Barbara*	*93105*	*434*		*0.26*	
4	9	1476 E VALLEY RD	Montecito	Santa Barbara	93108	350		0.54	
4	12	5960 CALLE REAL	Goleta	Santa Barbara	93117	315		0.15	
5	16	296 SANTA ROSA RD	San Luis Obispo	San Luis Obispo	93401	213	606	0.78	1.18
5	14	100 BARNETT ST	Arroyo Grande	San Luis Obispo	93420	275		0.22	
5	19	2000 EL CAMINO REAL	Atascadero	San Luis Obispo	93422	118		0.18	

13 It should be emphasized that the station prioritization shown in Tables 4-6 does not mean to imply that the highest ranked stations would be the first for hydrogen refueling placement, nor does it imply that only the sites shown would be considered and supported.

Figure 1 Tri-Counties Network of potential hydrogen refueling stations based on STREET modeling

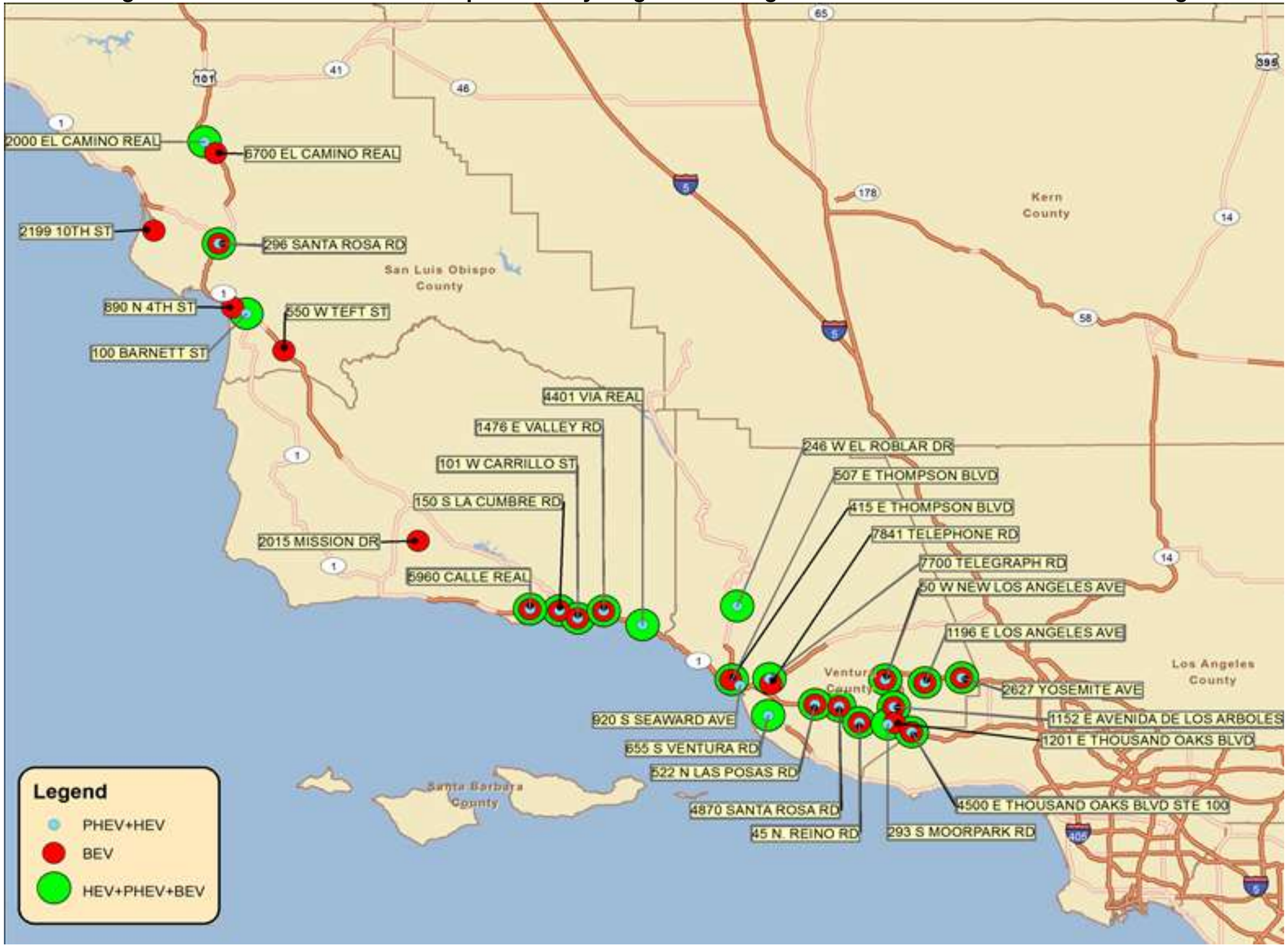


Table 4a Existing Gas Stations with High Suitability Ratings for Adding Hydrogen (East Ventura County)

Name	Address	City	Zip	SCORE
Hampshire Road Shell	395 Hampshire Road	Thousand Oaks	91360	18
7-Eleven #33162	609 Rancho Conejo Blvd.	Thousand Oaks	91320	18
Jenda, Inc.	3995 Thousand Oaks Blvd.	Thousand Oaks	91362	17
Rolling Oaks 76	293 S. Moorpark Rd.	Thousand Oaks	91361	17
Oaks Shell	56 E. Thousand Oaks Blvd.	Thousand Oaks	91360	17
Westlake Chevron	225 Hampshire Rd.	Westlake Village	91361	17
Borchard Arco AM/PM	2305 Borchard Rd.	Newbury Park	91320	21
GSE 76 Ventu Park	575 N. Ventu Park Rd.	Newbury Park	91320	20
Newbury 76	848 Wendy Dr.	Newbury Park	91320	18
USA Gasoline #68174	518 Rancho Conejo Blvd.	Newbury Park	91320	18
S & G Energy, Inc.	445 North Ventu Park Rd	Newbury Park	91320	18
Wendy Drive Chevron	2870 Camino Dos Rios	Newbury Park	91320	17
Borchard Chevron	2290 W. Borchard Rd.	Newbury Park	91320	17
Campus Plaza Shell	6599 Collins Dr.	Moorpark	93021	20
Moorpark Chevron	502 Los Angeles Ave.	Moorpark	93021	18
Union 76	550 W. Los Angeles Av	Moorpark	93021	17
Yosemite Shell	2627 Yosemite Ave.	Simi Valley	93063	21
Circle K #2211185	5195 East Cochran	Simi Valley	93063	20
Swank's Chevron	2449 Stearns Street	Simi Valley	93063	20
Chevron #9-1024	2568 Sycamore Drive	Simi Valley	93065	19
Apro LLC dba United Oil #10	108 Cochran Street	Simi Valley	93065	19
RJR Enter. dba Simi Valley Arco	25 Tierra Rejada Rd.	Simi Valley	93065	17
Kam's Canyon Mobil Service Ctr	2500 Tapo Canyon Rd	Simi Valley	93063	17

Table 4b Existing Gas Stations with Higher Suitability Ratings for Adding Hydrogen (West Ventura County)

Name	Address	City	Zip	SCORE
Arneill Chevron	255 Arneill Rd.	Camarillo	93010	20
Proud Auto	4676 Adolfo Rd.	Camarillo	93012	18
Las Posas Mobil, Inc.	501 Las Posas Road	Camarillo	93010	18
Chevron #200209	4870 Santa Rosa Road	Camarillo	93010	18
Tesoro Shell #68511	107 W. Ventura Blvd.	Camarillo	93010	18
Hilu Chevron	522 N. Las Posas Rd.	Camarillo	93010	17
Circle K #2709460	2200 N. Rose Ave.	Oxnard	93030	20
Chevron SS #20-8020	1900 N. Rose Ave.	Oxnard	93030	20
Circle K #2709483	490 S. Victoria Ave.	Oxnard	93030	19
7-Eleven Facility #33399	2201 E. Gonzales Rd.	Oxnard	93036	18
S & S Chevron	2901 Saviers Road	Oxnard	93033	18
Vineyard Mobil	2851 E. Vineyard Ave.	Oxnard	93036	17
Oxnard Vineyard Chevron	2251 N. Oxnard Blvd.	Oxnard	93036	17
Rose Shell	1901 N. Rose Ave.	Oxnard	93030	17
Chevron #9-0576	920 S Seaward Ave	Ventura	93003	21
California Chevron	507 E Thompson Blvd.	Ventura	93001	20
Johnson Drive Carwash & Gas	2757 Johnson Dr.	Ventura	93003	19
Seaward Oil, Inc.	779 South Seaward Ave.	Ventura	93001	19
Johnson Oil Corp. Fac. 309330	6762 North Bank Dr.	Ventura	93003	18
Zaitoon Inc.	605 S. Mills Rd.	Ventura	93003	17
Arco AM/PM	5669 Valentine Rd.	Ventura	93003	17
Tesoro Arco #42054	2124 East Harbor Blvd	Ventura	93001	17

Table 5 Existing Gas Stations with Higher Suitability Ratings for Adding Hydrogen (Santa Barbara County)

Name	Address	City	Zip	SCORE
Circle K Stores, Inc.	402 W. Mission Street	Santa Barbara	93101	19
Circle K Stores, Inc.	4801 Hollister Avenue	Santa Barbara	93111	18
Turnpike Fuel Partners, LP	250 N. Turnpike Road	Santa Barbara	93111	18
Janda Partners, L.P.	1085 Coast Village Road	Santa Barbara	93108	18
Tesoro Refining & Marketing Company LLC	340 W. Carrillo Street	Santa Barbara	93101	18
Chevron USA Products Company	115 S. La Cumbre Road	Santa Barbara	93105	17
World Oil Marketing Company	1800 State Street	Santa Barbara	93101	17
World Oil Marketing Company	5960 Calle Real	Goleta	93117	18
Circle K Stores, Inc.	49 N. Glen Annie Road	Goleta	93117	17
76 (Next to old Carrows)	4401 Via Real	Carpinteria	93013	19
Chevron	4290 Via Real	Carpinteria	93013	19
seven eleven	4410 Via Real	Carpinteria	93013	18
Moller Retail, Inc.	89 E. Highway 246	Buellton	93427	19
USA Gas	197 E Highway 246	Buellton	93427	19
Pacific Fuel Group	206 E. Hwy 246	Buellton	93427	19
Aljnar, Inc.	188 E. Highway 246	Buellton	93427	19
Tom's Gas	230 E Highway 246	Buellton	93427	17
ERN Oil, Inc.	605 Bell Street	Los Alamos	93440	17
Moller Retail, Inc.	910 E. Betteravia Rd.	Santa Maria	93454	20
Valley Pacific Petroleum Services, Inc.	1155 E. Betteravia Rd	Santa Maria	93455	19
Circle K Stores, Inc.	1220 E. Betteravia Rd	Santa Maria	93454	18
Main Street Shell Service	1204 E. Main St	Santa Maria	93454	17
Main Street Petroleum	1038 E. Main St	Santa Maria	93454	17

Table 6 Existing Gas Stations with Higher Suitability Ratings for Adding Hydrogen (San Luis Obispo County)

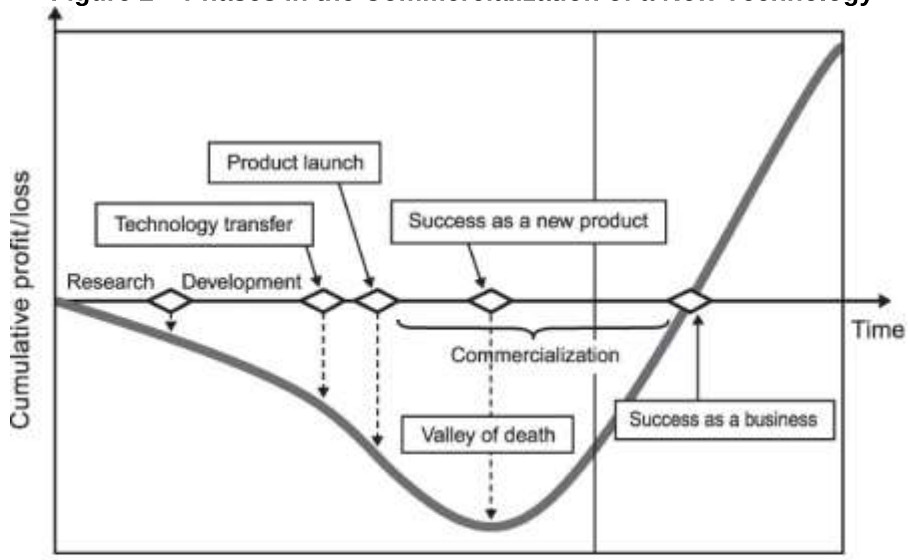
Name	Address	City	Zip	County	SCORE
Mission Station, Inc.	328 Marsh Street	San Luis Obispo	93401	SLO	19
Tesoro Station No. 68613	296 Santa Rosa Street	San Luis Obispo	93405	SLO	17
Chevron # 98169 (Trett's)	3180 S. Broad Street	San Luis Obispo	93401	SLO	17
Refuel	2211 Broad Street	San Luis Obispo	93401	SLO	17
ARCO - Arroyo Grande AM/PM	100 Barnett Street	Arroyo Grande	93420	SLO	19
Mobil (Petro Grande)	525 Traffic Way	Arroyo Grande	93420	SLO	17
Chevron - Kautz	1284 Grand Avenue	Grover Beach	93433	SLO	20
Grover Beach Flyers	684 West Grand Avenue	Grover Beach	93433	SLO	17
Five Cities Chevron	340 Five Cities Drive	Pismo Beach	93449	SLO	19
Spyglass Shell (AU Energy)	2699 Shell Beach Road	Pismo Beach	93449	SLO	17
Atascadero 76	6305 Morro Road	Atascadero	93422	SLO	19

Avoiding Stranded Assets

Clearly, there is a vital need for stations to be built concurrently with the growing number of FCEVs in the region, but it would not make financial sense to build "too many" refueling stations if FCEVs were not available for sale, or if they were not in demand by potential customers in this region.

The data included in Tables 1 and 2 above, can be used to project the pace of build-out necessary to support the growing demand for FCEVs. However, projections are notoriously unreliable for newly deployed vehicle types, and for any new technology there is a proving and acceptance period through which the technology has to go before it does (or does not) become mainstream. (Refer to Figure 2).

Figure 2 – Phases in the Commercialization of a New Technology



The sales projections which the OEMs have collectively shared with the state are probably the best indication of sales potential at this stage, so the numbers given above have been used as the basis for planning infrastructure needs in the Tri-Counties from present out to 2025.

