



Investing in Alternative Fuel Infrastructure: Insights for California from Stakeholder Interviews

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ABSTRACT

Increased interest in the use of alternative transportation fuels, such as natural gas, hydrogen, and electricity, is being driven by heightened concern about the climate impacts of gasoline and diesel emissions and our dependence on finite oil resources. A key barrier to widespread adoption of low- and zero-emission passenger vehicles is the availability of refueling infrastructure. Recalling the “chicken and egg” conundrum, limited adoption of alternative fuel vehicles increases the perceived risk of investments in refueling infrastructure, while lack of refueling infrastructure inhibits vehicle adoption.

In this paper, we present the results of a study of the perceived risks and barriers to investment in alternative fuels infrastructure, based on interviews with industry experts and stakeholders. We cover barriers to infrastructure development for three alternative fuels for passenger vehicles: compressed natural gas, hydrogen, and electricity. As an early-mover in zero emission passenger vehicles, California provides the early market experience necessary to map the alternative fuel infrastructure business space. Results and insights identified in this study can be used to inform investment decisions, formulate incentive programs, and guide deployment plans for alternative fueling infrastructure in the U.S. and elsewhere.

Keywords: Alternative Fuels; Transportation Infrastructure; Investment Risk; Infrastructure Deployment Barriers; Expert Elicitation; ZEV.

1. INTRODUCTION

Overview

The transportation sector accounts for 28% of U.S. energy consumption and 34% of energy-related greenhouse gas (GHG) emissions [1] [2]. While petroleum remains the predominate fuel source (92% [1]), alternative fuels such as compressed natural gas (CNG), hydrogen, and electricity offer the potential for reduced emissions, reduced oil dependency and improved air quality. However, the deployment of fueling infrastructure for low- and zero-emission vehicles (ZEV) remains a key barrier to their widespread deployment. This is a particular challenge in the passenger vehicle sector, which is responsible for approximately half of all transportation-related GHG emissions [3-7]. The State of California has been an early-mover in this area, most notably through Governor Brown's issuance of an executive order in March 2012 aimed to support and accelerate the market transition to ZEV. Nonetheless, growth in the fueling infrastructure and supporting supply chains remains slow.

In this paper, we present the results of an expert elicitation study to identify the barriers to investments in fueling infrastructure in California, focusing on CNG, hydrogen, and electricity for use in the passenger sector.

Background

One of the most significant barriers to growth within the alternative fuel vehicle (AFV) sector is the "chicken and egg" conundrum [8], [9], [10]: consumers are reluctant to buy alternative fuel vehicles until the refuelling infrastructure is well developed, and investment in alternative fuel infrastructure is only justified with assurance of a significant level of demand. As is often the case for innovative technologies, investors are reluctant to build the infrastructure required for large-scale adoption, due to intrinsic risks, absence of clear and long-term policies, uncertain future projections, lack of demand from consumers, and lock-in by existing technologies and sunk investment in existing infrastructure [9]). To address perceived risk, the public sector often develops policies to support early market development and promote adoption.

Since the 1973 oil crisis, when gasoline prices were high and fluctuating oil prices posed economic risks, multiple countries have promoted the adoption of alternative fuels [11]. In the 1980s New Zealand supported the use of CNG in the transportation sector. Despite government incentives, including maintaining CNG prices at half that of gasoline, consumers were reluctant to adopt the new technology and the program failed to replace gasoline-powered cars [11]. A similar program was promoted in Canada, and lack of infrastructure, in particular refueling stations, was identified as the main barrier to commercial success [12].

Argentina, where there was notable adoption of CNG vehicles, exemplifies one of the few successes. However this was mainly due to significant price savings compared to gasoline. The modest government funding for refuelling infrastructure development, compared to estimates from analysis studies, [13] appears to have played a minor role. Instead, it was the direct subsidies for the conversion of fleet vehicles to CNG, and CNG price controls, which ensured retailers that demand would emerge and a price advantage would persist. This effectively reduced risks associated with market entry and retail station investments [14]. In another success story, favourable financial conditions and sustained efforts from the Brazilian government have resulted in a large market for ethanol-fueled vehicles [11]. These experiences highlight how strong and sustained commitments by various stakeholders are usually required for the successful deployment of alternative fuel vehicle markets. As summarized by Greene *et al.*, "without policies in place to support development of a fuelling infrastructure, the level of risk and investment that industry would have to bear would be too high" [4].