This further emphasizes the need for close coordination in the planning and implementation process between the local communities, the vehicle manufacturers, and the government agencies that provide funding support for station construction and operation.

Hydrogen Station Priorities

The market proxy data summarized in Table 3 (above) indicate that there are likely to be strong markets in several cluster areas of the Tri-Counties, with highest demand projected in the eastern end of Ventura County, both in the Westlake/Thousand Oaks/Newbury Park area (1,927) and also Simi Valley/Moorpark (1,275). Third and fourth highest rankings using the proxy metric are the Santa Barbara County South Coast (1,242) and Camarillo/Ventura/

Oxnard (1,226) in western Ventura County. Stations in these four areas cover 90% of the initial FCEV demand projected for the Tri-Counties.

Thus, based on market demand potential alone, the initial station priorities for the Tri-Counties should be:

1. Thousand Oaks/Newbury Park/ Westlake (eastern Ventura County)
2. Simi Valley/Moorpark (eastern Ventura County)
3. Santa Barbara County South Coast (now in place and operational)
4. Camarillo/Ventura (western Ventura County)
5. San Luis Obispo County

Since the first station is already operational in Santa Barbara, the initial priorities to maximize potential are in Ventura County. With stations in these first four general locations, there would be sufficient coverage to provide a reasonable level of redundancy since the stations in Ventura County would be within about 20 to 30 miles of each other, and for vehicle owners in Santa Barbara, there could be an alternative station reasonably close by as soon as one is in place in the Camarillo/Ventura area.

Since each County is likely to set its own priorities for establishing hydrogen infrastructure, there is potential for Santa Barbara to address the redundancy issue more immediately by pursuing options for a second station somewhere between Goleta and Carpentaria.

After this initial round, the subsequent priorities would be to install additional stations to meet growing demand or to focus on a connector station in San Luis Obispo County to provide access to the Bay area along the 101 corridor. This would serve all vehicle owners to the south in this respect as well as serving local demand. The proxy data suggest that subsequent build out to meet demand is likely to be most needed in the following areas:

1. Thousand Oaks/Newbury Park/ Westlake – second station
2. Simi Valley/Moorpark – second station
3. Santa Barbara – second station
4. Camarillo/Ventura/Oxnard – second station

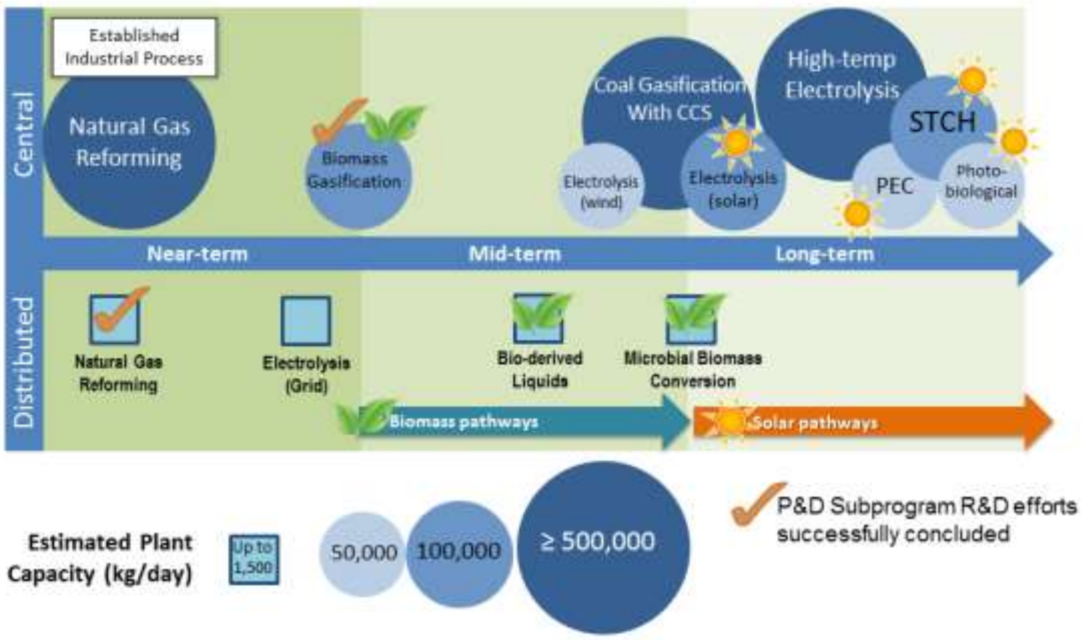
The main conclusions from this are that the Thousand Oaks area is clearly a top priority, and the second priority could be Simi Valley/Moorpark based on demand alone, or Camarillo/Ventura to meet demand and provide broader redundancy in the early years. Subsequently, the need for additional stations to meet demand in Ventura will be considered as well as the needs for a connector station in San Luis Obispo and a second station for local redundancy in Santa Barbara. Both of these latter locations would also serve growing local demand.

The field work done locally has shown that there are favorable gas stations having the necessary attributes for siting hydrogen dispensers in each of the priority areas. (Refer to Tables 4, 5 and 6 above).

Hydrogen Production and Distribution

The Department of Energy (DOE) maintains a website that provides a comprehensive summary of the available hydrogen production methods that could be developed in the near-term, mid-term and long-term (Figure 3 below).[14]

Figure 3 Hydrogen Production Pathways



Source: Department of Energy Office of Energy Efficiency and Renewable Energy
http://energy.gov/eere/fuelcells/hydrogen-production-pathways

While there are many potential options in the longer term, the figure shows that there are only two basic approaches that are viable in the near-term, and these are natural gas reforming and electrolysis. Factors that will influence the near-term pathway(s) chosen are likely to be the cost for hydrogen at the pump, and the carbon intensity of the life cycle process (well-to pump). Production and distribution both have an effect on carbon intensity.

The following considerations are relevant in this respect:

- There is a California mandate that requires 33 percent of all hydrogen produced for use in FCEVs will have to come from renewable sources – once the total quantity of hydrogen delivered in the state exceeds a defined level. Over time, this percentage is likely to increase as the state moves to achieve its goal of 80% reduction in GHG emissions by 2050.[15]

14 http://energy.gov/eere/fuelcells/hydrogen-production-pathways
15 SB 1505 Environmental Performance Standards for Hydrogen Fuel

- Each hydrogen production pathway has its pros and cons. For example, most of the hydrogen produced and delivered for FCEVs in California at this time comes from centralized production of hydrogen using Steam Methane Reforming (SMR). This is probably the least-cost option presently, but it has a relatively high carbon intensity because it uses natural gas as a source and the hydrogen must be distributed via trucked deliveries. In contrast, on-site electrolysis can have a low carbon intensity (dependent on the source of electricity used), but is currently more costly, and more difficult to produce at volume.
- In due course, there is a real possibility that distributed hydrogen production will become an option, for example through "compact onsite reformation". The implication of this is that there would be a reduced need for transporting hydrogen from central production facilities.
- As the above figure suggests, hydrogen production and delivery methods are likely to change and improve over time, so it would be prudent not to move too fast in one direction at this early stage. For example, by investing in too many stations dependent on centralized hydrogen SMR production. Stranded assets and investments need to be avoided. As such, it may be advantageous to keep options open with respect to production and delivery methods during the early years.

Steam Methane Reforming of Natural Gas

Today, SMR accounts for about 95 percent of domestic hydrogen production. In this process, natural gas is mixed with high-temperature steam in the presence of a catalyst to separate the hydrogen. Carbon dioxide is emitted as an effluent gas with this process. Most of the hydrogen produced in this way is used for industrial processes and in the refining of crude oil.

A recent report by the Institute for Transportation Studies at UC Davis concludes that natural gas will continue to be the least expensive and most energy-efficient resource from which to produce hydrogen through the 2020s.[16]

Use of Renewable Natural Gas for Hydrogen Production

The steam reforming process can be used to produce renewable hydrogen when the natural gas feedstock is replaced with biogas or landfill gas. A biogas or landfill gas feedstock can be used to produce hydrogen with a lower carbon intensity than natural gas SMR, but the actual value will depend on the fuel used for steam production and the need for distribution. Experience has shown that the biogas conditioning system needs to be effective and reliable to avoid having contaminant gases foul the fuel cell membranes (particularly in stationary applications). For transportation fuels, there are specified conditions for the hydrogen gas quality, so this should not be an issue for FCEVs. In the Tri-Counties, it is

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16 Joan Ogden, Christopher Yang, Michael Nicholas, Lew Fulton , NextSTEPS White Paper: The Hydrogen Transition, Institute of Transportation Studies University of California, Davis, July 29, 2014, p. 15 http://steps.ucdavis.edu/files/08-13-2014-08-13-2014-NextSTEPS-White-Paper-Hydrogen-Transition-7.29.2014.pdf unclear how much biogas or landfill gas would be available for the production of hydrogen, but the revised Low Carbon Fuel Standard proposed by CARB does allow for the use of out-of-state biogas or landfill gas to be purchased and used to offset the natural gas emissions. This latter approach is being used by hydrogen producers currently to meet or exceed the State 33% renewable hydrogen requirement.

Onsite Production of Hydrogen Using Electrolysis

Through this process, an electric current splits water into hydrogen and oxygen. With electrolysis, traditional methods use purified water and power from the grid. If the electricity is from a renewable source, then the hydrogen is also said to be renewable. Electrolysis of water is a less common method of producing hydrogen for FCEV use currently, but several production projects are being developed, including some that plan to use wind or solar power. Some experts maintain that onsite electrolysis is up to twice as expensive as hydrogen produced by steam reformation of natural gas.[17]

Emerging Technologies for Hydrogen Production

The development of clean, sustainable, and cost-competitive hydrogen production processes is essential to the success of hydrogen powered transportation. Research and development of alternative ways to produce hydrogen have been ongoing for several years, and continue to this day. In 2009, the Freedom Car and Fuel Partnership issued a paper called "Hydrogen Production – Overview of Technology Options" which included a summary of seven key production technologies in three broad categories (listed below).[18] Some of these approaches are approaching commercialization, but further research is ongoing at the national laboratories, universities and in the commercial sector.

Thermal Process

- Distributed natural gas reforming
- Bio-derived liquids reforming
- Coal and biomass gasification
- Thermochemical production

Electrolytic and Photolytic Processes

- Water electrolysis
- Photo electrochemical hydrogen production[19]
- Biological hydrogen production

17 Julia Pyper, "Is electrolysis the pathway to reach totally carbon-free hydrogen fuel?," Climatewire, November 20, 2014. http://www.eenews.net/stories/1060009250

18 Freedom Car & Fuel Partnership, "Hydrogen Production – Overview of Technology Options", 2009.

19 The photoelectrochemical production pathway is being pursued by several R&D groups including one local start-up in Santa Barbara called HyperSolar (hypersolar.com)

Another potential technology development that could be relevant in the near term is Carbon Capture and Sequestration (CCS). The first commercial scale carbon capture and sequestration projects are now operational, and SMR is one process where carbon capture can be accomplished at a reasonable cost, especially when there is a price on carbon emissions. One example is the Shell Quest project in Alberta, Canada. New technologies are also emerging in which a CO_2 stream is converted directly to carbon, avoiding the need to inject and store underground. One example is the LytEn carbon sequestration system which has been proposed with several hydrogen production pathways approved by CARB[20]. (Refer to Section 2.4.8, below for further details.)

Based on dialogue with community stakeholders through the planning period, it is evident that there is concern about building a hydrogen infrastructure that is dependent on hydrogen production from fossil fuels, including natural gas. This emphasizes the importance of continued progress in developing and implementing sources of cost-effective renewable hydrogen.

Water and Natural Gas Requirements

An important consideration in the development of new production pathways is the resources that are needed to produce the hydrogen. In particular, the transition from petroleum to hydrogen is less beneficial if the hydrogen is derived from natural gas – another fossil fuel – and electrolysis may be less appealing if the demand for water competes with existing needs for potable water.

Table 7 compares the resource requirements for hydrogen produced from steam reforming (natural gas and water) with the water needed for hydrogen produced by electrolysis. In general, it is apparent that the water requirements for either pathway are not substantial when compared with other existing water uses. This concern is further mitigated if non-potable sources of water can be used to produce the hydrogen in due course.

Hydrogen Distribution

Once hydrogen is produced, there are several ways to deliver it to vehicles. When produced centrally in larger production units, it is usually stored as a compressed gas or as a cryogenic liquid (at -253˚C), and then distributed by truck (or gas pipeline in some cases) to the hydrogen refueling station. When hydrogen is produced on-site at or near the refueling station, then the need for distribution is eliminated.

In the near term, most hydrogen delivered to the Tri-Counties would likely come by truck from sources in the Los Angeles area that currently produce hydrogen for other users. Relatively small amounts of gaseous hydrogen can be transported short distances by high-

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20 LytEn Low Carbon Fuel Standard Pathway for the Production of Hydrogen from Natural Gas and Renewable Natural Gas. https://www.arb.ca.gov/fuels/lcfs/2a2b/apps/lyt-H2-rpt-121715.pdf pressure tube trailers (at 250 bar or 3,600 pounds per square inch [psi]). A modern high-pressure tube trailer is capable of transporting approximately 600 kilograms (kg) of

Table 7 Fuel Production Resource Projections

(a) Steam Reforming							
	Use $2(H_2O) + CH_4 = CO_2 + 4(H_2)$						
		MW					
Ideal	H - 8 atoms	8	1	kg	Production of 1kg of hydrogen		
	C - 1 atom	12	1.5	kg			
	O - 2 atoms	28	3.5	kg			
	CH_4	16	2	kg	Needs 2kg of Natural Gas (CH_4)		
	2 (H_2O)	32	4	kg	Needs 4kg of Water (H20)	1.1	gallon
	CO_2	40	5	kg	Generates 5kg of CO_2		
Add process heat - assume this doubles the quantity of methane needed (actual data); assume 50% steam overfeed							
	CH_4		4	kg	Needs 4kg of Natural Gas (CH_4)		
	2 (H_2O)		6	kg	Needs 6kg of Water (H20)	1.6	gallon
	CO_2		10	kg	Generates 10kg of CO_2		
(b) Electrolysis							
	Use $2(H_2O) = O_2 + 2(H_2)$						
		MW					
	H - 4 atoms	4	1	kg	Production of 1kg of hydrogen		
	O - 2 atoms	28	7	kg	Generates 7kg of oxygen; no CO_2		
	2 (H_2O)	32	8	kg	Needs 8kg of water	2.1	gallon
Assume electrolysis is 70% conversion rate from water to hydrogen/oxygen							
	2 (H_2O)		11.4	kg	Needs 8kg of water	3.0	gallon
(c) Resource Needs (minimum) assuming 100% efficiency of hydrogen conversion process							
	Number of FCEVs	1	1000		Estimate for Tri-Counties, 2020		
	Hydrogen per year	254	254,148	kg	CARB 2015 Report		
	Steam Reforming:	1,017	1,016,593	kg NG			
		517	516,904	therm NG			
		1,525	1,524,889	kg water			
		404	404,187	gall water			
	Electrolysis	2,905	2,904,550	kg water			
		770	769,881	gallons, total			
Unit Conversion factors							
	Density of water	8.3	lb/gall	3.77	kg/gall		
	Natural Gas	1,017	kg NG	per vehicle per year			
		0.712	kg/m3				
		1,428	m3 NG				
		50,430	ft3 NG				
		1025	btu/scft				
		52	MMBtu	per vehicle per year			
		517	therms	per vehicle per year			
For Comparison							
	Typical Household in SB	500	therms per year (NG)				
		60,000	gallons water per year				

hydrogen (in contrast to gasoline tank trucks, which can transport nearly 14 times the equivalent energy). Tube trailers are currently limited by DOT regulations to pressures of less than 250 bar, but further development and testing of Types II, III, or IV higher-pressure composite vessels for hydrogen, along with the development of appropriate codes and standards, will eventually allow the use of higher-pressure hydrogen tube trailers that also comply with federal truck weight limitations.

The cryogenic liquid delivery option is more economical than gaseous trucking for high market demands (greater than 300 kg/day) because a liquid tanker truck with a capacity of approximately 4,000 kg can transport more than 10 times the capacity of a typical tube trailer. The energy cost for converting gaseous hydrogen to liquid is high because hydrogen has an extremely low condensing point (-423.2°F at atmospheric pressure). The theoretical thermodynamic energy needed for hydrogen liquefaction represents approximately 10% of the energy in the hydrogen (lower heating value). An estimate for current liquefaction is that the energy required amounts to about 35% of the energy content of the hydrogen.

Current analysis shows that pipeline delivery, where feasible, provides the lowest cost option for large refueling station demand (greater than about 600 kg/day). Compressed gas tube-trailers are well-suited for hydrogen delivery for smaller end-use demand and short distance deliveries due to their low payload (~300 kg).

The contribution of refueling station capital investment contributes approximately half of the total delivery cost. The capital investment at the refueling station is dominated by cost of compression and storage. The investment risk and the underutilization of the refueling station capital investment during the pre-commercialization and the transition to large scale deployment of fuel cell electric vehicles represent the major market barriers to the full commercialization of fuel cell electric vehicles.

Mobile Refuelers

The potential use of mobile hydrogen refueling trucks to service initial (lower) demand for fuel has been discussed. This could be an approach used by the Tri-Counties to provide temporary fueling capability in new market areas, and also as a way to fuel vehicles if primary stations are inoperable. Such units would be required to meet the National Fire Protection Association (NFPA) 2: Hydrogen Technologies Code and local codes.

Mobile refuelers have been used for early market hydrogen delivery in Japan. They combine hydrogen storage with a dispenser in a portable unit that can fuel vehicles directly, or to transfer hydrogen to a storage tank at a refueling station. Mobile refuelers have a typical capacity of 110 kg at 350 bar (5,000 psi) using steel tubes. Liquid hydrogen supply mobile refuelers combine a liquid cryogenic pump and heat exchanger/vaporizer to produce high-pressure gaseous hydrogen for fueling. The mobile refueler is transported using a separate traction vehicle.

Mobile refuelers are considered a short-term bridge technology, which would no longer be needed once a viable network of stations in operating.

Hydrogen Dispensing

FCEVs are designed to accept hydrogen in gaseous form pressurized at two levels, either 350 bar (5,000 psi) -- known as H35 -- or 700 bar (10,000 psi) – known as H70. Currently, 700 bar (H70) gaseous on-board storage has been chosen for the first generation of commercial vehicles, while 350 bar (H35) is typically used for buses, forklifts, and other lift trucks. A full tank of hydrogen on a light duty FCEV (usually about 4 to 6 kilograms) provides range of approximately 300 miles, which is almost comparable to a conventional vehicle.

Hydrogen refueling stations can be co-located with regular gasoline stations or they can be operated in stand-alone locations. Hydrogen dispensing equipment is similar in appearance to gasoline dispensers, although hydrogen fuel is delivered to vehicles in a gaseous state. Stations are designed for unattended operation.

Hydrogen dispensers being installed today usually have one hose and nozzle for each of the two standard delivery pressures. Users cannot attach the high-pressure nozzle to a lower pressure receptacle, so there is no chance of fueling at the wrong pressure level. When a driver activates the dispenser, hydrogen flows from the storage tanks and through the nozzle into the vehicle's on-board storage tanks. If filling with H70 (light-duty vehicle standard), the hydrogen passes through a booster compressor and chiller before entering the dispenser.

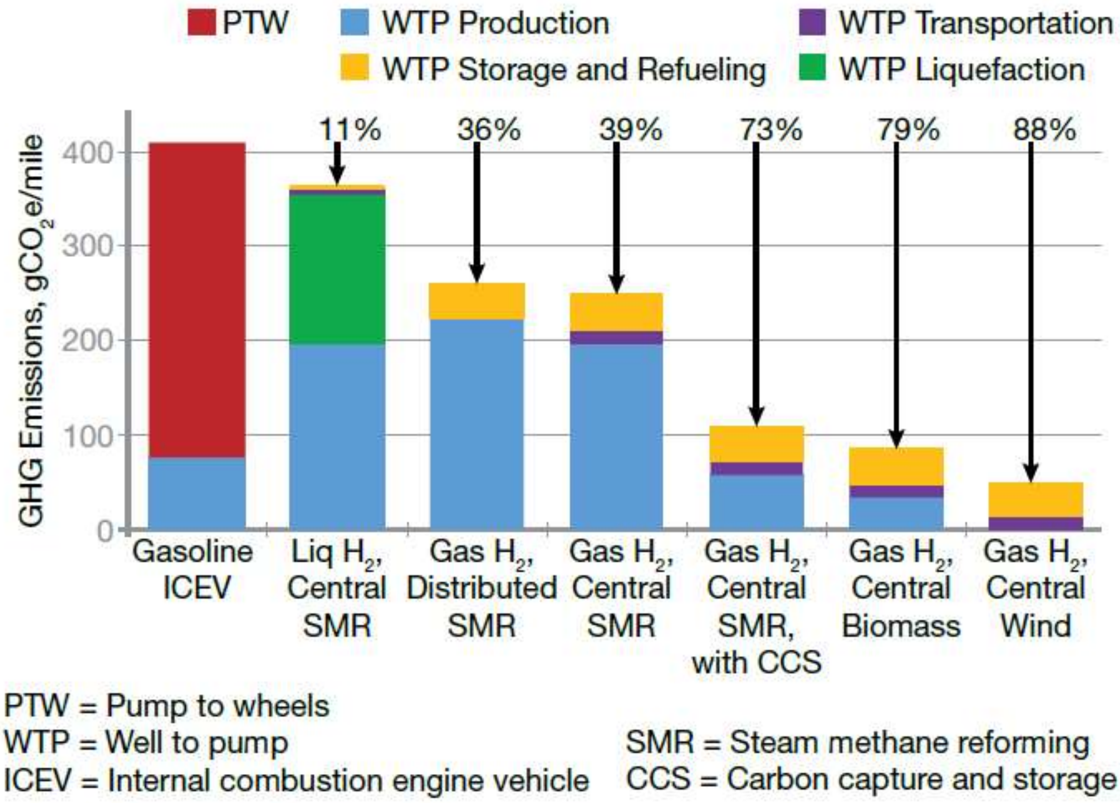
The dispensers are designed to accept credit cards and display sales information conforming to state weights and measures requirements. Volume is displayed in kilograms (kg). Fueling time is approximately 5 minutes per tank for a typical light duty vehicle. The State has made significant progress developing a reliable method for assuring the accurate measurement of fuel delivery to an FCEV.

Hydrogen leak detection, in the absence of odorizers, is a challenge. Currently, commercially available leak detection equipment is handheld. Ideally, an online leak detector (direct or indirect measurement) would be a desirable addition to a tube trailer.

Summary of Production and Distribution Pathways

Figure 4 below presents a summary of the GHG emissions for the various hydrogen production options, including distribution (Well to Pump). As part of the revision process for the LCSF regulation, CARB has recently issued an updated set of approved hydrogen pathways (Table 8). This table shows the production alternatives currently under consideration in California, and for providing hydrogen to the Tri-Counties region in the near term.

Figure 4 Comparison of GHG Emissions for Various Production and Distribution Combinations



Source: Reddi, Krishna; Amgad Elgowainy and Michael Wang, Argonne National Laboratory; Chemical Engineering Progress, AIChE, July 2016, page 51.

Of the 15 hydrogen pathways listed in Table 8, there are four variation of natural gas SMR (three central and one onsite); one SMR onsite using renewable feedstocks; four that use renewable biogas (two with 33% and two with 100%) – all with carbon capture; four with Landfill Gas with carbon capture; one using electrolysis with solar electricity; and one that is a "Tri-generation" process using a fuel cell and biogas. The table shows that, with the use of carbon capture, some of the pathways using non-fossil feedstocks can result in negative carbon intensity values. All of these pathways would be feasible at selected locations within the Tri-Counties region, though cost and available feedstocks would be important considerations.

Table 8 – Summary of LCFS Hydrogen Pathways

App #	Class	Applicant & Pathway Discription	Feedstock	Fuel Type	Current FPC	Current CI	Certification Date
	Lookup Table	CARBOB - based on the average crude oil supplied to California refineries and average California refinery efficiencies	Crude Oil	CARBOB	CBOB001	99.78	NA
	Lookup Table	California grid electricity	CA Grid Electricity	Electricity	ELC002	105.16	NA
	Lookup Table	Compressed H2 from central reforming of NG (includes liquefaction and re-gasification steps)	North American NG	Hydrogen	HYGN001	151.01	NA
	Lookup Table	Liquid H2 from central reforming of NG	North American NG	Hydrogen	HYGN002	143.51	NA
	Lookup Table	Compressed H2 from central reforming of NG (no liquefaction and re-gasification steps)	North American NG	Hydrogen	HYGN003	105.65	NA
	Lookup Table	Compressed H2 from on-site reforming of NG	North American NG	Hydrogen	HYGN004	105.13	NA
	Lookup Table	Compressed H2 from on-site reforming with renewable feedstocks	North American NG	Hydrogen	HYGN005	88.33	NA
	M2A/2B	LytOil (DBA LytEn): 33.3% Renewable Biogas, On- Site Hydrogen (Prospective)	Landfill Gas	Hydrogen	HYGN007	15.29	12/30/15
	M2A/2B	LytOil (DBA LytEn): 100% Renewable Biogas, On- Site Hydrogen (Prospective)	Landfill Gas	Hydrogen	HYGN008	-46.91	12/30/15
	M2A/2B	LytOil (DBA LytEn): 33.3% Renewable Biogas, Tube Trailer (Prospective)	Landfill Gas	Hydrogen	HYGN009	29.84	12/30/15
	M2A/2B	LytOil (DBA LytEn): 100% Renewable Biogas, Tube Trailer (Prospective)	Landfill Gas	Hydrogen	HYGN010	-32.36	12/30/15
	M2A/2B	FuelCell Energy, Inc.: Hydrogen produced in a fuel cell using biogas derived from the mesophilic anaerobic digestion of wastewater sludge, with electricity co-product credit.	Biogas from Wastewater Sludge	Hydrogen	HYGN011	-0.82	02/02/16
T2R-1080	Legacy	Fuel Producer: Alameda-Contra Costa Transit District (A149) Facility Name: Division 2 (F1600). Hydrogen production via electrolysis using solar electricity	Solar Elericity via Electrolysis	Hydrogen	HYGE200L	0.00	09/30/16
T2R-1033	Legacy	Fuel Producer: LytEn (L700) Facility Name: LytEn (K4933). Landfill gas to hydrogen production via cracking of methane and transport by tube trailer	Landfill Gas	Hydrogen	HYGLF200L	-5.28	09/30/16
T2R-1034	Legacy	Fuel Producer: LytEn (L700) Facility Name: LytEn (K4933). North American fossil NG and landfill gas to on-site hydrogen production via cracking of methane	Fossil NG & Landfill Gas	Hydrogen	HYGFLF200L	40.36	09/30/16
T2R-1035	Legacy	Fuel Producer: LytEn (L700) Facility Name: LytEn (K4933). Landfill gas to on-site hydrogen production via cracking of methane	Landfill Gas	Hydrogen	HYGLF201L	-12.65	09/30/16
T2R-1036	Legacy	Fuel Producer: LytEn (L700) Facility Name: LytEn (K4933). North American fossil NG and landfill gas to hydrogen production via cracking of methane and transport by tube trailer	Fossil NG & Landfill Gas	Hydrogen	HYGFLF201L	47.73	09/30/16

Source: CARB, December 2016. Note that CARBOB and Electricity pathways are also included to show respective CIs for reference.

Hydrogen Station Cost Estimates

Details of the costs for installing and operating hydrogen refueling systems is of interest to local decision makers who may be considering local support for building the regional infrastructure. The information summarized below is drawn from three main sources. These are: (1) the California AB8 Joint Agency Report: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California (mid-year 2015)[21]; (2) the California Hydrogen Business Council (CHBC) report titled "Financing the 101st Hydrogen Station"; September 2016[22]; and (3) DOE financial projections analysis[23].

Station Installation Cost

The AB8 Joint report summarizes investments made by the State over the last five years for hydrogen station installation. The report suggests that each station using delivered hydrogen costs about $2.1 million to install, of which the state has been contributing up to 85% of the total. This is based on awards made for the first 51 stations in California. This share is declining over time, and for the current round of funding (2016), the state contribution is expected to be 70%. Most of these stations have a capacity of about 18 kg/day.

Costs for stations with higher capacity – increased storage of hydrogen gas onsite, or by using liquefied hydrogen – will likely be higher than $2.1 million, and could be as much as $2.8 million for a 350 kg/day station with delivered liquid hydrogen. For a 130 kg/day station using present day electrolysis, the CEC data show that station installation costs are on the order of $3.1 million. Clearly, there is a considerable premium for delivering hydrogen using this technology.