This paper provides insights into the major barriers to investing in alternative fuels infrastructure, based on a set of interviews with stakeholders and field experts. The interview technique can provide insights into nascent markets for which sufficient quantitative data is not yet available, and the methodology has been widely used for forecasting of technology improvement (learning) and technology adoption in the energy and transportation sectors (*e.g.* [15], [16], [17]). Focusing on

alternative fuels, Zubaryeva *et al.*, [18] interviewed 17 experts to understand the influence of different factors on present (2012) and future drivers for plug-in electric vehicle market uptake. Infrastructure availability was among the most important factors identified, and it was given the highest importance by local authorities representatives. Zubaryeva and Thiel [19] used a similar approach to evaluate lead markets for hydrogen fuel cells in Europe, with eight experts identifying infrastructure availability as the most important factor both for the medium- (2030) and long-term (2050). Infrastructure for CNG is theorized to be equally important. Biofuels, while recognized as potentially valuable alternatives to petroleum products, present fewer infrastructure investment complications. Fiorese *et al.* [20] interviewed 15 European leading experts to understand the future potential of advanced biofuel technologies both in terms of costs and diffusion, and infrastructure was not identified among the barriers for large-scale diffusion. For these reasons, biofuels have been excluded from this study. Note, however, that biogas can be used in CNG vehicles, which would present similar infrastructure and investment requirements as CNG.

While the investment decision is considered critical for the deployment of alternative fuels, we are not aware of any expert elicitation study focusing specifically on investment in alternative fuels infrastructure. Investing in alternative fuel infrastructure can help station owners to distinguish themselves and make a profit in a very competitive business environment [21] [22], and has been identified as a key element for overcoming hurdles to AFV market growth [23].

Paper Structure

Section 2 provides an overview of the expert elicitation study reported in this paper, focusing on investment risk and barriers to deployment of alternative fuels infrastructure. For each of the fuels considered, Section 3 provides a market overview and a description of the current market barriers, as identified by the experts interviewed. A summary of the issues raised, and final remarks on the role of the public sector support for alternative fuels, are reported in Section 4.

2. STAKEHOLDER INTERVIEW APPROACH

This paper contributes to the understanding of investment challenges for alternative fuels infrastructure based upon expert feedback from phone interviews with seventeen different stakeholders in early 2014. Interviewees include alternative fuel station developers, equipment suppliers, industry analysts, venture capitalists with a history of investing in AFV technology companies, and administrators of public programs that are devoted to encouraging AFV development. The individuals are mainly based in California. Responses to key questions elucidate how market participants make investment decisions, the barriers they face in developing infrastructure, and lessons that may inform public sector decisions regarding policies and incentive programs to support AFVs deployment. The National Renewable Energy Laboratory (NREL) gathered this information by conducting a series of in-depth, semi-structured interviews, a qualitative method of inquiry that combines a pre-determined set of open questions with the opportunity for the interviewer to explore particular themes or responses further [24].

Questions posed to AFV experts included the following, with relevant adaptations according to the interviewee's industry role:

- What has your organization learned about the alternative fuel infrastructure investment decision process? What are the major barriers to investment?
- What questions do potential investors typically have?
- How does your company approach investment in AFV technologies, and how does this compare to your approach in other industries?
- Currently, what are the biggest risks in technology development facing AFV companies?
- Has your organization already communicated with the California energy Commission (CEC) on this topic?
- How can NREL best use our resources to add to what you have learned?
- How does the AFV market outside of California influence your company's investment decisions?

- How close to market must a particular AFV technology be to attract investment from your company?
- What are your thoughts on the CEC investments in this area to date? Are the funds being put in the right places? What is missing? What's the best role for CEC at this point?
- In your view, what information should we present to the CEC to best inform their funding decisions in this area?

Because some of the information shared by interviewees is viewed as proprietary or sensitive, the identities of the interviewees and their employers are not tied to specific ideas. The views expressed herein are not meant to represent the individual positions of any one interviewee or of NREL. The narrative has been built around points of consensus between the interviewees, although, interesting points made by a subset of interviewees are occasionally included to highlight alternative perspectives.