The hydrogen business community is concerned that the high cost for station installation will be an impediment to achieving the state's longer term goals for hydrogen. This is clearly expressed in the CHBC report referenced above. The report focused on the business case for commercialization of hydrogen station installation and operation, concluding that there are four primary variables that control station profitability as follows (based on assumptions for a 200 kg/day station):

- For each station there needs to be 400 vehicles clustered around the station, each using 0.5 kg/day of hydrogen
- Margin on hydrogen sales needs to be $3/kg or better
- O&M cost needs to be $100,000/year or less
- Capital cost of station must be $1,000,000 or less

21 AB8 Joint Agency Report: Assessment of Time and Cost Needed to Attain 100 Hydrogen refueling Stations in California, 2015 (California Energy Commission and California Air resources Board Joint Report to California legislature (with NREL Technical Support). Jim McKinney lead author, ARFVT Program Manager CEC. Ref CEC-600-2015-016

22 CHBC Report "Financing the 101st Station", September, 2016.

23 DOE NREL - reference

Meeting these targets will be a substantial challenge for California. The AB8 Joint Agency report projects that station costs could decline by as much as 50% if the global development of the hydrogen infrastructure continues which suggests that the station cost target of $1 million is achievable based on work being performed at NREL. Experience in other regions and countries (including the East Coast States and Japan) indicates that stations can be built and installed for less than $2.1 million. However, it is unclear what station design factors will change and how quickly this will become feasible.

The AB8 report recognizes that automakers are already contributing to station development costs, but there is a clear need to stimulate further station investments through innovative partnerships between government and the private sector.

Station Operating and Maintenance Costs

Operating and Maintenance (O&M) costs include equipment maintenance and onsite station operability. Given that there is low throughput for each of the stations installed to date, the State has been supporting station O&M with grants of up to $300,000 per station (over three years). Station throughput will need to increase substantially to deliver the margin needed to cover this together with a return on investment, but NREL modeling analysis shows that this would be achievable with 75% station utilization.

The cost for dispensed fuel is not included in the O&M package, as that is paid for separately at the “pump”. On average, the current price for hydrogen in California is about $14/kg (AB8 report) which equates to $5.60 per gallon of gasoline, taking account of the fact FCEVs are about 2.5 times more efficient than ICE vehicles (and 1kg of hydrogen has about the same useful energy as 1 gallon of gasoline).

DOE has projected that the future price of hydrogen could drop to $8/kg to $10/kg within a few years which would be competitive with gasoline as $3.50 per gallon. Longer range the cost could drop even further to $2-$5/kg (based on the DOE forecast included in the AB8 report).

In summary, it is apparent that O&M can be covered as soon as station utilization increases, and there is potential for fuel costs to decrease such that they are competitive with gasoline. The LCFS regulation, currently going through a revision process, will soon require all hydrogen fuel producers to participate in the LCFS program which in many cases will provide an opportunity for revenue generation. CARB has estimated that $2 to $3 per kg may be available for hydrogen generated using pathways with low or negative CI values. (AB8 annual report, 2016)

The station financial costs for installation and O&M were modeled by NREL using the H2FIRST model[24]. This acronym stands for Hydrogen Financial Station, a model developed by the DOE for cost estimation based on early work by Energy Independence Now (EIN)[25].

24 H2FIRST

25 EIN Financial Tool

Chapter 3: Hydrogen Station Permit Streamlining

The Hydrogen Station Permit Guidance provided in Appendix C is a set of recently issued guidance documents that may be used by permit agencies that are asked to review and permit hydrogen refuelling stations within their jurisdictions. These resources may also be useful to hydrogen refuelling infrastructure providers that are interested in working locally in the Tri-Counties region.

Introduction

Experience around the state has shown there can be significant delays in getting a hydrogen station installed because of unseen or unexpected issues that arise during the permitting process. Some of these delays have been two years or more, and this has created frustration and a cost burden that is an impediment to the smooth introduction of a hydrogen infrastructure.

Every time a station is proposed in a new community, there is potential for delays if hydrogen is perceived as a “new technology” and one with unreasonable safety concerns. That said, it is important that the permitting be done properly and thoroughly to provide early assurance that stations can be designed and built safely and in a way that meets applicable codes and standards. This is important if it is to operate successfully and be readily accepted in the community.

There is now a growing body of experience related to station permitting and there is a plethora of information that is available to permit agencies to help expedite the review process. The intent of this manual is to summarize that information so that there is clear guidance on resources that are available, and to summarize how each resource can be most useful. In this way the permit process may be expedited and streamlined in a way that leads to a consistent high-level of permitting across the Tri-Counties.

The guidance can help ensure that important considerations are not overlooked, and also to avoid any unnecessary time wasted in conducting studies and research on issues that have already been addressed effectively by others.

Review of Available Permitting Guidance and Resources

Table 9 (included at the end of this Chapter) presents a matrix of several key resources that are publically available to Planning and Fire Departments for performing plan checks. The table includes an indication of the content of each resource as it relates to hydrogen station permitting.

The California Governor’s Office of Business and Economic Development (GO-Biz) has issued a comprehensive “Hydrogen Station Permitting Guidebook”, which is an excellent resource for guiding the permitting process. Other sources of information included in this table include the State of California ZEV Readiness Guidebook, and permit tools available from the DOE H_2Tools website. These reference materials are described briefly below. Given that many of these references are likely to change and be updated, it is recommended that the links provided to electronic versions of these documents be used to access the most current versions when needed.

Hard copies of these primary resource documents are included in Appendix 3.

GO-Biz "Hydrogen Station Permitting Guidebook"

This reference document provides best practices for planning, permitting and commissioning for a new hydrogen refueling station. It was published by the Governor's Office of Business and Economic Development in November 2015 (First Edition).

https://gobiz.app.box.com/v/hydrogenpermittingguidebook

NREL –Guide to Permitting Hydrogen Motor Fuel Dispensing Facilities

This is a comprehensive guide for permitting resources recently released by DOE. It includes a detailed listing of applicable codes and standards for permitting a hydrogen refueling station. (First issued in 2016)

http://www.nrel.gov/docs/fy16osti/64042.pdf

DOE Permitting for Officials

This reference is called "Regulations, Codes and Standards (RCS) Template for California Hydrogen Dispensing Stations". It was published by the National Renewable Energy laboratory in 2013. Authors were C. Rivkin, C. Blake, R. Burgess, W. Buttner, and M. Post

www.nrel.gov/docs/fy13osti/56223.pdf

NFPA-2 Code

The NFPA-2 Code is available for purchase from the ANSI Publications website. Staff from NPFA have summarized the requirements of applicable requirements in a PowerPoint Presentation (Appendix C.7).

http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=2

http://catalog.nfpa.org/NFPA-2-Hydrogen-Technologies-Code-2016-Edition-P1144.aspx?icid=B484

Ongoing Support Efforts

In addition to making resources available to permit agency staff, another practice which can help to raise confidence in hydrogen as a transportation fuel is to encourage first-time permit authorities to make contact with their peers in other jurisdictions where hydrogen has been successfully permitted. A list of permit agency staff who would be willing to assist in this respect is included in Appendix B.

Where guidance is to be provided by local permitting authorities, it is important that the guidance be current and kept up to date through a formal review process. There may be merit in having a State agency take on that role through a centralized website to minimize the need for repeating this effort at every local agency.

Additional Resources

These following resources (with website links) are included in Appendix C.

- California Fuel Cell Partnership: "A California Roadmap: Bringing Fuel Cell Electric Vehicles to the Golden State Air, Climate, Energy, Water and Security Well-to-Wheels Report"
- Clean Cities Coalition: "H2 Readiness: Best Practices for Hydrogen Stations in Early Adopter Communities"
- Governor's Interagency Working Group on Zero-Emission Vehicles 2013 ZEV Action Plan
- Governor's Office of Planning and Research: "Zero Emission Vehicles in California: Community Readiness Guidebook"
- H2 Readiness - Best Practices for Hydrogen Station in Early Adopter Communities. Part of the Clean Cities California ZEV Action Plan, April 2014

Table 9 Hydrogen Permitting Resource Matrix

Permit Item	GO-Biz Hydrogen Station Permitting Guidebook	NREL Permitting Guide for Officials in California	DOE H2Tools – National Permit Guide for Hydrogen Refueling Stations, 2016
Permitting Guidebook	✓	✓	
Permit Template	p.42	p.4, p.14	
Permitting Activities Checklist	pp.1-4	p.2	
Zoning	p.22		
Setbacks	p.34		
Codes and Standards – General	p.35	pp.17-20	✓
Codes and Standards - California	p.24	pp.17-20✓	
CEQA Guidance	p.23	p.22	
Permit Review Process	p.26		
Construction	p.30		
Commissioning	p.31		
Safety Review	p.32		
Signage			
Permit Fees	p.25		
California Accidental Release Prevention Program		p.24	
Other topics			

Chapter 4: Promotion and Awareness of Hydrogen and FCEVs

Introduction

The purpose of developing a Promotion Plan for hydrogen and FCEVs was to engage with key stakeholders in the Tri-Counties region (including local officials, civic leaders, and community groups) to build support for hydrogen as a transportation fuel, and help them prepare for siting hydrogen refuelling stations in their jurisdictions, safely and efficiently. The activity included individual meetings, and outreach at community events, summits, and workshops. Promotional materials and information resources were also developed.

There is currently low awareness of hydrogen as a transportation fuel in the Tri-Counties and the important role it is expected to play in state goals related to climate change, air quality, and ZEV adoption. The limited familiarity with hydrogen and FCEVs among stakeholders became clear early on in the outreach process. In many cases, local officials and members of the public did not know that FCEVs were available for purchase or lease. Many outreach contacts also had little-to-no knowledge of FCEV benefits or state activities to help build a robust hydrogen refueling network.

Strategy

Previous outreach conducted for the AFV Readiness planning effort informed outreach activities for the regional Hydrogen Readiness project. In some cases, standalone workshops and information sessions conducted for the AFV Readiness plan were not well attended despite targeted promotion efforts in communities where these activities were conducted. In general, it has been more effective to "meet people where they are at" and incorporate outreach into events and forums that already have a large audience.

For the Hydrogen Readiness promotion task, awareness activities were conducted at larger community events and forums whenever possible. For standalone promotion and awareness events, robust media outreach and information campaigns launched to notify the public, news outlets, and local officials. In some cases, outreach events were targeted to both community members and local officials. Of the 7 promotion events held, 5 were attended by a mix of community members and local officials.

All promotion activities considered during this project for promoting FCEVs and hydrogen were designed to supplement outreach efforts associated with ongoing AFV readiness planning in the Tri-Counties, and provided specific emphasis on hydrogen. This was needed because of the general lack of awareness of FCEVs and hydrogen currently. The Tri-Counties Hydrogen Readiness project team also took steps to avoid duplicative promotional activities that were already being conducted in the region by other entities, including the CaFCP and OEMs offering FCEVs.

Outreach and awareness activities did not place extensive focus on promoting the FCEV adoption because of the current level of market development in the region. Only one hydrogen refueling station is operating in the Tri-Counties region currently and no local dealership are offering FCEVs for sale or lease. This limited the potential for FCEV adoption in the region during the project period, so promotional activities place greater emphasis on increasing "hydrogen literacy" and FCEV acceptance.

Promotion and Awareness Activities

The Tri-Counties Hydrogen Readiness Project Team engaged with local officials and community groups in the highest priority communities. The following outreach activities were accomplished:

- Made contact with officials in the highest priority municipalities, including the cities of Thousand Oaks, Moorpark, Simi Valley, Camarillo, Oxnard, Ventura, and Santa Barbara.
- Convened workshops to present the Hydrogen Readiness Plan effort. The intent of these workshops was to provide further awareness of hydrogen with public officials, and to discuss potential refueling locations as identified. (ongoing)
- Conducted community forums and meetings to present the primary benefits of using hydrogen to "help attain the State's climate change policies" and associated co-benefits.
- Coordinated closely with automakers and Dealers to ensure consistency in the promotional activities with their marketing plans for FCEVs.
- Developed outreach and education materials, including a brochure for use locally.

Table 10 provides a detailed account of promotion and awareness activities. Presentations and materials are provided in Appendix D.

Table 10 Promotion & Awareness Activities

Official Promotion Activities				
Date	Activity	Venue	County	Attendance
5/13/2016	Hydrogen Station Ribbon Cutting Ceremony*	Conserv Fuel (Santa Barbara, CA)	Santa Barbara County	15
10/27/2016	UC Santa Barbara Central Coast Sustainability Summit*	UC Santa Barbara (Santa Barbra, CA)	Santa Barbara County	35 est
12/7/2016	Future of Transportation' Forum*	Jeanette’s Edelweiss (Thousand Oaks, CA)	Ventura County	8
1/19/2017	Central Coast Clean Cities Coalition Workshop	Cal Poly San Luis Obispo (San Luis Obispo, CA)	San Luis Obispo County	11
2/22/2017	Drive Clean - Hydrogen and FCEV Forum*	Santa Barbara Public Library (Santa Barbara, CA)	Santa Barbara County	
Community Promotion Activities				
Date	Activity	Venue	County	Attendance
4/16/2016	Santa Barbara Earth Day Festival 'One Element' Workshop	Alameda Park (Santa Barbara, CA)	Santa Barbara County	11
5/13/2016	Hydrogen Station Ribbon Cutting Ceremony*	Conserv Fuel (Santa Barbara, CA)	Santa Barbara County	65
10/27/2016	UC Santa Barbara Central Coast Sustainability Summit*	UC Santa Barbara (Santa Barbra, CA)	Santa Barbara County	60 est
12/7/2016	Future of Transportation' Forum*	Jeanette's Edelweiss (Thousand Oaks, CA)	Ventura County	75
1/19/2017	Central Coast Clean Cities Coalition Workshop	Cal Poly San Luis Obispo (San Luis Obispo, CA)	San Luis Obispo County	12
2/22/2017	Drive Clean - Hydrogen and FCEV Forum*	Santa Barbara Public Library (Santa Barbara, CA)	Santa Barbara County	60

* Audience included both community member and officials

Outreach to Civic Leaders

A comprehensive list of local officials was compiled during outreach for the Alternative Fuel Vehicles Readiness Plan in 2015. This list was updated for Hydrogen Readiness outreach and used to contact officials at high-priority municipalities, as identified in the Hydrogen Station Siting Analysis (Chapter 2 above). The goal of this outreach to officials was to coordinate meetings with officials to brief them on the Tri-Counties Hydrogen Readiness planning effort.

In some cases, the lead up to elections in November 2016 delayed outreach to elected representatives and their staff. To help ensure that officials were aware of the regional Hydrogen Readiness effort, other approaches were used. These included delivering presentations and comments on the regional Hydrogen Readiness Plan at public meetings and submitting notification letters. A list of contacted officials and outreach materials is included in Appendix D.

Public Awareness

Community events focused on increasing public awareness of hydrogen and increasing acceptance of FCEVs, with particular emphasis on the benefits of FCEVs and the important role hydrogen is expected to play in meeting the state's climate goals. Opportunities to highlight hydrogen and FCEVs were identified and events were organized to gain attention from local media and community members.

In addition, FCEVs and hydrogen were also featured prominently at the Santa Barbara Earth Day Festival's annual Green Car Show, which attracts more than 30,000 community members each year. The show included a static FCEV display featuring the Toyota Mirai and Hyundai Tucson FCEV. A second Toyota Mirai was made available for test-drives at the festival's Ride & Drive event. During the two-day event, 104 rides and 118 test-drives were provided.

Promotional Materials & Information Resources

There is a strong need to make information about hydrogen and FCEVs readily available to elevate public awareness. Promotional materials and information resources created by the Tri-Counties Hydrogen Readiness project team include webpages, print materials, and press releases. Posts to social media, newsletter notifications, and blogs were also used to raise awareness of FCEVs and hydrogen. Examples are included in Appendix D.

Print material development was coordinated with the California Fuel Cell Partnership, the Air Pollution Control Districts and other partners to avoid duplicative efforts. Since the California Fuel Cell Partnership has already made a comprehensive brochure about hydrogen and FCEVs available at Santa Barbara hydrogen refueling station, the Tri-Counties Hydrogen Readiness project team developed a smaller brochure to serve as a supplementary resource. This brochure is available at the local hydrogen station in Santa Barbara and will be distributed at future outreach events. Promotional materials and a complete list of information campaigns are provided in Table 11.

Table 11 Promotional Materials & Information Campaigns

Information Resources	**Purpose**	**Distribution**	**Reference**
Earth Day Festival Guide	The guide promoted the Festival's Green Car Show and Ride & Drive events featuring FCEVs, and provided information about "One Element" workshop on April 16, 2016.	The guide was published in the Santa Barbara Independent, which reaches 135,000 readers in Santa Barbara County each Thursday.	Item 1 in Appendix D
Digital Hydrogen Ribbon Cutting Email Invitation	Developed to inform local officials, elected representatives, and community influencers of the Santa Barbara hydrogen refueling station's opening.	The PDF invite was distributed through a Mail Chimp email campaign.	Item 2 in Appendix D
Hydrogen Ribbon Cutting Campaign	Two press releases were developed for the hydrogen station ribbon-cutting ceremony to notify local and regional news media. A blog post, e-news feature, and social media were also used to promote the event.	Press releases were email to local news outlets and radio stations; additional promotion was web-based.	Items 3, 4, 5, & 6 in Appendix D
National Hydrogen & Fuel Cell Day Campaign	An information campaign was launched to increase awareness of hydrogen and FCEVs for the national celebration.	Included blog post on cecsb.org, an e-news feature, and social media posts.	Items 7 & 8 in Appendix D
Hydrogen & FCEV Webpage	The webpage covers the fundamentals of FCEVs and hydrogen, and is intended to serve a "living resource" that will be updated on a quarterly basis.	Online, with URL included in promotional materials	Item 9 in Appendix D
Santa Barbara Hydrogen Readiness Forum Campaign	Launched to promote a special community forum on hydrogen and FCEVs. Included press release distribution to media; advertising in the Santa Barbara Independent and Santa Barbara News Press; and blog post and e-news features	Press release to media, advertisements, online blog post, story, and social media posts	Item 10, 11 & 12 in Appendix D
Hydrogen & FCEV Handout	The handout address common questions about hydrogen and FCEVs, and supplements print materials made available locally by the California Fuel Cell Partnership	Available at the Santa Barbara Hydrogen refueling Station, and handed out during outreach events	Item 13 in Appendix D

Findings & Recommendations

Interactions with the public and stakeholders made it clear that there is a general lack of awareness about hydrogen and FCEVs among the public and local officials. In many cases, stakeholders were unfamiliar with the benefits and operating characteristics of FCEVs, and had limited knowledge of the role hydrogen is expected to play in attaining state ZEV and climate goals. The vast majority of outreach attendees at community events had little-to-no awareness of hydrogen's use as a transportation fuel and were unaware that FCEVs were available for sale or lease. This highlights the need for ongoing promotion and awareness activities.

Continuing promotion and awareness activities will play an important role in expanding acceptance of hydrogen and FCEVs, which is the first step toward accelerating market growth. In the early stages of FCEV and hydrogen market development, promotion activities should target the high-priority areas identified in the Hydrogen Station Siting Analysis. These high priority areas have a higher concentration of demographics that are most likely to be early adopters of FCEVs. Additional focus should be given to communities where hydrogen refueling infrastructure is installed to spur FCEV sales.

Our experience has shown that providing test-drives in plug-in electric vehicles (PEV) has been one of the most effective approaches for increasing acceptance among consumers. Similar experiential promotion activities are recommended for elevating consumer acceptance of FCEV in areas where hydrogen refueling station are operating or planned. These activities could include FCEV Ride & Drives at community events and loaning FCEVs to local organizations and municipalities.

Over the course of promotion activities for the Tri-Counties Hydrogen Readiness Plan, it also became clear that safety is a primary public concern. Obtaining testimony on hydrogen safety from an expert authority that is widely trusted – such as local fire officials and emergency response personnel – is one of the most effective ways to address safety concerns. Incorporating this testimony from trusted authorities into broader outreach and education campaigns will help allay unwarranted safety concerns about hydrogen and FCEVs – especially in communities where hydrogen refueling stations are in operation or planned. This was corroborated through discussions with the Santa Barbara City Fire Department Fire Chief.

The planning and permitting process for new hydrogen refueling stations provide additional opportunities for increasing awareness and addressing safety concerns. Jurisdiction or fueling infrastructure installers could benefit from launching a public relations campaigns that notifies community members about the new stations and provides opportunities to learn about the station's design and safety measures. It is important for permitting jurisdictions to demonstrate transparency and take proactive steps to inform members of the public during the planning process for new hydrogen refueling stations. (Refer to Chapter 3.)

The Promotion Plan in Appendix D provides additional guidance for increasing awareness of FCEVs and hydrogen, as well as addressing public concerns about safety.

Additional Resources

California Air Resource Board

Clean Vehicle Buying Guide and Information

https://www.driveclean.ca.gov/

California Clean Vehicle Rebate Program

Fuel Cell Electric Vehicle Consumer Rebates:

https://cleanvehiclerebate.org/eng

California Fuel Cell Partnership (Cafcp.org)

Hydrogen refueling Station Map

http://cafcp.org/stationmap

How It Works – Fuel Cell Electric Vehicles (included in Appendix D)
http://cafcp.org/sites/default/files/HowItWorks-Fuel-Cell-Booklet.pdf

Hydrogen - Frequently Asked Questions (included in Appendix D)

http://cafcp.org/sites/default/files/FCEV_factbooklet.pdf

Community Environmental Council

Hydrogen & FCEV Information Page:

http://CECSB.org/fcev

Santa Barbara County Air Pollution Control District

Hydrogen & FCEVs:

https://www.ourair.org/hydrogen-fuel-cells

Chapter 5: Hydrogen Safety, Awareness and Response

This chapter summarizes the tasks performed to assemble materials on hydrogen safety and emergency response for training and raising awareness with first responders in the region. Also included is a summary of the meetings and trainings held during the term of the planning project.

One significant learning from this effort was that Fire Departments are challenged with a heavy burden of training requirements for routine operations, and time is limited for scheduling additional (optional) training sessions. This changed the emphasis of this task in a way that focused outreach and engagement efforts on Fire Departments operating in the cities which were identified in the siting analysis as high priority based on anticipated market indicators.

Hydrogen Safety

The use of hydrogen for FCEVs introduces hazards that are applicable to the refueling stations, the vehicles, and the community. There is an abundance of material available on hydrogen safety from government agencies, industry associations and businesses involved in the production, distribution and use of hydrogen. The web-based H2Tools portal includes a number of summary sheets and fact sheets on hydrogen safety. The California Fuel Cell Partnership website is another source of information on hydrogen safety relevant to refueling stations and FCEVs.

Hydrogen is a flammable gas with a wide flammability range (4%–75% by volume) and relatively low ignition energy. It has a very low density and therefore must be stored at high pressures (10,000–15,000 psi range) to achieve enough mass for practical use. The ease of ignition and high storage pressure of hydrogen create a large portion of the risk associated with hydrogen usage.

Hydrogen also has the ability to attack—and damage to the point of leakage—certain materials that are used for the construction of storage containers, piping, valves, and other appurtenances. This destructive capability is sometimes referred to as hydrogen embrittlement (Cramer and Covino 2003). The mechanisms of hydrogen embrittlement can be complex and vary with several physical parameters including temperature and pressure. Hydrogen has a propensity to leak through conventional materials like steel, titanium and plastic because of its small molecular size, so this also contributes to the risk associated with hydrogen usage.

The hydrogen code (NFPA-2) includes an array of design features and systems that are intended to address the typical range of hazards that could occur from the use of hydrogen. Because of the requirements in this code, hydrogen stations are required to have multiple safety systems to protect against fire, leakage, and explosion. Retaining walls, equipment setbacks, and bollards are designed into the site plan to maximize safety. To date, there have been no known catastrophic failures of hydrogen refueling equipment for vehicles.

However, there has been at least one incident in which a hydrogen tube trailer was involved in an on-road accident which resulted in a short-lived but intense fire.

As for the vehicles, automakers and federal agencies have conducted extensive safety testing at the component, system and vehicle level. FCEVs have several safety systems designed for hydrogen and electric drive to protect passengers and first responders in case of an accident. FCEVs have been in real-world accidents and crash tests, and all have performed as designed with safety rating equivalent to ICE vehicles.

Appendix E.1includes a number of selected Hydrogen Safety Resources.

Training Resources for First Responders

From an extensive literature review and discussions with Fire Department personnel and the California Fuel Cell Partnership, it became clearly evident that the training materials recently developed by DOE in partnership with NFPA and the CaFCP were particularly well-suited for the need, so the resources assembled in this report and made available to the local Fire Departments are mostly based on this central set of resources. The resources include training curricula for (1) hydrogen awareness, and (2) hydrogen emergency response. Training materials are assembled in Appendix E.2.

In addition, the Fire Departments expressed concern about responding to hazards in general associated with any new alternative fuel vehicles, citing high voltage hazards as paramount. For this reason, the training materials assembled and included in Appendix E include auto manufacturer response manuals for the FCEV models that are current available for lease or purchase in California. (Appendix E.3).

Meetings and Trainings

Appendix E.4 includes a summary of the meetings and training sessions scheduled during the course of this project. A high priority recommendation included in this report is to ensure that competent training facilitators are available locally to deliver hydrogen awareness and response training to Fire Department personnel on an as-needed basis. Using the DOE training materials, this will ensure that a consistent level of training is made available to Fire Departments in future, and it can help ensure that materials are always kept current and consistent with best practices as they develop.

Chapter 6: Municipal Fleets

Introduction

The potential for early adoption of FCEVs among regional fleet operators was assessed as part of the regional Tri-Counties Hydrogen Readiness planning effort. Fleet operators in the region were contacted to gauge the current level of interest in FCEV adoption and to identify potential public hosts for hydrogen refueling infrastructure. Fleet operators were also asked about opportunities for siting shared public-private hydrogen refueling stations.

Information was collected from regional fleet operators through informational interviews and an online survey. Survey Monkey was used to distribute the online survey for the Tri-Counties Hydrogen Readiness project to 35 fleet operators in the Tri-Counties region. Items included in the survey were modelled after a questionnaire that the Southern California Association of Governments (SCAG) developed to gauge interest in hydrogen and FCEVs.

Of the 35 municipalities and public agencies contacted in the region, 26 provided information to the project team. This included 24 survey responses and 3 interviews with fleet operators that declined to complete the online questionnaire. Informational interviews were conducted with 12 fleet operators who completed the online questionnaire to obtain more detailed information about potential opportunities for FCEV adoption and hydrogen refueling station siting.

A comprehensive list of public fleet operators was compiled to conduct fleet outreach in the region and is provided in Table 12. Appendix F includes a comprehensive list of public fleet contacts, a copy of the online questionnaire, and an informational interview template.

Summary of Current Situation

No public fleets in the Tri-Counties region have incorporated FCEVs as of this report's publication. However, the County of Santa Barbara plans to lease a Toyota Mirai within the next year. Except for the County of Santa Barbara, no fleet operators who responded to the online questionnaire or participated in informational interviews are planning to purchase or lease an FCEV in 2017. However, numerous fleet operators expressed interest in purchasing or leasing an FCEV at some point in future.

No fleet operators in the region have hydrogen refueling infrastructure installed at their organization's site, and no contacts reported plans to install infrastructure in the future. Of the 25 fleet operators contacted, 7 indicated that they would be open to installing on-site hydrogen refueling infrastructure in the future if they could secure funding to reduce station costs.