3. RESULTS FROM EXPERT STAKEHOLDER INTERVIEWS

Alternative fuel vehicle investing is a broad category that includes several stakeholders working to solve transportation problems with a plethora of potential solutions. The AFV investment landscape is constantly changing, with some sectors experiencing more investment activity over time than others. Interviewees were asked to speak about trends in the AFV investment environment and, in particular, which sectors were subject to more investment activity than others.

3.1.1 *The Alternative Fuel Investment Community*

Interviewees identified five primary groups of investors that make up the AFV investment community: angel investors, venture capital, private equity, family estates and foundations, and corporations. Some of the trends in investment for each group are highlighted below:

Angels: Angels (including affluent individuals who provide capital for business start-up) are unlikely to invest in capital-intensive companies or technologies because of high capital risk and, in the case of companies focusing on EV charging infrastructure, the lack of a well-defined business model that generates returns.

Venture Capital (VC): VC firms are wary of both political and capital risk, and at the time of the interviews they were shifting their focus away from capital-intensive companies (such as manufacturers of vehicles and components) towards companies focusing on ancillary AFV services (such as fleet-management software, transportation mobile apps, and service companies).

Private Equity (PE): For the most part, PE firms are interested in investing in more mature companies that are underperforming, with the understanding that a change in the company's strategy or operations will return the company to profitability, creating value for the PE firm's investors. Interviewees noted that there is only a couple of potential AFV companies that are either mature enough or large enough to attract the attention of the general PE firms, leading the interviewees to believe it will be many years before PE firms are active in the AFV industry.

Family Estates and Foundations: Investors representing family estates and foundations could be attracted to AFV technology companies because of the "double bottom line", meaning they are interested in investments that have a socially responsible component in addition to a financial return. These investors will rarely be the sole investor in a company, but rather invest alongside VC firms and corporations.

Corporations: Investors in this group can be categorized as either traditional corporate investors or corporate venture capital investors. The difference arises from how the company makes its investments. With traditional corporate investment, corporate funds are used to support internal research and development of new AFV technology. Corporate venture capital is different in that corporate funds are invested in early-stage AFV technology companies that are not part of the firm. Interviewees noted that corporate venture capital investors have shifted away from a generalist

approach and are now pursuing a strategic model of investing, meaning they will invest in a company or project if it creates a product or service that can supplement its own business. Traditional corporate investors with a vested stake in the automotive industry, such as large automakers, may not be as averse to capital risk as VC firms, and they are making large investments to increase production of AFV vehicles.

3.1.2 Geographic Distribution of AFV Technology

Interviewees offered a near unanimous assertion that the AFV industry could become a global industry. In the meantime, however, most feel the industry is seeing a greater pace of development in some areas. As evidence of the industry's regionalized development pattern, interviewees routinely pointed to a lack of activity at the National level and the success of AFV deployment in California and Minnesota, where 263 local gas stations are reported to offer E85 [25]. While other cities or regions around the globe were mentioned as having successful adoption of AFV technologies, it was recognized that different regions have unique transportation challenges and that a single AFV technology or product likely will not be applicable everywhere around the world. This study focuses on AFVs in California, one of the largest existing markets for AFVs. The interviewees pointed out that both the size of the transportation industry in California and the state's progressive AFV policies allow companies to create products that satisfy the specific needs of customers in the state, yet still attract investment. However, most interviewees acknowledged a preference for companies with the potential to serve customers globally, rather than regionally.

3.2 Compressed Natural Gas (CNG)

3.2.1 Investment Landscape for CNG Infrastructure

The CNG market is composed of two separate sectors: personal passenger vehicles and commercial vehicles (e.g., taxis, shuttles, fleets, and trucks), leading to a variety of CNG station business models [26]. Growth in CNG infrastructure investments today are primarily responding to demand from commercial fleets and government grants, although some research studies are proposing residential refueling of CNG passenger vehicles [27].

In the United States, CNG fueling stations are being built using one of two business models [28]. In some states (such as Utah, Oklahoma, Texas, Georgia, and California) utilities are able to include the capital investments they make in CNG infrastructure in their rate-base. This means that the money utilities spend on facilities and equipment is reimbursed through the customer rates, which are usually set by a public utility commission. In this way, rate-basing of CNG stations significantly reduces the utility's perceived risk associated with the infrastructure investment.