The project team found that fleet operators had limited awareness of FCEVs and hydrogen. Many fleet operators were unable to explain the benefits and operating characteristics of FCEVs during informational interviews, and survey responses suggest that fleet operates may not have a good understanding of FCEV's operating characteristics and benefits. There is a need for ongoing work to expand fleet operator's understanding of FCEV and their

Table 12 Public Fleet Outreach Contacts

Public Organization	Contact	Completed Survey?	Interviewed?
County of Santa Barbara			
City of Carpinteria	Matt Roberts	Yes	No
City of Buellton	Rose Hess	Yes	No
City of Goleta	Bob Morgenstern	Declined	Yes
City of Lompoc	Dirk Ishiwata	Yes	Yes
City of Santa Barbara	Gary Horwald	Yes	Yes
City of Santa Maria	Robert Dupuis	Declined	Yes
County of Santa Barbara	Eric Baker	Declined	Yes
Santa Barbara MTD	Steve Hahn	Yes	Yes
UC Santa Barbara	John Behlman	Yes	Yes
County of Ventura			
City of Camarillo	Kevin Jorgensborg	Yes	No
City of Moorpark	Ashraf Rostom	Yes	Declined
City of Oxnard	Joe Rodriguez	Yes	No
City of Port Hueneme	Fred Camarillo	No	No
City of Santa Paula	Jose Arreola	Yes	Yes
City of Simi Valley	John Willoughby	Yes	Declined
City of Thousand Oaks	Larry McKinney	Yes	No
City of Ventura	Mary Joyce Ivers	Yes	Yes
County of Ventura	Peter Bednar	Yes	Yes
CSUCI	Ray Porras	Declined	Declined
Gold Coast Transit	Reed Caldwell	Yes	Yes
City of Ojai	Greg Grant	Yes	Yes
Ventura Unified School District	Wendy Stevens	Yes	No
County of San Luis Obispo			
Cal Poly Transportation/Facility Services	Tim Jones	Yes	No
Cal Poly University Police	Debbie Anderson	No	No
San Luis Obispo Regional Transit Authority	David Roessler	No	No
City of Morro Bay	Rob Livick	No	No
City of Pismo Beach Transportation	Dan Johnson	No	No
Cuesta College	Terry Reece	No	No
Lucia Mar Unified School District	Sharon Harwin	Yes	Yes
Port of San Luis Harbor District	Jay K. Elder	Declined	No
San Luis Coastal Unified School District	Annie Sharp	No	No
County of SLO	Rocky Buoy	Yes	No
City of SLO	Isaac Shuck	Yes	No
City of Arroyo Grande	Raul Juarez	Yes	No
City of Atascadero	Bob Joslin	Yes	No
City of Paso Robles	Bob Solway	Yes	No
Total Contacts		**Total Responses**	**Total Interviews**
35		**24**	**12**

environmental advantages, as well as the anticipated role that hydrogen is expected to play in reducing emissions of both GHGs and criteria air pollutants.

In general, fleet operators were unaware of State's effort to help fund the construction of 100 hydrogen refueling stations. Building greater awareness of the public-private partnership to create a robust hydrogen refueling network is an important step to increasing confidence in the fuel pathway among public fleet operators. Overall, these findings highlight the need for continuing outreach to local stakeholders that will elevate awareness of hydrogen and FCEVs.

Survey and Interview Analysis

Survey responses or informational interviews were held with 26 of the 35 public fleet operators contacted by the project team. The online survey had a response rate of 70%, with 24 of 35 survey recipients providing completed questionnaire via Survey Monkey. Data on respondent demographics and public fleet size was collected in Items 1 through 4 of the online survey.

All survey respondents self-identified as staff at local government entities or public institutions. More than half (54%) of all respondents indicated that they were responsible for making procurement decisions or recommend vehicles to a board. Another 40% of respondents recommend or suggest vehicles for procurement, but do not make final decisions. One respondent indicated that they were not responsible for procurement decisions and did not recommend vehicles for purchase to decision-makers.

Items 5 and 6 of the survey collected data on public fleet operators' current attitudes towards FCEVs and other alternative fuel vehicles. Overall, interest in FCEV deployment among fleet operators was mixed. For Item 5, twelve of the surveyed fleet operators expressed interested in incorporating FCEVs into their fleet in the future but did not have near-term plans to purchase or lease an FCEV. The project team learned that the County of Santa Barbara is planning to lease a Mirai in 2017. However, County of Santa Barbara staff did not complete the online questionnaire, so this is not reflected in survey results.

For Item 5, a total of 7 survey respondents indicated that they were not interested in adding FCEVs to their fleet and one fleet operator indicated that they did not consider hydrogen to be an alternative fuel. Interestingly, there was no relationship between current or planned deployment of plug-in electric vehicles (PEV) and interest in FCEVs.

In general, survey results for Item 6 suggest that acceptance and understanding of hydrogen and FCEVs is low among fleet operators relative to other alternative fuels. Table 13 shows the number of fleet operators who agreed with positives statements for different alternative fuels in Item 6 of the survey, and provides additional context

Only 2 out of 22 fleet operators indicated that the size and type of FCEVs they needed for their fleet are available. In contrast, more than 10 fleet operators felt that the size and type of vehicles they needed were available as battery electric, plug-in hybrid electric, natural gas, and clean diesel vehicles. Additionally, only 2 fleet operators (<10%) felt that they could justify the higher upfront cost of FCEVs. In general, more fleet operators indicated that they could justify costs associated with battery electric, plug-in hybrid, and natural gas vehicles.

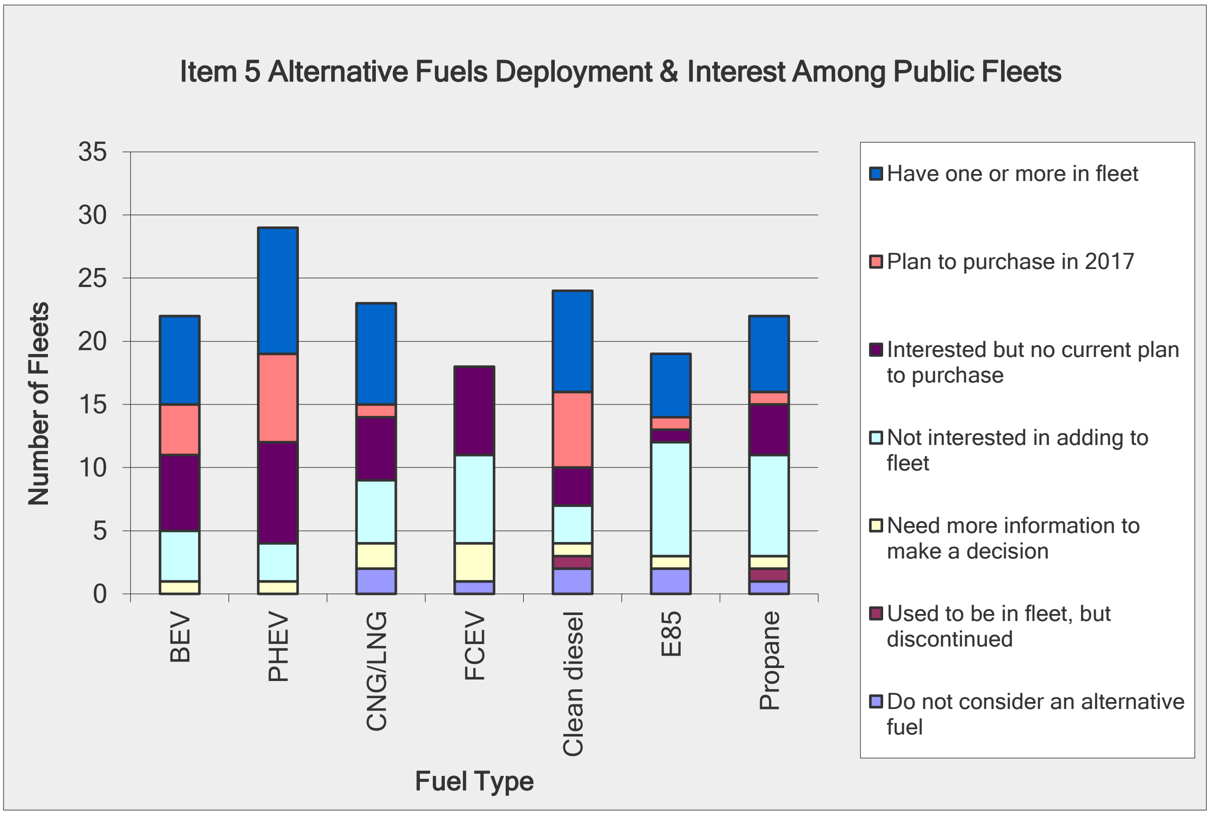
Few fleet operators agreed with positive statements about FCEV reliability, maintenance availability, fueling access, and performance relative to other alternative fuels.

Table 13 Public Fleet Manager Evaluations of FCEVs

Statement	BEV	PHEV	FCEV	NG	Clean Diesel	E85	Propane
Size and type of vehicles I need are available	11	13	2	12	12	7	6
Can justify the cost of vehicle, fuel, and ownership	7	10	2	13	8	4	4
Vehicles are reliable and maintenance is available	8	13	2	8	10	6	5
I have access to fueling or charging	11	12	0	7	9	1	4
Driving range or performance meets needs	8	11	3	11	8	5	4
Rebates and incentives are available	5	6	2	5	3	2	1
Federal tax credits are available for fleet operators	1	1	1	3	1	2	1
Is a public benefit (reduced GHGs, pollution, or petroleum)	11	14	6	11	5	6	5

* Provides the number of public fleet operators who agreed with each statement the listed vehicle types

Figure 5 FCEV Deployment & Interest at Regional Public Fleets



In Item 7 of the survey, fleet operators were asked to describe their challenges and concerns with adding alternative fuels to fleets in the online questionnaire. Additional information about these concerns and challenges was collected through information interviews. In general, the foremost concerns were related to the costs and affordability of alternative fuel vehicles and infrastructure. Procuring alternative fuel vehicles that are a good fit for some applications was also a commonly cited challenge. Other concerns centered around maintenance and the limited availability of alternative fuel vehicles. Informational interviews with public fleet operators made it clear that financial constraints present a major barrier to increasing the number of alternative fuel vehicles.

Item 8 asked survey respondents to evaluate sources of information or education that would help address the challenges and concerns that the respondent identified. Overall, public fleet operators felt that information about available rebates, mechanic training, and maintenance availability would be most effective for addressing their challenges and concerns. Information about total cost of ownership, government mandates and regulations, on-site fueling or charging infrastructure, and public benefits were also rated as important information sources to inform fleet management decisions. Many interviewed fleet operators indicated that grant funding from outside entities would be essential for deployment of hydrogen refueling infrastructure at their organizations.

Item 9 of the survey asked respondents to read the following paragraph about a new type of "green fuel vehicle" with the same operating characteristics, performance, and benefits as FCEVs:

> *Green fuel is a renewable, gaseous fuel used in vehicles that range from small off-road vehicles (forklifts, tugs) to passenger cars to transit buses. Green fuel is available at gas stations and the fuel's dispensers accept credit cards for payment. The vehicles fill in minutes, have range similar to their gasoline/diesel counterparts and have zero emissions. Operating the vehicles meets California's requirement for ZEVs and the vehicles are eligible for HOV stickers. Purchase price is higher than conventional vehicles, but can be offset with rebates and cost of ownership is similar to other alternative fuels.*

After reading the paragraph, 14 of the 26 surveyed fleet operators said that the benefits and rebates for the green fuel vehicle could justify the higher purchase price and 15 of the 26 respondents indicated that paying for fuel with a credit card would not be a problem. Also, 14 of the 26 responds said that obtaining ZEVs was important for meeting state and local requirements.

Interestingly, most respondents felt that the attributes and operating characteristics of the green fuel vehicle described in Item 9 would justify a higher purchasing price for but only 2 respondents felt that they could justify the higher purchase price of FCEVs when answering Item 5. Since the green fuel vehicle has the same operating characteristics and benefits as an FCEV, it is possible that responses on Items 5 and 9 diverged because fleet operators lacked of awareness about FCEVs or had negative perceptions of FCEVs.

Many fleet managers who participated in follow-up interviews with the project team showed greater receptiveness to FCEVs after being briefed about their benefits and learning about hydrogen's anticipated role in attaining state climate and air quality goals. None of the contacted fleet operators expressed negative views about hydrogen or FCEVs during interviews. This suggests that a lack of awareness among fleet operators skewed their evaluations of hydrogen and FCEVs in Item 5, and is likely responsible for the divergent responses for Item 9.

The final question on the survey, Item 10, asked fleet operators to the 3 most effective ways of learning about the green fuel described in Item 9. The largest number of fleet operators felt that a green fuel website would be the most effective way to learn more about the green fuel. Presentations at association meetings or workshops were identified as the second most effective way of learning, followed closely by vehicle loaner programs.

Barriers & Challenges for Public Fleets

Informational interviews were conducted to obtain addition insight into the barriers and challenges that make it difficult for public fleet managers to purchase or lease FCEVs. Vehicle and infrastructure costs were the most commonly cited barriers to incorporating FCEVs and other alternative fuel vehicles into public fleets. Financial constraints and concerns about cost are particularly relevant since FCEVs have a higher cost than other comparably-sized vehicles. Public fleets operators are not eligible for many of the incentives, tax credits, and rebates offered for alternative fuel vehicles in California and the United States. The inability to leverage incentives and rebates that reduce the final purchase price of FCEVs presents a challenge to public fleet adoption.

The lack of publicly-accessible hydrogen refueling stations presents another challenge to the purchase and lease of FCEVs by public fleets. All interviewed fleet operators said that the high cost of hydrogen stations would a major barrier to installing onsite hydrogen refueling infrastructure. Until station costs fall, most fleet operators with FCEVs will need to rely on off-site hydrogen refueling stations that are privately owned and operated unless they can secure grant awards or outside sources of funding for onsite station installations. Numerous fleet operators also expressed concerns about the risk of stranded FCEV and hydrogen assets.

Many fleet operators indicated that the availability of medium- and heavy-duty AFVs is a major challenge. The medium- and heavy-duty AFVs that are available, including larger classes of FCEVs, are generally too expensive for fleet operators to justify unless incentives or grant awards can be leveraged. Since larger vehicles are associated with higher fuel consumption, the limited availability of medium- and heavy-duty AFVs is a barrier to reducing GHG and air pollution emissions from fleet operations.

In some cases, institutional barriers also prevented fleet operators from incorporating more alternative fuel vehicles into their organization's fleet. Incorporating cleaner alternative fuel vehicles such as FCEVs was not a priority at 2 of the 25 organizations contacted. In other cases, fleet managers with an interest in deploying FCEVs and other alternative fuel vehicles did not have sufficient internal support from decision-makers or managers.

Appendix F provides a listing of fleets in the Tri-Counties based on best-available data at the time of this planning and outreach project. The goal of the survey was to measure awareness and interest in hydrogen and FCEVs. Questions are taken from the California Fuel Cell Partnership survey made available by Keith Malone.

Potential Opportunities for Public Fleet FCEV Adoption

Fleet operators at 12 public organizations were interested in deploying FCEVs. The organizations that expressed the greatest interest included UC Santa Barbara, the County of Ventura, City of Ventura, City of Thousand Oaks, City of Santa Barbara, and the Santa Barbara County APCD. The City of Oxnard, City of Lompoc, City of Carpinteria, Cal Poly San Luis Obispo, Santa Barbara Metropolitan Transit District, and Gold Coast Transit District were open to exploring opportunities for FCEV deployment. In the near term, the greatest opportunities for public fleet adoption of FCEVs will be at government entities in Santa Barbara and Thousand Oaks that are located near public hydrogen refueling stations.

LDVs make up the largest share of vehicles in public fleets. As older LDVs are replaced and more hydrogen refueling infrastructure comes online in the region, there will be opportunities to incorporate more FCEVs into public fleets. In the near term, incentive and rebate programs for public fleet operators will be key to driving increased FCEV adoption. Providing fueling infrastructure at a nearby location will be key to increasing FCEV adoption among public fleets. Several fleet operators indicated that they would be open to refueling at a public station, and were willing to drive up to 3-5 miles to refuel in most cases.

FCEVs are also well-suited to medium- and heavy-duty applications. As the availability of medium- and heavy-duty FCEVs increases and purchase prices fall, there may also be opportunities to deploy more medium- and heavy-duty FCEVs in local fleets. Providing hydrogen refueling infrastructure for these larger vehicles at or near fleet headquarters will be key to increased medium- and heavy-duty FCEV adoption by fleets. In the near term, projects supported with outside sources of funding will be the most effective way to support deployment medium- and heavy-duty FCEVs in public fleets.

Light Duty Vehicles - Municipal fleets and private sector fleets include light duty vehicle fleets, transit bus fleets and suitable heavy duty fleets.

Buses and Heavy Duty Vehicles - Transit buses are one of the best early transportation applications for fuel cell technology. Buses operate in congested areas where pollution is already a problem. These buses are centrally located and refueled, highly visible, and subsidized by government. By evaluating the experiences of these early adopters, DOE has determined the status of bus fuel cell systems and established lessons learned to aid other fleets in implementing the next generation of these systems.

However, there was low interest in FCEV buses and hydrogen among local transit authorities. Local transit agencies have already invested heavily in alternative fuel pathways for compressed natural gas, clean diesel, or electricity. Contacts at these transit agencies expressed concerns about adding another alternative fuel to the mix. Limited space in transit fleet yards also presented a barrier to the installation of onsite hydrogen refueling stations. At some transit agencies, union rules would present barrier to refueling at off-site. Awareness of FCEVs and hydrogen was low at local transit agencies.

Shared Private-Public Stations

Few fleet operators could identify opportunities for public-private fueling at their organizations. Overall, all but two fleet operators felt that shared public-private fueling was not viable for a station installed onsite at their organization. Public access issues, siting limitations, and liability concerns were the primary barriers identified for shared public-private refueling. However, contacts at the County of Ventura and UC Santa Barbara were open to exploring shared public-private fueling opportunities in the future if they received financial support to install a hydrogen refueling station onsite.

Fleet operators were more supportive of using nearby, publicly accessible hydrogen refueling stations to fuel FCEVs in their fleet. Fleet managers at the City of Santa Barbara, City of Ventura, County of Ventura, and UC Santa Barbara indicated that they would be willing to drive a short distance (no more than 5 miles) to refuel fleet FCEVs. In the near term, installing hydrogen refueling stations in high-priority areas at locations that are near major fleet headquarters is likely to be the best strategy for increasing fleet adoption.

Summary

Ongoing outreach and engagement activities will play an important role in increasing awareness of FCEVs among regional fleet operators and elevating receptiveness to FCEV adoption. Outreach activities made it clear that there is a general lack of awareness regarding FCEVs and hydrogen among fleet operators. There is also a need to build greater institutional support for FCEVs, as well as other alternative fuels. Outreach to local officials and elected representatives will help to build this internal support for hydrogen and FCEVs.

Moving forward, it will be important to provide fleet managers and officials with more information about the benefits, economic performance, and operating characteristics of available FCEVs, as well as the role that hydrogen is expected to play in reducing emissions of both GHGs and criteria air pollutants. Surveyed fleet operator also indicated that information about total cost of ownership, government mandates and regulations, on-site fueling infrastructure, and public benefits would help them address challenges and concerns related to FCEV deployment.

To familiarize fleet operators with FCEVs and hydrogen, vehicle loaner programs should be coordinated between OEMs and public agencies located near hydrogen refueling stations. Research shows that hands-on experience with new vehicle technologies such as FCEVs and battery electric vehicles is one of the most effective ways to increase their acceptance among potential early adopters. Toyota recently provided a Mirai on loan to the City of Santa Barbara and UC Santa Barbara, which helped elevate interest in FCEVs at these organizations.

To provide additional education about FCEVs and hydrogen, a regional website should be developed with targeted information for fleet operators, as well as other consumers and potential fueling station site hosts. Additionally, presentations at regional fleet associations and workshops or forums connected to local symposiums or conferences could be conducted to increase fleet operators' knowledge of FCEVs.

Vehicle and infrastructure costs were also identified as major barriers to incorporating FCEVs and other alternative fuel vehicles into public fleets. Public fleet operators tend to focus on the costs of vehicles and infrastructure when making decisions about vehicle procurement. The project team recommends developing more state and local programs that reduce the final cost of FCEVs with incentives or financing options that will reduce the total cost of ownership for public fleets. Grant funding opportunities for FCEV pilot project and hydrogen refueling stations should also be tracked and shared with eligible entities.

Providing fleet operators with information about mechanic training resources and maintenance availability for FCEVs will also help increase uptake as more hydrogen refueling stations come online in the region. To address this need, resources and OEM contacts for mechanic trainings could be compiled and shared with fleet operators. Providing local mechanic trainings through local fleet associations could also help more mechanics and technicians prepare for work on FCEVs.

Many of the public organizations contacted by the project team have adopted Climate Action Plans (CAPs). However, few public entities in the region have implemented specific policies or targets for reducing fleet GHG emissions. Policies that specifically address fleet GHG emissions but provide enough flexibility to accommodate operational needs could help to accelerate the adoption of FCEVs and other alternative fuels among fleet operators. These policies could be included in new CAPs or incorporated into existing CAPs when they are updated.

Implementation of additional recommendations in the Central Coast Alternative Fuel Vehicles Readiness Plan will also support adoption of FCEVs among local fleets as more hydrogen refueling infrastructure comes online. These recommendations include:

- Developing goals and policies for public fleets to incorporate alternative fuels delivering the greatest suite of benefits, considering GHG and air quality impacts, economy of operation on a life-cycle basis, and operational requirements.
- Creating Green Fleet Spreadsheets that identify the actions, AFV investments, fuel and operating cost savings available through accelerated deployment of Alternative Fuel Vehicles.
- Revising and updating green fleet plans on an annual basis to assess the economic and environmental benefits of AFV fleet procurement.
- Collecting fleet baseline data and analyzing specific opportunities for optimization related to vehicle specifications, route characteristics, and other important parameters.

Chapter 7: Findings, Recommendations and Next Steps

During the course of implementing the Tri-Counties Hydrogen Readiness Planning project work plan, a great deal was learned about the current state of readiness in the region, and the most important needs for successful deployment of FCEVs in the near term. All work tasks proposed in the PON grant agreement have been completed, and a number of key findings have come up from this work, and these are summarized in this section. Details of the analyses and observations that lead to these findings are presented throughout the body of this report.

Also included are a series of recommendations which are intended to provide guidance and direction to community leaders for continuing with the FCEV deployment effort in the region, and to provide feedback for state agencies and other regions that may learn from our experience with this project.

At the end of this section, key priorities for the region to consider are summarized as Next Steps. These priorities apply to the development of the hydrogen refueling network and deployment of FCEVs in the tri-Counties region.

Findings and Recommendations

Local and Regional

1. Finding: The recommendations included in this report will need community leaders to continue efforts to support and encourage ongoing efforts to build out the hydrogen infrastructure in the Tri-Counties.

   Recommendation: Ensure ongoing local support for hydrogen planning and infrastructure build-out.

2. Finding: The statewide target of 100 stations is being used to guide statewide infrastructure efforts. Regional targets can similarly help guide regional infrastructure development. Without a basic network of hydrogen stations, automakers are reluctant to designate dealerships to sell FCEVs locally, and most potential buyers in the Tri-Counties are unwilling to travel 100 miles plus to purchase and service their vehicles. Eventually, hydrogen would need to be available at 5-10 percent of the stations in the region to alleviate driver concerns about fuel availability.

Recommendation: Set a local target for infrastructure. The immediate target would be for the installation of another station in close proximity to the existing station, to entice local dealers to offer vehicles for sale in the region.

3. Finding: Many community stakeholders are in favor of hydrogen as a fuel, but only if it is generated through renewable processes.

   Recommendation: Support ongoing research and adoption of renewable hydrogen.

4. Finding: Hydrogen planning efforts are not expected to be static. New information and new guidance regularly becomes available from national, state and industry sources.

   Recommendation: Keep the plan a living document. One way to do this would be to support an ombudsman for the region.

5. Finding: Many cities have now gone through the hydrogen station permitting process, and there is a growing body of experienced people who are willing to offer help and support to those going through this for the first time.

   Recommendation: The planning focus going forward should be on making sure agencies know where available resources are and helping them get in touch with peers who have already handled station applications.

6. Finding: First responders are faced with extensive demands for required training and the available time for additional training such as hydrogen awareness training is limited. Comprehensive training materials are available through a collaboration of experts coordinated by the DOE National Laboratories. However, to date there are only a small number of competent trainers who have experience delivering this training (for example, staff with at the CaFCP).

   Recommendation: For first responders the focus should be on providing access to training resources and support for local trainers. There is need to recognize the time constraints on first responders given the extensive amount of training they need to take.

7. Finding: There is a significant lack of awareness about hydrogen and FCEVs among the public, local officials, and municipal fleet managers. In many cases, stakeholders were unfamiliar with the benefits and operating characteristics of FCEVs, and had limited knowledge of the role hydrogen is expected to play in attaining state ZEV and climate goals.

   Recommendation: Conduct ongoing outreach to expand awareness of hydrogen and fuel cell electric vehicles, with a focus on highlighting benefits. FCEV test-drives and vehicle loaner programs should be used when possible since research shows that firsthand experience with new vehicle technologies is effective at increasing acceptance.

8. Finding: Community outreach made it clear that safety is a primary public concern. These safety concerns are largely connected to the general lack of familiarity with hydrogen and FCEVs. However, specific strategies will help overcome this barrier to broader acceptance of FCEVs and hydrogen.

   Recommendation: Obtain testimony on hydrogen safety from an expert authority that is widely trusted, such as local fire official and emergency response personnel. This testimony can be incorporated into broader outreach and education campaigns in communities where hydrogen refueling stations are in operation or planned. Public notifications, community workshops, and information resources should be provided during the planning and permitting process for new hydrogen stations to help ensure that safety concerns are addressed.

Suggested Actions for the State

1. Finding: Currently there is no collaboration at a local level between the hydrogen installers and local government agencies and local hydrogen stakeholders. This could be counter-productive to the purpose of developing regional plans for infrastructure development. Vendors typically respond to the general criteria and priorities set by the state, without consideration of local government interest.

   Recommendation: Ensure station construction/funding is informed by the regional plans. CEC grant application criteria could be revised to call for a demonstration of how the grant proposal matches the siting analyses in the plan for the proposed station's region.

2. Finding: During the project, extensive efforts were dedicated to reviewing the available guidance and training resources that are useful and applicable at all local levels. This effort is likely to be repeated in other regions where hydrogen readiness efforts are under way. This could be a redundant and time consuming process.

   Recommendation: Develop a central statewide website for regional plans and resources (permitting, safety training, etc.). For example, as hydrogen codes and guidance are revised (such as NFPA-2 or the GoBiz Hydrogen Station Permitting Guidebook), then links should be updated to ensure the resources and guidance materials are current.

Next Steps

Going forward it is evident that there are three key priorities for ongoing hydrogen readiness planning efforts in the Tri-Counties. These are:

(1) to secure funding to support hydrogen infrastructure build-out, vehicle incentives and outreach efforts (for example from public-private partnerships, CEQA mitigation, settlements, and grants, etc.);
(2) to develop a strategy for creating commercial opportunities locally for the production and delivery of low-carbon hydrogen; and
(3) increasing public awareness of hydrogen and FCEVs to facilitate early adoption and create a foundation for broader consumer acceptance in the future.

Much of this effort would need to be done locally given the intense competition that now exists for limited state funds. Local agencies, particularly the three APCDs in the Tri-Counties region, will need to recognize this as a key challenge if there is real intent to accelerate the adoption rate for hydrogen vehicles.

If these three priorities are successfully addressed in the near term, there will be a much greater chance that the Tri-Counties region will become a vibrant new “hub” for clean hydrogen transportation. This, in turn, would have significant secondary benefits for lowering carbon intensity of the local energy infrastructure, also resulting in many environmental co-benefits. This is an audacious goal, but the opportunity is real if the intention is sincere.

References and Resources

2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025, GO-Biz, (Feb. 2013) opr.ca.gov/docs/Governor%27s_Office_ZEV_Action_Plan_%2802-13%29.pdf

2014 Update: Hydrogen Progress, Priorities and Opportunities (HyPPO) Report, California Fuel Cell Partnership. cafcp.org/sites/files/Roadmap-Progress-Report2014-FINAL.pdf

2014-2015 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program (CEC-600-2013-003-CMF) http://www.energy.ca.gov/2013-ALT-02/.

2016 ZEV Action Plan: An updated roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025, GO-Biz. www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf

2016-2017 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program, CEC. www.energy.ca.gov/2015publications/CEC-600-2015-014/CEC-600-2015-014-CMF.pdf

A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles, California Fuel Cell Partnership. cafcp.org/sites/files/A%20California%20Road%20Map%20June%202012%20%28CaFCP%20technical%20version%29_1.pdf

A Road Map for Fuel Cell Electric Buses in California – A zero-emission solution for public transit, CaFCP. cafcp.org/sites/files/A_Roadmap_for_Fuel_Cell_Electric_Buses_in_California_FINAL.pdf

AIChE, Special Section Report on Fuel Cells and Hydrogen. Chemical Engineering Progress July 2016.

Air Products and Chemicals, Inc. Principal Investigator Edward C Heydorn. California Hydrogen Infrastructure Project; DOE DE-FC36-05GO85026. January 2013.

American Fuel Cell Bus Project Evaluation: Second Report, L. Eudy and M. Post, NREL. www.nrel.gov/docs/fy15osti/64344.pdf

Assembly Bill No. 8 (Perea, Statutes of 2013, Chapter 401).

Bay Area Air Quality Management District, *Air District Funds 12 New Bay Area Hydrogen Re-fueling Stations*, Vols. 2015-3, 2015.