In states that do not allow utilities to rate-base CNG infrastructure, private companies play a larger role in the infrastructure market. However, the land and capital intensity of CNG fueling infrastructure limit the number and type of market participants. Most existing retail fuel stations, especially those in dense urban areas, do not have the additional land needed to install CNG fueling equipment. In addition to space limitations, there is still insufficient demand for CNG fueling to warrant the significant capital investment required of commercial station owners. As a result, there are a limited number of private companies actively developing CNG fueling stations.

Establishing contracts with fleets would provide more predictable income and allow potential CNG station owners to calculate economics and payback time prior to investment. This is currently not an option for hydrogen fuel distributors or electricity providers because AFVs using these fuels are more likely to be owned by non-fleet entities. A rule of thumb is that a solid anchor customer that off-takes 20% of the maximum capacity of a station is necessary to warrant investment, a level of demand that can be derived from just one or two fleet contracts.

Multiple investors view the recent push for long-haul trucking being pushed by natural gas producers, with some suggesting that CNG investments are other alternative fuel investments, such as biofuels.

At the same time, the lack of a well-defined exit strategy for early-stage investors makes CNG unattractive to some.

3.2.2 Barriers to CNG Infrastructure Development

Interviewees noted several current barriers to the development of CNG infrastructure:

Need for Unbiased Information. A lack of reliable, unbiased information is one barrier inhibiting the transition to CNG vehicles by both fleets and individual drivers, which in turn may deter investments in CNG fueling infrastructure. Industry participants agree that potential investors are most compelled by information from their colleagues and peers, rather than from utilities or private businesses that may hold financial interest in their decision to invest in CNG technology. Potential fleet owners or infrastructure developers want to hear the successes, the challenges, and the “fixes,” from previous commercial experiences with alternative fuels, and they are typically wary of information from private equipment supply companies. There is a need for a single repository for unbiased information and case studies on CNG fleet transitions, heavy-duty vehicles, and fueling infrastructure (similar to case studies reported by the Alternative Fuels Data Center at: <http://www.afdc.energy.gov/case>). Market participants see information provision as an excellent role for government.

Cost of Onsite Infrastructure Upgrades. CNG station owners are responsible for paying for the extension of pipelines to provide natural gas to a new fuelling station. The costs of these extensions can be a significant, and sometimes prohibitive, cost to a prospective station owner. A new CNG fueling station is a benefit to the gas company, since it provides a new source of sales. Ensuring that this benefit is accounted for in the pricing of line extensions, as well as identifying regulatory requirements or incentive mechanisms to encourage gas companies to offer lower cost line extensions to CNG fueling developers, could help increase deployment of CNG stations.

Implementing Codes and Standards. There is a need to educate local officials about CNG technology, in order to facilitate construction of new stations by before new CNG markets grow within local jurisdictions. This can reduce lead times for construction approvals and increase success rates. Some educational courses have been developed, including some that focus on informing local officials. In addition, it is important for government to establish uniform codes and standards for inspectors of CNG stations and ensure that inspectors are well versed in the relevant issues related to CNG infrastructure development. To this end, state government could produce a set of recommended codes and standards for adoption at the local levels and ensure that localities are aware of the need for uniformity and clarity. The state could also hold inspector trainings to provide information specific to CNG infrastructure development and increase the confidence of inspectors.

Need for Corridors. To address range anxiety for potential fleet owners and long-distance heavy-vehicle drivers, corridors through common routes need to be developed. There has been some success in developing initial corridors [29], but expansion of corridor networks could have a significant impact on market momentum. CNG corridors are expected to increase the value of CNG vehicles, similar to hydrogen connector stations or DC fast charging station corridors for electric vehicles [30].