CalHEAT Research and Market Transformation Roadmap for Medium- and Heavy-Duty Trucks, CALSTART. www.calstart.org/Libraries/CalHEAT_2013_Documents_Presentations/CalHEAT_Roadmap_Final_Draft_Publication_Rev_6. sflb.ashx

California Air Resources Board, "Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Deployment" June 2014. http://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_final_june2014.pdf, accessed July 24, 2014.

California Air Resources Board. *2015 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* July 2015. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2015.pdf.

California Air Resources Board. *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* July 2016. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf.

California Air Resources Board. *Mobile Source Strategy.* May 2016. https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.

California Code of Regulations (CCR) Title 4, Division 9, Chapter 6, Article 8, Sections 4180 and 4181. The CCR adopts the SAE International J2719, "Hydrogen Fuel Quality for Fuel Cell Vehicles." http://standards.sae.org/j2719_201511/.

California Department of Food and Agriculture, Division of Measurement Standards. *Registered Service Agency Program: Information Guide.* https://www.cdfa.ca.gov/dms/programs/rsa/rsaInfoGuide.pdf.

California Dept of Food and Agriculture, Division of Measurement Standards. Hydrogen Fuel. California Hydrogen Fuel Advertising and Labeling Guidelines for Retailers. CDFA website, 2016.

California Dept of Food and Agriculture, Division of Weights and Measurement Standards. Field Reference Manual. NIST Handbook 44, 3.39 Hydrogen Gas Measuring devices.

California Energy Commission. *Grant Funding Opportunity (GFO)-15-605: Alternative and Renewable Fuel and Vehicle Technology Program, Light Duty Vehicle Hydrogen Refueling Infrastructure, Application Manual.* April 2016. http://www.energy.ca.gov/contracts/GFO-15-605.

California Fuel Cell Partnership Heavy Duty Fuel Cell Electric Truck Action Plan for California. October, 2016.

California Fuel Cell Partnership Hydrogen Fueling Station Network Update. Joe Gagliano & Ben Xiong. August 31, 2016.

California Fuel Cell Partnership Road Map http://cafcp.org/carsandbuses/caroadmap.

California Fuel Cell Partnership, "A California Road Map: Bringing Hydrogen Fuel Cell Vehicles to the Golden State," describing the infrastructure necessary to successfully launch commercial FCEVs. http://cafcp.org/RoadMap

California Hydrogen Business Council, Financing the 101st Station. Report for June 14-15, 2016 Workshop (Wagner and Serfas). June 2016

California Hydrogen Business Council, Hydrogen Storage White Paper; Power to Gas: The Case for Hydrogen. October 8, 2015

California State Fire Marshal. *Information Bulletin 14-010: Adoption of NFPA 2 Hydrogen Technologies Code for the Supplement to the 2013 California Building and Fire Code Effective Date*. November 2014. http://osfm.fire.ca.gov/informationbulletin/pdf/2014/IB_14010codesupplementNFPA2.pdf.

California State Fire Marshal. *Information Bulletin 16-004: Adoption of 2016 Edition of NFPA 2 for the 2016 California Fire Code*. March 2016. http://osfm.fire.ca.gov/informationbulletin/pdf/2016/IB_16-004_-_2016_NFPA_2.pdf.

California Sustainable Freight Action Plan, Air Resources Board. www.casustainablefreight.org/files/managed/Document/288/CSFAP_Main%20Document_FINAL_07272016.pdf

California, Governor's Interagency Working Group on Zero-emission Vehicles Governor Edmund G. Brown Jr., February 2013, "2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025," http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf

CARB First Advanced Clean Local Trucks Workgroup meeting Discussion Guide. January 20, 2017

CARB Mobile Source Control Unit. Advanced Clean Transit, May 2015.

CARB Mobile Source Strategy, Discussion Draft October 2015

CSA Group (formerly the Canadian Standards Association, CSA), Toronto, Canada. *CSA Hydrogen Gas Vehicle (HGV) 4.3 Test Method for Hydrogen Fueling Parameter Evaluation*: 2012.

DOE Hydrogen and Fuel Cells Program. Hydrogen production Case Studies, 2016. Https://hydrogen.energy.gov/h2a_prod_studies.html

Draft Technology Assessment: Medium- and Heavy-Duty Fuel Cell Electric Vehicles, Air Resources Board. www.arb.ca.gov/msprog/tech/techreport/fc_tech_report.pdf

Eckerle, Tyson and Remy Garderet, "Incentivizing Hydrogen Infrastructure Investment: An analysis of the use of Cash Flow Support To Incentivize Early Stage Hydrogen Station Investment," Energy Independence Now, June 19, 2012. http://cafcp.org/incentivizing-hydrogen-infrastructure-investment

Energy Independence Now (EIN) Briefing paper. Crediting Hydrogen, November 2014

Energy Independence Now, Hydrogen Network investment Plan. Tyson Ekerle and Remy Garderet October 11, 2013.

First Element Fuels. Moving Toward Hydrogen Network Expansion. Presentation by Joel Ewanick and CARB Advanced Clean Cars Symposium September 2016.

FuelCell Energy Inc. Renewable Hydrogen from Tri-Generation Fuel cells. LCFS Pathway December 2016

GoBiz permitting guide

Gov Office of Planning and Research. Zero Emissions Vehicles in California. Community Readiness Guidebook. 2013

Governor's Interagency Working Group on Zero Emission Vehicles, *2013 ZEV Action Plan: A roadmap towards 1.5 million zero emission vehicles on California roadways* by 2025, Sacramento, 2013.

Governor's Interagency Working Group on Zero-emission Vehicles. October 2016. *2016 ZEV Action Plan: An updated roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025.* https://www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf.

Governor's Office of Business and Economic Development. *Hydrogen Station Permitting Guidebook: Best practices for planning, permitting and opening a hydrogen fueling station.* November 2015. www.business.ca.gov/Programs/Permits/HydrogenStationPermitting.aspx.

Green Car Congress. "Linde starts small-series production for hydrogen fueling stations; agreement with Iwatani for delivery of 28 units," July 14, 2014. http://www.greencarcongress.com/2014/07/20140714-linde.html

H2Logic A/S, "H2 LOGIC DELIVERS NINTH HYDROGEN FUELING STATION FOR DENMARK," 3 March 2016. [Online]. Available: http://h2logic.com/h2-logic-delivers-ninth-hydrogen-fueling-station-for-denmark/. [Accessed 17 June 2016].

Hamilton, Jennifer, CaFCP - notice of briefing to Fire Marshalls. (This is for Marshalls who would be permitting, not Chiefs who would be responding). Oakland in May, and Cerritos College in July

Hamilton, Jennifer presentation to SB Fire Chiefs

Harris, Aaron P., Daniel E. Dedrick, Angela Christine LaFleur, and Christopher W. San Marchi. *Safety, Codes and Standards for Hydrogen Installations.* Sandia National Laboratories, SAND2014-3416. April 2014. http://energy.sandia.gov/wp-content/gallery/uploads/SAND_2014-3416-SCS-Metrics-Development_distribution.pdf.

Implementation of Energy Commission Activities within the Zero Emission Vehicle Action Plan http://www.energy.ca.gov/2013-ALT-01/documents/index.html.

J. T. News, "Japan eyes 40,000 fuel-cell cars, 160 hydrogen stations by 2020," 16 March 2016. [Online]. Available: http://www.japantimes.co.jp/news/2016/03/16/business/japan-eyes-40000-fuel-cell-cars-160-hydrogen-stations-by-2020/#.V1Hv6vkrKUk. [Accessed 17 June 2016].

Jim McKinney, et al., "Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California," California Energy Commission, Sacramento, 2015.

Li, Xuping and Joan Ogden, "Understanding the Design and Economics of Distributed Tri-generation Systems for Home and Neighborhood Refueling, Part II: Neighborhood Refueling Case Studies," Journal of Power Sources 197 (2012), pp. 186– 195.

LytEn LCFS Pathway for the Production of Hydrogen from Natural Gas and renewable Natural Gas. LCA.6094.118.2015. November 2015

Malone, Keith; California Fuel Cell Partnership. Presentation to SBCAPCD Board, June 18, 2015.

McKinney, Jim, et al. 2015. *Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.* California Energy Commission. Publication Number: CEC-600-2015-016. http://www.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf.

McKinney, Jim, et al. 2017. *Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.* California Energy Commission. Publication Number: CEC-600-2017-002. http://www.energy.ca.gov/2017publications/CEC-600-2017-002/CEC-600-2017-002.pdf.

National Fire Protection Association, *NFPA 2: Hydrogen Technologies Code, 2016 Edition.* http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=2.

National Fire Protection Association. *NFPA 55: Compressed Gases and Cryogenic Fluids Code, 2005 Edition.* http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=55

Nicholas, M. A. and Ogden, J. M. "Detailed Analysis of Urban Station Siting for California Hydrogen Highway Network," *Transportation Research Record* 1983. 2007, 121–28.

Nicholas, M., Handy, S., and Sperling, D. "Using Geographic Information Systems to Evaluate Siting and Networks of Hydrogen Stations," *Transportation Research Record* 1880, 2004, 126–34.

NREL Fuel Cell Transit Bus evaluations, NREL/Tp-5600-49342-1. November 2010

NREL Hydrogen and Fuel Cell research, Hydrogen Production and Delivery. Website www.nrel.gov/hydrogen/proj_production_delivery.html#water

NREL Hydrogen Financial Analysis Scenario Tool (H2FAST). Presentation by Marc Malaina at HTAC Meeting. April 21-22, 2015

NREL Hydrogen Financial Analysis Scenario Tool (H2FAST). Spreadsheet Calculation Tool. April, 2015

NREL with Strategic Analysis Inc. Forecourt Hydrogen production cost determination. March 2012

Ogden J.M. and L. Anderson, Sustainable Transportation Energy Pathways, Institute of Transportation Studies. University of California, Davis, Regents of the University of California, Davis campus. Available under a Creative Commons BY-NC-ND, 3.0 license, August 2011.

Ogden, J. and Nicholas, M. "Analysis of a "Cluster" Strategy for Introducing Hydrogen Vehicles in Southern California", *Energy Policy*, 39, 2011, pp.1923–1938.

Pacific Northwest National Laboratory. *Safety Planning for Hydrogen and Fuel Cell Projects.* March 2016. https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects-March_2016.pdf.

Pearson, Molly; SBCAPCD. Presentation to SBCAPCD Board, June 18, 2015

Pratt, Joseph, Danny Terlip, Chris Ainscough, Jennifer Kurtz, and Amgad Elgowainy. *H2FIRST Reference Station Design Task, Project Deliverable 2-2*. National Renewable Energy Laboratory and Sandia National Laboratories, 2015. doi:10.2172/1215215. http://www.osti.gov/scitech/servlets/purl/1215215.

SAE International. *J2600 Compressed Hydrogen Surface Vehicle Fueling Connection Devices*: 2015. http://standards.sae.org/j2600_201510/.

SAE International. *J2601 Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles*. http://standards.sae.org/j2601_201612/. Note: SAE International was established as the Society of Automotive Engineers.

SAE International. *J2719 Hydrogen Fuel Quality for Fuel Cell Vehicles*: 2015. http://standards.sae.org/j2719_201511/.

SAE International. *J2799 Hydrogen Surface Vehicle to Station Communications Hardware and Software*: 2014. http://standards.sae.org/j2799_201404/.

Satyapal, S. "U.S. Update," Hydrogen and Fuel Cells Program, U.S. Department of Energy, presented at the International Partnership for a Hydrogen Economy Steering Committee Meeting, November 20th, 2013, Fukuoka, Japan.

South Coast Air Quality Management District, Technology Advancement Office. *Clean Fuels Program 2015 Annual Report and 2016 Plan Update.* March 2016. http://www.aqmd.gov/docs/default-source/technology-research/annual-reports-and-plan-updates/2015annualreport_2016planupdate.pdf?sfvrsn=6.

Southern California Association of Governments. *2016-2040 RTP/SCS Mobility Innovations Appendix*. http://scagrtpscs.net/Documents/2016/final/f2016RTPSCS_MobilityInnovations.pdf.

The Linde Group, "Hitting the road to hydrogen mobility," 2016. [Online]. Available: http://www.the-linde-group.com/en/clean_technology/clean_technology_portfolio/hydrogen_energy_h2/experience_h2/beezero/index.html. [Accessed 17 June 2016].

The Zero Emission Vehicles in California: Community Readiness Guidebook http://opr.ca.gov/docs/ZEV_Guidebook.pdf.

U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, Fuel Cell Technologies Office http://energy.gov/eere/transportation/hydrogen-and-fuel-cells.

United States Department of Energy, "Alternative Fuels Data Center: Fuel Cell Motor Vehicle Tax Credit," [Online]. Available: http://www.afdc.energy.gov/laws/350. [Accessed 17 June 2016].

US Department of Energy, Hydrogen and Fuel Cells Program "Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Program," Department of Energy, September 2012. Available online at http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_2012.pdf

US Department of Energy, Hydrogen and Fuel Cells Program, Annual Progress Report FY12, http://www.hydrogen.energy.gov/annual_progress12.html

Yang, C. and J. Ogden. “Determining the Lowest-cost Hydrogen Delivery Mode,” *International Journal of Hydrogen Energy.* 32. p 268–286. 2007.

Yang, C. and J. Ogden. “Renewable and Low Carbon Hydrogen for California – Modeling The Long Term Evolution of Fuel Infrastructure Using a Quasi-Spatial TIMES Model.” *International Journal of Hydrogen Energy.* 38 (11) p 4250-4265. 2013.

NREL Fuel Cell Transit Bus Evaluations, NREL/TP-5600-49342-1, November 2010

CAFCP Fuel Cell Bus Fact Sheet, October 2016

CARB Advanced Clean Transit Workshop, May 2013

APPENDIX A:
Summary of Adopted County Plans

See https://www.ourair.org/hydrogen-fuel-cells/ for appendix material.

Appendix B: Modeling and Field Assessment Results

See https://www.ourair.org/hydrogen-fuel-cells/ for appendix material.

Appendix C: Hydrogen Station Permitting Guidance

See https://www.ourair.org/hydrogen-fuel-cells/ for appendix material.

Appendix D: Promotion and Outreach

See https://www.ourair.org/hydrogen-fuel-cells/ for appendix material.

Appendix E: Resources for Hydrogen Safety, Awareness, and Response

See https://www.ourair.org/hydrogen-fuel-cells/ for appendix material.

Appendix F: Fleets

See https://www.ourair.org/hydrogen-fuel-cells/ for appendix material.

Appendix G: Administrative

See https://www.ourair.org/hydrogen-fuel-cells/ for appendix material.