3.3 Hydrogen

3.3.1 Investment Landscape for Hydrogen Refueling Infrastructure

While a number of fuel cell electric vehicle (FCEV) models are available in the commercial and passenger vehicle markets, infrastructure development for fueling these vehicles is lagging behind. As of June 2016, California had 25 operational hydrogen stations (20 of which were open for public use) and several stations in development [31]. This is somewhat less than the 68 stations suggested by the 2012 California Fuel Cell Partnership (CaFCP) Roadmap for 2016 [32], but in line with the 2015 goal. Previous estimates that more stations would be constructed in California did not come to fruition, and the goal was pushed into the future. Station construction received a boost in May 2014 with investment by the CEC in nearly \$50 million in 28 new stations [33]. After a series of station

awards in 2015, an additional \$33 million in planned funds was announced in the CEC's 2016 call for proposals [34]. Given this increase, California is on track to achieve projected levels of station development, although recent vehicle deployments have been dampened by the limited number of public stations [31].

The lack of private interest in hydrogen station refueling has been a major factor inhibiting FCEV market growth. FCEV manufacturers look to the public sector to stimulate development of hydrogen refueling stations. Interviewees commented on the potential for FCEVs to become a larger part of the transportation mix in the future. While investment in this sector has yet to approach the same level as PEV or natural gas vehicles, many see fuel cell vehicles as a high potential long-term solution to mitigate transportation GHG emissions. Accordingly, investors in this sector are taking a longer-term view of fuel-cell technologies, and have tailored their expectations for near-term investment returns.

Some large hydrogen producers have been slow to cultivate interest in hydrogen refueling infrastructure development. Some production and delivery companies, typically referred to as industrial gas companies (IGCs), have shied away from hydrogen fueling station investments, in part due to unfamiliarity with consumer-oriented fuel retailing. Unlike traditional fuel marketers that have contacts with hundreds (or even thousands) of retail distributors, IGCs do not have the benefit of an established network of retailers that can provide the public interface. As a result, they are forced to restructure their traditional business-to-business model if they want to enter the hydrogen vehicle fueling market successfully. Despite this historical trend, some recently established hydrogen fueling stations have adopted a canopy banner advertising the IGC company name [35].

IGCs do not take the decision to participate in the hydrogen FCEV market lightly. Today's FCEV market is a long-term, high-risk market with many remaining uncertainties around vehicle production, consumer uptake, permitting, environmental compliance, and codes and standards. Despite these risks, a few large IGCs have entered into hydrogen infrastructure development in a major way, primarily in California, Germany, Denmark, Japan and South Korea [36].

3.3.2 Barriers to Hydrogen Refueling Station (HRS) Infrastructure Development

Interviewees noted several current barriers to the development of HRS infrastructure:

Lack of Connection between Hydrogen Producers and Retail Stations. The petroleum fuel market functions under a vertical business model; producers sell fuel to marketers who then re-sell it to retailers (*e.g.*, fueling stations). Marketers base their business success in their connections with both suppliers and retailers. Hydrogen suppliers do not have contacts and relationships directly with retailers, and these relationships are challenging and time consuming to form because retail station owners are often small businesses.

Permitting, Codes, and Standards. The lack of uniform codes and standards across states and even across jurisdictions within California adds complexity, expense, and increased risk to the process of HRS development. In some cases, it is challenging to determine which authorities must provide approvals. The list may include city councils, planning departments, fire marshals, environmental protection authorities, and others. In California, this problem has been partially addressed through the creation of an Ombudsman in the California Governor's Office of Business and Economic Development (Go Biz) Office, which helps developers navigate the permitting process and coordinate with cities.

Demand Uncertainty. Hydrogen production companies are also reluctant to invest in fueling stations that do not promise immediate returns. While CNG station developers that serve the fleet market rely largely on contracts with fleets and public entities and have relatively predictable returns, hydrogen stations primarily serve the passenger vehicle market. Passenger vehicle markets, and corresponding fuel demands, are inherently more difficult to predict.

Length of Time To Develop Infrastructure. Once the decision to invest has been made, it can take up to 3 or more years to construct a single hydrogen fueling station, though these lead times have been declining with more recent stations [37]. While there are marketing benefits to placing HRSs at existing gasoline retail sites that customers already visit, some installers have had challenges maintaining retail station owner support throughout the HRS equipment installation timeframe. In contrast, other retailers are enthusiastic about having HRS equipment installed at their location. Increased communication and awareness upfront in a station project can reduce the risk of having to relocate a planned HRS as a result of losing site-owner support.

Lack of Information for Retail Station Owners. Retail station owners have very little knowledge about hydrogen fuel and have little time or economic incentive to seek information. Without clear information regarding the benefits of hosting hydrogen infrastructure and the requirements associated with the fuel, station owners are challenged to make the decision to invest. Station owners could benefit from an unbiased source of information regarding the practical issues, such as the space needs and safety requirements, as well as the economics and market outlook for hydrogen fuel.

3.4 Electricity

3.4.1 Investment Landscape for Electric Vehicle Supply Equipment (EVSE)

Interviewees note a substantive growth in California's EV market in, confirmed by a public perception that EVs are a real alternative to conventional vehicles. They acknowledge the important contribution of the Governor's Action Plan in stimulating this growth trend and point to California as the model for EV adoption. Growing demand for EV charging is exceeding infrastructure supply in some areas, and workplace charging has become an emphasis for future infrastructure growth. Two U.S. nationwide programs have resulted in significant expansions of infrastructure, ChargePointAmerica and the EV Project. In California, the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) has also made major contributions to infrastructure growth [38].

However, interviewees from the investment community recognize there has been a dramatic pull-back from investment in EVSE because few companies have implemented a successful business model that provides the high returns early-stage investors prefer. Moreover, residential charging provides an alternative to public recharging stations, which hinders their commercialization. Therefore, location of public and fast charging stations is a key element for successful adoption. One example is the placement of charging stations in corridors that connect large residential centers.

Recognizing the difficulties in investing in EV infrastructure companies, interviewees suggest that, under current market conditions, EV charging will likely need to be secondary or supportive to an additional line of business. Several investors note there is more interest in investing in EV service companies that create additional value for owners of EV vehicles through products such as mobile apps and repair services.

Electric utility companies have become increasingly interested in participating in EV infrastructure development. "Smart" EV charging infrastructure can provide electricity system benefits and utilities could financially benefit from the increased load growth spurred by wide-scale EV deployment. But there is still little agreement on the desirability of utility involvement in EV infrastructure development. Based on concerns of the anticompetitive effect of utility investment, and the impacts of rate-basing EV charging infrastructure across a broad customer base, the California Public Utilities Commission (CPUC) banned utilities from investing in EV infrastructure in 2001. This decision was reversed in 2014 [39], and the next year the legislature directed that utilities should file applications with the CPUC for investments in EV infrastructure. Several proposals for pilot programs representing a variety of business models were approved in 2016 [40]. Driving this policy change is a new understanding that there is not a strong business case for third-party investment in public charging stations, since selling electricity alone yields little value. Nevertheless, the business models

being tested in the pilot programs include participation by third party vendors, who act in some cases as the financiers, and in other cases as charging station operators.

3.4.2 Barriers to EVSE Infrastructure Development

Interviewees noted several current barriers to the development of EVSE, some of which mirror those discussed above for CNG and HRS. Since the focus of this study is retail investments, the electric grid is not considered as a requirement for deploying EVSE. This is because modifications to the distribution network are less relevant to electricity, as compared to other alternative fuels, and EVs can be seen both as a challenge (increased peak load) and as an opportunity (flexible load, potential storage and grid services) for the electric grid [41].

Mismatched Costs and Benefits (principal-agent barrier). Installation of commercial EVSE is more complex and expensive than installation of residential EVSE, which usually presents a significant barrier only when the homeowner must perform substantial electrical work. More importantly, there is often a disconnect between who pays for commercial EVSE installations and who benefits from them. For example, the landlord of a retail strip mall might invest in EVSEs, but they will unlikely see a return on that investment in the near future. The tenants of the strip mall, however, could benefit directly because EV drivers are incentivized to visit. Similar dynamics are at play for workplace charging when the tenant does not own the building. While the tenant may benefit from providing EV charging to its employees (in the form of employee satisfaction), the landlord may not see direct gains from the investment. Because this disconnection between costs and benefits is very difficult to bridge, commercial landlords might require incentives to install EVSE.

Inadequate Financial Incentives. Currently, there are no federal-level grants for EVSE and state funding does not provide the incentives required for large-scale EVSE deployment. In addition, one-time subsidies, which constitute most of the current EVSE incentive programs, are seen by some to be an inefficient use of available incentive funds.

Short Vehicle Range and High Battery Costs. The cost and technical specifications of current battery technology limit the range of EVs, as compared to other alternatives. This leads to consumer “range-anxiety”, which inhibits demand for EV technology and its associated charging infrastructure.

Perceived Lack of Commitment to EVs. Some individuals and fleets doubt that automakers will continue to manufacture EVs, which creates uncertainty about whether new EV models and factory support for existing vehicles will be available in the future. Regions with increased education, awareness and outreach experience increased stakeholder engagement.

Lack of National Codes and Standards. Similar to HRS, the variation in EVSE codes and standards by state and local jurisdiction hinders EVSE deployment. Compatibility across large regional networks may favor sales of some EVs over others.

4. CONCLUSIONS: THE ROLE AND IMPORTANCE OF PUBLIC SECTOR SUPPORT FOR AFV TECHNOLOGY

Interviewees agreed unanimously that public sector organizations, like the California Energy Commission, have an important role to play in the development and deployment of AFV technologies. Interviewees noted that if state and federal governments enact legislation and communicate clear goals related to the reduction of GHGs and the consumption of petroleum products, those same entities can support the private sector in developing and deploying new technologies to achieve those goals.

Public sector financing organizations have recently assisted private sector companies working on early-stage AFV technologies by supplying them with direct federal support programs, awarded after a lengthy application process. The experts’ consensus was that, while this support helped the deployment of AFV technologies, this approach forces a public organization to essentially “pick winners” in the race to develop the next AFV technology. More than one interviewee mentioned the

highly publicized bankruptcies of Solyndra, A123 Systems, and Fisker Automotive as examples of how this funding strategy can backfire. In addition, one investor expressed caution of companies that rely on large amounts of grant financing, because expending time and effort writing the grant funding applications can yield a low return on investment and detract from the work of improving the company's business model.

While each interviewee had their own opinion on how to improve public sector financing of AFV technology, there was agreement that, rather than picking winners, public sector organizations may better level the playing field for all companies by making it more cost effective for all of them to operate. This would allow consumers and other market forces to choose which companies and products provide the best solutions to combat emissions and rising fuel costs, while remaining neutral and avoiding the negative consequences of "picking winners".

Interviewees offered many other specific suggestions, including:

- Organizations could consider policies that encourage more collaboration among companies in the industry by organizing working groups that aim to identify the obstacles and barriers facing AFV development, while assigning each company a role in addressing them.
- Organizations could benefit from partnering with other research foundations to sponsor an incentivized prize competition related to AFV technology, similar to the XPRIZE. This would remove the need for organizations to pick individual companies or technologies that receive benefits, and instead allow the organization to set lofty goals that all companies have the opportunity to achieve.
- Programs that leverage the limited public capital to encourage private-sector lenders to increase investment activity in the AFV industry were viewed more favorably than programs without much multiplier impact. Examples of this type of policy included loan-loss reserves to investment dedicated to AFV technology development, or by matching funds contributed by the private sector to deploy AFV technology.
- Interviewees routinely pointed to AFV infrastructure investment as among the most difficult business models to successfully develop. To combat the challenge public finance organizations could partner with research organizations to explore and study potential AFV infrastructure business models and collect and analyze data on existing AFV infrastructure. Research on innovative financing and capital recovery for public AFV infrastructure could benefit all industry participants.
- Organizations could also promote education and outreach programs for consumers, companies, and decision makers looking to implement AFV solutions. Manuals and best practice guides, including case studies, can help individuals identify the best solution for their particular problem, and educate decision makers on appropriate laws and regulations that will help meet climate-related goals.

4.1 Towards an explanatory model of investment decisions

Taking a step back, while investment decisions in alternative fuel infrastructure are context-specific, two factors have the greatest impact on who considers investment and how the final decision is made. First, is the business case for building fueling stations (*i.e.* the expected return on investment for fuel sellers), which is generally challenging for alternative fuels given the lack of demand, and more recently low gasoline and diesel prices. Second, is the dependence of the business case on coordination amongst automotive, fleet, and fuel providers. That is, the degree to which automotive companies provide information on future target markets, participate in placement decisions for fueling stations, and make direct investments in infrastructure.

These two dimensions predicate four distinct investment environments, summarized in Figure 1. These markets range from highly-dependent, where stations receive public and perhaps automaker funding to bolster the business case (bottom left), to independent and market-driven, similar to the existing market for gasoline retail stations (top right). AFV infrastructure currently functions within

the highly dependent quadrants, with both strong (e.g., CNG fleets) and challenging (e.g., EV) business cases represented.

Despite the strength of the business case, coordination is key to moving toward a sustainable, competitive market. Strong coordination between auto and fuel providers is critical in overcoming the “chicken and egg” conundrum. This is exemplified by the current challenges faced by hydrogen and public L2 EVSE or DCFC stations (in the bottom left quadrant), which struggle with lack of demand and limited capital recovery opportunities. These may pass through a valley-of-death investment environment as automaker coordination becomes uncoupled from station business models. But coordination is still necessary in situations where there is a strong business case. For example, CNG stations serving private or public fleet vehicles can have a strong business case if competing against relatively high diesel prices and if established as highly utilized anchor stations with firm, long-term demand (top left). However, continued success relies on coordination with fleet operators to maintain operation as anchor stations with committed CNG vehicles [42]. Achieving this fleet coordination, along with low CNG prices relative to diesel, may be sufficient to initiate the transition to independence.

During this transition, information to guide investments, prices, utilization rates, and consumer preferences all become more susceptible to market forces. While some private DCFC and HRS connector stations have received strong automaker support (e.g., Tesla DCFC networks or Toyota-Honda co-funded HRS), these business models may face new challenges as they become uncoupled from auto manufacturer ties. In other words, the cases depicted in the far bottom left corner are strongly coupled fuel-vehicle co-products. They are highly dependent upon automaker coordination and support, and may require tailored market support mechanisms to successfully transition through the Valley of Death to reach competitive markets. Means of facilitating this transition may be analogous to those used to catalyze innovative technology solutions in auto industry assembler and supplier relationships (c.f., [43]).

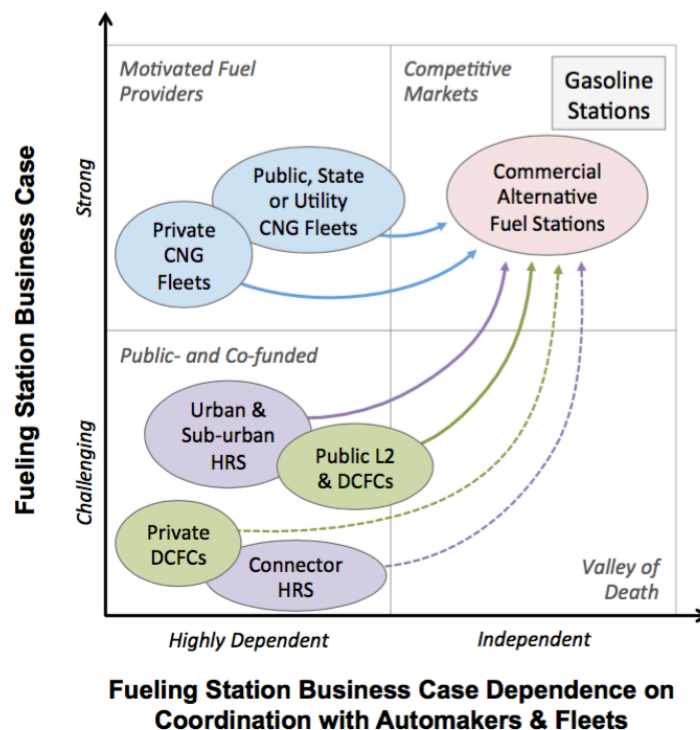


Figure 1. Summary of investment types across a spectrum of alternative fuel stations business case strengths and dependence on automaker and fleet coordination.

The explanatory model that maps the investment space in alternative fuel infrastructure reported in Figure 1 may help to orient different alternative fuel infrastructure investment decisions across a spectrum of station business cases and degrees of dependence on fleet and automaker coordination and support. The current business model and the potential path towards a competitive market are different for different alternative fuels infrastructure. Combined with results of the expert elicitation reported in this paper, these insights can help to explain, anticipate, and stimulate future investments in alternative fuel infrastructure, and foster larger and more effective deployment plans for alternative fuels in the U.S. and elsewhere.

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